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CONTENTS

News

8

Young blood turns back clock

First results of human trials of transfusions to fight ageing



On the cover

30

The Higgs bang

How the world's most famous particle also started the universe

- 34 Up your nose Fragranced health stinker
- 38 A billion birds Shocking death toll
- 11 Paranoid android Robots that doubt
- 6 True dawn Humans evolved earlier than we thought
- 42 Poisoner-in-chief Meet the one-man environmental disaster



Features

34

Up your nose

Why fragranced products are a stinker for your health



Coming next week...

Burn out

How stress makes your body attack itself

Finding the flow

The universal laws that govern how life moves



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this magazine please recycle it.

Volume 234 No 3129

This issue online
newscientist.com/issue/3129

Leaders

- 5 The US is becoming a green pariah. UK election promises on R&D ring hollow?

News

UPFRONT

Discovery of oldest modern human fossils. Google plans to block ads. SpaceX relaunches old cargo capsule

NEWS & TECHNOLOGY

Automatic translator for sign language. Plan to revive extinct Galapagos tortoise. Vocal synth mimics dog barks. Mild drinking in pregnancy linked to baby's face shape. Insecure robots could be better at their jobs. Drug boosts self-confidence. Methane bomb craters found in Barents Sea. LIGO detects third black hole merger. Monkey brain signals used to recreate photos of face

IN BRIEF

Computers to beat humans at everything by 2060. Vaginal microbes hamper HIV drug. Super Jupiter is hottest exoplanet ever found

Analysis

- 22 US climate decision What Donald Trump's plan to ditch Paris means for the rest of us

COMMENT

Ocean seeding trial must be scrutinised. NASA right to call probe after living scientist

INSIGHT

How dark online ads could swing UK election

Aperture

- 28 The physical embodiment of consciousness

Features

- 30 The Higgs bang (see above left)

- 34 Up your nose (see left)

- 38 A billion birds The shocking death toll from flying into things

PEOPLE

Thomas Midgley, environmental disaster

Culture

- 44 The power of good Kim Stanley Robinson hopes a utopian story can break the hold of dystopias. PLUS: A review of his new book

- 46 Keep it real Brecht's *Galileo*, a rave version

Regulars

- 52 LETTERS Where consciousness hides

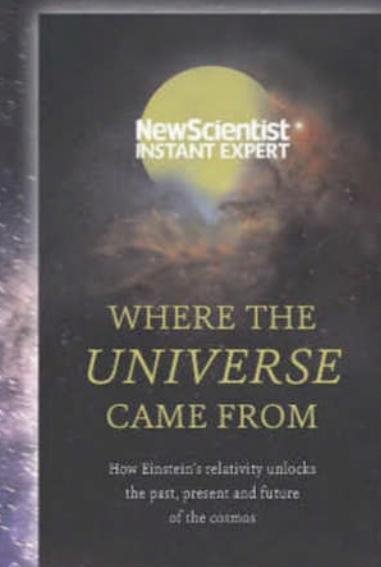
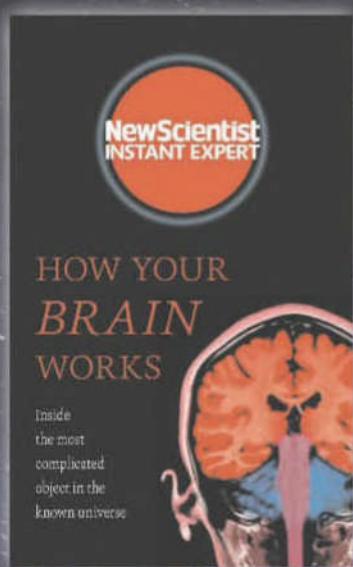
- 55 CROSSWORD

- 56 FEEDBACK Interstellar budgeting

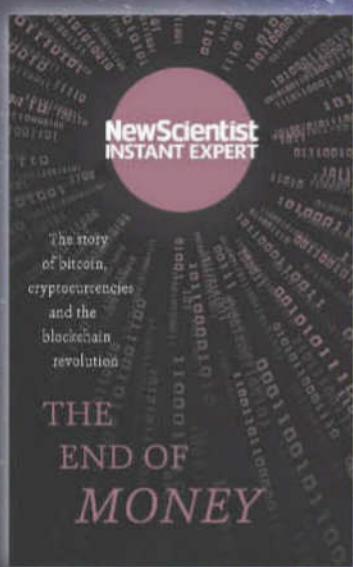
- 57 THE LAST WORD It ain't sneezy

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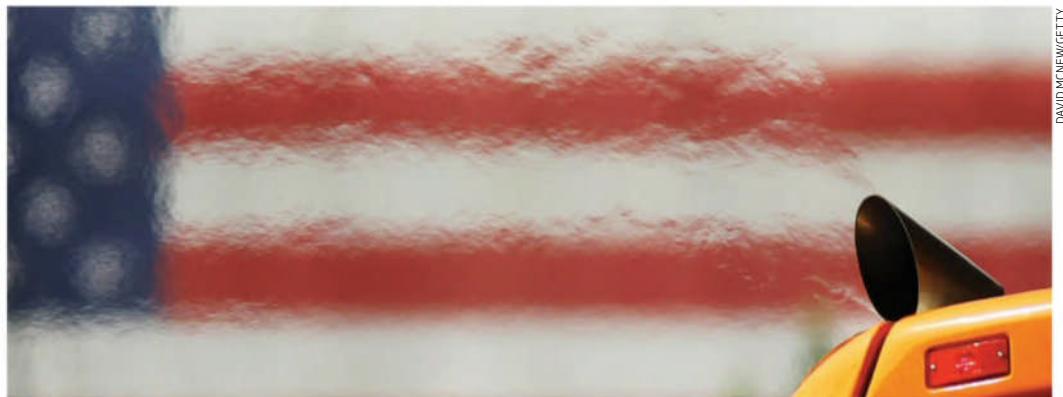
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DAVID MCNEW/GETTY

Making Earth dirty again

The US used to be a green pioneer. It is fast becoming a pariah

IN 1974, the US Environmental Protection Agency began one of the most successful clean-up operations in history. Under the Clean Air Act, it demanded that lead be phased out from gasoline. Within a few years, lead in the environment had dropped to its lowest level for decades.

The rise and fall of leaded fuel is a warning from history. Introduced in the 1920s, it was known to be horribly toxic but the profits proved hard to resist (see page 42). With no environmental red tape to get in the way, "Ethyl" was soon being added to fuel all over the world.

The result was a humanitarian disaster. Lead is a neurotoxin that particularly affects developing

brains. According to the World Health Organization, exposure in childhood reduces IQ, shortens attention span and increases antisocial behaviour. Lead poisoning also causes anaemia, immunotoxicity, high blood pressure and damage to the kidneys and reproductive organs. The effects are irreversible and there is no safe level of exposure.

True to form, the Trump administration has declared war on the EPA, vowing to cut its funding to the bone. A Republican congressman has even tabled a bill to "terminate" the EPA at the end of 2018. The bill is largely symbolic, but encapsulates the GOP's reckless attitude to regulators as a needless drag

on US competitiveness.

Decimating the EPA threatens to take us back to the dark days when the environment was a cheap and convenient waste dump and the human cost mere collateral damage. Walking away from the Paris Agreement on climate change is equally bad.

There are similar fears that the UK's departure from the EU will be an excuse to water down or abolish environmental and consumer protection. Anyone who thinks that is a good idea should acquaint themselves with the history of leaded petrol.

The US Clean Air Act saved lives. But maybe the lingering effects of lead poisoning are still affecting some people's brains. ■

Empty promises?

THE UK general election campaigns have inevitably been dominated by two issues: Brexit and national security. But behind the headlines, science has also become a battleground.

Two of the main parties have promised large investments in research and development. The Conservatives have pledged to increase it to 2.4 per cent of GDP by 2027, up from its current 1.7 per

cent. Labour has gone higher, but over longer: 3 per cent by 2030.

It almost feels like a bidding war. That's welcome progress on 2015, when neither party made specific manifesto pledges. But let's not get carried away. The figures include both public and private-sector money, so hardly amount to a spending splurge. Many other advanced economies already invest comparable figures

on R&D, so the promises actually mean that the UK will merely catch up – and long after the next parliament is history.

The more immediate risk is Brexit. Universities say they are already experiencing "brain drain". If free movement ends, what will that mean for the UK as a venue for world-class science?

That will be worth bearing in mind as Brexit negotiations open, just days after the election. The scientific community will be watching closely. ■



Wow! 350,000 years old

FOSSILS found in Morocco suggest our species began to appear as early as 350,000 years ago – adding as much as 150,000 years to *Homo sapiens* history.

It was a big wow moment, says Jean-Jacques Hublin at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, one of the leaders of the work.

Conventional thinking suggests that *H. sapiens* emerged in East Africa some 200,000 years ago. But some suspect that our roots run deeper, given that fossils from South Africa resembling modern humans have been tentatively dated at 260,000 years old.

The new evidence provides solid support for those suspicions. It comes from a Moroccan site called Jebel Irhoud. Hominin remains were

found at the site in the 1960s. But their odd mix of ancient and modern features meant they were initially mistaken for an African version of Neanderthals.

But the fresh excavations found stone tools and more hominin bone fragments, including pieces from an adult skull. An analysis of the new fossils, and of those found at the site in the 1960s, confirms that these hominins had a primitive, elongated braincase. But the new adult skull combines this ancient feature with a small, lightly built “modern” face – one the team says is indistinguishable from our own (*Nature*, DOI: 10.1038/nature22335).

Shannon McPherron, also at the Max Planck Institute for Evolutionary Anthropology, and his team dated both the stone tools and the hominin

bones to somewhere between 250,000 and 350,000 years ago (*Nature*, DOI: 10.1038/nature22336)

The researchers suggest that modern humans had begun to emerge – literally face-first – at this time. Although other features of their anatomy still looked primitive, the Jebel Irhoud hominins should be considered the earliest known members of our species, they say.

Not everyone agrees with this assessment, but Aida Gómez-Robles at University College London thinks it makes sense given that we already know our lineage became distinct from the Neanderthal line at least 500,000 years ago. “I would predict that we will find in the future even older transitional forms for both Neanderthals and modern humans,” she says.

SpaceX flies again

ON 3 June, SpaceX sent a used Dragon cargo capsule back to the International Space Station, the first time a private company has twice put the same craft into orbit.

It first flew to the ISS in 2014 and was recovered after splashing down in the Pacific. To return to space, it got a new heat shield, parachutes and minor repairs.

The recycled capsule ferried the first Chinese experiment to join the US-led portion of the ISS. It will study the effects of space radiation on DNA and will be confined to a platform run by NanoRacks, the company hired by Chinese scientists to perform the experiment. This set-up skirts a 2011 ban on NASA working with

“The Dragon capsule’s trip to the ISS makes SpaceX the first firm to put the same craft back into orbit”

the Chinese government.

Dragon also carried items for more than 200 other projects on the ISS, including fruit flies that will be used to test how weightlessness affects the heart, and the Neutron Star Interior Composition Explorer (NICER). This will take the most precise measurements yet of neutron stars, and test how to use these dense stellar corpses as beacons for interstellar navigation.

Cancer successes

A FLURRY of promising results in the fight against cancer were presented at the annual meeting of the American Society of Clinical Oncology in Chicago this week.

Two studies suggest the drug abiraterone dramatically improves prostate cancer survival. Together, the studies followed 3200 men, and found that those who received abiraterone alongside standard hormone therapy were 38 per cent less likely to die within around 30 months of treatment,

and 37 per cent less likely to die within around 40 months. "Abiraterone not only prolonged life, but also lowered the chance of relapse by 70 per cent," says Nicholas James of the Queen Elizabeth Hospital in Birmingham, UK, who led one of the studies.

The conference also heard about an experimental ovarian cancer drug, BTG945, that shrunk the tumours of seven women in a trial of 15 women. "It's rare to see such clear evidence of reproducible responses in early stages of drug development," says Udai Banerji of the Royal Marsden Hospital in London.

Blocked by Google

OK GOOGLE, get rid of bad ads. The tech giant has announced that it will introduce its own ad blocker to the Chrome browser next year to remove the most intrusive ads. It will also let websites remove ads for people who pay to go ad-free.

Many people, including a quarter of UK adults, use ad-blocking software. But Google hopes that blocking the worst offenders itself will encourage people to put up with the rest. The company makes 86 per cent of its revenue from advertising, so has a large stake in making sure most adverts get through.

Chrome will block pop-ups, autoplaying video ads with sound, and ads shown before a page opens, among others. "It's far too common that people encounter annoying, intrusive ads on the web," wrote Sridhar Ramaswamy, Google's senior vice-president for ads and commerce in a blog post. "These frustrating experiences can lead some people to block all ads."

Starting first in North America, the UK, Germany, Australia and New Zealand, people using Chrome will have a choice: put up with ads that meet Google's standards or pay a small fee to publishers, which includes a cut for Google, to browse ad-free.

Encryption flaw

IN THE wake of last week's terrorist attack in London, the UK prime minister Theresa May again called for laws to regulate the internet. She demanded that internet companies do more to stamp out places where terrorists can communicate freely.

"We cannot allow this ideology the safe space it needs to breed," she said.

Yet most experts agree that undermining cryptography to remove safe spaces simply couldn't work. A ban on encryption would make it

impossible to do anything online that relies on sending details securely, such as using your credit card. And any back-door access to encrypted messages granted to

"If you stop 'safe places' for terrorists, you stop safe places for everyone, and we all rely on those places"

security services would become an obvious target for hackers.

"If you stop 'safe places' for terrorists, you stop safe places for everyone, and we rely on those places," says Paul Bernal at the University of East Anglia, UK.

Ice shelf hanging on by a thread

A HUGE chunk of the Larsen C ice shelf on the Antarctic Peninsula now looks doomed to calve into the Weddell Sea.

"It could be any time, maybe within weeks, or possibly months," says Adrian Luckman of Swansea University, UK, head of Project MIDAS, which monitors the ice shelf.

Its fate is being sealed by a 200-kilometre-long ice crack making a sudden change of direction. It had been running parallel to the Weddell Sea, but it has now turned seaward, satellite images have revealed.

The rift grew 17 kilometres between 25 and 31 May, having been stationary since January, and is now just 13 kilometres from the sea. "Now that so little ice remains joining the

iceberg to the ice shelf, we expect propagation to be quicker," says Luckman. Covering 5000 square kilometres, the future iceberg is in the top 10 largest ever recorded, he adds. When it finally breaks free, it will take with it 10 per cent of the Larsen C ice shelf. Two other northerly ice shelves on the peninsula - Larsen A and B - have already broken up.

Because the ice is already afloat, it won't affect sea level when it calves. But Larsen C holds back glaciers from the Antarctic Peninsula ice sheet, so losing the ice shelf altogether could also accelerate glacier loss. "What's happening at Larsen C may be a useful lesson as to what may eventually happen to the much larger and more critical ice shelves," Luckman says.



A giant iceberg in the making

Suspicious statistics

Dozens of clinical studies have been identified as having statistical patterns that are unlikely to appear by chance - suggesting they may be incorrect or falsified. A review of 5087 clinical trials published during the past 15 years uncovered 90 studies with unlikely patterns (*Anaesthesia*, doi.org/b78d).

Cloud on the horizon?

NASA's New Horizons team is checking its next target for danger. After passing Pluto, the craft is headed for a Kuiper belt object called 2014 MU69 that is 6 billion kilometres from Earth. On 3 June, 2014 MU69 passed in front of a star, allowing us to look for any dust or rings that could pose a problem.

Apple assistant

Apple will launch a voice-activated loudspeaker called HomePod later this year to compete with Google Home and Amazon Echo. The speaker is billed as a music player that runs the Siri virtual assistant. Siri will answer questions and can control things like lights in the home.

Pucker up to avoid sting

When sucking a stinging coral's flesh out of its razor-sharp skeleton, the tubelip wrasse fish avoids getting a face full of cuts thanks to its fleshy lips, which are loaded with special mucus-secreting cells. A protective slime comes out of thin folds that look like the gills of a mushroom (*Current Biology*, DOI: 10.1016/j.cub.2017.04.056).

Cut that lie-in short

A study of how much 984 adults shifted their waking and sleeping hours at the weekend has found that, for every extra hour a person's schedule shifts, there is an 11 per cent increase in the likelihood that they have cardiovascular disease. The phenomenon is called social jetlag, because it's often caused by social commitments conflicting with when our bodies want to sleep.

First tests of 'youth elixir'

People getting transfusions of younger blood plasma seemed to show improvements in several signs of age-related disease, finds **Sally Adee**

TRANSFUSIONS of young blood plasma may cut the risk of cancer, Alzheimer's disease and heart disease in older people, according to a controversial new study which required participants to pay for their treatment.

"I don't want to say the word 'panacea', but there's something about teenagers," Jesse Karmazin, founder of start-up Ambrosia, told *New Scientist*. "Whatever is in young blood is causing changes that appear to make the ageing process reverse."

Since August 2016, Karmazin's company has been giving people aged 35 to 92 transfusions of blood plasma from people aged between 16 and 25. So far, around 100 people have been treated. The fact that they all paid \$8000 to be included, as well as the study's lack of a placebo group, has attracted much criticism.

Karmazin spoke to *New Scientist* ahead of presenting the study's first results at Recode, a technology conference in Los Angeles last week. These results come from blood tests on 70 people before a plasma transfusion and a month later.

None of the people in the study had cancer at the time of the transfusion, but Karmazin's team looked at their levels of proteins called carcinoembryonic antigens. These chemicals are found in the blood of healthy people at low concentrations, but in larger amounts can be a sign of cancer. The levels of these antigens fell by around 20 per cent in the blood of those treated, the team found.

Karmazin says the team also saw a 10 per cent fall in blood cholesterol. This may help explain why a study last year by a different company, Alkahest,

found that heart health improved in old mice given blood from human teenagers.

Ambrosia also reported a 20 per cent fall in the level of amyloids – a type of protein that forms sticky plaques in the brains of people with Alzheimer's disease.

However, the significance of these findings remains to be seen. At least five experts contacted by *New Scientist* refused to discuss

"I don't want to say the word 'panacea', but there is something about teenage blood"

the results on the record because no paper has been published, and the results haven't yet been peer-reviewed. Karmazin says they hope to publish soon. Those who agreed to discuss the results were keen to make it clear that they are not endorsing the trial.

Tara Spiers-Jones, at the University of Edinburgh, UK, doubts whether a 20 per cent

reduction in blood amyloid levels would benefit people with Alzheimer's disease. "Amyloid in the blood is not a good proxy for amyloid in the brain," she says. That said, removing amyloid from the blood is unlikely to be bad, she adds. "We just don't know whether there will be any brain effects."

One study participant, a 55-year-old man with early onset Alzheimer's, reportedly began showing improvements after one plasma treatment, and his doctors decided he could drive a car again. An older woman with more advanced Alzheimer's is showing slower improvements. But the placebo effect in dementia can be huge, says Spiers-Jones, and can even change body biochemistry.

As for the 20 per cent reduction in carcinoembryonic antigens, it isn't clear whether this is likely to affect an otherwise healthy person's chances of developing cancer. "Without the context of a medical history of that patient,



JOSEPH SUPRSTOCK

plus information from other clinical findings in relation to that patient, risk would be hard to assess," says a spokesperson for University College London's Cancer Institute.

Whether a 10 per cent reduction in blood cholesterol would be beneficial to heart health is also tricky to say. The link between cholesterol and heart disease is disputed, but a 10 per cent drop is in line with what can be expected from statin therapy.

AGEING ANTIDOTE?

Vampire stories aside, the idea of rejuvenating the body with young blood dates back to macabre 1950s experiments that stitched young and old mice together so they shared a circulatory system. The health of the older mice improved, while the younger ones deteriorated.

Then an experiment in 2005 found that young blood returned the liver and skeletal stem cells of old mice to a more youthful state, and work in 2012 discovered that young blood can reverse heart decline in old mice.

But the big question is whether youthful human blood has the right ingredients to restore youth. A study

last year by the firm Alkahest found that injecting the blood of teenagers into old mice improved their memory, cognition and physical activity.

Now the first results from giving young blood to people have been announced (see main story), stoking excitement that such transfusions might be an antidote to ageing.

But even if clinical trials go on to prove that young human blood has rejuvenating effects, we don't yet know if these will be enough to counteract the ageing effects an older person's own blood may have on their body.

Placebo predicament

"There is no telling what may be down to the placebo effect," says Arne Akbar at University College London.

The high cost of the treatment could itself encourage people to imagine any effects they felt to be bigger. Without a placebo group for comparison, it's impossible to know how much of an effect this may have had.

The gold standard in clinical trials is a randomised, placebo-controlled study. But such a setup is difficult when participants are

In this section

- Mild drinking in pregnancy linked to baby's face shape, page 11
- What Trump's plan to ditch climate agreement will mean, page 22
- How dark online ads could swing UK election, page 25



Turning back the clock

paying to be included. Karmazin says he wants to do placebo-controlled studies, but it will be more difficult to fund these. Such a trial could cost tens of millions of dollars, and getting financial backing from pharmaceutical firms would probably be difficult, given that blood is not a treatment that could be patented.

Placebo groups haven't only been a problem for Ambrosia. Tony Wyss-Coray of Alkahest has had to scrap the placebo group for the safety phase of a trial of young blood plasma as a treatment for Alzheimer's because of a lack of recruits. "If the treatment takes several hours, people may not volunteer for a placebo-controlled study," says Wyss-Coray.

In the absence of controls, David Gems at University College London would like to see more tests. "It would be best to be tested at several time intervals before and after the treatment, and ideally to have the tests done under similar conditions," he says. "A single test before and after will be too anecdotal."

Wyss-Coray thinks tests will

ultimately show that plasma can influence brain health. "It is unclear how young plasma benefits old brains, but it is likely that multiple pathways are involved," he says. "Factors may trigger fat tissue or muscles to produce fewer inflammatory factors and more beneficial factors, which benefit the brain."

If plasma transfusions really do reverse ageing, the effects don't last forever. "Some people have felt great since they had the treatment nine months ago," says Karmazin. "Others felt the effects wore off after a few months."

We all age at different rates, but Karmazin thinks that, on average, people will benefit most from receiving plasma about twice a year. "We haven't treated enough people to say with certainty."

Other studies could soon give further indications of the powers of young blood. In addition to Alkahest's Alzheimer's trial, a study in South Korea is testing the effects of young blood on older people's strength and the deterioration of their chromosomes. ■

Automatic translator works with sign language

LANGUAGE barriers continue to fall. Machine translation systems that convert sign language into text and back again are helping people who are deaf or have difficulty hearing to speak to those who cannot sign.

KinTrans, a start-up based in Dallas, Texas, is trialling its technology in a bank and government offices in the United Arab Emirates. SignAll, a company based in Budapest, Hungary, will begin its own trials next year.

KinTrans uses a 3D camera to track the movement of a person's hands and body as they sign words. A sign language user can approach a bank cashier and sign to the KinTrans camera that they'd like assistance, for example. The device then translates the signs into English or Arabic text for the cashier to read.

Translation works both ways.

A person who can't use sign language can type a reply and have it converted into signs recreated by an animated avatar on a screen. It is often more natural for people who use sign language to interact this way than via text, says Sudeep Sarkar at the University of South Florida.

Around 70 million people sign as a first language and there are more than 100 different dialects used around the world. Word order in sentences can differ between these

languages as well as from written text. So KinTrans's machine learning algorithm translates each sign as it is made and then a separate algorithm turns those signs into a sentence that makes grammatical sense.

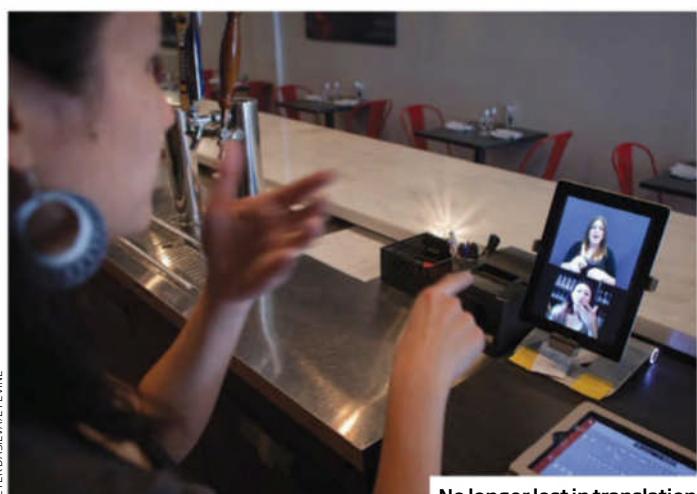
Founder Mohamed Elwazer says his system can already recognise thousands of signs in both American

"It's great to see innovative technology that could transform the lives of sign language users"

and Arabic Sign Language with 98 per cent accuracy. Future versions will include support for Portuguese Sign Language and Indo-Pakistani Sign Language, he says.

Meanwhile, SignAll's system uses four cameras that capture data from a signer's face as well as their hands and body. "In sign language, half of the information is in the face," says CEO Zsolt Robotka. Raising your eyebrows turns a sentence into a question, for example.

"It's great to see innovative technology being developed that could really transform the lives of sign language users," says Jesal Vishnuram at Action on Hearing Loss, the UK's largest charity for people who are deaf. Matt Reynolds ■



No longer lost in translation

PETER DASILVA/EYEVINE

Lifeline for extinct Galapagos tortoise

Sam Wong

A SPECIES of giant tortoise unique to Floreana Island in the Galapagos and considered extinct since the 19th century could soon be brought back from the dead.

Galapagos giant tortoises are often divided into 15 species, 11 of which survive today. The tortoise populations on all the islands were decimated after humans arrived in the archipelago and began loading them onto ships for their meat. Sailors also brought animals such as rats, which can eat young tortoises, and goats, which destroy the reptiles' habitat.

Tortoises were eliminated from Floreana Island shortly after Charles Darwin's visit in 1835. Another species, the Pinta Island tortoise, lost its last remaining member, named Lonesome George, in 2012.

But these species may not be gone forever. Both Floreana and Pinta tortoises have a saddle-shaped shell, allowing them to raise their necks to reach higher

vegetation. In 2008, researchers discovered a few tortoises living around Wolf volcano on Isabela Island that had saddle-like shells, rather than the dome-shaped shells usual on the island. DNA collected from the saddle-shelled

animals suggested they were descended from Floreana and Pinta Island tortoises. It is thought that tortoises were moved between the islands on ships.

In 2015, biologists returned to Wolf volcano to look for more tortoises with Floreana and Pinta ancestry. They carried out blood tests on 144 individuals, then lifted 32 promising candidates onto a ship by helicopter and took them to a captive breeding centre on Santa Cruz Island.

Genetic tests suggested that two of the tortoises may be purebred Floreana tortoises – which might imply that the Floreana species isn't actually extinct. Alternatively, the two may have had very recent purebred ancestry. Another 63 are thought to have Floreana ancestry, but none appear to descend from Pinta tortoises (*bioRxiv*, doi.org/b733).

Conservation biologists have begun a captive breeding programme, with the aim of returning these tortoises to Floreana Island.

The Galapagos National Park Service has already had success with breeding tortoises in captivity. There were just 15 Española Island tortoises left by the 1960s. All of them were brought to the breeding centre, and more than 2000 bred in captivity have now been returned to the island.

It's a "sensational opportunity for conservation to save a species that was thought to have been lost forever", says Axel Moehrenschlager, chair of the Reintroduction Specialist Group at the International Union for Conservation of Nature. "This would be important for the valuable ecological function giant tortoises provide on a landscape level." ■



JUAN CARLOS MUNOZ/NATUREPL.COM

I'm not dead yet!

Woof! Vocal synth creates realistic barks

ROBOTIC canine companions are getting an upgrade. Artificially generated barks that match a robot dog's physical characteristics can stop it falling into the uncanny valley.

As tech improves, robot pets are set to become more popular. But they will need to sound the part. Most existing robo-dogs are programmed to play pre-recorded woofs or growls that rarely fit the robot's outward appearance, says Roger Moore at the University of Sheffield, UK. He's

developed a vocalisation synthesiser that generates biologically fitting sounds for land mammals of any size. "You could dial up the body size to an elephant and it would still generate an appropriate sound," he says.

When tasked with giving a voice to MiRo – a robotic dog developed by UK-based start-up Consequential Robotics – Moore simply input the dog's body weight and let his algorithms get to work.

Moore's synthesiser models the key parts of a mammal's vocal system, including the lungs, larynx and vocal tract. The synthesiser then combines values for each of those features to create an acoustic wave appropriate for an animal with that vocal system.

For MiRo, a relatively small pair of lungs and short vocal tract produce a high-pitched yap you would expect of a small dog.

MiRo also responds to touch and sound. Moore's system allows its bark to change to suit the interaction. For example, if it is stroked, its bark gets shorter and more expressive – mimicking the change in airflow into the lungs of a happy, excited dog. Even a small change in MiRo's mood will create a noticeable change in its bark, says Moore. He will present his

"You could dial up the body size to an elephant and it would still generate an appropriate sound"

research at the Living Machines conference in California in July.

Nathan Lepora at Bristol Robotics Laboratory, UK, is impressed by the technology and says it could be useful for making realistic-sounding robot companions for the elderly. Robots are already being trialled as a way of improving the lives of people with conditions such as dementia. A cuddly robotic seal called PARO is being used by two NHS trusts in the UK and initial research suggests that it relieves stress, promotes social interaction and improves fluency of speech.

Moore is now experimenting with insect and dolphin vocal synthesisers. He just needs the right robots to put them in. Matt Reynolds ■

Even minimal drinking alters a baby's face

DRINKING low levels of alcohol when pregnant seems to subtly affect how a baby's face develops, including the shape of the eyes, nose and lips.

Heavy drinking during pregnancy can cause fetal alcohol syndrome, characterised by facial features such as small eye openings, a short, upturned nose and a smooth philtrum over the upper lip. Children with this condition are likely to have attention and behavioural disorders and a lower IQ, says Jane Halliday of the Murdoch Children's Research Institute in Victoria, Australia.

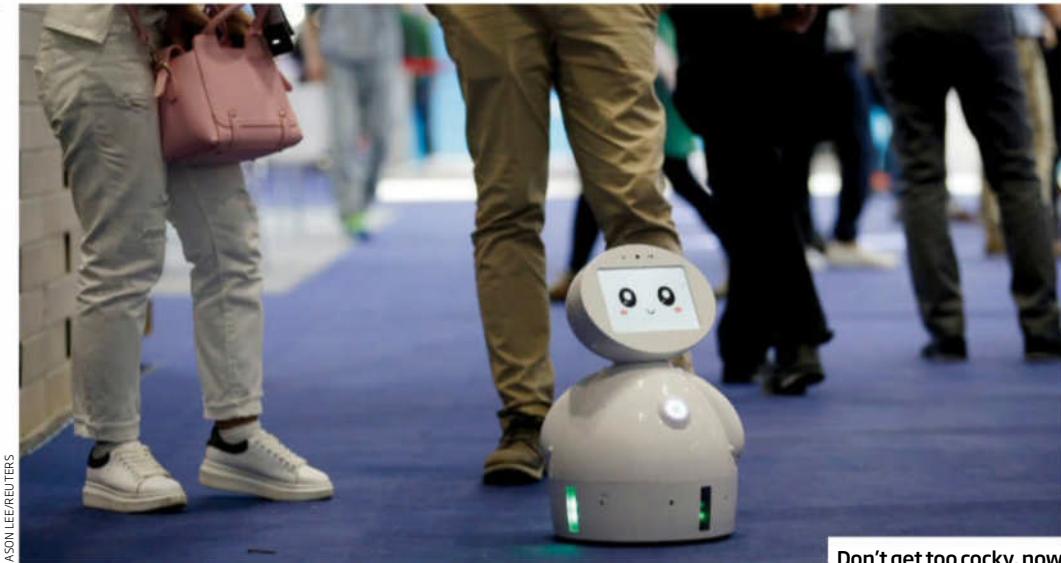
To see if low levels of alcohol consumption can also affect fetuses, Halliday's team studied 1570 women throughout their pregnancies. Of these, 27 per cent said they continued to drink at least some alcohol.

When the children were 1 year old, Halliday's team photographed the faces of 415 of the babies from many different angles, creating detailed composite images. These showed subtle differences in the faces of babies whose mothers had drunk alcohol compared with those whose mothers hadn't. These included a slightly shorter, more-upturned nose.

Even low levels of alcohol – such as no more than two drinks on any one occasion, and no more than seven a week – were linked to changes in face shape detectable by image analysis, but not by the naked eye (*JAMA Pediatrics*, DOI: 10.1001/jamapediatrics.2017.0778).

Halliday says women who have drunk a little when pregnant shouldn't worry, and that the effects might not be lasting. "We have not identified any problems for people to worry about."

"Fetal alcohol syndrome is a huge problem and it is widely under-recognised or misdiagnosed," says Christina Chambers at the University of California, San Diego. Halliday's technique might help us "identify kids that might be affected and understand the full spectrum of effects", she says. Jessica Hamzelou ■



Don't get too cocky, now

Insecure robots could be better at their jobs

CONFIDENCE in your abilities is usually a good thing – as long as you know when it's time to ask for help. As we build ever smarter software, we may want to apply the same mindset to machines.

This is the idea behind an experiment that explores a robot's sense of its own usefulness, something that could help guide how future artificial intelligences are made.

Overconfident AIs can cause all kinds of problems, says Dylan Hadfield-Menell at the University of California, Berkeley. Take Facebook's newsfeed algorithms, for example. These are designed to suggest articles and posts that people want to see and share. Yet by following this remit unquestioningly, they fill some people's feeds with fake news.

For Hadfield-Menell and his colleagues, the answer is to make AIs that seek and accept human oversight. "If Facebook had this thinking, we might not have had such a problem with fake news," he says. Rather than pushing every article it thinks Facebook users want to see, an algorithm that was less sure of its abilities

would be more likely to defer to a human's better judgement.

To explore this idea, the Berkeley team designed a mathematical model of an interaction between humans and robots called the "off-switch game". In the theoretical set-up, robots are given a task to do and humans are free to switch

"If Facebook's newsfeed algorithm was less certain of its abilities it might seek more human oversight"

them off whenever they like. However, a robot can choose to disable its switch so the person cannot turn it off.

As the model played out, robots given a high level of "confidence" that they were doing something useful would never let the human turn them off, because they tried to maximise the time spent doing their task. In contrast, a robot with low confidence would always let a human switch it off, even if it was doing a good job.

Yet Hadfield-Menell thinks it would be a mistake to make an AI too insecure. If an autonomous

car were driving a young child to school, the car should never allow the kid to take control, for example. In this case, the AI should be confident that its own abilities outstrip the child's, whatever the situation.

AIs that refuse to let humans turn them off might sound far-fetched, but such considerations should be critical where robots work alongside humans, says Marta Kwiatkowska at the University of Oxford.

Machines such as driverless cars and robot firefighters will be asked to make decisions about human safety, so it is vital that the ethical framework for these decisions is put in place sooner rather than later, she says.

The off-switch game is only the start, says Hadfield-Menell. He plans to explore how a robot's decision-making changes when it has access to more information about its own usefulness. For example, a coffee-making robot might consider its task more useful in the morning.

Ultimately, he hopes his research will lead to AI that makes decisions that are easier for humans to understand. "If you're sending a robot out into the real world, you want to have a pretty good idea of what it's doing," he says. Matt Reynolds ■

Drug boosts self-confidence

Helen Thomson

LIFE is full of decisions, and it can be hard to know if you're making the right one. But a drug that blocks the rush of noradrenaline through your body could boost your confidence, and lead to new treatments for obsessive compulsive disorder.

How much we trust our decisions is governed by the process we use to assess our own behaviour, called metacognition. "We see many symptoms associated with poor metacognitive judgement in schizophrenia and OCD," says Tobias Hauser at University College London. "In OCD, for instance, people may constantly go and check whether they've closed a door. They are poor at judging whether they have done something correctly or not."

Little is known about the neural underpinnings of metacognition, but it is likely to involve brain areas modulated by the chemicals dopamine and noradrenaline. So Hauser's team asked 40 people to take a drug that blocks dopamine or noradrenaline either before or after a placebo. Another 20 people

received two doses of the placebo.

Eighty minutes after receiving their second treatment, the volunteers performed a task in which they had to decide whether the overall motion of a burst of randomly moving dots was directed to the left or right. They also indicated how confident they were in each judgement.

Comparing self-assessed confidence against actual performance revealed that reducing noradrenaline boosts people's metacognitive insight. The drug that does this, called propranolol, made volunteers more likely to accurately say whether their answer had been correct or wrong, without affecting the accuracy of their decisions (*eLife*, doi.org/f955nn).

"This study is the first to show that metacognition can be selectively enhanced by drugs in the absence of differences in task performance," says Steve Fleming at University College London, who wasn't involved in the study.

Hauser says noradrenaline is released when we unexpectedly encounter uncertainty, such as when we make an incorrect decision. "We think this burst of



SUEHDHANG/PLAINPICTURE

Sure you're choosing the right one?

noradrenaline when you make an error erases the information about a task that you recently stored in your memory."

This could mean that someone who has struggled to reach a decision may have their system reset, rendering them unable to draw on as much information to evaluate this decision. "You are no longer able to properly judge how well you did in the task because you're judging your decision using less evidence," says Hauser.

Blocking noradrenaline seems to reduce this. Propranolol is used to treat high blood pressure, but it may also prove useful for some of the symptoms of OCD and schizophrenia.

People without conditions like these may also benefit. "It is likely to have an effect in real-life decision-making. Whether you trust what you're writing, whether you're confident in what you're saying – all our actions involve metacognition," says Hauser. ■

Huge methane blowout as the ice age ended

CALL it the largest fart in Earth's history. As the ice age came to a close 12,000 years ago, retreating glaciers in the Barents Sea north of Norway triggered unprecedented blowouts of methane gas from massive dome-like features - pingos - on the seabed.

Karin Andreassen at the Centre for Arctic Gas Hydrate, Environment and Climate at the Arctic University of

Norway, and her colleagues, pieced together the story using detailed seismic and geologic data of the Barents seabed captured through high-resolution echo sounding from ships. They also looked at the composition of methane-containing gases still spewing up from the remains of 100 pingos.

Analysis of the gas profiles revealed that the methane originated 30,000 years ago from hydrocarbon-containing rock about a kilometre below the seabed. Thick layers of ice over the seabed kept any methane that percolated upwards trapped in

the uppermost layer of sediment. Inside the sediment, the gas was converted into a solid ice-like mixture called a gas hydrate.

Then, 17,000 to 15,000 years ago, the ice sheet began to retreat rapidly. The hydrates began to decompose, forming the kilometre-wide methane blisters, or pingos, on the seafloor, beneath a thin crust of remaining gas hydrate.

"When the ice sheets melted the pingos burst, belching methane into the atmosphere"

By 12,000 years ago, the ice sheets had melted and the pingos were exposed to warm water that weakened the remaining gas hydrates so much they burst, belching methane into the atmosphere (*Science*, DOI: 10.1126/science.aal4500).

The risks of something similar happening today are hard to predict.

"Unless a glacier happens to cap a deep thermogenic [hydrocarbon] source, the lack of any carbon would preclude the formation of massive shallow hydrates," says Patrick Crill at Stockholm University in Sweden. "So I'm not too worried." Andy Coghlan ■

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All in a spin

Black hole merger rattles the cosmos

Leah Crane

THREE'S a party. For the third time, the LIGO collaboration has detected gravitational waves emanating from a pair of merging black holes – yielding clues about how these duos form and building up our catalogue of them.

"The first one was a novelty. The second one was confirmation that the novelty of the first one was not a fluke. The third one is astrophysics," says LIGO spokesperson David Shoemaker at the Massachusetts Institute of Technology (MIT).

LIGO detects waveforms, which are readouts of the ripples in the fabric of space-time caused by masses moving through it. The spins of merging black holes can warp those waveforms, which are mostly produced by their orbits and eventual collision.

The first event yielded too little information to determine the direction of each black hole's spin. The second provided a bit more information, indicating that each black hole was probably spinning in the same direction as

they were orbiting one another.

But this third pair of black holes tilts towards Earth in a different way from the other two, according to Shoemaker, allowing LIGO to see more about how each one spins.

This view has revealed that they aren't spinning in the same direction as their orbit. That means they're probably spinning

"Spins, and particularly misaligned spins, will help us figure out how pairs of merging black holes form"

in different directions or – far less likely – not spinning at all.

"Spins, and particularly misaligned spins, will help us figure out how these things are formed," says Carl Rodriguez at MIT. Going beyond detection to examining these objects' properties turns this into a "new branch of astronomy", he adds.

Black hole binaries are either born together from a pair of orbiting stars, or form separately in a dense stellar cluster and later drift together at its centre. In the

first case, the pair should rotate in the same direction they orbit, as binary stars do. In the second, says Rodriguez, "they're pointing in whatever directions they please".

LIGO's second detection, a black hole binary discovered in 2015, seemed to be from black holes born orbiting together. But this new pair, found on 4 January, may have formed independently.

At least one of the black holes seems to spin in a different direction to its orbit. The differences indicate that both formation scenarios can occur.

Because this new black hole binary is about 3 billion light years away – twice as far as the others we've detected – its gravitational waves have to ripple through more space-time before they reach Earth. That distance allows us to get greater insight into potential deviations from Einstein's theory of general relativity (*Physical Review Letters*, doi.org/b73r).

General relativity states that all gravitational waves should travel at the same speed – the speed of light. Because the waves seemed to do that in this case, even over such a huge distance, they backed up Einstein's cosmic rule.

The research marks the start of an era of using gravitational waves to study the cosmic kin of black hole binaries. ■

Brain signals used to recreate photos of faces

PRECISION images of real faces have been recreated by monitoring the activity of certain cells in the brains of macaque monkeys as they looked at photographs of people.

The study is the first to provide a full and simple explanation of how the brains of macaques – and by implication, humans – generate composite images of any face they see. "We've cracked the brain's code for facial identity," says Doris Tsao at the California Institute of Technology.

The brain has regions of specialised face cells, which become active when a person sees a face. Tsao and her colleague, Steven Le Chang, inserted electrodes into three patches of these cells in macaques, enabling them to record the activity of 205 neurons.

The pair then showed three of these macaques 2000 images of human faces. They discovered that each of the face cells is tuned to view faces in slightly different ways – as if photographing a face from multiple angles at once. The combined signals from these cells encode 50 different aspects of a face – for example, shape, distance between eyes and skin texture.

When all these are combined, they give a clear composite image. "The key is that even though there's an infinite number of faces, you can describe all of them with just these 50 dimensions," says Tsao.

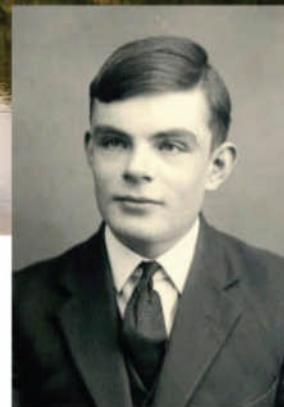
The researchers developed algorithms from the face-cell feedback that enabled them to recreate composite facial images from monkey brain-cell activity (*Cell*, doi.org/b73v).

It is likely that memories of familiar faces are held by a different type of cell in the hippocampus.

"Tsao's work provides the first specific hypothesis for how the response of face cells in the cortex can be utilised by cells in the hippocampus to form memories of individuals we've seen before," says Ueli Rutishauser at the Cedars-Sinai Medical Center in Los Angeles. Andy Coghlan ■

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The strange conifer that leans towards the equator

PERHAPS they're pining for warmer climes? The towering Cook pine tree tends to lean towards the equator – the only tree known to grow in such a fashion.

Matt Ritter at California Polytechnic State University was writing up a description of the Cook pine (*Araucaria columnaris*) for a book on the urban trees of California when he realised that the pines always leaned south. So he rang up a colleague in Australia to see if the same was the case there. It wasn't – instead, the pines usually leaned north.

"We got holy-smoked that there's possibly a tree

that's leaning toward the equator wherever it grows," says Ritter.

He and his colleagues studied 256 Cook pines scattered across five continents. They collected tree data at 18 locations between latitudes of 7° and 35° north, and 12° and 42° south. The team calculated that the trees tilt by 8.55 degrees on average (*Ecology*, doi.org/b73f).

The trees also slant more the further they are from the equator. "It's a shockingly distinct pattern," says Ritter. One tree in South Australia slants at 40 degrees.

Trees normally correct for such asymmetry in their growth, but for some unknown reason the Cook pine does not, says Ritter. "We could be just dealing with an artefact of its genetics," he says. Alternatively, it could be an adaptation to catch more sunlight at higher latitudes.

AI will best us by 2060, say experts

ENJOY feeling superior while you still can. According to a survey of more than 350 people developing artificial intelligence, there is a 50 per cent chance that machines will outperform humans in all tasks within 45 years.

AI is predicted to be better than us at translating languages by 2024, writing high-school essays by 2026, driving a truck by 2027, working in retail by 2031, writing

a bestselling book by 2049 and surgery by 2053. In fact, all human jobs will be automated within the next 120 years, say the respondents. The survey, by the University of Oxford and Yale University, took the views of AI researchers around the world.

We're not completely outdone, however. Computers may be able to beat us at specific activities, but it will be a long time before we see

an AI with human-like versatility, says Eleni Vasilaki at the University of Sheffield, UK.

What's more, the survey focused on the cognitive aspects of intelligence that fit well-defined tasks. "But parts of intelligence, such as emotional intelligence, go beyond cognition," says Georgios Yannakakis at the University of Malta. "It would be interesting to ask when AI will surpass humans at being art or movie critics."

Cuttlefish mimics crab to catch fish

CALL it a scuttlefish. The pharaoh cuttlefish (*Sepia pharaonis*) can walk like a crab – adding to its reputation as a mimic.

Kohei Okamoto at the University of the Ryukyus in Okinawa, Japan, and his team spotted the molluscs raising their front arms while they bent their other legs, as if they had joints. They moved these legs rapidly to mimic scuttling (*Journal of Ethology*, doi.org/b7zz).

Posing as hermit crabs could deter predators, given that cuttlefish lack the hard shell that helps keep crabs safe.

It could also be a tactic to get close to prey, as crabs don't hunt. The team found that pharaoh cuttlefish making crab-like arm movements caught about twice as many fish.

"It's possible that the distance between cuttlefish and their prey is reduced when they exhibit the behaviour," says Okamoto.

Mars lake layers right for microbes

ANCIENT Mars's lakes may have had two habitable zones.

NASA's Curiosity rover has inspected Gale crater on the Red Planet, revealing rusty oxidised iron deposits at the edges and non-oxidised samples from the middle.

This oxidation gradient shows the lake could have been ripe for life – types that need oxidants as well as those that don't (*Science*, 10.1126/science.aah6849).

The two zones can tell us about past atmospheric oxygen levels and the ancient Martian climate. More than 3 billion years ago, the planet's overall climate began to cool and dry out, but these zones show warming over a shorter period of time. This adds to past evidence that ancient Mars had an environment hospitable to life.

Brain switch lets voles find 'love'

TALK about flipping a switch. Activating circuits in the brains of female prairie voles can make them "fall in love".

Robert Liu at Emory University in Atlanta, Georgia, and his colleagues chose to study pair-bonding in prairie voles because this species is one of the few to mate for life.

The group implanted electrodes into the brains of females to identify the circuitry activated when they naturally formed a pair bond and mated. Connections in a specific circuit were found to get stronger, especially after mating.

Next, the researchers devised a way to activate this "love" circuit themselves in female voles. They inserted genes into neurons that would activate the cells when exposed to light. They then fed pulses of light into this circuit through a fine optical fibre while female voles were housed with - but did not mate with - males.

Later, they gave the females a choice of mating with the male they had met earlier or a stranger. Ten out of 12 females chose the familiar male. Yet just three out of 10 females in a control group preferred mating with a male they had met earlier (*Nature*, doi.org/b722).

"We think it's likely the same brain areas are involved when people fall in love, but it may not only be these areas," says Liu.



YVA HOMATIUK AND JOHN EASTCOTT/MINDEN PICTURES

Vaginal bacteria hamper HIV drug

THE bacteria living in the vagina can influence how effective a medicated gel is at protecting against HIV.

The drug tenofovir is a mainstay of HIV treatment and prevention. When taken orally, it protects well against infection, but it works less well when applied to the vagina as a microbicidal gel.

The vaginas of healthy women are dominated by *Lactobacillus* bacteria, while the presence of other species, such as *Gardnerella vaginalis*, has been linked to bacterial vaginosis, a common

condition that causes abnormal discharge and odour.

Now Nichole Klatt at the University of Washington, Seattle, and her colleagues have found that the types of microorganisms living in the vagina are linked to how effective tenofovir gel is at protecting against HIV infection.

"It's a really serious effect," says Klatt, whose team analysed samples from a clinical trial. "We went from 60 per cent protection if you have good *Lactobacillus*, to 18 per cent if you have bad bacteria."

G. vaginalis seems to be the main culprit. It takes up tenofovir and chemically processes it at high rates, stopping the drug from entering the cells it is intended to protect (*Science*, DOI: 10.1126/science.aai9383).

The finding raises the question of whether the microbiome may help explain the different protective effects of oral PrEP, a preventative HIV procedure, in men and women. Men can skip the pill for a day or two, but to be protected, women are less likely to get away with missing a day's pill.

Super Jupiter is hottest planet ever

A NEW exoplanet is too hot to handle. It is so close to its star that surface temperatures hit more than 4300°C – making it almost as hot as the sun.

Twice the size of Jupiter, KELT-9b is likely to be tidally locked, with a scorching dayside always facing the star and a cooler nightside facing away. "The planet's dayside is going to glow a bright orange, and then on the nightside, it's going to be deep, dark red," says B. Scott Gaudi at Ohio State University. His team detected KELT-9b by observing the dip in light as the planet passed between us and its star, which is about 650 light years away (*Nature*, doi.org/b73g).

Most worlds orbiting hot stars like this one have no chance of being habitable, so researchers have focused on dimmer, cooler stars. The star's intense light and heat would evaporate the gas giant's atmosphere at a rate of up to 10 million tonnes per second, which may render the planet a naked core by the time its star expands and envelops it.

KELT-9b isn't heated from internal atomic fusion, so it will never be a star, but it's still hotter than most stars in the universe.



SURVIVALPHOTOS / ALAMY STOCK PHOTO

Tick's clinging power explained

HOW does a tick stick? It uses a foldable pad between its claws that can spread out like a fan and adhere to the smoothest of surfaces.

Ticks lie in wait on plants and leaf litter until they can latch on to a passing bird or animal. They then search their host for a suitable place to clamp down and suck blood.

To do all this, a tick needs legs that can grip a variety of surfaces and support the increase in body weight as it feeds – a female tick can swell to 135 times her initial size after a meal.

To work out how it's done, Dagmar Voigt and Stanislav Gorb at the

University of Kiel, Germany, looked at the legs of the castor bean tick (*Ixodes ricinus*) using a microscope. At the end of each leg is a pair of curved claws. But the researchers spotted something new: a pad made of three lobes held together by tiny plates that can mould to a surface and stick using inter-molecular forces (*Journal of Experimental Biology*, doi.org/b7zv).

"The common opinion about tick attachment was interlocking with their claws," says Voigt. "Our study finds proof of the adhesive properties of the pads on tick's feet."



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It's not the end of the world

Donald Trump's decision to turn his back on climate change means the rest of us have to pull together to save the planet, says **Catherine Brahic**

LAST week, US president Donald Trump declared "we're getting out" of the Paris climate agreement, swiftly followed by a pledge to begin negotiations to re-enter it on "better" terms.

The decision will unavoidably damage businesses and research in the US, as well as the health of its population and its international reputation. But how much damage will it inflict on global efforts to keep warming below 2°C? In short, has Trump doomed us all?

Current policies, including US targets set by the last president, Barack Obama, add up to a global temperature rise of 3.6°C. To bring that down to 2°C, global emissions must peak as soon as possible,

coal will remain expensive," says Niklas Höhne of the New Climate Institute in Cologne, Germany.

At the same time, the cost of renewable energy has been slashed, largely thanks to Chinese investment and development. As a result, emissions from industry and energy have held steady for three years in a row even as the global economy has continued to grow. To many, this signals the early stages of the long-awaited

transfer to a low-carbon economy. Suddenly, a global peaking of emissions by 2020 looks possible.

There is already movement towards a green economy in the US, despite Trump's announcement. In the last few weeks, major businesses, including General Electric and Exxon Mobil, have called on Trump to remain in the Paris Agreement. Google, Apple and Facebook have committed themselves to using

100 per cent renewable energy within the next few years. None of these elements are dependent on federal participation in the Paris Agreement.

"These are not tree-huggers. They are leading industrialists who have built some of the biggest companies in America," says Mindy Lubber of sustainability non-profit Ceres, based in Boston, Massachusetts.

US states and cities can also

"Trump will not be able to reverse coal's decline. Renewables will remain cheap and coal expensive"

ideally within the next three years, and cease entirely by 2070.

That's a tall order, but the energy sector and industry more generally have undergone a remarkable transformation in recent years. Best of all, much of it is happening on the international stage, independent of US federal decisions.

First, the dirtiest of fossil fuels – coal – is in decline, most notably in the US and China. As Trump is at pains to point out, the US coal industry is dying; most agree his best efforts are unlikely to reverse that. Coal-fired power stations around the world are being retired at unprecedented rates and in the last few years, the amount of coal mined globally has fallen.

"Trump will not be able to reverse these developments. Renewables will remain cheap and

XINHUA NEWS AGENCY/REX/SHUTTERSTOCK



Heading backwards

act without federal leadership. On 1 June, a clearly peeved governor of California, Jerry Brown, said: "Trump has absolutely made the wrong choice." Brown left no doubt that California – the second largest emitter of greenhouse gases in the US and the world's sixth largest economy – would pursue its aggressive policies to cut emissions. These include a cap and trade programme, energy efficiency targets and a goal to get 50 per cent of its energy from renewable sources by 2030.

"We're all in," said Brown, who, alongside the governors of New York and Washington states, announced the formation of the United States Climate Alliance, committing their states to upholding the Paris Agreement. Mayors of big cities across the US like Los Angeles and New York rushed to make similar statements.

Trump effect

So despite a shift in federal policy, action on the ground is likely to continue. "States and corporations have a lot of power – on the same order of magnitude as Trump I'd say," says Höhne. Judging from the anger that was being expressed last week, it is possible Trump's decision will backfire and end up galvanising more climate action.

Trump's past statements have already spurred China into action. Once a reluctant actor on the environmental stage, China has been far more forthcoming about its intentions to cut emissions since the US election in November. Last week, during an official visit to Germany, Chinese premier Li Keqiang confirmed his nation's commitment to the Paris Agreement and to working with other nations to combat climate change.

So progress will continue both in the US and internationally. "That's not to say Trump's decision is not going to be a problem – it will throw obstacles into the process. How that plays

WE'LL ALWAYS HAVE PARIS?

While Donald Trump has made it clear that he wants the US to leave the Paris climate agreement (see main story), the reality is that pulling out can't happen any time soon.

That's because back in 2015, when the deal was brokered, world leaders, including then US president Barack Obama, were only too aware of the country's track record with UN climate deals: the US signed the Kyoto Protocol in 1997, but George W. Bush dropped out in 2001 and Congress never ratified it. Keen to avoid a rerun, the Paris Agreement was engineered so the US could ratify it without a vote in Congress. There is also a clause that says any nation wishing to withdraw can only formally express its intent to do so three years after the agreement

out quantitatively is difficult to say," says David Waskow of the World Resources Institute in Washington DC.

Remember that global emissions need to hit zero by 2070. The world is still emitting 40 gigatonnes of carbon dioxide each year and the US is the second largest emitter. Each year, it releases 1.5 gigatonnes of CO₂ that will stay in the atmosphere for hundreds to thousands of years. Zero global emissions isn't possible without it on board.

More renewables and less coal is great, but it's not enough. Coal is still responsible for around 40 per cent of the global energy mix. We also need to eliminate gas and oil, find a way to fly and ship goods without burning any fossil fuels, and feed 9 billion people without emitting vast quantities of CO₂ and methane.

In practical terms, that means a massive acceleration of the move towards renewables. We need to rebuild electricity grids to accommodate them, re-think how we price them so they can outcompete fossil fuels, and come up with cheap solutions to store vast quantities of electricity.

We also need to find new fuels for aviation and shipping, and, in

entered into force, and the withdrawal process would then take another year. None of this was accidental.

If he wishes, President Trump can present himself to the UN on 5 November 2019 and make a formal declaration of his desire to leave the Paris Agreement on 5 November 2020 – which just happens to be two days after the next US presidential election. Some hope that by that time, China, India and European countries will have made so much money from the new green economy that he will be less inclined to do so. Or maybe mid-term elections will have changed his mind. Or maybe he will have been impeached.

To some extent, these are all technicalities. In practical terms,

all likelihood, rethink the West's meat-heavy diets. There's no denying that all this is helped by strong political incentives. Although the reaction to Trump's decision shows the will is still there, his administration may slow things down.

The timing of the US pull-out is particularly bad. Waskow says there's enough momentum in the US system to keep the low-carbon ball rolling until about 2025, by which time the US will have a new president. But as global emissions need to be in a downward spiral by 2025, the next few years are going

"Despite a shift in US federal policy, action on the ground is likely to continue"

to be critical for accelerating action after 2020 – something Trump is unlikely to prioritise. The terms of the Paris Agreement mean the earliest any nation can formally leave is 5 November 2020 (see "We'll always have Paris?", above), but that won't prevent US inaction.

And then there's money. Under the Paris Agreement's Green Climate Fund, wealthy developed nations have promised billions in

a US president can do whatever they want within their own borders. Paris commitments were always voluntary. The UN doesn't have the power to force any government to take action at home. In other words, Trump's decision is more political grandstanding than anything else.

What about renegotiating better terms? Christina Figueres, head of the UN climate talks, practically laughed at the notion last Thursday. After leaving the agreement in 2020, the US, perhaps with a new administration, could ask to re-enter it. "But you cannot renegotiate individually," said Figueres. "This is a multilateral agreement. That's why it took six years. No one country can unilaterally renegotiate."

finance for developing nations that will experience the worst impacts of climate change. The US promised \$3 billion. On 1 June, Trump was adamant that this was a bad deal for the US. Last year, the country paid \$1 billion into the fund. The remaining \$2 billion is unlikely to materialise.

China seems likely to stay the course, but changes to the Green Climate Fund could rub smaller developing nations the wrong way. "Unfortunately, I think negotiations will be injected with a dose of acrimony," said Christina Figueres, head of the UN climate talks, last Thursday.

Just how much hotter the world will get as a result of the US pull-out is difficult to predict, but pessimists will point out that even a fraction of a degree could matter if it pushes us past irreversible tipping points. To avert that, we are now probably a little more likely to reach for geoengineering, large-scale interventions in the world's climate systems.

With Trump in the White House, there's really only one option on the table: to work around him. If anything, this week has shown how anger and dismay will shift political alliances to do just that. ■

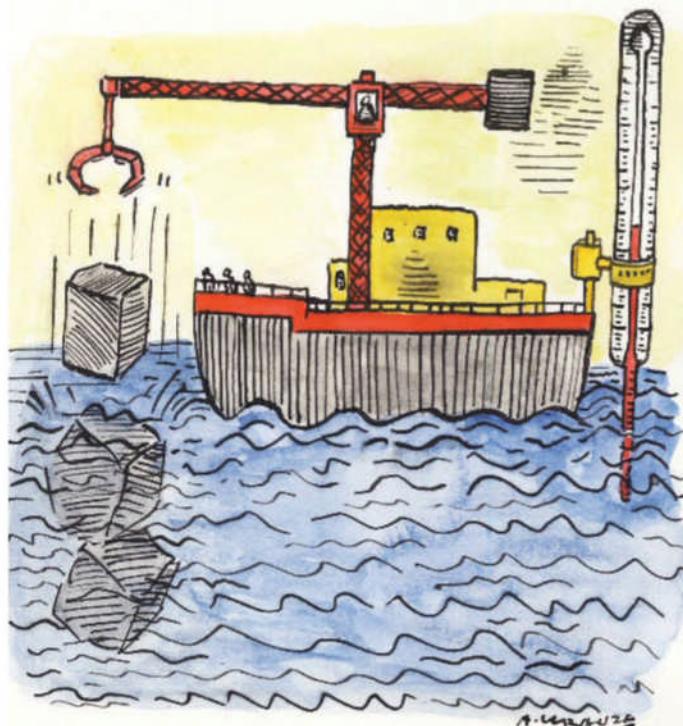
Making waves

Talk of dumping iron into seas off Chile to boost plankton is a return of a controversial idea that warrants scrutiny, says **Olive Heffernan**

TEN tonnes of iron dust will be dumped into the sea off Chile if a Canadian team gets its way. The non-profit Oceaneos Marine Research Foundation aims to use “ocean seeding” to replenish nutrients vital for phytoplankton growth, boosting the food chain in a bid to revive fish stocks.

This has clear appeal. Globally, fisheries are in dire straits and could be exhausted by 2048. Chile is a case in point – most of its big fisheries have been decimated.

But the Canadian proposal has sparked concern among some scientists sceptical of the benefits and worried about other possible implications. In particular, they are concerned that such trials could set the scene for something far more elaborate and potentially profitable – the showcasing of seeding as a means of slowing climate change, with the know-how largely in private hands.



The idea that ocean seeding could cool the planet by removing carbon dioxide from the air isn’t new. It was first proposed in 1998 by US biochemist John Martin who said: “Give me half a tanker of iron, and I’ll give you an ice age.”

His idea was that plankton blooms would suck carbon out of the atmosphere as they grew. Once dead, the plankton sink to the ocean floor, burying that carbon for centuries.

Since 1990, at least 12 open-ocean trials have collectively shown that – as a concept – this has merit; one five-week test in the Southern Ocean triggered a large bloom, at least half of which sank below 1000 metres to the seabed. But the fear that we will end up nourishing deadly toxic algal blooms or trigger some other unintended outcome led the UN to ban commercial ocean fertilisation in 2008. Only non-

A star turn

NASA is right to rip up the rule book and pay homage to the living, says **Geraint Lewis**

TRADITION has been broken. NASA last week named one of its missions, a sun-skimming spacecraft, after a living scientist for the first time.

The Parker Solar Probe honours Eugene Parker, a retired US astrophysicist about to turn 90 years old. Earlier examples – Hubble, Planck,

Fermi and Chandrasekhar – have all been named posthumously.

“We are about to make history,” said Thomas Zurbuchen of NASA’s science mission directorate, ahead of the announcement.

You’ve probably never heard of Parker, but he is a stellar choice. His work focused on the solar corona, the tenuous outer atmosphere of

the sun. Unlike the relatively balmy solar surface, which is a mere 6000 °C, the corona roars at a few million degrees. But what gives it the energy to be so much hotter than the surface?

Astronomers have long suspected that the sun’s powerful magnetic fields play a part, but the precise mechanism remains mysterious. In the 1980s, Parker suggested that the culprit may be “nano-flares” – intense magnetic bursts popping off all over the

“It is easy to see why tradition honours science’s dead greats, but why not honour the living too?”

sun’s surface and dumping energy into the corona. Such nano-flares are smaller versions of the immense solar flares that can reach Earth and fry our electronics and knock out satellites.

NASA’s probe will search for evidence of these, and examine the origin of the solar wind, a phenomenon Parker theorised in the 1950s in the face of much scepticism. His thinking on that was vindicated and he was hailed a hero. So when the spacecraft’s first close encounter with the sun happens in 2024, it will be the crowning glory of a highly productive career. That will be the first in a series of passes to within

commercial small-scale seeding for research purposes is allowed.

The Chile trial fits this bill. The backlash comes, in part, because of the legacy of a similar scheme by a different organisation in 2012 off British Columbia, Canada. In that case, there was no firm evidence of benefits to the salmon population it was hoping to revive, or to the Haida community that helped fund it. And it was a commercial project in open ocean despite the moratorium.

In a previous incarnation, the organisation behind the Chile proposal sought to present seeding as a means to remove carbon from the atmosphere, a technology it applied to patent. What's more, the new plans are opaque, with the details of compounds and methods not yet spelled out.

Given the pace of climate change, maybe we'll have to turn to geoengineering, be it seeding oceans or deflecting the sun's rays. While neither is desirable, to choose the best course of action, research will be vital.

It's also vital that any trials that inform geoengineering – whether intended for this or not – are done for the public good. ■

Olive Heffernan is a freelance environment writer

six million kilometres of the surface of our star, travelling at several hundred kilometres per second, making it the fastest object ever launched. Reinforced instruments will sample the corona, revealing the secrets of one of the harshest places in the solar system.

Could this be the start of a new trend in honouring living scientists in mission naming? It is easy to see why tradition honours science's dead greats, but why not recognise the living too? ■

Geraint Lewis is a professor of astrophysics at the University of Sydney, Australia

INSIGHT Political adverts



Feeling targeted?

We need transparency over dark social ads

Matt Reynolds

A shadowy battle is being fought in the Facebook feeds of UK voters. Political parties are using the online giant's wealth of data on its users to send precisely targeted adverts that they hope will swing this week's general election. But there is little clarity about what the ads are saying.

These "dark ads" allow political parties to tailor a message to pop up only in the newsfeeds of specific audiences, leaving non-targeted people unaware. These ads don't appear publicly anywhere, which is raising concerns about their content.

"It's fundamental to a healthy democracy that claims and promises made by candidates and parties before an election should be open to scrutiny and challenge. Dark ads made over closed social media platforms are not," says Martin Moore of the Centre for the Study of Media, Communication and Power at King's College London.

There is no indication that parties are using these ads to mislead voters, but without seeing what's in them, it is impossible to know. During the Brexit vote last year, the Vote Leave

campaign was criticised for its inaccurate claim that the UK sends £350 million to the European Union every week, but this claim was plastered on the side of a bus for all to see. What goes on in personalised newsfeeds is another matter entirely.

A small group of online vigilantes aims to find out what's in the messages. Who Targets Me? is a browser extension that extracts every political advert that 6000 volunteers stumble across in their Facebook feeds.

"We've tracked over 1100 versions of the same message from the Liberal Democrats alone," says Louis Knight-

"These ads allow parties to tailor a message to appear only in the Facebook feeds of specific people"

Webb, co-founder of the project. Some adverts targeted Facebook users more likely to be concerned by funding cuts to the military, while other people saw a similar ad about grammar schools.

Knight-Webb thinks there should be a public repository of these adverts so anyone can vet politicians' claims. It is also important that voters can poke

their heads out of their own filter bubbles and see what messages other people are being exposed to, he says.

Another way to shine a light on these messages would be to require parties to give more detail about their spending on social media campaigns. The Electoral Commission, which governs campaign spending, reports that UK parties spent £1.3 million on Facebook advertising during the 2015 election campaign, £1.2 million of which came from the Conservative party. But this doesn't tell us how that money was used or who was targeted.

And although Electoral Commission rules regulate the money that parties can spend during campaigns, social media advertising is blurring the lines between different types of spending. If a national Facebook advert campaign is targeted at people who are more likely to live in one area, is it local spending or national?

The Electoral Commission deals with who the parties give money to, not what that money is used for, says its spokesperson. It also doesn't vet the accuracy of political adverts. However, the Information Commissioner's Office, the UK body that protects data rights, has launched an investigation into the targeting of voters through social media.

To ensure there is clarity over the use of dark ads, the UK's electoral laws will need updating for the social media age. Until then, the electorate remains in the dark. ■



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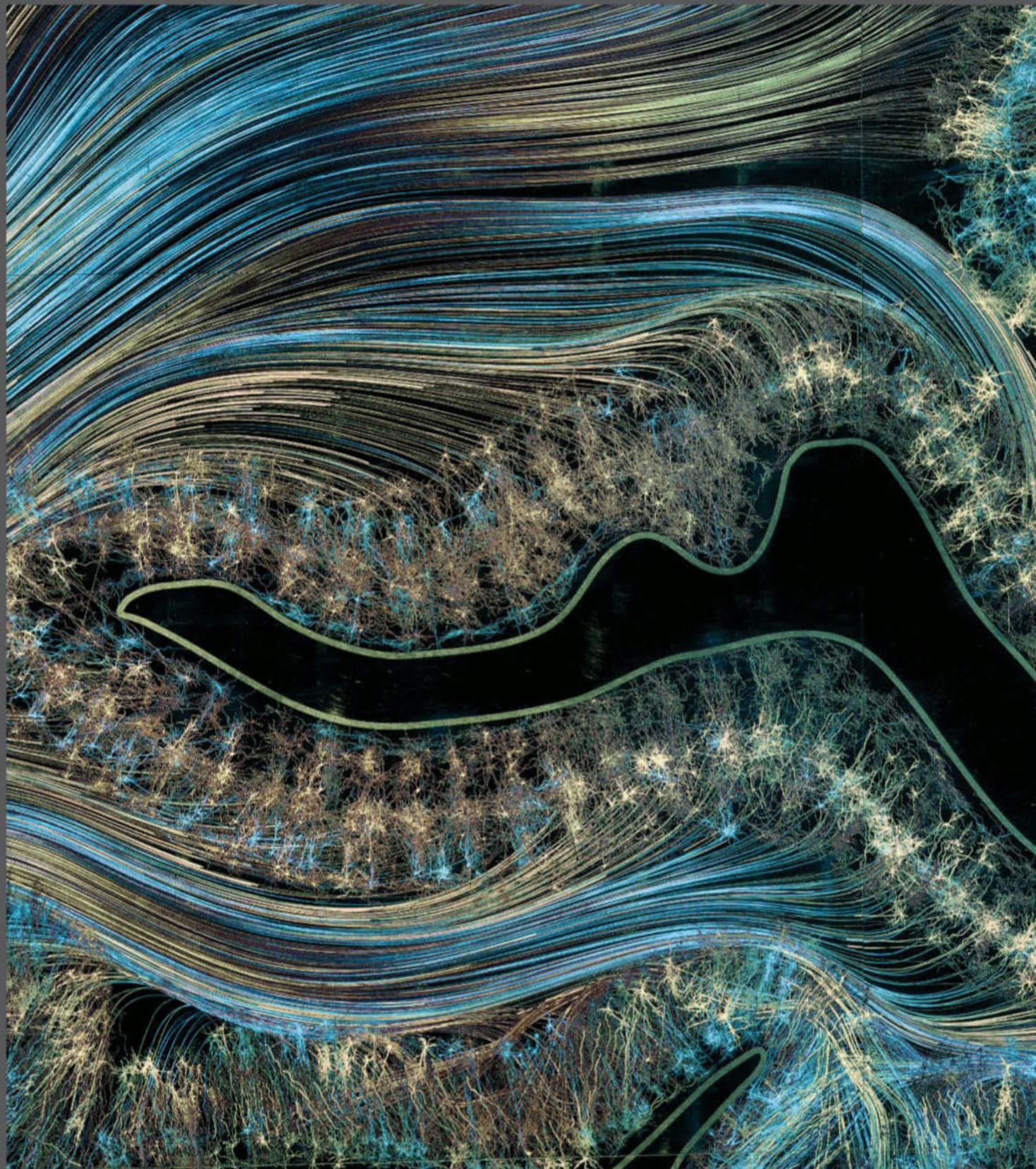
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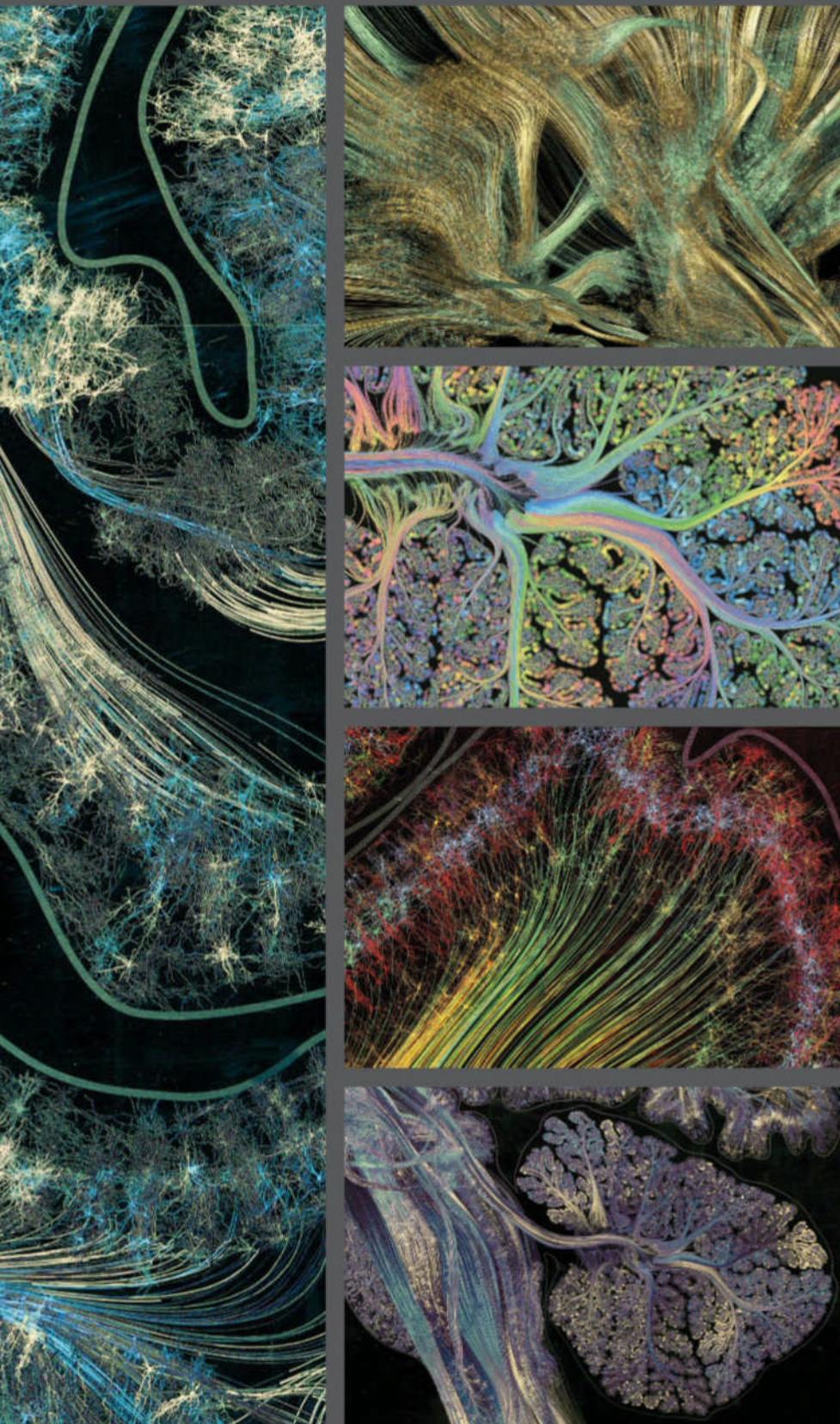
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Beautiful thoughts

THIS is what consciousness looks like – but these aren't brain scans. Neuroscientist-turned-artist Greg Dunn created the art, aided by artist and physicist Brian Edwards, largely by hand, and using a special etching technique. "The piece was designed to be an unprecedented image of the brain," says Dunn of his project, titled *Self Reflected*.

The main image depicts the visual cortex. The others show, from the top: the thalamus and basal ganglia (which govern our senses, movement and decision-making), the cerebellum (which oversees movement and proprioception – an awareness of one's own body), the parietal gyrus (which integrates movement and vision) and the brainstem and cerebellum (which handle movement and proprioception plus basic functions such as breathing).

To create the artworks, Dunn first collected reams of information on the human brain, including scans and detailed depictions of neurons, and how they connect to each other. He used these as inspiration for hand drawings on transparent sheets.

Working with Edwards, Dunn fed these drawings through a computer model that mimics how neurons communicate with each other, simulating the movement of signals throughout the brain. The pair then printed the resulting patterns using a technique that etches layers of gold leaf.

As a result, the images appear to come to life as light moves across them, highlighting different layers of neurons and the flow of information between them. "We're demonstrating the depth and breadth of neural activity that allows us to go about our existence," says Dunn. Jessica Hamzelou

Artists

Greg Dunn and Brian Edwards

gregadunn.com

Self Reflected (details), 22K gilded microetching, 96" X 130", 2014–2016

THE ~~H~~**BIG**^{HS} BANG



Did the mass-giving particle make the universe too, asks Jon Cartwright

THEY say it started with a bang, but in truth it misfired. The universe began as a hot speck of energy and, for an instant, remained just that. Then it blew up: from this initial seed, trillions upon trillions of times smaller than an atom, everything suddenly ballooned into the gargantuan proportions of a Tic Tac. In a mere fraction of a second, the universe expanded by nearly as many orders of magnitude as it would in the following 13.8 billion years.

Believe it or not, this burst of cosmological inflation, followed by a slower, tamer expansion, is the most sensible way to explain how the universe looks today. But there's something missing: what did the inflating?

The answer could be everywhere, and right under our noses. When a long-sought particle finally appeared a few years back, it seemed to close a chapter in physics without giving any clue about what happens next. Read between the lines, though, as some theorists recently have, and you see that the famous Higgs boson – the particle that gives mass, or inertia, to all other particles – might have an explosive secret. "If the Higgs gives inertia to particles," says Juan García-Bellido at the Autonomous University of Madrid, "can it give inertia to the entire universe?"

Inflation wasn't always in our cosmological story. For a long time, theorists assumed that the universe expanded steadily from the start,

with no sudden burst. This was driven by the natural desire of energy to spread itself in all directions.

Yet something about this picture didn't quite ring true. Look at large enough scales, and the stars, galaxies and other structures in the universe don't appear to be scattered randomly; even matter at opposite ends of the universe seems to be distributed in the same pattern of webs and clusters wherever you look, almost as if some interaction evened them out as the universe expanded. But that's impossible. Something would have had to travel faster than the speed of light between these distant points – a serious physics no-no.

Explosive urge

Inflation, first proposed by Alan Guth at the Massachusetts Institute of Technology and others in the early 1980s, offers a way out. The idea is that a minuscule fraction of the primordial cosmos ballooned exponentially in the blink of an eye. Tiny, short-lived quantum fluctuations that are always bubbling away in space-time got caught in the whirlwind expansion and amplified, becoming the seeds of the stars and galaxies we see today. The patterns didn't evolve – they were there from the start.

There are plenty of other reasons to like inflation, but they don't change the fact that we haven't got a clue how it happened. Cosmologists suppose there must be an "inflaton", an energy field with dynamite properties. But what and where is it?

We have an idea about what to look for: the inflaton must be a scalar field. This is just a mathematical way of describing a field that

acts in all directions but whose strength can change over space and time. One way to think about it is like a weather map of air pressure. Air pressure varies depending on the location and day of the forecast, but unlike wind strength, say, it is directionless.

What we are searching for, then, is an invisible fluid-like substance, one that suffuses all of space and has the potential to influence everything in it. Or at least it did. The inflaton field must have generated something akin to extreme antigravity – a cosmic urge that blew up the fabric of space-time – but then quickly lost its impetus, to the point at which its influence essentially disappeared and normal expansion resumed.

In principle, there is nothing stopping us from tracking an invisible energy field that has lain low for 13.8 billion years. Particle physicists can isolate a little pocket of a field, otherwise known as a particle, by smashing other particles together to generate a momentary flash of energy. We discovered some of the most elusive fundamental particles, such as the quarks, in this way. But those particles are not associated with scalar fields. And in the decades following the proposal of inflation, our best particle colliders failed to find anything that was.

Then, in 2012, a fundamental scalar particle finally showed up: the Higgs boson. Discovered at the Large Hadron Collider (LHC) at CERN on the France-Switzerland border, the Higgs had long been predicted as the particle that endows all others with mass. Finding it was a momentous triumph.

As the world celebrated, however, a handful of theorists saw the arrival of the Higgs in a different light. Two of these were Fedor

Bezrukov and Mikhail Shaposhnikov at the Swiss Federal Institute of Technology in Lausanne (EPFL). Having anticipated the Higgs discovery for several years, they had begun to consider what attributes it might have besides the gift of mass-giving.

On the face of it, the Higgs and the inflaton are different in a crucial way. Although both are scalar fields, unlike the inflaton, some of

"A supercharged Higgs would flood the universe with extreme antigravity"

the Higgs field remains when it falls into its lowest energy state. It is precisely this sticky residue that manifests as the property of mass for other fundamental particles. But that is in today's universe. Bezrukov and Shaposhnikov realised that it is possible to tweak the properties of the Higgs field so that in the moment following the big bang, it could have mustered enough force to flood the still-minuscule cosmos with inflationary gusto.

They fiddled with the Higgs's "potential curve" – essentially the energy a particle needs in order to have a certain effect, such as bestowing mass on other particles. Picture this as a ball on a steep-sided hill. For most particles, when the background energy is low, the ball comes to rest in the valley. The particle's location determines its effect, and right in the middle of the valley the effect is "zero", meaning the particle is essentially switched off.

The Higgs is special, however, in that its potential curve is shaped not like a typical valley, but like the bottom of a champagne bottle, with a bump in the middle (see

"Potentially suspect", opposite). Given that it would take energy to push the ball up that central bump, when background energy is low, the Higgs comes to rest in the valley to one side, where it turns "on". This is how the Higgs has the effect of giving mass to other particles, even when its field has no external energy to fuel it.

Bezrukov and Shaposhnikov spotted that there was nothing in known Higgs behaviour to stop them from adjusting the sides of its potential curve. What if, at some point high up on the curve, those steep sides flattened out somewhat? If the ball was hoisted up there for a brief time, the Higgs could sit in a supercharged "on" state, where it would flood the universe with extreme antigravity, enough to drive apart space-time itself.

Unexpected accomplice

True, it would require a hefty shot of energy to scale the sides in the first place. But there was an awful lot of background energy around at time-zero (*Physics Letters B*, vol 659, p 703). "The Higgs can make the universe expand," says Bezrukov, now at the University of Manchester, UK. "It could be the inflaton."

Finding out for sure would require a test of the particle's interaction with gravity: if the Higgs interacts strongly with gravity, then the sides of the potential curve might be flattened out as the researchers propose. Unfortunately, gravity is too weak on Earth for that to be measured at the LHC, so collider data alone can't tell us whether the Higgs potential has inflaton-capable flattened sides.

For García-Bellido, the tidiness of the Higgs explaining both the origin of mass and inflation was too hard to resist. But the more he thought about it, the less tidy things



HENRIK SØRENSEN/GETTY

Pop went the universe, but what blew it up?

WHY ANYTHING AT ALL EXISTS

Inflation isn't the only outstanding mystery of the early universe. The big bang created equal amounts of matter and antimatter. These two annihilate each other whenever they meet, which means they should have wiped each other out almost immediately, leaving the universe devoid of anything to form stars and planets and life. Needless to say, we're here, so something tipped the balance.

According to Alexander Kusenko at the University of California, Los Angeles, and others, that something could be the Higgs boson, the particle and associated field that gives other particles mass. Our best measurements of the mass of the Higgs itself suggest its field could have been much stronger during cosmological inflation, when the early universe ballooned (see main story) before settling down to the value

we find today. As it relaxed after inflation, the Higgs's changing value could distinguish between particles and antiparticles, creating favourable conditions for matter to win out.

But the Higgs would need a little help from a friend – a heavy "Majorana" neutrino that boasts the unusual quality of being its own antiparticle. Kusenko and his colleagues suggest that these two-faced particles might have provided a route through

which antimatter particles could convert to matter once the shifting Higgs value favours the latter (*Physics Review Letters*, vol 114, p 061302).

It's an appealing idea, but of course there's a catch: no one has ever seen a heavy Majorana neutrino. Then again, observed masses of known neutrinos do seem to point to their existence, and the search is ongoing at several dedicated neutrino experiments.



(*Physical Review D*, vol 84, p 123504). “That’s the beauty of this model,” says García-Bellido.

“First it solves inflation; second, the accelerated expansion of the universe. It’s extremely economical.”

The name of the new particle, the dilaton, reflects its close entwinement with Higgs physics. Specifically, it would prevent the Higgs’s mass from “dilating” too much – useful because without it we don’t have much of a clue why the Higgs mass has the value it does. So although the dilaton itself would be massless, it would be an influential background operator, fixing the mass of the Higgs and, by extension, all other fundamental particles. Dark energy would be its biggest footprint in the universe.

Bold claims indeed. Alas, not everyone is won over. Veronica Sanz at the University of Sussex, UK, thinks that the Higgs as mass-giver and inflaton is too contrived. Instead, she backs the possibility that the Higgs and the inflaton are part of a whole new family of scalar particles that we have barely begun to uncover. All other known particles reside in families, she says, so why should the Higgs be the only scalar particle?

If Sanz is right, the Higgs would be a mere spectator in the early universe, but it would be influenced by its sibling, the inflaton, and that would show up in Higgs data from the LHC. Sanz says she prefers that idea because it is easier to test with current colliders than that proposed by García-Bellido and his colleagues. “In cosmology, there’s always a plethora of ideas that are hard to tell apart experimentally,” she adds. “I don’t like that.”

It’s a fair point: the LHC alone can’t rule out the Higgs-dilaton model, because the dilaton would hardly interact with other particles. But to see if the Higgs has what it takes to put the bang into the big bang, García-Bellido is not relying on the LHC. Instead, he will stare into the distance to study the afterglow of the big

seemed. In 2011, working with Shaposhnikov and others, García-Bellido realised that the mathematical tweaking of the Higgs potential created an imbalance in the underlying equations, one that could only be remedied by a second scalar particle. This was a surprise, but not necessarily an unwelcome one.

Since the late 1990s, astronomers have known that the universe’s current expansion is accelerating. They suggested that some unknown source of energy is behind the acceleration, and modern observations indicate that it must account for more than two-thirds of all the energy in the universe. The only problem is that no one knows what this so-called dark energy is.

Handy, then, that the new particle inferred by García-Bellido and his colleagues could have just what it takes to solve this mystery too. It wouldn’t be nearly as burly as the Higgs, but according to the team’s calculations, its field would be present in small quantities throughout the lifetime of the universe, providing just the right boost to expansion

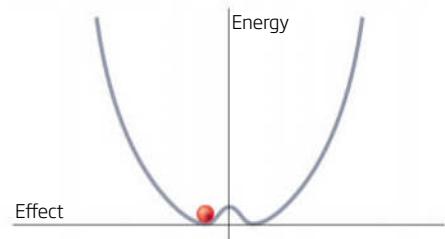
This new particle happens to have just what it takes to solve dark energy too”

bang, the cosmic microwave background.

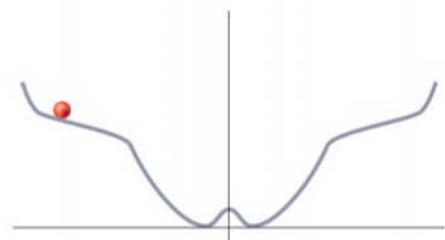
The smoking gun for an inflationary Higgs would be a particular twist in the polarisation of this ancient light. The presence of a dilaton field would be trickier to spot, but not impossible. García-Bellido thinks it should have left a mark in any gravitational waves that imprinted themselves on the background after the tumult of inflation. Broadly speaking,

Potentially suspect

The Higgs boson might have driven cosmic inflation, when the early universe ballooned. It depends on the Higgs’ potential curve, which describes the energy a particle or field needs to produce a certain effect



The bottom of the Higgs’ potential curve is shaped like the base of a champagne bottle, so even when background energy is low, as it is today, the particle sits in a position that means it gives other particles mass



But if the Higgs’ potential flattens out at the sides, when there is more background energy, as there was in the earliest moments of the universe, its field can be supercharged. This could have generated enough antigravity to drive cosmic inflation

that means making precise measurements of differences in the levels of microwaves coming from various directions in space.

Currently, the best picture we have of the microwave background is that recorded by the European Space Agency’s Planck spacecraft in 2013. There wasn’t quite enough detail for García-Bellido’s purposes, but a raft of new instruments ought to do the trick. They include the Simons Observatory, under development in the Atacama Desert in Chile, Japan’s forthcoming LiteBIRD satellite and the latest BICEP/Keck telescope at the South Pole.

We will have to be patient. The Simons Observatory will only begin studying the heavens in the next few years, while LiteBIRD is not due for launch until the 2020s. For García-Bellido, however, that is not long to wait to solve two of the greatest mysteries of cosmology in one fell swoop. “We’re on the verge of a breakthrough,” he says. ■

Jon Cartwright is a freelance journalist based in Bristol, UK

Something in the air

From scented candles to cleaning products, our lives have become fragranced like never before. What's the effect on our health, asks Clare Pain

KATE Grenville realised in her early 30s that wearing perfume gave her a headache. She could manage that. Then it was other people's perfumes too. But things really got out of hand on a recent trip when she was forced to ask her taxi driver to remove the air freshener in his cab, and later caught herself sealing her hotel room door with tape to keep out the smell from corridor fragrance diffusers.

"I had a nasty feeling that I'd just crossed one of life's little boundaries," she writes in her new book *The Case Against Fragrance*. "It was possible I'd joined the section of humanity that thinks the moon landings were faked by the CIA."

In fact, when Grenville started investigating, she found she was far from belonging to such a clique. Surveys suggest that many of us feel negative health effects from fragrances, and if recent headlines are to be believed, our love of a good spritz could be causing asthma, migraines and even cancer. The issue is causing such a stink that some compare it to passive smoking, and are calling for scent-free workplaces and schools.

"The results are stunning and consistent. In Australia, a third of the population, and in America, over a third of the population, report one or more types of health problems when exposed to fragranced consumer products," says Anne Steinemann of the University of Melbourne.

So how worried should we be? Are scented products making people sick, and what should we do about it?

Fragranced goods haven't always been so ubiquitous. Prized by the ancient Egyptians and Romans, fragrances started off as luxuries, made from plant extracts and,

in the case of musk, animal gland secretions. But these natural products were expensive and hard to come by. From the late 19th century, advances in industrial chemistry meant that synthetic scents could be developed that were much cheaper and more varied. The fragrance industry boomed.

The final step was a marketing push that saw perfumes move from personal care to everyday household products. Advertisers told us things were only truly clean if they also smelled good – our kitchen surfaces, toilets and laundry all gradually came to smell of lemon and pine. Humans have never been as exposed to synthetic fragrance chemicals as they are today.

Secret scents

This raises questions around what chemicals go into scented products and whether they are safe. But it is hard to know what's in these goods. Global fragrance is big business and the ingredients are trade secrets. In the US, Canada and Australia, scent ingredients don't have to be declared – they can instead just be labelled as a "fragrance" or "parfum". Rules are stricter in the European Union, where the 26 chemicals most likely to cause skin reactions must be named.

The onus, then, is on manufacturers to ensure their scented products are safe, rather than requiring every ingredient to be approved by a regulatory authority. One way the industry seeks to do this is through the Research Institute for Fragrance Materials, a US-based body funded largely by companies involved with fragrance or scented products. The RIFM researches the safety of fragrance ingredients and its findings are reviewed by ➤



MORGAN SCHWEITZER



an independent panel of experts. But that doesn't solve the problem. "No law requires disclosure of all chemicals in a fragranced consumer product," Steinemann says, "and even if we did have a list of all the chemicals, how would a consumer assess safety?"

The issue is further complicated because the chemicals used readily react with ozone in

"The message has been twisted into 'scented candles give you cancer'"

the air to create new, secondary compounds, and that affects our indoor environments.

"I notice when I go to the supermarket almost everything smells now. You can even buy scented toilet paper. It's bizarre," says Richard Corsi, who studies indoor air quality at the University of Texas at Austin. "There certainly has been a big increase and that's transformed the nature of buildings. That's made buildings more chemically reactive."

If ozone in the air mixes with these scenting agents, "you get bursts of literally hundreds of chemical products that come out of the reactions", says Corsi. "There's a huge question mark as to whether the products of the reactions – what they are transformed into – are harmful to us," he says.

This reactivity is the basis of many cancer claims made about scented products. The key concern is that when they react with ozone, some of the chemicals in fragrances produce formaldehyde. At high exposures formaldehyde is carcinogenic and can also cause eye and airways irritation.

Last year, one piece of research was the focus of numerous articles making the cancer claim. The study, carried out by the BBC in collaboration with Alastair Lewis, who studies atmospheric chemistry at the University of York, UK, found high levels of limonene, which is responsible for citrus scent, in a number of homes. Limonene is one chemical that reacts with ozone to create formaldehyde.

But the media overhyped the findings, says Lewis. "We raised this as something worthy of further study," he says. "Of course that message has been twisted into 'scented products give you cancer', which is not what we were saying at all."

Corsi agrees that more needs to be done to understand what reactions are taking place in our homes as a result of perfumed products and how this impacts on our health, but says we shouldn't be overly worried about

formaldehyde. "Generally, the amount of formaldehyde that's formed is pretty tiny compared to other sources of formaldehyde in the house," he says.

Formaldehyde in buildings tends to come from wood and furnishings, agrees Peder Wolkoff, at the National Research Centre for the Working Environment in Copenhagen, Denmark. And most Western homes and offices fall well under the limit set by the WHO, he says.

New, large-scale projects are underway to properly probe the chemistry of our indoor environments, but until those results are in, it seems the most far-fetched headlines are just that.

"The majority of fragrance molecules are present in such low concentrations that, apart from things like sensitisation and migraine headaches, the likelihood of them causing cancer or endocrine disruption is very low," says Ian Musgrave, a toxicologist and pharmacologist at the University of Adelaide, Australia.

But that doesn't mean there aren't other effects. Steinemann has conducted surveys of the health effects of exposure to perfumed products. In one study of more than 1000 people in the US, over a third of respondents reported problems, including migraines, skin reactions and respiratory difficulties such as asthma attacks when exposed to fragranced products. Steinemann has found similar reported health impacts in Australia, and expects to publish a UK study

OVERWHELMING REACTION

Around one in 300 people have such a strong response to smells that they are often driven into isolation. Known as multiple chemical sensitivity (MCS), the condition is controversial within the medical profession. "There is no pattern connecting symptoms to the exposure," says Jesper Elberling of Gentofte hospital in Denmark, who studies MCS. One person may react to a perfume with a throat problem and headache, while another will say the same perfume produces itchy eyes and exhaustion.

Elberling thinks MCS is similar to a chronic pain condition in that it has a neurological component, and that the brains of those affected overreact to smells.



this year with comparable findings.

One problem with Steinemann's studies is that they are self-reported. "Her work involves talking to people in short interviews, and just by raising the issue of adverse effects, you are negatively biased," says Wolkoff.

There may still be cause for concern, however. "Even if we don't have good, robust experiments with large numbers of people, it certainly seems that some fraction of the population is sensitive to breathing these chemicals," says Corsi.

One possible cause is the sense of chemesthesia, which is responsible for the tingly, hot sensation you get from spicy food. Most food flavours are transmitted to the brain as smells, but this spicy sensation triggered by chilli peppers, garlic and wasabi instead acts on the brain via the trigeminal nerve.

High concentrations of fragrance chemicals in the air can trigger this irritant system in the nose, throat and airways. "As far as we know, any odour can also be an irritant at sufficient concentration, so just about anything people can smell could in theory irritate," says Paul Wise at the Monell Chemical Senses Center in Philadelphia, Pennsylvania. The sensation produced "can be anything from a low-level kind of warming or prickling sensation all the way up to something stinging and frankly painful," he says.

For most people the concentrations in scents would be too low to irritate, but some people may be more sensitive, says

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No perfume in my hairspray, please!

MARTIN PARR/MAGNUM PHOTOS

Wise, although little is known about the range of irritation thresholds in the normal population.

As well as general irritation, chemesthesia may also be involved in reported cases of smell-induced migraine. Depending on the country, between 10 and 14 per cent of Steinemann's respondents reported migraine headaches after exposure to scents. Some people who experience migraines say perfumes are a trigger and many find smells unpleasant during an attack, a phenomenon called osmophobia. A study of those who get migraines found that 86 per cent report osmophobia during one.

It's also possible to trigger migraines using smell. In another study, people susceptible to migraine were exposed to a floral scent for a minute. More than a third developed a headache within an average of 2 hours and 7 per cent reported no headache, but did feel nauseous, which is a migraine symptom.

One theory is that people who get migraines may have normal sensitivity to smell, but an abnormally sensitive sense of chemesthesia. The trigeminal nerve is known to play a role in migraine.

But there's another explanation, according to Peter Goadsby, a neurologist at King's College London who specialises in migraine. He points out that osmophobia can be present in the premonitory phase that comes hours before a headache, a phase many people don't even notice.

This poses a problem when it comes to

assessing the effect of perfumes, he says. "They could be a chemical trigger – or it could be that if you are sensitive to smells you notice a perfume in the premonitory phase, and then when 3 hours later you get a headache you think the smell must have triggered the attack, whereas it was going to happen anyway," he says.

When it comes to asthma, the findings are also mixed. About 8 per cent of Steinemann's respondents said fragrances triggered their asthma, and other research has found that 10 per cent of people with asthma cite fragrances as a trigger. But few experiments have examined possible links between fragrance and asthma, and those that have don't show an effect.

"There is no experimental evidence to support [the idea] that people get asthma or exacerbated asthma from exposure to fragrances," says Wolkoff. He suspects psychology is at work instead.

A big problem with experiments that expose people to fragrances is that blinding is virtually impossible: the subject knows they are smelling a scent and this may affect their response.

But there are ways around this. Pamela Dalton, a psychologist at Monell Chemical Senses Center in Pennsylvania, who studies psychological aspects of odour perception, recruited 17 people with moderate asthma. She told around half that they would be exposed to a fragrance that could make their condition worse. The rest were told they would smell a scent that could be therapeutic. Both groups were then exposed to the same rose scent.

She expected those who were misled into thinking the scent could do harm to report



more symptoms, which indeed they did. "What we didn't expect was to see a true physiological change as we did with their exhaled nitric oxide levels, which is a measure of inflammation," says Dalton. Even 24 hours after exposure to the smells, levels of nitric oxide remained high. Dalton thinks the fear of the scent led to a physiological response and says that stress is known to exacerbate asthma.

These findings suggest it might not matter whether fragrances and the chemicals that make them actually do trigger effects like migraine and asthma – the consequences are none the less very real for those who experience them. Combine that with the question marks over the chemicals created

"The fear of a scent alone can lead to a physiological response"

by reactions between scented products and indoor air, and the fact that our noses are incredibly sensitive, and it's understandable that some might want to take action.

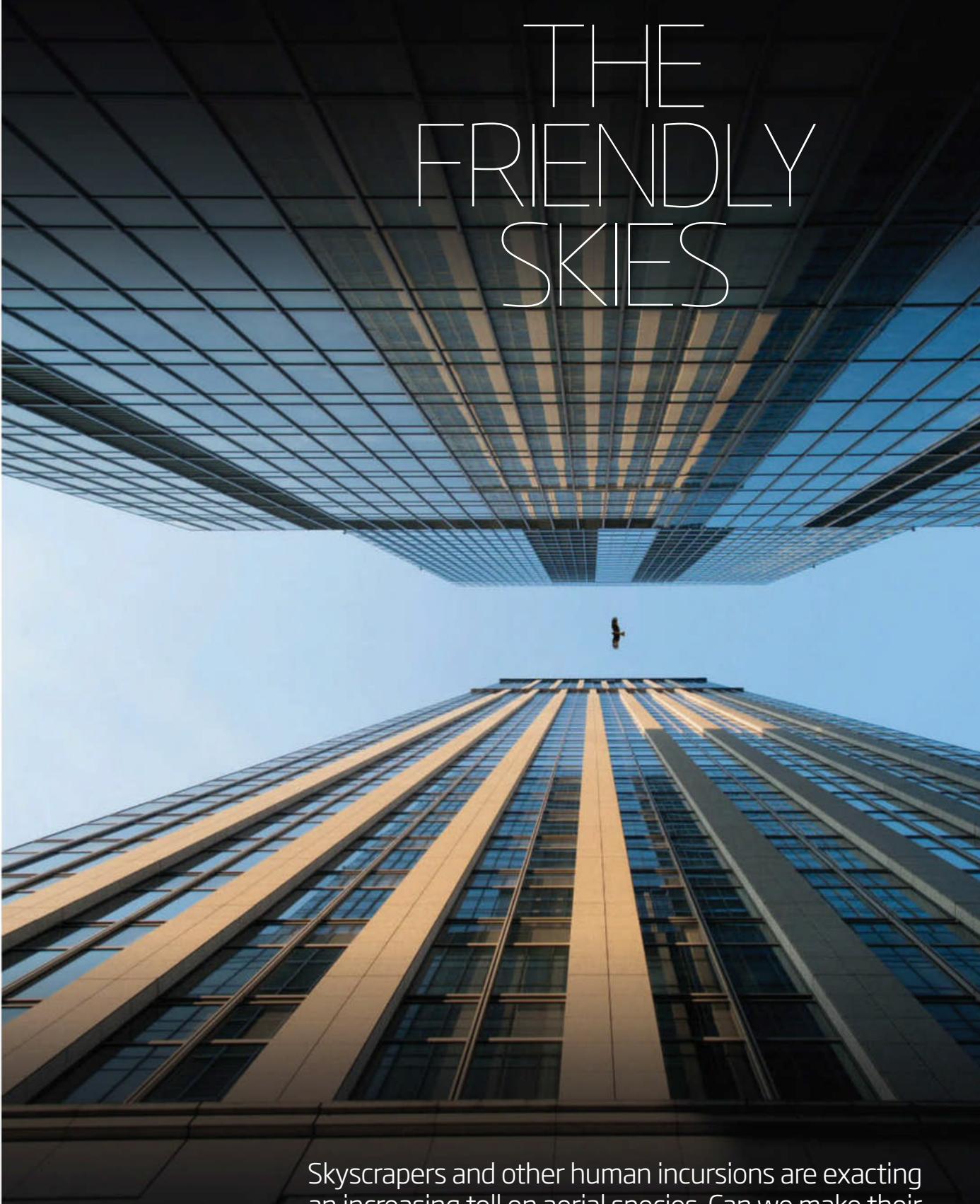
Increasing ventilation and using fragrances in moderation are sensible steps. A more radical solution is to go scent-free, an idea that is gaining ground.

In 2010, the city of Detroit was ordered to make all its workplaces fragrance-free and pay \$100,000 to one of its employees who suffered from a chemical sensitivity to scented products, which the court ruled was a disability. The US Centers for Disease Control and Prevention has a fragrance-free policy in all its offices.

This may not prove popular with all employees, but it can be effective. Corsi has been researching air pollution in Texan high schools, including some with a fragrance-free policy. "We do find that the schools that have aggressive no scent policies have much lower levels of these chemicals," he says.

So if you love scented sprays and feel that your essential oils really are just that, remember not everyone feels the same way – there might well be someone in the hotel room next to yours taping up the cracks under the door and wondering whether they've lost their senses. If someone tells you they have a problem, it's not to be sniffed at. ■

Clare Pain is a science and medical writer based in Sydney



THE FRIENDLY SKIES

Skyscrapers and other human incursions are exacting an increasing toll on aerial species. Can we make their lives easier, asks **Lesley Evans Ogden**



THE Federal Bureau of Investigation has a spectacular view of the city skyline from its Chicago office tower. But when special agent Julia Meredith arrived at work one Monday morning, her eyes were focused firmly on the ground. That's where the bodies were – more than 10 of them.

Some of the dead were Blackburnian warblers, birds with bright yellow and orange plumage that are rarely seen in the city. They had been on their way to their wintering grounds in South America when they had collided with the building's glass facade. "They had come all this way and here they were, dead," says Meredith.

It's not an isolated incident. Just last month, 395 migrating birds were killed in one building strike in Galveston, Texas. The world over, wherever humans are extending their buildings, machines and light into the sky, the lives of aerial creatures are at increasing risk. We don't have very accurate figures, but in the US, casualties are thought to run into the hundreds of millions every year. Yet while efforts to protect areas on land and in water have accelerated since the 1970s, the sky has been almost entirely ignored.

That could be about to change if a new wave of conservationists have their way. They want to reclaim the air for its inhabitants, creating protected areas that extend into the sky and designing buildings to avoid death. If this noble aim is to succeed, however, we must first address a more fundamental question: what exactly is it that we are protecting?

A huge range of creatures are at home in the air. Along with the thousands of bird species that flit from perch to perch, there are others, such as the albatross and Alpine swift, that spend much of their life aloft. Bats, mostly nocturnal fliers, often dine on the myriad insects that share their airspace. Millions of other insects, from butterflies to beetles, occupy the skies by day. Ballooning spiders are at the mercy of winds that catch long trails of web and carry them far from home. Microbes, winged seeds and spores are also all transported on the breeze, and can travel hundreds or thousands of kilometres.

If we ever consider the aerial ecosystem occupied by these creatures, we tend to think of it as one vast expanse of sky. "The minute they take off into the air, we don't really have a mechanism in place to define that habitat type. But it's really critical," says Christina Davy at Trent University in Ontario, Canada.

Earlier this year, as a first step to protecting the biodiversity of airspace, Davy, along with Kevin Fraser at the University of Manitoba and Adam Ford at the University of British Columbia, put forward the idea that we should think about aerial habitats as layers, similar to the way that marine habitats are characterised by depth. They propose three subdivisions of the troposphere, the lowest zone of the

atmosphere rising to roughly 15 kilometres up. The basoaerial habitat extends from the ground up to 1 kilometre. Here human threats range from tall buildings to wind turbines and moving vehicles (see diagram, page 38). The mesoaerial habitat, between 1 and 8 kilometres in altitude, is characterised by steadily decreasing temperatures and oxygen levels; the main threats here are light pollution and aircraft. In the epiaerial habitat, between 8 and 13 kilometres up, temperatures plunge towards -56°C at mid-latitudes; its inhabitants, mainly microorganisms, require special adaptations to survive.

A better definition of habitats is only part of what's needed if "aeroconservation" is to take off, however. For a start, we're not even really sure how big the problem is we're trying to solve. A meta-study published in 2014 put the number of birds killed in building collisions at between 365 million and 968 million a year in the US. It is estimated that 140,000 to 328,000 birds are killed annually by wind turbines and thousands by civilian aircraft. In the UK, the British Trust for Ornithology estimates that 100 million birds crash into windows annually, and in Canada, more than 50 million adult birds are thought

"In the US, bird casualties are probably in the hundreds of millions every year"

to die each year from collisions with buildings, wind farms, communication towers and other human structures that invade the skies.

On their own, though, such numbers only say so much. "What we have are mortality counts," says Davy. "We don't have the data that we need to be able to say whether [such counts equate to] 1 per cent or 100 per cent of the population." That's because we just don't know how many creatures call the sky home.

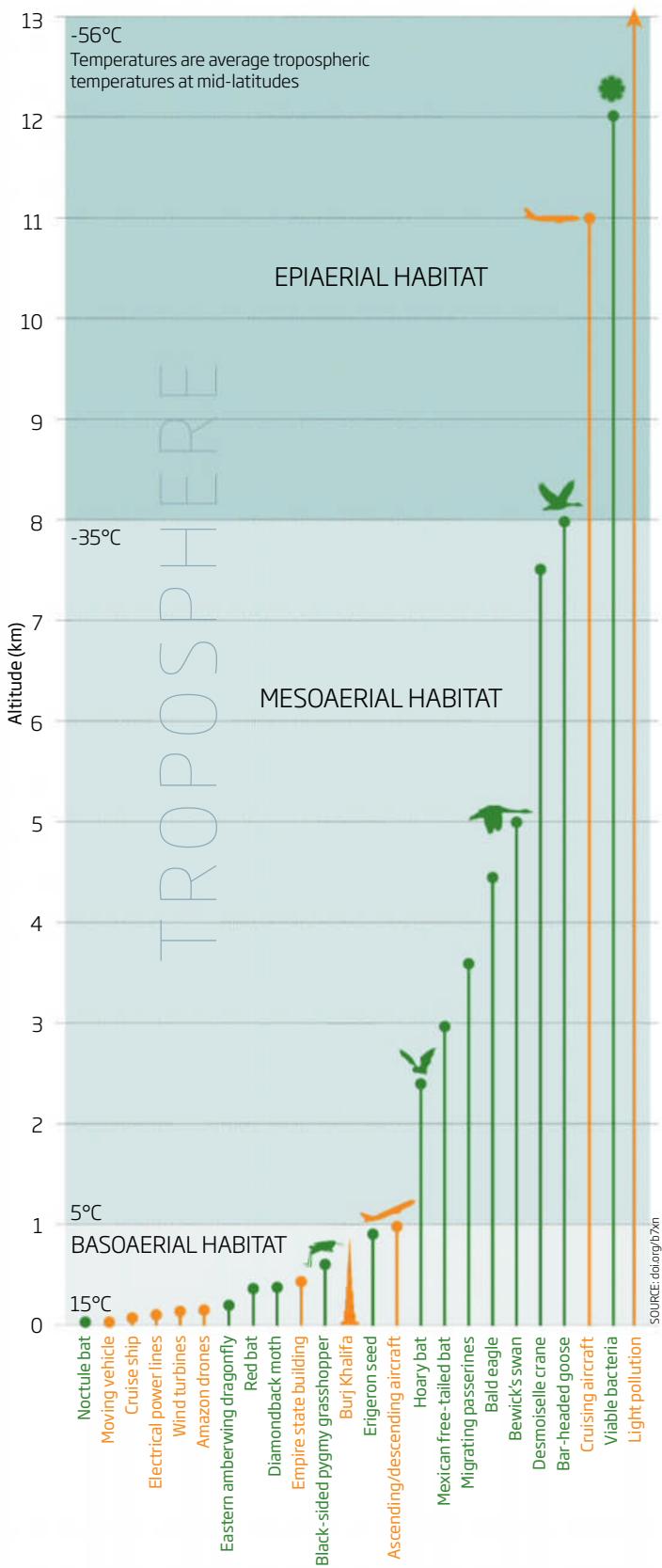
For birds, efforts to estimate populations are well under way, aided by decades of counts, ringing schemes and newer methods such as tracking with telemetry and GPS. But for other airborne creatures, we are further in the dark. Population estimates for bats are often murky or non-existent. Some early attempts to quantify insects, meanwhile, have produced staggering numbers: more than a trillion are thought to migrate over the southern UK each year, for example.

Numbers are one thing; behaviour is another. "We can't track three-dimensional locations of small organisms for any distance because it's too hard to put a tracking device on them," says Robb Diehl, an ecologist with the US Geological Survey who uses radar to study migratory birds.

In the past, we have rarely looked at how aerial species move in 3D "because it's easier to do in 2D", says Sergio Lambertucci at the ➤

Blue-sky thinking

By dividing the aerial habitat into three zones, aeroconservationists want to change the way we think about this neglected ecosystem and protect the **organisms** that live within it from **human incursions**



National University of Comahue in Argentina. Tools such as accelerometers and GPS are changing that. Progress is being made in charting the behaviour of larger animals, including bats, and Lambertucci is using the technology to study several raptor species, Andean condors among them.

Until we know more, it is hard to judge the effects of our airspace incursions. But we can look at how animals in other ecosystems are affected by our activities and apply these lessons to the sky. On land, habitat fragmentation has detrimental impacts on living things, for example. In aerial habitats, this could take the shape of animals making long detours to avoid tall buildings and cities, or being lured into spending time circling light sources while travelling at night. "What are the costs of that movement to migration duration, energetic reserves and fitness once they get to their breeding sites?" asks Ford.

Seeing the light

Light pollution, in particular, could have a big impact in all three aerial zones. "You can see light from outside of our atmosphere," says Travis Longcore at the University of Southern California, who researches the impact of artificial light on biodiversity. Many studies have reported effects such as seabird chicks becoming disoriented by overhead lights on their first flight out to sea and crashing. Future research aims to find out the thresholds at which artificial light levels begin to affect the navigation, dispersal, communication and reproduction of different species, get a handle on the size of those effects and determine the size of dark refuges needed to maintain natural ecosystem processes.

Computer modelling is helping to quantify the whole-population effects of both artificial light spilling skyward and, more generally, our structural cluttering of the air. Projections for hoary bats, the species most frequently killed by wind turbines in North America, for example, suggest lethal collisions with blades could spell serious trouble for population numbers over the next century, seeing them decline by as much as 90 per cent.

Given the ubiquity of our aerial incursions, why hasn't the idea of protecting aerial habitats come to our attention earlier? "We are terrestrial creatures," says Diehl. "In our evolutionary history, we've lived off the land and, to some extent, out of the water." He suspects that our notions of habitat are deeply ingrained and, like our science, oriented towards the landscape. We may need

to step away from the biases of our senses and education to lift our gaze upwards. This offers the chance of some blue-sky thinking, says Diehl: the concept of aeroconservation is so novel that, in theory at least, solutions are limited only by our imagination.

One unknown in future efforts to protect airspace is whether it comes under the umbrella of environmental law. At the moment, even the way we define ecosystems works against aeroconservation. The International Union for Conservation of Nature, for example, recognises terrestrial, aquatic and “other” habitats, but doesn’t explicitly mention the air. This oversight extends to international policy such as the UN Convention on the Conservation of Migratory Wild Species of Animals. Neglect of airspace as habitat is problematic for creatures whose lifestyles include air travel, say Davy, Fraser and Ford.

Nevertheless, legal protection of airspace isn’t without precedent. No-fly or restricted zones for drones and aircraft exist, mainly above politically or militarily sensitive zones such as the centre of Washington DC. But a no-fly zone over wildlife habitat at the Boundary Waters Canoe Area Wilderness in northern Minnesota has existed since 1948 and restrictions are in place over parts of some US national marine sanctuaries to protect marine mammals and seabirds from disturbance.

Current laws have also been invoked by campaigners. Groups including the Toronto-based Fatal Light Awareness Program have been drawing attention to bird-building collisions and rescuing injured birds for decades. “But the biggest shift came when we found ourselves as witnesses in a court of law,” says executive director Michael Mesure.

That case, in 2010, was brought in Canada by environmental law charity Ecojustice against Cadillac Fairview, a commercial property owner and manager, after hundreds of migratory birds had died in collisions with its buildings’ mirrored windows in Toronto. The judge ruled that Ontario’s Environmental Protection Act and Canada’s Species at Risk Act prohibit reflected daylight from building windows, because the glass creates a mirage of habitat and sky, fooling birds, with potentially fatal consequences.

As a result, bird safety is now more commonly taken into account in the planning and construction of buildings in many Canadian cities. In addition, LEED – a popular green certification scheme for buildings worldwide – is piloting the inclusion of bird-friendly architecture in its points system for

Glass windows and disorienting light pollution are just two threats to aerial life



BOTTOM: NASA; TOP: KAY ROXBURY/ALAMY STOCK PHOTO

“green buildings”. Windows can be treated with special film, translucent tape or spaced wires to make them visible to birds. Avoiding positioning outdoor plants near windows may also help. But all windows reflect daylight and although the laws of Ontario say they shouldn’t, in practice this isn’t being enforced – and it is unclear how it could be.

Invoking building codes is no panacea. In Canada, more than 25 million birds are thought to die annually after colliding with power lines, with raptors such as owls, kestrels and eagles particularly prone. This could be tackled by placing markers on wires to make them more visible,

“Anything we do is going to look better than a bunch of dead birds”

or putting them underground. Electrocution of birds that can straddle two power lines is also a big killer, particularly of Europe’s white storks. A possible solution is to increase the distance between wires.

Progress is being made here: countries such as Germany require bird protection measures to be incorporated into the design of new and upgraded power lines. With wind turbines, the UN-sponsored Migratory Flying Birds project is building protection measures into new wind

energy projects along important migratory routes up through eastern Africa and the Middle East, including radar sensors that enable turbines to be shut down within minutes when a flock is approaching.

As for addressing light pollution, aeroconservationists have a natural ally: the International Dark Sky Association. A movement founded by astronomers, its aim is to preserve some of Earth’s natural darkness. In some US national parks, retrofitting has already begun to reduce upward spillage of light. Commercial lighting companies are making changes too, although progress is slow, says Longcore.

While developments are small-scale and piecemeal for now, they are no less important for the creatures concerned. These include the Blackburnian warblers that migrate through Chicago each year. Though it took time to seek expert help and navigate the bureaucracy, Meredith eventually secured an FBI-approved plan: netting put up during the migration season now protects birds from the building that had been killing them. It may temporarily restrict the spectacular views, but Meredith is convinced it is a price worth paying. “Anything we do is going to look better than a bunch of dead birds,” she says. ■

Lesley Evans Ogden is a freelance writer based in Vancouver, Canada. On Twitter @ljevanso

The one-man environmental disaster

From poisonous cars to the destruction of the ozone layer, Thomas Midgley's talent for invention and lack of scruples was a killer combination

BY THE time of his death in 1944, Thomas Midgley Jr was regarded as one of the great inventors of the 20th century. From cars to kitchens, his creations ran the gamut. He had turned Henry Ford's "bangers" into speedy, must-have Cadillacs with a magic ingredient added to petrol, and for an encore found a chemical that made killer refrigerators and aircon units safe for millions of homes.

On the face of it, an enviable legacy – except that the products of Midgley's genius were fatally flawed. His lead-based petrol additive damaged the developing brains of millions of children globally; and Freon, the first CFC, almost destroyed Earth's ozone layer. Midgley is now seen as the world's worst inventor.

Born in 1889, Midgley's first claimed invention – made in high school – was a method for curving the flight of baseballs, by rubbing them with the chewed bark of the slippery elm. It was widely used thereafter by baseball pitchers. Later, after a stint working for his father's tyre development company, Midgley came under the wing of Charles Kettering, the inventor of the electric starter motor for cars. In 1916, Kettering set 27-year-old Midgley to work on a solution to the problem of car engine "knock".

Caused by the badly timed ignition of fuel, knock was noisy, jolting and effectively prevented the use of more efficient higher-octane fuel. It probably led to early automobiles being dubbed "old bangers". Midgley came up with no fewer than 143 fuel additives to deal with knock. The initial front runner was ethyl alcohol, made from grain. But to Kettering and the paymasters at General Motors, he backed a different contender: tetraethyl lead (TEL), a compound first discovered in the 1850s and known to be highly poisonous.

So why choose it? Midgley always said it was simply the most practical solution. It was cheap to make, and just a couple of grams in a gallon of fuel was enough to prevent knocking, compared with the 10 per cent dose required for ethyl alcohol. And there was a key difference between the two: TEL was patentable. Midgley calculated GM could make 3 cents on every gallon of leaded fuel sold. In those days, health and safety regulation was at a minimum and within 15 months of his advocating TEL, the first fuel containing the magic anti-knock ingredient was being pumped on forecourts.

From the start, medical researchers warned

that it could poison the nation. In early 1923, William Clark at the US Public Health Service predicted that lead oxide dust would build up along busy roads. The following year, toxicologist Yandell Henderson of Yale University prophetically warned that "the development of lead poisoning will come on so insidiously that leaded gasoline will be in nearly universal use... before the public and the government awaken to the situation."

Midgley was having none of it, even when several workers exposed to TEL fumes at the manufacturing plant died in 1924. Others suffered bouts of violent paranoia and were hauled away in straitjackets to asylums. Midgley was a canny salesman, and insisted they marketed TEL as "Ethyl", with no reference to lead. He claimed there were no substitutes, when he knew better than anyone how numerous they were. Journalists asked questions about the workers' deaths, but Midgley responded with showmanship, rubbing TEL on his hands and holding a bottle under his nose, proclaiming "I am not taking any chances whatever". He knew that was a lie. In early 1923, just before GM installed him as vice-president of Ethyl Corporation, the firm producing TEL, he had taken weeks off work because "after about a year's work with organic lead, I find that my lungs have been affected."

Lethal or not, TEL transformed motoring. Engines could run with much higher compression in their cylinders, producing markedly more power. Soon, all over the US, old bangers were replaced by the likes of sleek, powerful and knock-free GM Cadillacs. The American dream was on a roll.

By 1945, the whole world was driving on leaded fuel. And the science had been hijacked by a web of corporate-funded denialists. For



He might not have been so keen had he known the truth...



CORBIS/VIA GETTY IMAGES

the four decades from 1925, almost all the research into possible health effects of TEL was conducted by employees and contractors of the Ethyl Corporation. Not surprisingly, perhaps, it got a clean bill of health.

Meanwhile, Midgley had gone back to the lab. In 1930, working with Kettering for GM's Frigidaire subsidiary, he set out to solve another problem holding back a growing industry. Most refrigerators at the time were industrial units dependent on fluids that were poisonous or apt to catch fire, such as methyl chloride, sulphur dioxide and ammonia. These were no good for Frigidaire, which wanted to put a refrigerator in every home and an air conditioner in every office.

Midgley swiftly found a safe, synthetic

alternative, called dichlorodifluoromethane, which he branded Freon. It was the world's first CFC. According to Kettering, it was "highly stable, non-inflammable and altogether without harmful effects on man or animals". Like TEL, it was also patentable. Frigidaire introduced it to public fanfare in April 1930. Domestic refrigeration never looked back.

During the second world war, Freon was an ideal propellant for spraying insect repellents such as DDT during jungle warfare. That led to household aerosols such as antiperspirants. By the 1970s, as much as a million tonnes were being released into the air annually.

Midgley was a hero among American chemists, winning all the prizes and securing over a hundred patents. Then, in 1940, he

caught polio, which left him weak and unable to get around. True to form, he invented a system of pulleys and ropes to hoist him from his bed to his wheelchair.

However, the disease took a big toll on Midgley, and within a few years he knew his time was past. As president of the American Chemical Society, he gave a lecture in 1944 that ended in verse: "When I'm gone, I have no regrets to offer... let this epitaph be graven on my tomb in simple style, this one did a lot of living in a mighty little while." A month later, in November 1944, he was found suspended above his bed, strangled by his hoist.

Obituaries, and a recent biography by his grandson, all call his death a tragic mishap. The media have jumped on this idea, relishing the narrative that a man whose inventions led to such harm was ultimately undone by his own ingenuity. But a colleague called to the scene said it was "no accident", and Midgley's death certificate and cemetery records called it suicide.

"Workers suffered bouts of violent paranoia and were hauled away in straitjackets"

The master inventor was long gone before his creations lost their lustre. It wasn't until the 1970s that Freon's ozone-destroying properties were pinned down. And then, with some 75 trillion litres of leaded gasoline burned, science woke from its amnesia about the dangers of lead. The turning point came with studies into impaired child development by psychiatrist Herbert Needleman at the University of Pittsburgh, based just a few miles from Midgley's childhood home.

Thankfully, the world Midgley made is receding. Levels of lead in the blood of children across the US and in most of the world's cities have declined by more than two-thirds since the widespread banning of leaded petrol. Only a handful of countries continue to sell the stuff. And the 1987 Montreal Protocol was the beginning of the end for Freon. Today, our protective ozone layer is slowly recovering – leading to fewer deaths from skin cancer as our exposure to ultraviolet radiation returns to its previous level.

As legacies go, environmental historian John McNeill offered one of the most chilling epitaphs: Midgley had "more impact on the atmosphere than any other single organism in Earth's history". Nothing to envy there. ■

By Fred Pearce

The power of good

Stories about a better future can break the hold of stories that say you're screwed, says sci-fi writer **Kim Stanley Robinson**

The drowned city on the cover of your book *New York 2140* may mislead people that it's a dystopian climate change book. But it's fun, a tale of driving stakes into vampire capitalists - the superwealthy who don't even generate wealth.

I've always written utopian science fiction. The story to tell now is utopian science fiction jammed into near-future history. To avoid an environmental crash, we need an economic solution. I wanted to show people coming together in an accidental collective to do good things – financiers, reality stars, Silicon Valley people. There's a revolution at the end, but it's by no means the end of the problems, it's the first step.

The kind of sci-fi one reads does seem to be important. Is there, for example, a relationship between engineers and writers, with writers creating imaginary worlds and engineers making them?

I think that's real. I know my *Mars* trilogy inspired young people to be geologists, or go to Mars. Science fiction also provides inspiration to get into science. Scientists are idealistic. What gives life meaning beyond making a buck? Science. It's a higher calling. And it's a response to our basic curiosity, our desire to make things better.

Does that mean writers should avoid creating dystopias?

I don't agree with writers telling other writers what they should do. Anyway, dystopia isn't new: it's a

PROFILE

Kim Stanley Robinson is best known for the *Mars* trilogy, and the *Science in the Capital* series. He has spent time with the US National Science Foundation. His latest book is *New York 2140* (Orbit Books)

version of satire, an Ancient Greek form. It's a warning. But there can be flavours of dystopia, characterised by the epoch. In the 1980s, for example, cyberpunk claimed to be the great expression of American science fiction. I was always a great enemy.

Why did you dislike cyberpunk?

It was basically saying finance always wins. All you can do is go onto the mean streets, find your corner, pretend you're in a film noir and give up. I thought it was capitulationist, nostalgia for the cynicism of the 1940s. I wrote utopian-scientific stuff, saying no, it's way more interesting, there are lots of possibilities.

Aren't we living in a dystopia now? Here's the dilemma. Capitalism is the system we have agreed to live by. Its rules, while being legal and not involving anyone being evil or cheating, are nevertheless destroying the world. So we need to change the rules.

In 2140, two of your characters, both programmers, try to overthrow the system. Is that what you're talking about?

No. They represent the Silicon Valley dream of a tech solution – if only we could just hack the

system. As if, like graffiti, you can paint over the problem and make it go away. But if the laws stay the same, you can't hack them. If the fundamental rules are bad, you need to change them. To do that, you need political economics.

What is political economics?

It's the idea that politics and economics are melded together into one power trip running the world. It's a field most universities don't have any more, and it combines economics and politics with sociology and anthropology.

It's weak now because there's no money thrown into it so the most sophisticated theorists go into the trivial pursuits of economics rather than deeper questions of political economics. No economist is going to talk about changing the fundamental rules. That's why we need political economics: it is post-capitalism.

Could it help us claw back our society from vampire capitalists?

It's interesting to look at what happened after the 2008 financial crash. People stopped paying their bills because they couldn't afford them, and finance crashed. That showed us something very intriguing: in theory, you can pop the bubble of finance any time you want, by everybody agreeing to go on a payment strike. This is essentially the plot of *2140*.

Surely after every bubble, the 1 per cent tell the same story of shortages and terrorists to pit us against each other while they take

JOHN SHIREMAN/GETTY

New York, under water by 2140, has people living in office blocks

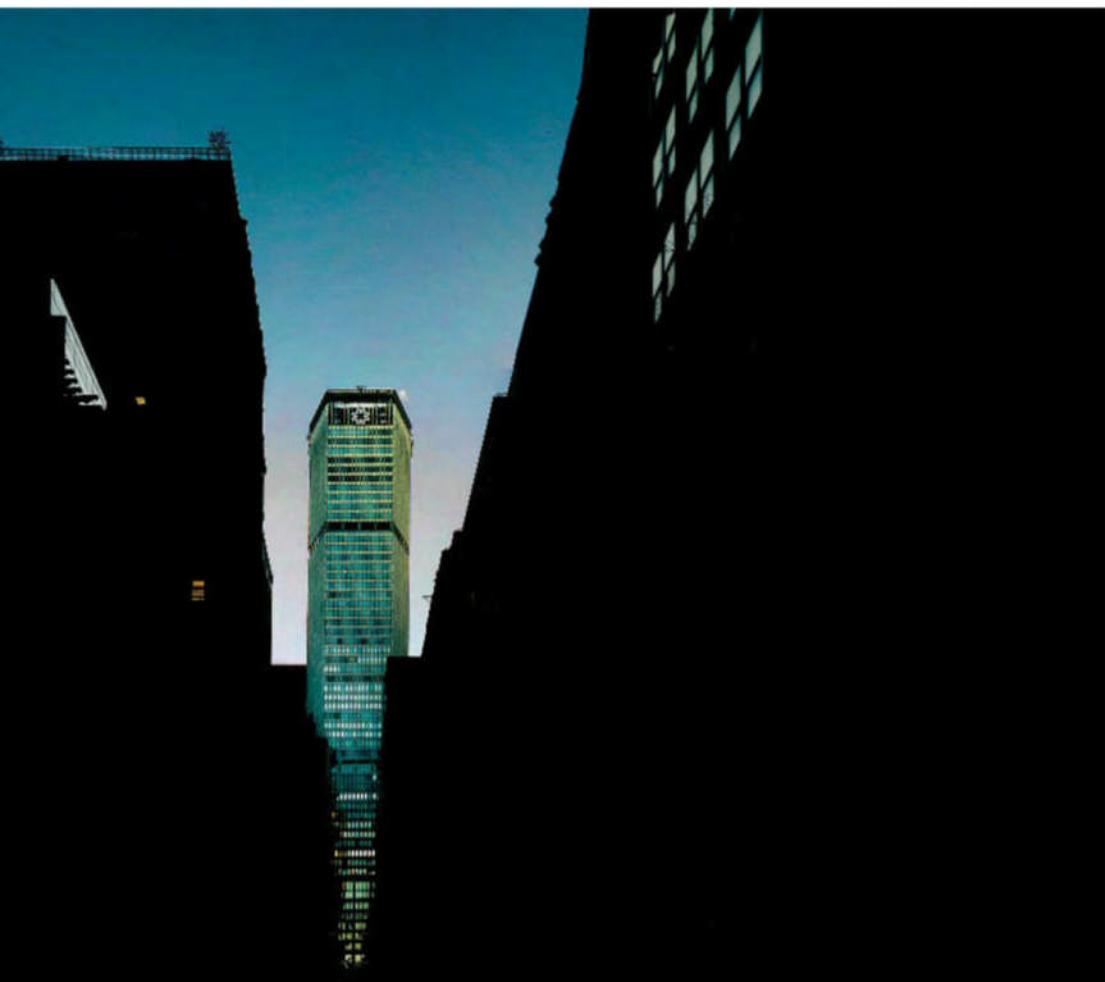
99 per cent. How do we fight back?

That is the story they're trying to get us to believe. The one thing the 1 per cent can do is buy the storytelling apparatus, the major media, and they have.

Why is ownership of the media so important?

We understand the world through a master story we tell ourselves, that's our ideology. Everybody has an ideology. If you didn't have one, you would be disabled, somehow. The Italian Marxist theorist Antonio Gramsci said that people obey the dominant powers of their time – without guns in their faces – by way of stories. This





hegemony, or dominance, is created by ideology, including those master narratives.

Is this another reason why the kind of stories we tell right now matter?
It's important what story you tell about the future. Stories that say the future can be better because people are smart, because they want democracy, because, ultimately, people rule and banks don't, can be self-fulfilling. They give people actions to help break the story that says they are screwed because international finance is way more powerful.

This sounds like you have a blueprint to save Earth?
There are some blueprints right now. Basic minimum income for one. Or employee-

owned cooperatives such as Mondragon, the Spanish workers' cooperative federation. To me, Mondragon is important because it's a form of post-capitalism that already exists, is legal and runs a multi-billion economy for 200,000 people in the Basque part of Spain. It could work anywhere.

"We understand the world through a master story we tell ourselves, that's our ideology"

Are you comfortable being the guy who pulls the world towards a plausible, not dystopian, future?
Yes. It's a little bizarre. I have definitely done the hard work. I have taken the utopian road, the scientific road and ground out

stories where it isn't obvious why they should be fun to read. Most of my novels, I think, are actually fun because I'm doing realism in a way the world needs.

As for anyone picking up the mantle, there's a group of young writers who call themselves solarpunk, and what they're trying is all about adaptation.

Brexit, identity politics, attempts to divide people... Do you still believe in the utopia of people working together?

This is one of those tests of history. The next century or so will tell whether people can get it together. Because occasionally things happen that are quite shockingly positive. ■

Interview by Sally Adee

A tale of hope, money and fightback

New York 2140 by Kim Stanley Robinson, Orbit Books

WHAT people do to their environment and what it does to them has long fascinated Kim Stanley Robinson. Of late, the science fiction writer has been inspired by modernist author John Dos Passos to combine stories of individuals with bird's-eye views of the systems around them, plus news clippings, technical descriptions, lists, history and quotations.

New York 2140 is his third such novel. Rising seas have decimated coastal cities. New York City's geographical traits (plus the uniqueness of its people) allow it to survive, in a fashion. Midtown is now a high-tech Venice, its offices converted into self-sufficient residential centres.

One such is the Met Life tower on Madison Avenue, now a co-op producing food and power as well as providing shelter. As the crisis passes, the finance industry inches back, hoping to monetise the quasi-socialist community of staff, residents and squatters.

The book's core question is whether New York is a centre of popular innovation onto which finance has latched, or a city of finance that tolerates innovation as adornment. It isn't clear how we are to view the city's survival. But near the end, the book veers towards wish fulfilment when NYPD officers back the have-nots. This plus the near-invisibility of non-white communities are reminders of Robinson's blind spots. That said, *2140*'s vision is so convincing as a cautionary tale and promise of hope, one can only feel galvanised to prevent the worst and fight for the best. ■

Abigail Nussbaum is a programmer and literary critic based in Tel Aviv, Israel

Keep it real

Is a pumped-up version of Brecht's *Galileo* right for today, asks **Shaoni Bhattacharya**

Life of Galileo, the Young Vic, London, to 1 July

FLASHY, fun, comedic. Not the normal epithets given to a play by agitprop master Bertolt Brecht. Nor indeed to the story of astronomer Galileo Galilei, who narrowly escaped being burned for heresy by the Catholic church in the early 17th century.

But this is director Joe Wright, and he has scattered some of his A-list film glitter (*Atonement* and upcoming Churchill biopic *Darkest Hour*) over the Young Vic's *Life of Galileo* – that and a large helping of The Chemical Brothers.

Wright has created a giant planetarium with circular chill-out zone in the centre, girdled by a wooden gangway of a stage and flanked by the audience. The set, a clever echo of circular orbits, also resembles a ship's deck, with staircase and scaffold-like rigging to one side and two mini platform stages at opposite ends like ships' bridges. Above, stars shine in the planetarium's dome. The projections (using NASA and European Space Agency images) are worth the ticket price alone.

The entire set is a physical embodiment of the inextricable link between the stars and navigation, and voyages of discovery of every sort.

Random people (actors and audience members) loaf on cushions in the chill-out zone. On one platform, a scruffy, slightly paunchy bloke in jeans, T-shirt and New Balance trainers fist-pumps enthusiastically to the visceral trance beats.

Is this beardy, beefy, middle-

aged raver meant to be Galileo? Indeed he is: Australian actor Brendan Cowell, an exuberant, earthy Galileo, is at times more 1990s MC than tortured scientist.

There are real belly laughs when Copernicus (Kippernikus in this translation) gives Wright licence for a *Carry On*-style "copper knickers" joke. And you guffaw when the aides of a supposedly science-friendly new pope pull a ripped torso over his pudgy body.

But I did begin to crave a deeper tone. That comes in the second half with supporting actors such as Billy Howle (Andrea, son of Galileo's housekeeper – and his protégé) deeply convincing as they tackle the play's emotional

heart. With Cowell, it proves hard to get past his cocky, swaggering Galileo to the real angst.

Galileo was an obvious choice for Brecht. In 1543, Nicolaus Copernicus had proposed a solar system with the sun at its centre,

"The power of science, truth, social responsibility are more relevant when facts can be dismissed"

upsetting 2000 years of belief and challenging the very idea of heaven. Some 70 years later, Galileo's telescope provided evidence to back Copernicus by observing the movements of the planets and the changing light

and faces of our moon, and discovering the moons of Jupiter.

This threatened not only the church, but also the status quo. With no heaven, there might be no God. What would stop the poor revolting? As Brecht's Galileo says, forget "divine poverty", what about "divine anger"? Eventually, to his followers' dismay and with the inquisitor upon him, Galileo recanted and lived out his life under house arrest in Florence.

Brecht wrote *Galileo* in 1938, after fleeing the Nazis. Some years later, he revised it in the light of the Manhattan Project and the first nuclear bombs. The soul-searching of those times is riven deep through the work's complex interplay of science, politics and what it is to reason and be human.

Near the end of the play, Galileo hands Andrea his book *Discourses* to smuggle across the border. As Galileo talks about being true to science and how that may conflict with the world, he says: "Your cry of achievement will be echoed as a universal cry of horror."

That conflict – the tantalisingly transformative power of science running alongside its unknown, maybe harmful effects – has only intensified as technologies such as genome editing and AI emerge. And the power of science, truth and social responsibility running throughout *Galileo* are even more relevant at a time when facts and evidence can be lightly dismissed.

Does this version lighten Brecht too much? Whatever. Put on your New Balances, enjoy the rave, the stars and the ideas. What the show may lose in gravitas, it makes up for in sheer exuberance. ■

A sun-centred solar system upset old mechanisms of social control



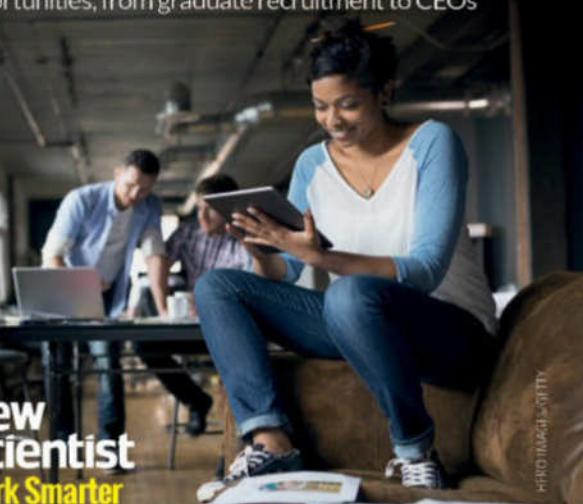
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Shaoni Bhattacharya is a consultant for *New Scientist*

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EDITOR'S PICK

Where we might find consciousness



**From Michael Wigley,
Romsey, Hampshire, UK**

Bob Holmes observes that signs of consciousness have been found in animals from at least three different phyla, suggesting it evolved more than once (13 May, p 28). This makes me wonder whether we should be watching harder for signs of machine

intelligence. If it happened so many times in the animal kingdom, unless you ascribe a religious reason, surely it will happen in computers? If it arises, we may need to set up "Turing Police" to keep an eye out – to stop them being mistreated as much as to stop them mistreating us.

*From Mark Costello,
Auckland, New Zealand*

Your article on consciousness quotes a scientist who dismisses emotional responses in amphibians and fish because they don't show elevated body temperature and heart rate. But they are cold-blooded, so this is not a suitable measure. In any case, at least fish show the same adrenalin-cortisol response as mammals, so they can experience stress, fear and excitement. They also have several

"signs of consciousness": a need for sleep, sensitivity to anaesthetics, focused attention, and learning. There is a convenient history in science of assuming "lesser life forms" don't feel stress and fear.

I wonder whether a mobile lifestyle is associated with consciousness? It increases opportunities for finding patchy food, more complex social interactions and parallel development of visual, hearing, smell and other senses; all these need greater cognition and mind maps of the environment, including other animals.

*From David Ashton,
Sheringham, Norfolk, UK*

What seems remarkable about the evolution of our minds is that an originally unconscious universe is asking questions about its existence.

Why are there so few conservative academics?

*From Gael Price,
Wellington, New Zealand*

Alex Berezow suggests that an "absence of intellectual diversity has contributed to a toxic and intolerant American university culture" (6 May, p 25). The only evidence cited in support is the declining number of conservatives in academia. Uncritically repeating this common claim isn't helpful for understanding partisan attitudes.

Other causes could be responsible for there being fewer conservative academics: fewer conservatives in society, different preferences for academic careers among conservatives and liberals, issues with definition or measurement, or even something inherent to conservatism. Without proper study it is

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"That would explain why game theorists have so few friends"

Gareth Edwards draws a conclusion from the finding that we should charge our friends to borrow things (3 June, p 7)

impossible to determine what's driving the changing political mix of campuses – intolerance or something else.

The claim that academic culture is intolerant is often used to attack the generation of "millennial" students and to discredit their moral or political leanings.

Rather than feeding this intergenerational conflict, *New Scientist* could contribute to debate by presenting evidence and calling for more research.

A numbat where there shouldn't be one

*From Timothy Haas,
Binalong Bay, Tasmania, Australia*
As a Tasmanian, it seems to me that the jury is still out on the survival of our "tiger" (6 May, p 40). With 40 per cent of Tasmania protected in reserves, much of it is very wild country.

But Cape York in the far north of Australia is a very different place. I don't know about the Tasmanian tiger, but I can say I saw a numbat there, even though textbooks confine these marsupial "banded anteaters" to the south-west of Western Australia.

I got separated from my friends on an expedition to the Jardine swamp area of Cape York in the mid-1980s. I was left at a track junction to wait. A numbat trotted past not more than 2 metres away. I was naturally thrilled, and as a keen field naturalist I knew what it was: but I didn't know it wasn't supposed to be there.

Elections are to get rid of politicians, not pick them

*From Liam O'Keeffe,
Abinger Hammer, Surrey, UK*
Campbell Wallace suggests the ancient Greek system of selecting

officials by lot as an alternative to elections (Letters, 20 May). It is true that elections often lead to unsatisfactory outcomes. I'm sure that, like me, many have voted for politicians who have betrayed us or let us down once in office.

Because we cannot accurately predict how a politician will behave once in power, the true purpose of elections is to peacefully remove leaders who have failed us.

Never mind the snow, obey thermodynamics

*From Sam Edge,
Ringwood, Hampshire, UK*
You mention the idea of using artificial snow to replenish a glacier (6 May, p 7). It's a terrible idea. How much energy will it require to freeze and deploy the snow? How much extra carbon dioxide will that pump into the

atmosphere? The plan seems to me to be akin to trying to cool a room down by opening the refrigerator door.

This letter does not in fact describe itself

*From Chris deSilva,
Dianella, Western Australia*
Brian Smith asks whether the word "heterological" is self-descriptive and thus autological, or heterological and non-self descriptive (Feedback, 22 April). The question was discussed by the German mathematician Kurt Grelling in 1908 and is known as the Grelling-Nelson paradox.

As Feedback notes (20 May) it is one of a class of self-referential paradoxes. Probably the oldest of these is the statement of Epimenides the Cretan that "all Cretans are liars". A more direct example is the sentence "this ➤

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sentence is false", which is the centrepiece of Kurt Gödel's proof of the inconsistency of complete logical systems – and thus an inspiration for Alan Turing's definition of computing.

My answer to the question about the word "heterological" is simple: it is neither autological or heterological but paradoxical.

We can't know if we are in the Anthropocene

From Andrew Sanderson, Spennymoor, County Durham, UK
Owen Gaffney says the age of the Anthropocene is now, with humanity now being a prime driver of change in Earth's system (22 April, p 24). We were discussing this on a distance-learning course on the geology of Yorkshire and northern England.

From that point of view, if there is an Anthropocene epoch, where do we put the "golden spike" – the place where the base of the time period can be clearly seen? Our consensus was that it is too early to define a new epoch.

Will concrete be identifiable in 10 million years? What is the

breakdown period for tyres? How much radioactivity will remain from our nuclear activities?

Might it be better to consider this as a cultural time period, rather like the Neolithic, which is not constrained by a specific starting point but encompasses the relevant human activity? We considered a name for this period of human culture and came up with the Anthrotechnic.

Exceeding your allotted number of heartbeats

From Guy Cox, St Albans, New South Wales, Australia
Bryn Glover notes that he is way over his allotted number of heartbeats, given that every mammal can expect to expire after about 1.5 billion (Letters, 20 May). You respond that life expectancy in the past was only about 40 years.

Life expectancy is a confusing statistic (Letters, 10 November 2007). The low figure is largely the consequence of infant and child mortality. Some who survived childhood could expect to live to a ripe old age.

To give an extreme example, sea turtles live for around a century. But a turtle hatchling has only about a 1 in 1000 chance of reaching adulthood: so its life expectancy is a month or two.

Is beauty in the eyes of the spider beholder?

From Rob Holmes, Lesmurdie, Western Australia
Adrian Barnett's review of Richard O. Prum's *The Evolution of Beauty* suggests an interesting and persuasive argument that sexual selection leads to a sense of beauty (6 May, p 44). Many species of jumping spiders weighing just a microgram or so have elaborate and colourful sexual displays. Are they on the way to evolving a sense of beauty? Maybe not.

Automated automobiles will break the law

From Nigel Brown, Wells, Somerset, UK
Bob Cory suggests that nobody will write code that breaks the law for a self-driving car (Letters, 20 May). I disagree. Given the

prevalence of computer hacking, the Volkswagen emissions scandal and the hobby of tweaking engine management systems, it seems that the question is not whether self-driving cars will break the law, but when.

A feast for the emotions in New Guinea

From Rod Murphy, Blairgowrie, South Africa
Julian Ash discusses attitudes to cannibalism (Letters, 15 April). Thirty years ago, a close friend was invited to a traditional feast in New Guinea. He reported that he'd asked the head man what the meat was and that the answer was "long pig". Further enquiry revealed that a pit was dug and lined with hot coals: the long pig was covered up for 24 hours. Several beers later it was revealed that long pig was human.

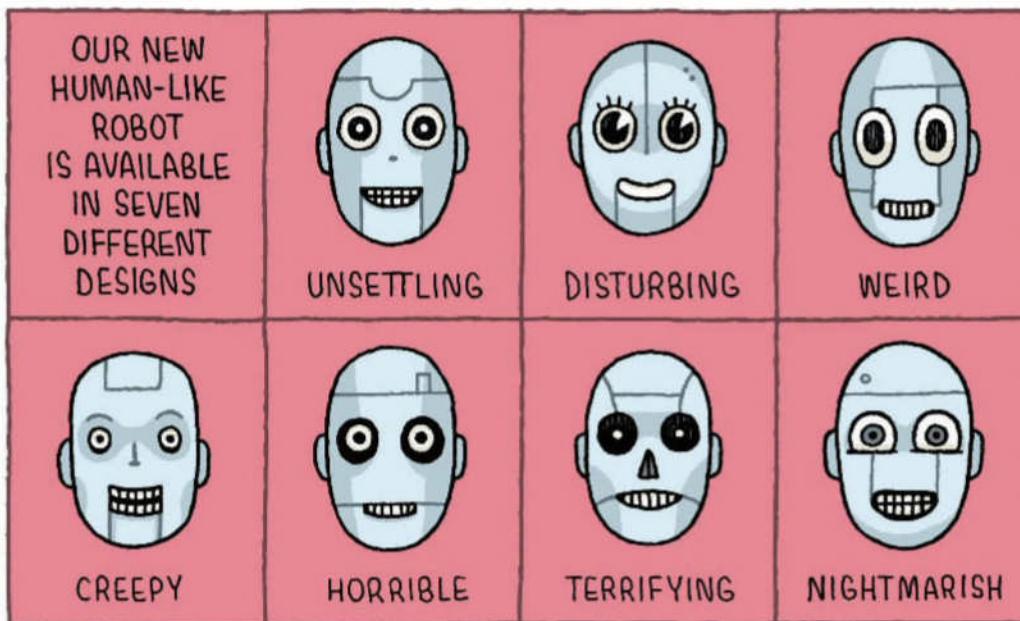
This is perfectly rational behaviour, isn't it?

From Brian Horton, West Launceston, Tasmania, Australia
While reading Elizabeth Landau's article on hoarding (29 April, p 34), I started to wonder whether the large amount of stuff in our home counted. Finding that the most commonly hoarded items were magazines, I started to panic, thinking of our collection of *New Scientist* going back more than 40 years. My wife assured me, though, that I don't need treatment for my condition, because keeping copies of *New Scientist* forever is perfectly rational and doesn't count as hoarding. I have been a home subscriber since 1975.

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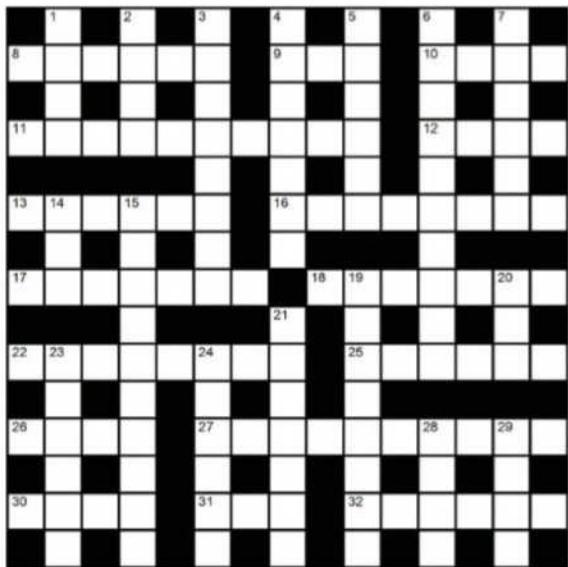
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TOM GAULD



CROSSWORD

Compiled by Richard Smyth



Crossword No7

ACROSS

- 8 Sir Bernard ___ (1913-2012), first director of Jodrell Bank Observatory in Cheshire (6)
9 Deoxyribonucleic acid (1,1,1)
10 Ed ___ (b.1981), science writer, author of the 2016 book *I Contain Multitudes* (4)
11 Rosebay ___ , wild plant known in the US as fireweed (10)
12 Of or relating to the ear (4)
13 Epoch characterised by low temperatures and glaciation (3,3)
16 Diagram showing the deviation of the sun from its mean motion in the sky (8)
17 Viral disease also known as German measles (7)

DOWN

- 1 The positions of genes on a chromosome (4)
2 Jocelyn ___ Burnell (b.1943), Belfast-born astronomer who discovered pulsars (4)
3 Component attached to a rotating shaft so as to smooth out delivery of power from a motor (8)
4 ___ cortex, part of a gland in humans responsible for producing steroid hormones (7)
5 λ (6)
6 Of a needle, designed for use beneath the skin (10)
7 Metallic element, number 49 (6)
14 Central processing unit (1,1,1)
- 15 Instrument for measuring wind speed (10)
19 Alexander von ___ (1769-1859), naturalist, geographer and explorer (8)
20 Uniform resource locator (1,1,1)
21 A vertebrate group comprising reptiles, birds and mammals (7)
23 Industrial installation that supports drilling machinery (3,3)
24 African state, home to Volcanoes National Park (6)
28 Geometrical solid tapering from a flat base to an apex (4)
29 Lunar ___ , kind of shield volcano found on the moon's surface (4)

Answers to Crossword No6

ACROSS: 1 STROBE, 4 BAOBAB, 8 MEITNER, 9 NITRILE, 11 STALACTITE, 12 TIME, 13 RENAL, 14 OLIVETTI, 16 GENOTYPE, 18 NOBEL, 20 SMOG, 21 WATER CLOCK, 23 STANNIC, 24 CUTICLE, 25 ROCKET, 26 HERINA. **DOWN:** 1 SMELT, 2 RITALIN, 3 BLETCHLEY, 5 AZINE, 6 BURETTE, 7 BELL METAL, 10 KILOHERTZ, 13 RHEOMETER, 15 INNER TUBE, 17 ORGANIC, 19 BILLION, 21 WHITE, 22 CILIA.

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YOU may have heard of the UK Independence Party - whose members, we hear, long for a return to 1950s Britain, perhaps because of the abundance of fortified bunkers facing the English Channel. However, nobody could accuse South Suffolk UKIP candidate Aidan Powlesland of being isolationist.

His pamphlet informs voters in the constituency that Powlesland will work to slash the welfare budget, close the deficit and cancel plans for a local bypass, because by the time it is completed in 2030 we can expect self-driving, electric, flying cars. "Moreover," he adds cryptically, "population is likely to decline in the wake of Brexit".

But what really catches our eye is Powlesland's comprehensive plan for a £1.2 billion interstellar programme. This includes £40 million for a fleet of small scout craft, £60 million to build an interstellar communications array, £1 billion to mine the moons of Jupiter and Saturn for platinum and water, and £100 million for a colony ship to transport people beyond our solar system. Bold figures, given that the

current budget for a planned railway connecting London to Birmingham (a mere distance of 220 kilometres, or 0.00000147 astronomical units) is an eye-watering £27 billion.

The importance of this plan to the constituency of South Suffolk? Powlesland says this mission is needed "for all our profit and the chance to begin anew".

But given his party's rabid opposition to immigration (which extends, we presume, to the interplanetary variety), we can't help but wonder who he plans to put in this interstellar spaceship.

US TREASURY officials may be nursing a monster headache after overspending by a cool \$2 trillion in their latest budget. Officially titled "A New Foundation For American Greatness", it projects a decade of ruddy-cheeked growth in GDP, delivering an extra \$2 trillion to government coffers. The foundation of this new greatness? A \$2 trillion tax cut.

Still, you have to speculate to accumulate, the saying goes.

PAUL McDDEVITT

Costa coffee informs Natalie Emma Roberts that "Our napkins have been cleaning happy faces since 1971". Natalie says "On second thought, I'll use a wet wipe."

And the US president is a man who knows a thing or two about speculating with huge sums of other people's money.

Feedback recalls that when visiting the US president in January, UK prime minister Theresa May gifted him a traditional Scottish cup of friendship. Touching, but perhaps a calculator would have been more useful for his treasurers.

FEARING that our run on retronyms is coming to a close, Bryn Glover sends us a hasty note. "You introduced the concept of a nominative retronym," he writes, "and I felt that I had to slip in possibly a presidential example, namely Dubya, before the covers of the file finally slammed shut."

Hold the door! This angle may open new avenues to explore yet, Bryn, as Feedback counters with a famous little droid named Artoo. Meanwhile, in a moment of serendipitous synchronicity, Brian Reffin Smith writes in to offer "Bébé, or as many others knew her, Brigitte Bardot."

ALSO looking for names is Nina Baker, who says "I am sure Feedback's fan base is familiar with eponyms, where a thing or concept takes the name of its discoverer or inventor." She cites famous examples such as watts, joules and newtons. "But are there any reasonably well-known science or engineering eponyms relating to a woman's name?"

A quick search by Feedback uncovers just one: goeppert-mayer, a unit describing two-photon absorption cross section, named for physicist and Nobel laureate Maria Goeppert-Mayer.

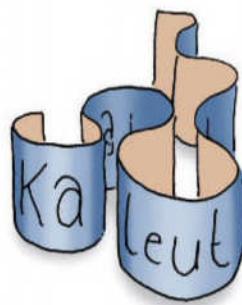
Naturally, our thoughts turned immediately to curies, both the units and the couple, but it's not clear which of the two the unit was named for – a grey area that seems to have been wholly intentional. Can you think of any others?

PREVIOUSLY Stephen Jorgenson-Murray discovered trains running across Europe through a portal

spanning ten longitudinal degrees (27 May). "Google may have moved Mikulczyce from Poland to Germany, but at 18° west, you have moved it into the sea off the south coast of Ireland," says John Woodgate.

There is, of course, an alternative explanation. "This seems to be using a longitude calculation based on a zero meridian running through, or very close to, Addis Ababa," says Geoff Convery. "If you're taking the Greenwich meridian as zero then 18° west places the Mikulczyce bus stop in the Atlantic ocean." This, he says, could give travellers even more problems than locating it in Dornheim.

"SURELY John King is incorrect in his etymology of the word Nazi," says Stuart Tallack (27 May). "It does not derive from the pronunciation in German of the letters N and Z, but is a contraction



of a type common in German at the time." Stuart cites other examples such as *Kapitänleutnant* becoming Kaleut, and *Geheime Staatspolizei* becoming the more familiar Gestapo.

He wonders if there is a name for this kind of word formation. Feedback suspects that it's a lesser sibling of acronym, but we do like Stuart's suggestion that "in view of the time it would have taken to type the full version, how about 'stenonym'?"

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.

It ain't sneezy

I am an amateur singer and during the high season for allergies in Canada I completed three performances of Beethoven's ninth symphony. Many singers were unwell but there was not one cough or sneeze on stage. Why is it that once a singer steps on stage, symptoms are seemingly suppressed?

■ The answer is adrenaline, which is the proper treatment for allergies because it antagonises the changes caused by histamine, a compound released as part of the body's immune response.

I was suffering from hay fever when I took my pharmacology vivas at the height of the pollen season. Afflicted by the usual symptoms of histamine release, I was sure that my examiners, desperate for something non-

"I was sure my examiners would see my stuffed nose and red eyes and ask me about antihistamines"

routine to test me on, would spot my stuffed nose and red eyes and ask about antihistamines.

In the event, my nose and eyes cleared as I waited to be examined. The stress of my impending inquisition, and the consequent release of adrenaline into my circulation in a "flight or fight" response, was sufficient to relieve all my symptoms. I'm sure that actors and singers benefit from the same mechanism.

John Davies
Lancaster, UK

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Bolted on

Is the exact spot where a bolt of lightning will strike the earth pretty much predetermined at the moment it leaves a cloud? Or does it continuously change direction on the way down? (Continued)

■ Thunderstorm clouds have mostly negatively charged bases, from which streamers (or so-called stepped-leader discharges) arise. But sometimes the cloud bases are positively charged, in which case the leader discharges arise from the presence of negative charges in the ground. To complicate matters, some large thunderstorms have both negatively and positively charged regions, leading to cloud-to-cloud discharges.

The streamer discharges travel downwards at about 100 kilometres per second, but take an uncertain and hesitant route. When one of these meets a streamer travelling upwards near the ground, a full-blown lightning discharge occurs from ground to cloud along the pre-existing ionised path. This is the brilliant light show we see, which can lead to currents peaking at 200,000 amps and travels at about one-third the speed of light.

Videos of lightning in slow motion show how the leader discharges develop. Given their random and uncertain progress towards the ground, the strike location cannot have been predetermined. Tall conducting

structures such as towers and masts, which are frequently struck by lightning, are the exceptions.

Discharges from the tip of a nail in an electric field and St Elmo's fire on masts are simply coronal discharges that occur when the electrical stress at a conductor surface exceeds the breakdown stress of air, which is 3 kilovolts per millimetre (at normal temperature and pressure).

Ron Barnes
Electrical power engineer
King's Lynn, Norfolk, UK

■ Lightning is better understood than people think. Benjamin Franklin and Thomas-François Dalibard revealed the electrical nature of lighting in the 1750s, and Franklin then suggested using elevated, earthed metal rods to protect buildings. This idea was quickly taken up by the Royal Navy, which had lost many wooden ships from fires caused by lightning strikes.

Our knowledge of lightning was later improved by the invention of the Boys camera, which allowed sequential photographs of lightning flashes.

Basil Schonland, for example, used a Boys camera to take many photos in South Africa at a rate equivalent to 26,000 frames a second, and revealed numerous previously unknown aspects of lightning.

A typical thundercloud has a large negative charge in its lower part and a large positive charge in

its upper part. However, there is also a smaller positive "shielding" charge below the negative one, so the cloud has both positive and negative charges low down.

Meanwhile, Franklin rods (or lightning conductors) don't do anything significant to prevent lightning or to discharge the cloud. That is not their purpose.

"Benjamin Franklin suggested using elevated metal rods to protect buildings from lightning"

Instead, these rods provide a preferred attachment point for a downwards leader, so the lightning current can be conducted safely to the ground without damaging the building to which they are attached.

Brian Burrows
Culham Laboratory Lightning Studies Unit
The BSI committee on lightning protection
Sutton Courtenay, Oxfordshire, UK

This week's question

DIVERSE OPINION

Invasive species often start with just a few individuals and multiply to huge numbers across a continent, but they don't seem to suffer from a lack of genetic diversity. Or do they? If not, why not?

John Buermeyer
Winnipeg, Canada

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

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Professor Dame Carol Robinson

2015 Laureate for United Kingdom

By Brigitte Lacombe



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