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WEEKLY July 8 - 14, 2017

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Driverless taxis hit the streets of London

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LIGHT IS THE DRUG Dazzling new treatments for mental illness

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MAKE EVERYONE NORMAL...
PUT SECURITY ABOVE PRIVACY...
ALLOW ROBOTS TO KILL...
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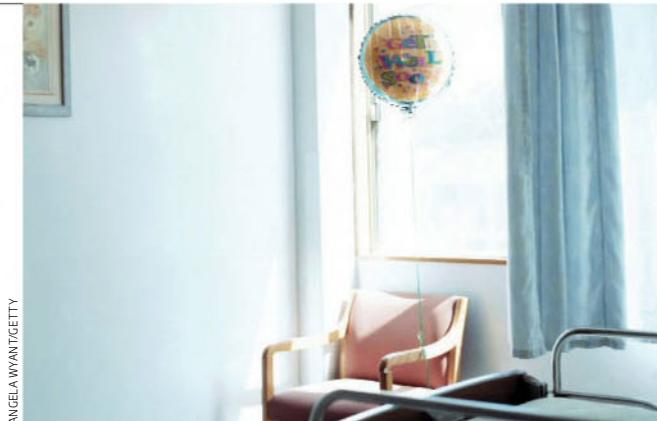
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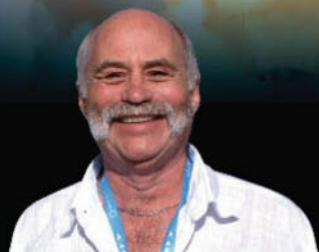
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Space flight: A history

A two-week, action-packed tour in the US with astronomy and space experts

DEPARTURE:

25 SEPTEMBER 2017



Nigel
Henbest

》 VISIT THE TRINITY SITE

Join a small group *New Scientist* readers and local experts on 7 October at the Trinity site in New Mexico, the desolate spot where the first atomic bomb was tested. Seldom open to the public, it will be a rare opportunity to get close to some of the key science behind space flight engineering.

》 AN APPOINTMENT WITH APOLLO 11

Gaze at the Apollo 11 capsule as you enter the Smithsonian Air and Space Museum before studying the Viking lander and the Gemini and Mercury capsules. Venture into the Spaceport Operations Center at Virgin Spaceport America and interact with crewmembers. Explore the US Space and Rocket Center where the Saturn V Moon Rocket is displayed.

》 QUIZ AN ASTRONAUT

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© 2017 New Scientist Ltd, England.
New Scientist ISSN 0262 4079 is published weekly except for the last week in December by New Scientist Ltd, England.
New Scientist (Online) ISSN 2059 5387
New Scientist at Reed Business Information 360 Park Avenue South, 12th floor, New York, NY 10010.
Periodicals postage paid at New York, NY and other mailing offices.
Postmaster: Send address changes to New Scientist, PO Box 3806, Chesterfield, MO 63006-9953, USA.
Registered at the Post Office as a newspaper and printed in USA by Fry Communications Inc., Mechanicsburg, PA 17055



PETER GLASS/DESIGN PICS/PLANPICTURE

The only way is ethics

As controversial decisions loom, the public must be involved

LAST year, the UK became the first country to formally approve a therapy called mitochondrial replacement, which can prevent children from inheriting devastating genetic disorders.

The decision to approve "three-parent babies" was difficult and controversial. The science had advanced to the point where it was safe and effective. But it was also a step towards human genetic modification – to some, a red line.

The decision was the right one, at least given the state of scientific knowledge and society's ethical priorities. We can be especially sure of that latter point because the decision was made in the full glare of public consultation, with all of the controversies laid bare.

For many in policy circles, that initiative set the gold standard for handling future ethical dilemmas. And we can be sure there will be no shortage of those.

The march of science gives us the power to influence more lives than ever before. And as we take ever bigger strides, we need to be careful who we step on. The decisions we must make are more important than setting the direction of science or medicine. They are about the sort of society we want, the principles that we live by and the beings we value (see page 28).

The three-parent baby debate shows that we know how to have these discussions in biomedicine. Other fields could learn from it.

Climate scientists should consider the ethical implications of geoengineering; tech giants and governments must talk seriously about privacy.

At present, such debates are largely conducted behind closed doors. Those with expertise worry that the public is too ill-informed to make the right decisions. The public responds with mistrust.

That is no way to reach a durable consensus. Opening these discussions up means ceding some control, but not doing so is undemocratic. Public involvement does not always produce a knee-jerk rejection. The converse, locking people out of crucial decisions, would be both unwise and unethical. ■

Burst your carbon bubble

CLIMATE change denialism has always carried a strong whiff of self-interest. Highly profitable fossil fuel companies have little incentive to change the status quo. Owning one is as close as it gets to a licence to print money.

But beyond the quarterly balance sheet lies an even bigger financial barrier to change. The world economy is heavily, almost suicidally, invested in the future

discovery and exploitation of oil and gas reserves (see page 20).

If radical action against fossil fuels becomes necessary, these investments will suddenly turn bad. Oil and gas reserves in the ground will become worthless, stranded assets; bets backing future discoveries will be binned.

These investments aren't owned exclusively by distant financial elites, however. Anybody

who has a private pension, savings account or other financial product will probably be invested in such assets. In other words, many of us have a reason to deny the science, or stall for as long as we can.

The way out is to gradually deflate the carbon bubble rather than ignore it until it bursts. From a personal perspective, that means finding out what you are invested in, and considering getting out of fossil fuels. Think of it a bit like recycling: a chore, but part of your duty as a responsible citizen. ■

Long-range missile test

NORTH Korea claimed to have tested its first intercontinental ballistic missile in a launch on Tuesday.

The North has previously conducted satellite launches that critics say were disguised tests of its long-range missile technology.

But a test launch of an intercontinental ballistic missile, if confirmed, would be a major step forward in the country's development of a nuclear-armed missile that can reach anywhere in the US.

The launch came on the eve of the US Independence Day holiday, days after the first face-to-face meeting of the leaders of South Korea and the US, and ahead of a global summit of the world's richest economies.

A North Korean newsreader said the rocket flew 933 kilometres,

reaching an altitude of 2802 kilometres in a flight time of 39 minutes.

If these figures are correct, the missile would have been on a very highly lofted trajectory and could have a possible maximum range of around 6700 kilometres, estimates David Wright, a US missile scientist at the Union of Concerned Scientists in Cambridge, Massachusetts. This could put Alaska in range, if fired at a normal trajectory, he says.

North Korea has a reliable arsenal of shorter-range missiles, but is still trying to perfect longer-range ones.

Some analysts believe North Korea has the technology to arm its short-range missiles with nuclear warheads, but it is unclear if it can build an atomic bomb that can fit on a long-range missile.



Kim Jong-un watches it go

DeepMind rapped

THE UK's data protection watchdog has ruled that a deal to share 1.6 million NHS patient records with the Google-owned artificial intelligence company DeepMind "failed to comply with data protection law".

The data-sharing agreement was first reported by *New Scientist* in April last year. After a year-long investigation the Information

have been more transparent.

"There's no doubt the huge potential that creative use of data could have on patient care and clinical improvements, but the price of innovation does not need to be the erosion of fundamental privacy rights," said Elizabeth Denham, the information commissioner.

The ICO says the Royal Free will now have to "establish a proper legal basis under the Data Protection Act for the Google DeepMind project". DeepMind started its own review panel last year to look at its work with the NHS. Despite the ICO investigation, two other NHS foundation trusts – Imperial College and Taunton and Somerset – have since signed agreements with DeepMind to use Streams.

In a statement, DeepMind said it welcomed the ICO's "thoughtful resolution of the case". It said: "In our determination to achieve quick impact... we underestimated the complexity of the NHS and of the rules around patient data, as well as... fears about a well-known tech company working in health."

"The price of innovation does not need to be the erosion of fundamental privacy rights"

Commissioner's Office (ICO) found shortcomings in the handling of the data, though it has so far stopped short of ordering the data to be deleted.

The agreement gave DeepMind access to patient data from the Royal Free London NHS Trust to help develop an app called Streams, which would monitor kidney disease. The ICO found that patients were not told that their data would be used in this way and that the trust should

Damp squib

CHINA'S latest space launch has flopped. The Long March 5 rocket took off successfully at 11.23 am GMT on Sunday from the Wenchang Space Launch Centre in China, but after only an hour came tumbling back down to Earth.

Once in the air, mission control in Beijing tried to save the rocket by changing its flight plans, but to no avail. The rocket, along with the experimental communications satellite it

was carrying, crashed into the Pacific Ocean.

The cause of the failure is still being investigated, and is likely to delay future launch plans.

China had planned to send a rover into space by the end of this year, destined for the far side of the moon, with the hope of bringing rock and soil samples back to Earth. But the mission relies on hitching a ride aboard a Long March 5 rocket, so may not go to plan if the causes of the latest failure take a while to find and rectify.

San Fran's flavour ban

TOBACCO is to lose its taste in San Francisco. The Californian city has become the first in the US to ban all sales of flavoured tobacco.

Starting next April, the ban covers any tobacco product with a "distinguishable taste or aroma", including menthol cigarettes and flavoured vape fluids. Its backers say it will protect certain minorities.

Research by the California Tobacco Control Program suggests almost three-quarters of black adult

smokers, and half of gay smokers, buy menthol cigarettes, compared with only a fifth of white adult smokers. Menthol seems to boost addictiveness, other work shows.

"This ordinance says to the world that San Francisco is in the front line of defence against a social injustice that has been affecting African Americans, the LGBTQ community and other communities of colour," says Valerie Yerger at the University of California, San Francisco.

60 SECONDS

Protecting the bees

PRESSURE is growing on the European Union to introduce a full ban on neonicotinoids after two studies confirmed that the world's most widely used insecticides are bad for bees. A

"You'd have to be pretty unreasonable at this point not to accept that these chemicals harm bees"

temporary ban is in place for bee-attractive crops.

The largest field trial to date, led by Richard Pywell at the UK's Centre for Ecology and Hydrology, tested impacts of neonicotinoids clothianidin and thiamethoxam on honeybees, bumblebees and solitary bees at 33 oilseed rape sites in the UK, Germany and Hungary. Overall, both were found to be harmful (*Science*, DOI: 10.1126/science.aaa1190).

Another study, led by Nadejda Tsvetkov at York University in Toronto, Canada, found that bees exposed to realistic levels of clothianidin in the lab died younger and their colonies were more likely to lose queens (*Science*, DOI: 10.1126/science. aam7470). "You'd have to be pretty unreasonable at this point not to accept that, at least some of the time, these chemicals harm bees when used in normal farming practice," says Dave Goulson at the University of Sussex, UK.

YAHIA ARHAB/EPA/REX/SHUTTERSTOCK



Yemen's war frustrates treatment

In cholera's grip

YEMEN's cholera death toll last week exceeded 1500, and the number of cases there will soon reach 250,000. Fresh medical supplies should help treat more people, but won't be enough to stop the epidemic's spread.

Cholera is caused by ingesting food or water contaminated with *Vibrio cholerae* bacteria. The resulting severe diarrhoea and dehydration can be deadly, although oral rehydration

"We're currently in a situation of treating patients, but not limiting the spread of cholera"

solutions or intravenous fluid are easy and effective treatments. In Yemen, however, two years of civil war have put the healthcare system under huge strain, and cholera has been spreading for several months.

The arrival of a shipment of supplies from the World Health Organization on 2 July should help. It includes 20 ambulances, 100 cholera kits and 128,000 bags of intravenous fluid.

But doctors in Yemen say this won't end the epidemic. "More than half the health structures within the country are not functioning, and health workers haven't been paid since August

SPENCER PLATT/GETTY



These vape fluids will soon vanish

Artificial organ

Artificial bile ducts have been grown in mice. A University of Cambridge team cultured cells taken from healthy bile ducts into mini organs, which then developed into functioning bile ducts when implanted (*Nature Medicine*, doi.org/b89s). The technique may one day help people with bile duct problems, for whom the only current option is a liver transplant.

Rigging revealed

Statisticians have taken on riggers. Both Venezuela and Russia experienced rigging in the last 10 years, according to an analysis of voting patterns in 21 elections in 10 countries. Small polling stations were the most susceptible (*Science Advances*, doi.org/b88z).

Cyber blame game

Ukraine has claimed Russia was behind a new ransomware attack on computers that caused havoc around the world, but which seems to have hit Ukraine the hardest. The malware, dubbed NotPetya, hit Ukraine's national bank, public transport hubs and supermarkets.

Phew! What a scorcher

The temperature in the city of Ahvaz in Iran soared to 53.7°C last week, according to Etienne Kapikian, a forecaster at French meteorological agency MeteoFrance. If verified, this fell just short of the hottest temperature detected on Earth in the modern era, of 54.0°C in Death Valley, California, in 2013 and Mitrabah, Kuwait, in 2016.

Walk the walk

Cell phones are making people walk differently. A study that tracked how 21 people negotiated an obstacle and a step, without a phone or while texting, reading the screen, or making a call, found that using a phone made people walk slower and in less of a straight path, particularly when texting (*PLoS One*, doi.org/b89t).

The light way to better brain health

Linda Geddes

BILLIONS of dollars have been spent in search of treatments for psychiatric conditions and brain disorders, when a cheap and effective drug may have been right under our noses: light. Now hospitals are turning to light to treat depression, strokes and Parkinson's disease, using it to hit the reset button on our internal clocks.

From green light soothing the pain of migraine, to blue light reducing organ damage during surgery, recent small studies have uncovered some intriguing effects of this therapy. But apart from easing seasonal affective disorder, we've been slow to embrace light as a serious contender for treating neurological conditions.

We've known for 15 years that a special kind of receptor in our eyes transmits information directly to the body's master clock, as well as other brain areas that control mood and alertness. These cells are particularly responsive to bluish light, including sunlight.

These receptors enable light to act as a powerful reset switch, keeping the clock in our brain synced to the outside world. But this clock can fall out of sync or weaken as part of ageing or a range of disorders – a problem doctors are now starting to treat with light.

Most hospitals have small windows and 24-hour lighting, both of which might exacerbate health problems. To tackle this, several hospitals in Europe and the US are installing dynamic "solid state" lighting, which changes like daylight over the course of a day. Such lights can,

for example, shine bright whitish-blue in the morning, grow warmer and dimmer throughout the day, and turn orange or switch off at night.

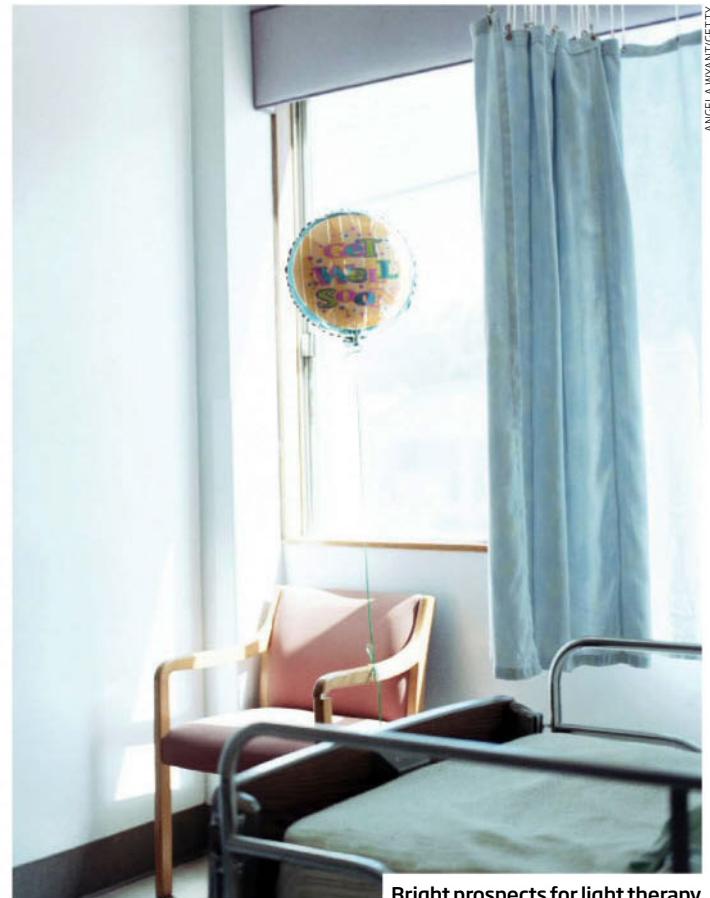
But it hasn't been clear if such lights make a difference to health. Now Anders West at Glostrup Hospital in Copenhagen and his team have shown it

"I think we're going to see a complete revolution in lighting and architecture in a very short space of time"

helps people recover from strokes.

Up to a third of people are depressed in the weeks following a stroke, while up to three-quarters experience fatigue and poor sleep. "These symptoms can have an adverse effect on cognitive function, recovery and survival," says West.

He presented data at the Society for Light Therapy and Biological Rhythms conference in Berlin in June, which showed that people recovering from strokes score lower for depression and fatigue, and show more robust circadian rhythms when exposed to solid



Bright prospects for light therapy

state lighting. "The effect was comparable to giving patients antidepressants," says West.

Hospital lighting also seems to have a dramatic effect on severe depression, which often involves a disrupted circadian clock with delayed sleep periods. At the

Berlin conference, Klaus Martiny of the Psychiatric Centre in Copenhagen presented research showing that people being treated for severe depression were discharged almost twice as quickly if their rooms faced south-west in comparison with those whose rooms had a north-west aspect. Depending on the time of year, the intensity of daylight in the south-west rooms was 17 to 20 times brighter.

"These are very depressed patients who tend to stay in their rooms and isolate themselves, so they're more exposed to differences in light intensity," says Martiny. The 67 people in the study had been randomly assigned rooms, and those who stayed in the brighter rooms were discharged after 29 days on average, compared with nearly 59 days for those in darker rooms.

"We don't know the precise

MORNING DOSE OF SUNSHINE

If light can be a drug, should healthy people be wary of how they use it?

Much has been said in recent years about the harmful effects of blue-enriched light at night from smartphones and other screens, but we are still untangling the effects.

A study published this month found that exposure to bright blue-enriched light for 3 hours during the morning lessens the impact of evening blue-light exposure on sleep and circadian rhythms (*Neuropsychobiology*, doi.org/b88v).

Compared with people exposed to a warmer, dimmer light in the morning, these people also had faster reaction times in both the morning and evening, suggesting they were more alert.

"Light from iPads or whatever will have detrimental effects if people are spending their daytime in darkness, but if they have been in bright light during the day, it [matters less]," says Dieter Kunz of the Charité-Universitätsmedizin hospital in Berlin.

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mechanism, but I think it's to do with exposure to the morning light, which advances and stabilises their sleep-wake cycles," says Martiny. His team's findings are now informing the design of a new psychiatric centre, due to open in Copenhagen in 2022.

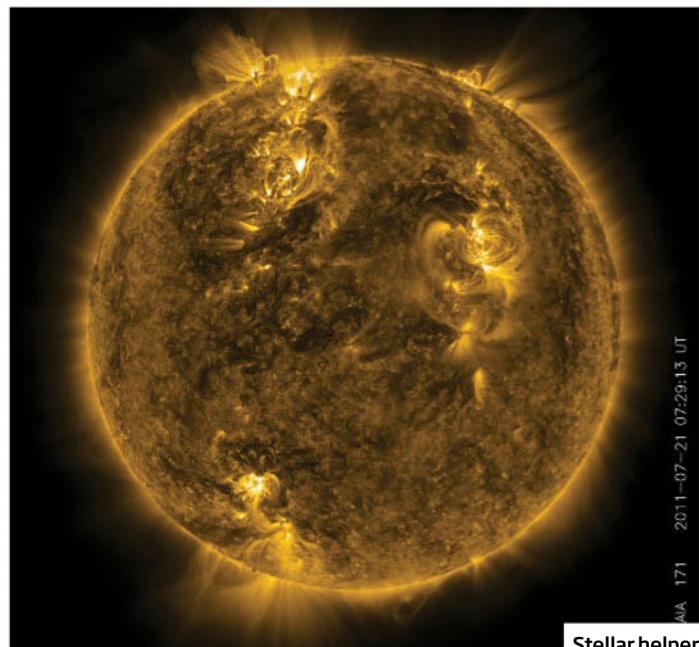
Using light to alter circadian rhythms could also help Parkinson's disease. "One of the main challenges for people with Parkinson's disease is that they keep waking up in the night, and a lot of them also have problems staying awake in the daytime," says Aleksandar Videnovic at Massachusetts General Hospital in Boston.

In previous work, his team found that the rhythmic expression of certain genes was flattened in Parkinson's disease, suggesting a sluggish circadian clock. So Videnovic decided to try treating people with the condition using a light box that emits bright white light twice a day, for two weeks. The idea wasn't to shift the timing of the clock, but to strengthen it.

The study, published earlier this year, found that those exposed to the bright light slept better at night and were less sleepy and more active in the day, compared with people given a dim red light box as a control (*JAMA Neurology*, doi.org/b88s). The team also saw improvements in some of the movement symptoms of early Parkinson's disease.

"We're at such an interesting time," says George Brainard at Thomas Jefferson University in Philadelphia. "On the one hand, solid state lighting has emerged that is exquisitely tunable, and can do numerous things," he says. "At the same time, there's a matured understanding that light truly affects health."

Brought together, this provides a very exciting opportunity, says Brainard. "I think we're going to see a complete revolution in lighting and architecture in a very short space of time." ■



Sun's gravity could boost video from deep space

NEED to send a message across interstellar space? Use the sun for a signal boost. A new proposal suggests using our star's gravity to amplify signals from an interstellar space probe, allowing video to be streamed from as far away as Alpha Centauri. Better still, the technology to do it has already been invented.

Though we don't yet have probes far out enough to take advantage of this technology, it may eventually come in handy for sending images between star systems. Building such a communications grid now would make calls to our own spacecraft - or from an alien race - a future possibility.

Independent astrophysicist Michael Hippke found that to receive even a single-watt signal sent by a probe at Alpha Centauri, the nearest star system to our own, an Earth-based instrument would need to be 53 kilometres across - that's bigger than New York City.

In his study, Hippke proposes instead that a telescope about a metre across could relay the signal. It would just have to be placed at a point about 90 billion km from the sun - a distance

that would optimise an effect known as gravitational lensing to magnify the signal (arxiv.org/abs/1706.05570).

The effect, predicted by Albert Einstein and first observed in 1919, focuses light to a point as it passes the edge of a massive object such as the sun. Because space-time curves near a massive body like the sun, light passing nearby bends into what's called an "Einstein ring" that makes

"The data rate should be high enough to send pictures and video - but it would take years to arrive"

stars appear nearly a billion times brighter than they would if viewed head-on.

Such a signal boost could allow us to build receivers for any mission to interstellar space. Without it, we'd need to construct massive telescopes on Earth and send probes to interstellar space large enough to carry immense power sources.

Even the largest telescope currently under construction - the

39-metre European Extremely Large Telescope - falls far short of the size needed, and comes with a price tag of nearly one billion euros.

With the gravitational-lensing effect, a little power would go a long way towards transmitting data back to our solar system. "Around the nearest stars, a handheld laser pointer could do it," says Hippke.

The potential data rate should be high enough to send pictures and video, although it would still take four years to receive any data stream sent from as far away as Alpha Centauri.

The latest proposal for sending probes to this star system is Breakthrough Starshot, which would dispatch a fleet of miniature spaceships weighing only a few grams each and powered by light sails. The sails, the lasers to power them and the electronics will need years of development.

Not so for Hippke's design, which uses only off-the-shelf technologies. But that doesn't mean it's an easy feat. To act as a relay, his spacecraft would need to be more than four times as far away as the current position of Voyager 1, which is 20.8 billion km from the sun - the most distant spacecraft humans have sent into space to date, after being launched 40 years ago.

Any closer than 90 billion km and the sun would block the signal rather than boosting it.

Slava Turyshev, a physicist at NASA's Jet Propulsion Laboratory in California, says Hippke's plan is "challenging but not impossible". The receiving spacecraft needn't even come to a complete stop because it could still get signals up to 300 billion km from the sun.

Turyshev says a slingshot manoeuvre around the sun might work to get one out to the 90-billion-kilometre mark in a time frame of 25 to 30 years.

Despite the challenges involved in such an ambitious project, Hippke says humans have created larger space telescopes than the one he proposes launching.

"This is much easier than building the Hubble Space Telescope," he says. Jesse Emspak ■

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Our forgotten fling with Neanderthals

Aylin Woodward

IT'S a sex-laced mystery. If modern humans didn't reach Europe until about 60,000 years ago, how has DNA from them turned up in a Neanderthal fossil in Germany from 124,000 years ago?

The answer seems to be that there was a previous migration of early humans – more than 219,000 years ago. One that we're only just starting to reveal from piecemeal evidence that is DNA extracted from fossilised bones.

The story, as far as we knew it, was that the ancestors of modern humans diverged from Neanderthals and Denisovans between 550,000 and 765,000 years ago. While Neanderthals and Denisovans inhabited Eurasia, modern humans stayed in Africa until about 60,000 years ago. Then they entered Europe, too.

There is ample evidence of breeding between Neanderthals and the ancestors of modern humans some 50,000 years ago. "Everyone knows Neanderthals gave us genes," says Cosimo Posth at the Max Planck Institute for the Science of Human History in Leipzig, Germany.

Analysis of mitochondrial DNA from a Neanderthal femur found in south-western Germany now adds to evidence that there was earlier interbreeding. The DNA in the energy-producing mitochondria in our cells is different from that in our cell nuclei, and is passed only down the female line.

Puzzlingly, the mtDNA in Neanderthal bones is more similar to that of modern humans than it is to that of the Denisovans.

Posth and his colleagues looked at differences between the mtDNA in this femur and in other Neanderthals, and used mutational rates to calculate that the bone is 124,000 years old. The approach also indicates that this Neanderthal split from all other known Neanderthals sometime between 316,000 and 219,000 years ago. Yet it still contains key elements of early human mtDNA.

This means that modern human ancestors must have interbred with Neanderthals before 219,000 years ago – and hence could have migrated out of Africa and into Europe much earlier than we thought (*Nature Communications*, DOI: 10.1038/ncomms16046).

"We are realising more and more that the evolutionary history of modern and archaic humans was a lot more reticulated than we would have thought 10 years ago," says team member Fernando Racimo of the New York Genome Center. "This and previous findings are lending support to models with frequent interbreeding events."

The team says an earlier migration event is also compatible with evidence of archaeological similarities between Africa and western Eurasia. "It would be interesting to analyse multiple lines of evidence of possible connectivity between continents and see if there was potential contact that spread not only genes but also cultural information," Posth says.

The results also suggest that Neanderthals had a much greater genetic diversity and larger population than we realised.

This study broadens our view, from the genetic perspective, of who the Neanderthals were as a species, says Toomas Kivisild at the University of Cambridge. "Previous work based on more than a dozen Neanderthal samples whose mitochondrial DNA had been sequenced has portrayed Neanderthals as a species of very low effective population size and genetic diversity," he says. ■

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We have a thing for Neanderthals

Driverless taxis set to open doors to public

STEP into a taxi in south London later this year and you might not have to think about paying a tip. The UK's first fully public trial of autonomous vehicles will soon be under way.

For four weeks, a fleet of driverless shuttles will each ferry up to five passengers and a "safety warden" along a 2-kilometre route in Greenwich. Previous trials there and

in the town of Milton Keynes required participants to register in advance. This time the vehicles will pick up anyone wanting a ride.

The four-stop route will connect a hotel close to the O₂ Arena concert venue with the Millennium Village housing development. En route, the shuttles will also call at a river-bus stop and a cable car terminal.

Similar shuttles are already in use at London's Heathrow airport, but are confined to a purpose-built area off limits to other traffic. In Greenwich, pedestrians and cyclists will be able to access the test route.

The vehicles will lack conventional controls, although the wardens will be able to slow them to a crawl or shut down the autonomous system.

There's little danger of a high-speed collision: the shuttles will be limited to travelling at 15 kilometres per hour.

The taxis could carry hundreds of passengers daily during the trial, according to Simon Tong at TRL, a transport consultancy involved in

the work. The trial, funded by the UK government, is part of the wider Gateway project to use Greenwich as a test bed for driverless vehicles.

Zia Wadud at the University of Leeds, UK, thinks that public transport is the ideal application for driverless vehicles. Autonomous cars can reach places not usually served by buses or trains, he says.

Driverless taxis are coming into service elsewhere, too. Last September, Uber began using them in Pittsburgh, and its rival, Lyft, will test its own autonomous cars in Boston later this year. Matt Reynolds ■

'Autonomous cars can bring public transport to places not usually served by buses or trains'

Plastic particles get fingerprints for secure keys

MICROSCOPIC wrinkles squeezed onto the surface of tiny plastic particles could be used to create security keys that are impossible to duplicate.

The randomly generated wrinkles are a lot like our own fingerprints, says Derek Bredt at Saint Vincent College in Pennsylvania, who wasn't involved in the work. Since each pattern is unique, it could be used to verify a person's identity instead of a security card or their own fingerprint.

Security keys made this way would be nearly impossible to clone, says Wook Park at Kyung Hee University in South Korea, who developed the technique along with his colleagues.

Their method involves coating plastic particles with silica, then soaking them in ethanol. As they dry, wrinkles form in the thin silica layer, creating a fingerprint-like structure (*Science Advances*, doi.org/b88r).

Tiny irregularities in temperature, or the presence of dust or other particles, influence the patterns. "It's a very chaotic process," says Bredt, making it almost impossible to accurately recreate a wrinkle pattern.

Although the pattern generation is largely random, Park and his team can partly control it. After they hardened parts of the plastic particles by exposing them to light, each hardened dot formed a "decision point" where the wrinkles either finish, bend or split.

This could be handy for creating a matching set of secure keys. Manipulating a group of particles in the same way - exposing them to the same pattern of light, for example - would lead to keys with similar decision points.

Although the overall fingerprint will still be random, a scanner reading the particle would be able to recognise the location of these points. It would thus know that a particular key belonged with a group of similar keys that open the same door, for instance, so they can be shared among a group. Matt Reynolds ■



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Wipe out?

Cancer vaccines could eliminate tumours

COULD this be the cancer advance we have been waiting for? Cancer vaccines that can trigger a person's immune system into killing a tumour have long been a goal. Now two slightly different ways of doing this have had promising results.

The therapies need to be tested in bigger trials, but the initial results from a small number of people with skin cancer are being heralded as major progress. "This could be huge," says Cornelis Melief of Leiden University Medical Center in the Netherlands.

Our immune system recognises bacteria and viruses as foreign invaders by the different protein molecules they have on their surface. Because tumour cells have mutations that also make them look different, the immune system sometimes targets them - but the cancers that prove fatal somehow escape this attack.

For decades, researchers have been trying to find ways to ramp up the immune response to tumours, usually by injecting

people with immune-stimulating drugs and the molecules thought to be present on the surface of the cancer cells. However, so far, nothing has worked well.

Part of the problem may be that all cancers are different - each person's tumour can have hundreds of mutations. Also, prompting the immune system to

"What's really exciting is that it involves tumour sequencing and a bespoke, customised vaccine"

target one particular molecule can fail because tumours can mutate again and stop being recognised.

The new techniques involve making a personalised vaccine that targets many of a person's cancer molecules at once. Both start in the same way, by taking samples from someone's tumour, sequencing its genes and comparing them with those from the person's healthy cells to reveal the cancer mutations. Then software is used to predict which parts of the mutant protein

molecules are most likely to be bound strongly by immune cells, triggering a successful attack.

The two approaches differ in what happens next. Catherine Wu of the Dana-Farber Cancer Institute in Boston and colleagues injected up to 20 of the mutant protein molecules into the skin of six people with cancer. Four had no recurrences of their cancer after two years (*Nature*, DOI: 10.1038/nature22991).

In the second approach, Ugur Sahin of BioNTech, a German biotech firm, injected people with RNA instead of protein molecules. Normally, cells make proteins using RNA "instructions", and injecting these can lead to some cells turning the RNA into proteins. The end result of both methods was therefore the same: snippets of cancer molecules were exposed to the immune system. With the RNA approach, tumours didn't recur in eight out of 13 people after two years (*Nature*, DOI: 10.1038/nature23003).

In some of the people in both trials who did develop metastases, a second therapy, called a checkpoint inhibitor, was found to wipe them out. Checkpoint inhibitors block a signalling pathway that helps tumours stop immune system attacks. "It makes sense to put a cancer vaccine together with a checkpoint inhibitor," says Wu.

"What's really exciting about this approach is that it involves sequencing their tumour and making a bespoke, customised vaccine," says Kevin Harrington of The Institute of Cancer Research in London. "When we have previously given vaccines, we have taken a generic approach and it was a bit hit-and-miss."

Although this method might work with any kind of cancer, skin tumours may be more vulnerable to immune attack. "You could in theory vaccinate any tumour type," Harrington says, "but some will be more amenable to this sort of approach than others." Clare Wilson ■

'Missing link' baleen whale fossil found?

Luisa Mostert

HOW did the largest creatures ever to live on Earth evolve to feed on minuscule ones? A fossil skull belonging to a whale that could both filter feed and catch large prey reveals the first step in this process.

Baleen whales like the blue whale suck in enormous mouthfuls of water and then force it out through the baleen filter hanging from their upper jaw, retaining prey such as krill and small fish. But early whales had big, sharp teeth for catching large prey. So how one branch of the family evolved into filter feeders with baleen "sieves" made out of keratin – the same stuff as fingernails – has been a mystery.

The current idea is that the ancestors of baleen whales lost their normal teeth and only later evolved a sieve. But the skull of a previously unknown species of

whale suggests alternatively that they started filter feeding by adapting teeth to act as sieves.

The 30-million-year-old skull was found on the bed of South Carolina's Wando river by a scuba diver about a decade ago. It has now been analysed and described

by a team led by Jonathan Geisler at the New York Institute of Technology.

This early whale, dubbed *Coronodon havensteini* by the team, had sharp, pointed front teeth that it used to catch large prey, like other early whales. But it also had unusual saw-like back teeth, shown below (*Current Biology*, doi.org/b87s).

"The wear indicates they were not used for shearing food or for biting off chunks of prey," says Geisler. "It took us some time to

come to the realisation that these large teeth were framing narrow slots for filter feeding."

The whale probably couldn't suck in big mouthfuls of water like today's baleen whales, though. Instead, the team think it was a ram feeder, opening its mouth and charging at shoals of small prey.

Modern leopard seals have evolved similar feeding habits: they can filter feed on krill as well as catching larger prey like penguins. In fact, it was predicted that leopard seals would filter feed based on the shape of their teeth before it was actually observed.

Not everyone is convinced by the idea that *C. havensteini* was a filter feeder, though.

"The small amount of wear found on the teeth does not give a clear indication of specialised filter feeding," says evolutionary biologist Alistair Evans at Monash University, Australia. He thinks the back teeth were used for cutting large prey.

Whichever idea is right, the skull doesn't reveal how baleen evolved. This is hard to study because baleen doesn't fossilise as well as bone. ■



GESLER ET AL

Sieve-like teeth

Peering inside an AI's brain will help us trust it

TAKING a glimpse inside the mind of a machine could explain why they can be tricked into seeing things that aren't there – a problem we need to overcome given the advent of things like driverless cars. A test that reveals which parts of an image an AI is looking at hopes to do just that.

Artificial intelligences don't make decisions in the same way that we do. Even the best image recognition algorithms can be tricked into seeing a robin or a cheetah in images that are just white noise, for example.

It's a big problem, says Chris Grimm at Brown University in Providence, Rhode Island. If we don't understand

why these systems make silly mistakes, we should think twice about trusting them with our lives in things like driverless cars, he says.

So Grimm and his colleagues created a system that analyses which part of an image an AI is focusing on when it decides what the image is depicting. Similarly, for a document-sorting algorithm, the system highlights which words the algorithm used to decide which category a particular document should belong to.

It's really useful to be able to look at an AI and find out how it's learning, says Dumitru Erhan at Google. Grimm's tool provides a handy way to check an algorithm is coming up with the right answer for the right reasons, he says.

To create the tool, the team wrapped a second AI around the one they wanted to test. This "wrapper AI" replaced part of an image with white

noise to see if that made a difference to the original software's decision. If replacing part of an image changed the decision, then that area of the image was likely to be an important area for decision-making.

Grimm tested his technique on an AI trained to sort images into one of 10 categories, including planes, birds, deer and horses. His system mapped

'Even the best image-recognition algorithms can be tricked into seeing a robin or a cheetah'

where the AI was looking when it made its categorisation. The results suggested that the AI had taught itself to break down objects into different elements and then search for each of those elements in an image to confirm its decision.

For example, when looking at images of horses, Grimm's analysis showed that the AI first paid close attention to the legs and then searched the image for where it thought a head might be. The AI took a similar approach with images containing deer, but in those cases it specifically searched for antlers. The AI almost completely ignored parts of an image that it decided did not contain helpful information.

Grimm thinks that his tool could help people work out how AIs make their decisions. For example, it could be used to look at algorithms that detect cancer cells in lung scans, making sure that they don't accidentally come up with the right answers by looking at the wrong bit of the image. "You could see if it's not paying attention to the right things," he says. Matt Reynolds ■

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Gecko-like gripper to snag space trash

Leah Crane

IN SPACE, grabbing things is hard: an accidental nudge can send stuff flying. A robot with grippers inspired by gecko feet could solve that problem, helping to clear up the mess of debris orbiting Earth.

The toaster-sized device can hold on to and move around large, smooth surfaces – both curved and flat – in microgravity. To do this, it uses a “dry adhesive” material created by Hao Jiang at Stanford University in California and his colleagues.

“This ability to grab on to an object nearly anywhere, instead of needing a specific grapple point that may not even be there, is really advantageous,” says Matthew Spenko at the Illinois Institute of Technology in Chicago. “It means you don’t need a precision approach.” Such flexibility is key when handling space debris that could be moving faster than the speed of sound.

The team wanted to mimic the ability of geckos to grip almost any smooth surface with their toes, which are covered in tiny rubbery hairs that bend when pulled along a surface. This causes

the ends of those hairs to split into small strands that interact with the molecules of any surface a gecko climbs. The result? A Velcro-type clinging effect.

To emulate this in a gripper, the researchers used a thin sheet covered in protruding wedges one-tenth of a millimetre wide. These micro-wedges bend when pulled across a smooth surface, sticking to it.

Single sheets of this type have been used before to create tiny robots that can climb smooth walls while dragging heavy loads. Jiang’s team used two wedge-covered sheets with a robotic pulley that secured them together once they touched an object. Attached to a robotic arm, the device could gently grab and secure even large pieces of debris (*Science Robotics*, 10.1126/scirobotics.aan4545).

Of the hundreds of thousands of pieces of space junk in Earth’s orbit, more than 20,000 are larger than 10 centimetres across – big enough to smash a piece off a satellite and create even more orbiting junk. But the harsh environment makes methods we use to grab things on Earth



PLAINPICTURE/NATUREPL/INGO ARNDT

Can't put a foot wrong

ineffective. A suction-based system can’t be used, because there’s no air. Normal adhesives stop being sticky in the cold vacuum, and the force required to attach a piece of sticky tape is enough to make the target object float away.

Other ideas for sweeping up the debris include a giant magnetic net and vaporising laser beams, but none have yet worked out. For now, nobody is picking up the trash.

That’s where this robot comes in. The researchers tested its gecko-inspired grabber using pressurised air at NASA’s Jet Propulsion Laboratory (JPL), and

in the temporary weightlessness of a parabolic plane flight. They also sent a pared-down version to the International Space Station.

On the plane, the device could grasp and move around cubical, cylindrical and spherical objects, and gently release them without affecting their motion. At JPL, it autonomously attached to drifting objects more than 100 times its size and mass. On the space station, it held on to a wall for weeks at a time.

The gripper might be deployed to collect space debris for disposal, but it could also be used on a maintenance robot to allow it to climb the outside of spacecraft. ■

Children who sleep less may age faster

A LACK of sleep doesn’t just turn children into a grumpy handful, it may also accelerate their cellular ageing – a process that could have long-term health effects.

Telomeres – the caps at the ends of our chromosomes – get shorter every time our cells divide, and when they get too short, it is thought that cells are no longer able to divide to repair

and replenish the body – a sign of ageing. Some small studies in adults have suggested that sleep might be linked to telomere length.

To find out if it is also the case in children, Sarah James and Daniel Notterman at Princeton University and their team dug into a database. It included information on average sleep duration collected from 1567 9-year-old children from cities across the US. The team extracted DNA from saliva samples from the children, and examined the length of their telomeres.

They found that telomeres were

shorter in children who slept less (*The Journal of Pediatrics*, doi.org/b87r). “Telomere length is 1.5 per cent shorter for each hour less that children sleep per night,” says James.

Short telomeres have been linked to cancer, heart disease and cognitive decline, but these children showed no signs of these diseases – probably because of their young age. However, they may have a higher risk of

“Having short telomeres has been linked to cancer, heart disease and cognitive decline”

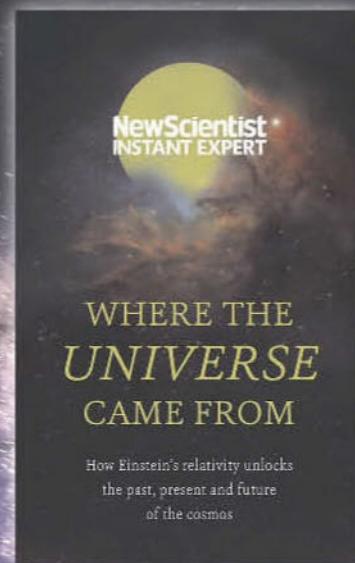
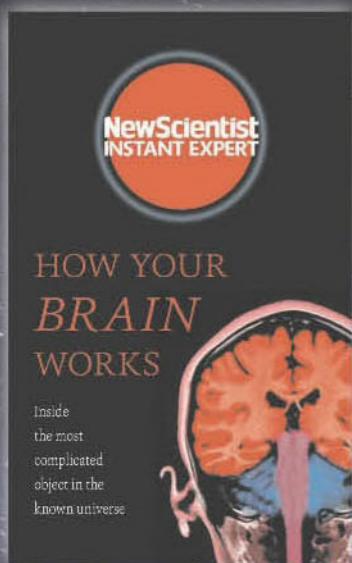
developing these disorders in later life, says James. “It raises concerns.”

Some research in adults suggests that too much sleep might be as bad for your health as too little. But in the children in the study, at least when it came to cell ageing, more sleep was associated with longer telomeres.

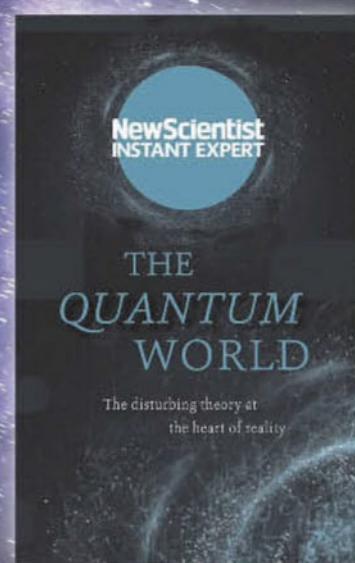
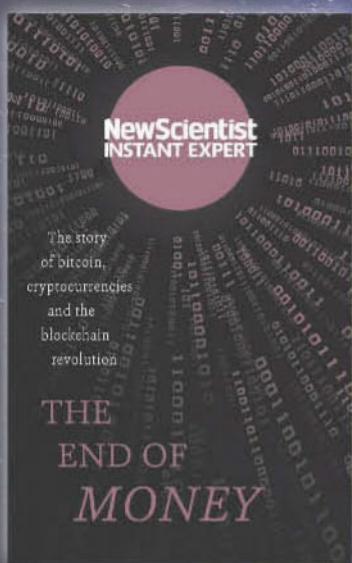
The team doesn’t know whether telomere shortening can be reversed with more sleep, but says the study reiterates the importance of getting plenty of slumber. “The current recommendation is for such children to get between 9 and 11 hours of sleep,” says James. Jessica Hamzelou ■

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AI's genre-defying artworks win fans

Chris Baraniuk

PAINTERS like Claude Monet and Pablo Picasso transformed art by inventing new styles such as impressionism and cubism. Could a machine do the same? Perhaps, now that the public has given the thumbs up to unconventional images created by an artificial intelligence.

The idea is to make art that is "novel, but not too novel", says Marian Mazzone, an art historian at the College of Charleston in South Carolina, who worked on the system.

Mazzone and her colleagues at Rutgers University in New Jersey and Facebook's AI lab in California modified what's known as a generative adversarial network (GAN), pitting two neural nets against each other to get better and better outcomes. The general idea is that one of them creates a solution, the other judges it – and the algorithm loops until it attains the desired result.

The team built a generator network that devised images to be scrutinised by a discriminator network, which had learned from analysing 81,500 paintings to

distinguish between images we would class as artworks and those we wouldn't – such as a photo or diagram. The discriminator had also learned to distinguish between styles of art, such as rococo or cubism.

The twist is that the generator was primed to produce images that the discriminator recognises as art, but that don't fall into existing styles. "You want to have something really creative and striking – but at the same time not

go too far and make something that isn't aesthetically pleasing," says team member Ahmed Elgammal at Rutgers University.

Once the AI had produced a series of images (some examples are pictured below), an online survey allowed members of the public to judge them alongside paintings by human artists, without knowing which was which. Participants answered questions about how complex or novel they felt each work was, and whether it inspired them or elevated their mood.

To the team's surprise, many of the images by the AI scored slightly higher than those by humans (arxiv.org/abs/1706.07068).

"I like the idea that people are

starting to push GANs out of their comfort zone – this is the first paper I've seen that does that," says Mark Riedl at the Georgia Institute of Technology in Atlanta.

The results of the survey are interesting, says Kevin Walker at the Royal College of Art in London. "The top-ranked images contain an aesthetic

"Many of the images by the AI scored slightly higher with the public than work by human artists"

combination of colours and patterns in composition, whereas the lowest-ranked ones are maybe more uniform," he says.

Walker also notes that creative machines are already producing work for galleries. For example, two of his students are using AI that learns to produce its own images based on their drawing styles. One of them, Anna Ridler, has used the technique to create frames for a 12-minute animated film.

Riedl notes that the human story behind an artwork is often an important part of what endears us to it. But Walker thinks the lines will soon get blurry. "Imagine having people over for a dinner party," he says, "and they ask, 'Who is that by?' And you say, 'Well, it's a machine actually'. That would be an interesting conversation starter." ■



A hit with the public

Cockatoos use drumsticks to tap out rhythms

IT'S the original jungle beat. Male palm cockatoos beat trees with drumsticks they've crafted to impress the girls.

They are the only species other than ours known to make a musical tool or instrument, perform with it and repeat musical patterns throughout their performance, says Robert Heinsohn at the Australian National University in Canberra.

The rhythmic drumming was first described in 1984, but has only now been studied in detail. Over a seven-year period, Heinsohn and his colleagues filmed more than 60 drumming events in Queensland's Kutini-Payamu National Park.

The drumming is part of a complex display that males put on for any watching females. Sometimes the males drum with a large seed pod. On other occasions, they snap off a small branch, trim it down to about 20 centimetres and bring it to the nests they make in tree hollows. They hold the drumstick in their left foot

and bang it on the tree while making complex calls, flapping their wings and erecting their feathery crest.

Each of the 18 birds that the team observed had its own unique drumming style. Some had a slow and steady beat, others played faster and with more variability. The females watch performing males closely to assess their skills, Heinsohn says. But they don't dance to the beat or respond in any observable way (*Science Advances*, doi.org/b88n).

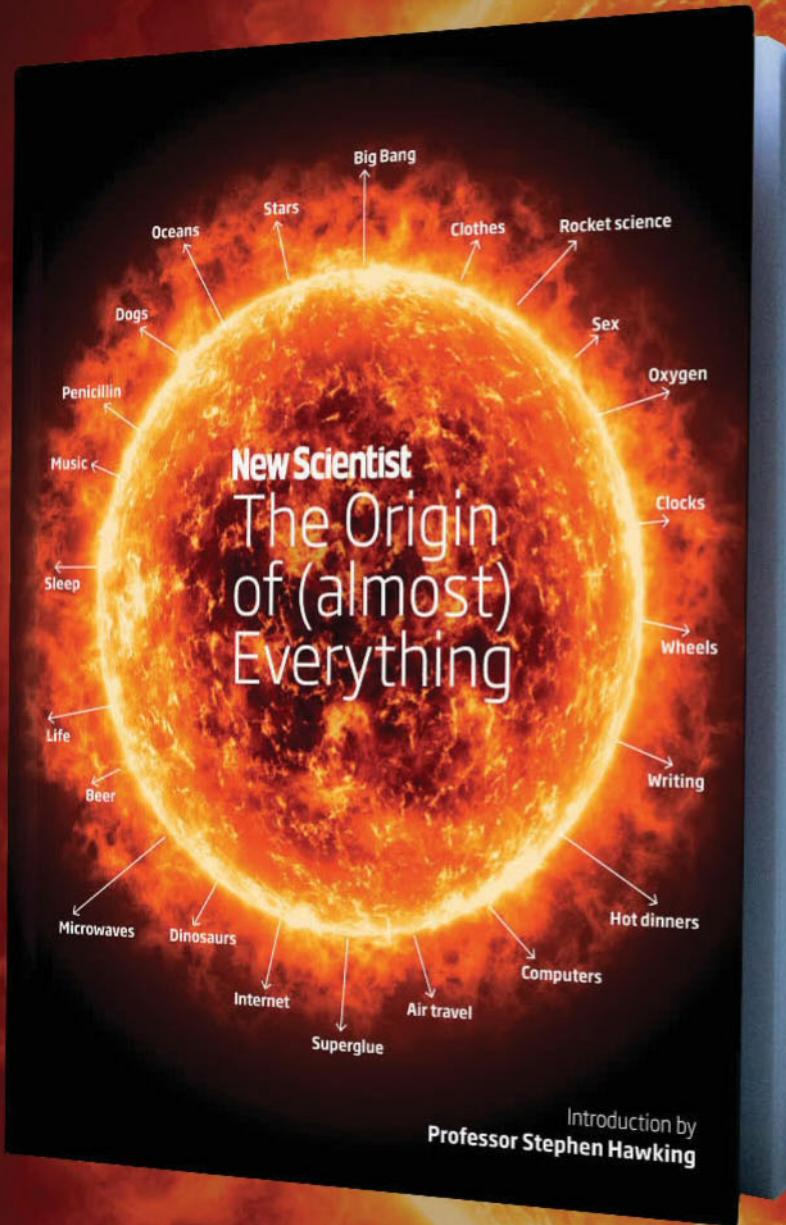
Many animals, such as birds and frogs, call or sing in highly regular ways – but they don't use tools to do it.

And those animals that do use tools do so to get food. For instance, chimpanzees fashion spears for hunting bushbabies or use twigs for catching termites.

Wild chimps, bonobos and gorillas sometimes drum on tree buttresses with their hands or feet, but they don't keep a steady beat. However, in 2005, a captive chimp called Barney spontaneously played an impressive five-minute drum solo on a bucket.

Heinsohn hopes to find out more by seeing how the birds respond to rhythmic and non-rhythmic beats. Aylin Woodward ■

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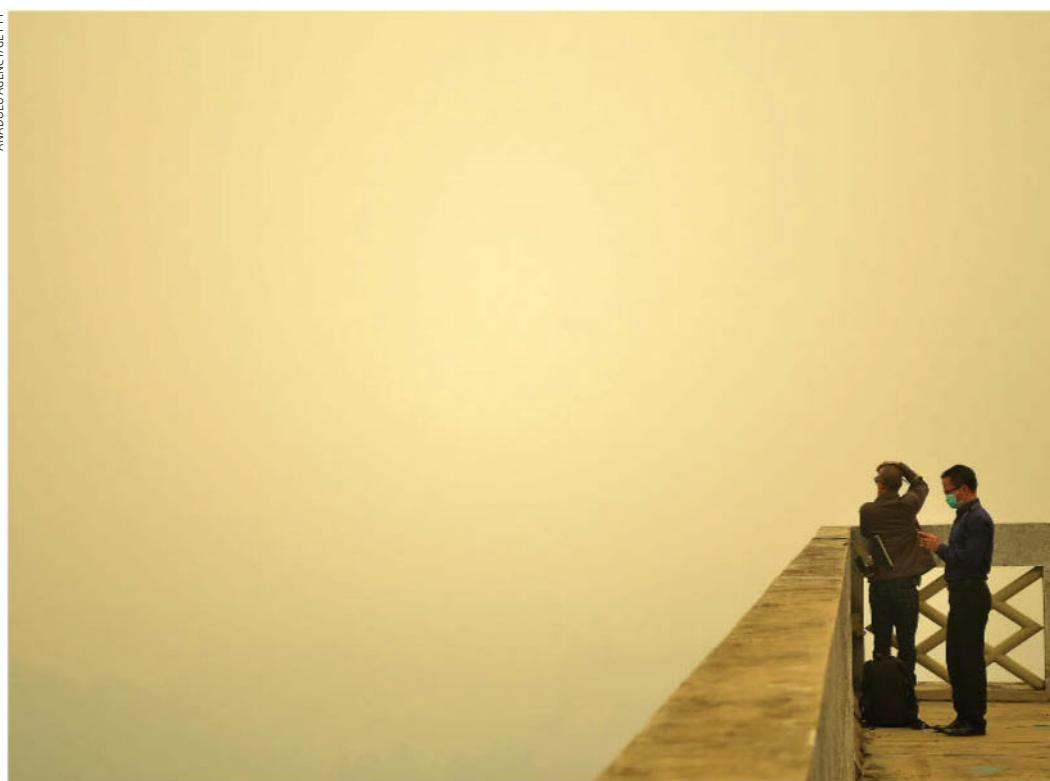
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'Killer haze' tracked with Twitter as it spreads

WHEN Indonesia's peatlands burn, the thick smog that fills the air can be deadly. Haze from wildfires in 2015 may have caused more than 90,000 deaths in the country. To help it keep on top of active fires and save lives, the Indonesian government is trying out a tool that monitors references to haze on social media.

Called Haze Gazer, the tool taps Twitter data to reveal where haze hotspots are – and how locals respond to government-issued evacuation notices. The software was built by a team from the University of Kassel in Germany and Global Pulse, a UN programme set up

to use big data for humanitarian ends. The researchers say Haze Gazer is now being used in the Indonesian president's situation room.

To monitor wildfire haze and track citizens' movements in real time, the team suggested using Twitter because Indonesia has the fifth-largest number of Twitter users worldwide. To test the idea, the researchers analysed 29 million tweets posted in 2014 by more than 575,000 people from the Indonesian island of Sumatra – about 1 per cent of the island's population. Using geolocation data attached to tweets with hashtags mentioning haze, the team was able to map hotspots as they appeared. The tweets also revealed people's movements, allowing the government to see whether people were acting on official evacuation advice (arxiv.org/abs/1706.05406).

Early moon had lopsided atmosphere

BILLIONS of years ago our moon had a magma ocean and a sodium atmosphere.

That's according to a model created by a team including Prabal Saxena at the NASA Goddard Flight Center in Maryland. Saxena compares the early moon to a rock star: a metal-dominated thing that collapsed quickly and intensely.

Immediately after it formed, the moon's surface was probably

covered by a deep magma ocean. The top layers of this ocean would have been vaporised by the heat coming off Earth, which was still hot from a moon-forming impact. This created an atmosphere containing elements like sodium and silicon, which reached temperatures above 1700°C and would have been mostly on the Earth-facing side (arxiv.org/abs/1706.07501).

The difference in temperature and pressure between each side of the moon may have caused supersonic winds to blow from the Earth-facing side to the far side. The new model shows that the winds may have been strong enough to make waves in the magma ocean.

Sodium escaping the moon's atmosphere could also help explain the mystery of why many moon rock samples have less sodium in them than Earth rocks.

Smart kids more likely to reach 80s

PEOPLE with higher IQs are less likely to die before the age of 79, according to a study of more than 65,000 people.

All of the participants were born in 1936 in Scotland, and took an intelligence test at the age of 11. Their health was then followed for 68 years. Now an analysis by Ian Deary at the University of Edinburgh, UK, and his team has found that a higher test score in childhood was linked with a 28 per cent lower risk of death from respiratory disease and a 25 per cent reduction in coronary heart disease risk.

People with higher scores were also less likely to die from injuries and dementia, even when socio-economic status was taken into account (*BMJ*, doi.org/b87h).

"I'm hoping it means that if we can find out what smart people do and copy them, then we have a chance of a slightly longer and healthier life," says Dreary.

The cuckoos that mimic a mammal

COPY that. *Neomorphus* ground-cuckoos in Central and South America seem to mimic the sounds made by the pig-like peccaries they live alongside, perhaps to ward off predators.

Cibile Biondo at the Federal University of ABC in Brazil and her team analysed the cuckoos' bill-clacking sounds. The sounds were distinct from the bill clacks of the closely related roadrunner, but similar to the sounds peccaries make when they clack their teeth to warn off big cats (*Journal of Avian Biology*, doi.org/b87v).

Biondo thinks the cuckoos might imitate the peccaries to deter predators, particularly since hunters rely on hearing in the dark, dense forests where the cuckoos and peccaries live.

It's official: Rubik's cubes are tricky

IF YOU thought solving a Rubik's cube was difficult, you can now feel smug that the maths backs you up. The question of whether a jumbled Rubik's cube of any size can be solved in a given number of moves turns out to be NP-complete – that's mathematical lingo for a problem even the pros find hard.

Researchers at MIT have shown that finding the shortest solution to a Rubik's cube of any size will also yield a solution to another problem that is known to be NP-complete: the Hamiltonian path problem.

That question asks whether, given a diagram of nodes connected by lines – like a triangle, pentagram or a depiction of the vast connections in a social network such as

Facebook – there is a route that visits each node exactly once (arxiv.org/abs/1706.06708).

It's reminiscent of the travelling salesperson problem, which aims to find the shortest route that visits several cities only once – probably the most famous NP-complete question of all.

Solutions to NP-complete problems are easy to check, but the amount of time it takes to find them explodes as the complexity goes up, at least with the algorithms we know about today.

So if you're frustrated by how long it takes you to solve a Rubik's cube, it's no reflection on you.



MARCO MRKONJIC/PIXSELL/PA IMAGES

Proton sheds mass for latest weigh-in

THE proton has lost a little of its bulk. The latest assessment of the subatomic particle's mass is three times more precise than before and makes it 30 billionths of a per cent lighter than we thought.

Sven Sturm from the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, and his colleagues used an electron beam to rip electrons from atoms inside a vacuum-sealed can, freeing protons. The team trapped a single proton in a combination of electric and magnetic fields, using a set-up

known as a Penning trap. By measuring the proton's velocity as it moved in circles in the magnetic field, the team could calculate its mass.

The new mass could help us fine-tune experiments that aim to understand why the amount of matter in the universe dwarfs antimatter, says Makoto Fujiwara, who works on the ALPHA antimatter experiment at CERN. More precise measurements of the proton should make it easier to look for discrepancies between it and the antiproton.

No one is yet sure why these results disagree with previous ones (arxiv.org/abs/1706.06780). It could be an indication of new physics – or simply an error in the experiment that the researchers overlooked, says Peter Mohr of the Committee on Data for Science and Technology (CODATA), which publishes standard scientific values. This means CODATA will have to carefully consider how it uses this new value, he says.

Sturm and his colleagues plan to repeat and refine the measurement.

Drug gives old mice a hearing boost

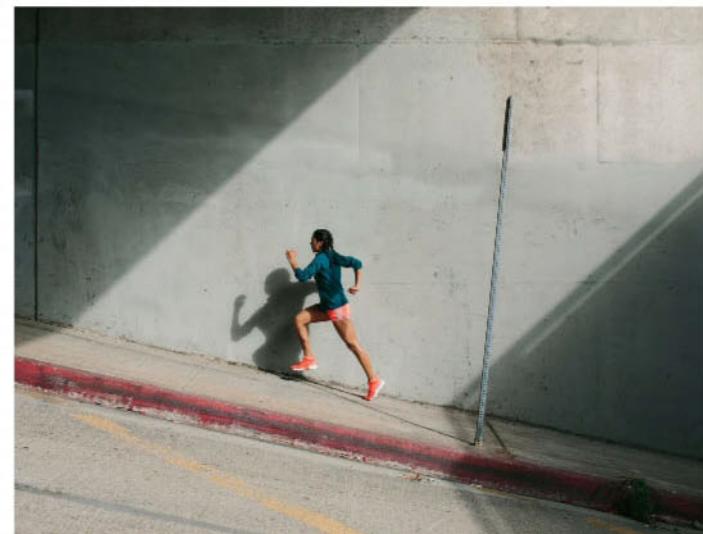
EVER noticed that learning languages gets harder with age? It may be because your brain's ability to distinguish sounds is declining – in which case there might also be a way to tackle it.

As mice age, levels of a chemical called adenosine rise in the thalamus, a part of the brain involved in sensory processing. This impairs learning in the auditory cortex, meaning old mice can't discriminate between two tones that are close in pitch.

Now Jay Blundon at St Jude Children's Research Hospital in Memphis, Tennessee, and his team have restored that ability in aged mice, using a drug that reduces the activity of adenosine (*Science*, DOI: 10.1126/science.aaf4612).

When the team blocked adenosine, they saw a rise in the number of neurons in the auditory cortex responding to sounds. This may be why tone discrimination improved, says Blundon: mice exposed to one sound were now startled to hear a second tone of similar pitch.

If something like this could work in older people, it might ease their learning of new musical skills or languages, says Blundon.



PLAINPICTURE/CAVANIMAGES

Why running hurts your lower limbs

LOVE running, but keep getting leg injuries? That could be because the way we run focuses jogging's hard impacts in our lower limbs.

In a light, half-hour run, the average recreational runner's feet will strike the ground about 5000 times, absorbing shocks with every strike. Now Delphine Chadefaux at Aix-Marseille University in France and her team have used tracking techniques to study these vibrations in more detail than ever before.

Analysing 10 recreational runners, they found that the foot absorbs the most energy from the impact of your

foot hitting the ground, and a bit less goes into the shin bone and knee. By the time shocks reach the hip, they have almost entirely dispersed.

Chadefaux told a conference of the Acoustical Society of America in Boston last week that this suggests the way we use our muscles when we run is geared towards protecting the upper body from impacts.

She thinks understanding how the body does this might lead to ways to reduce shock in the lower part of the leg, and prevent common injuries such as stress fractures and joint problems.

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Insurance nightmare

The next big crash

Will saving the planet mean financial doom, asks **Michael Le Page**

THE great crash of 2008 made the 2007 financial crisis look like a blip. It was triggered by US president Bernie Sanders signing emergency measures to slash carbon emissions. Investors started panic-selling stocks in fossil fuel companies. Trillions were wiped from the stock markets within days – and hundreds of millions of people around the world lost their pensions.

Impossible? Not according to financial regulators, who are so concerned about the prospect of climate-related financial crashes that they are already taking action to stop them happening. They want all big organisations to start assessing and disclosing

3 out of 5

Top US coal firms filing for bankruptcy since 2010

SOURCE: BANK OF ENGLAND

their climate-related risks.

“The whole point of this exercise is to avoid that kind of crash happening,” says Michael Wilkins of credit rating agency S&P Global Ratings, a member of the Task Force on Climate-related Financial Disclosures, which unveiled its guidelines last week.

But the guidelines are voluntary. They will work only if they are widely adopted, and the companies facing the biggest

risks will be the most reluctant to disclose them. So can we really prevent a financial crash when we get serious about limiting global warming? Or does saving the planet inevitably involve a very bumpy economic ride?

The rapid warming of the planet poses two related threats to the financial system. There is the cost of physical damage inflicted by a changing climate, which is already high and climbing. For instance, insurance market Lloyd’s of London estimates that sea level rise due to climate change increased the losses from Superstorm Sandy by a third, adding around \$5 billion to the cost.

“The increase in the severity

and the frequency of losses incurred due to climatic events such as floods, heatwaves and so on, let alone the damage caused by rising coastal waters, is causing billions and billions of losses to economies right now,” says Wilkins.

The costs could rise so high that insurers either go bust or drastically limit what they cover. This could lead to existing properties becoming unsellable and a halt to further developments in at-risk areas. “We believe absolutely as an insurance company that climate risk presents an existential crisis for the insurance sector north of 4°C [of warming],” says Steve Waygood of Aviva Investors, another member of the task force.

The second threat is the fact that the financial industry – almost certainly including your bank and pension fund – is betting heavily on things carrying on as they are now. They are investing in companies trying to find yet more oil and gas, in car firms with no plans to switch to electric vehicles, in real estate threatened by rising seas and more.

On paper, these investments are worth trillions. But their value depends on investor confidence in the status quo. If that changes, their value will plummet.

The low-carbon transition will lead to the reallocation of a significant fraction of the world’s capital. If this happens suddenly, it could lead to “a rapid system-wide adjustment that threatens financial stability”, the Bank of England warned in June.

This is what happened in 2007, when it became clear banks had been making high-risk loans that would never be repaid. The end result, of course, was the worst crash since the 1930s and the loss of trillions of dollars of wealth as the value of stock-market listed firms was rapidly reassessed.

The danger could be more immediate than many think. In June, one real estate investment

company started recommending against investing in property in South Florida because there is no way to protect most of it against rising seas and storms. If enough follow suit, property prices in the area will fall.

The risks are certainly worrying Mark Carney, governor of the Bank of England and chair of the Financial Stability Board, an international body that aims to identify and address financial vulnerabilities. It was the FSB that set up the Task Force on Climate-related Financial Disclosures, at Carney's instigation. Already, institutions responsible for \$25 trillion in assets have said they support the initiative, including Barclays, Morgan Stanley and PepsiCo.

Ignoring the risks

Unsurprisingly, some in the fossil fuel industry dismiss the idea that they are exposed to any risks, let alone that they should have to disclose them.

For instance, a recent report from the Independent Petroleum Association of America claimed pension funds would lose trillions if they sold all their shares in oil firms. But the report is based on the assumption that oil companies will do as well over the next 50 years as they did in the past 50 years. That's laughably absurd.

Last year, another report for the oil industry attacked the idea of a carbon bubble – that the value of oil and gas companies depends on reserves that they will be unable to sell as we shift away from fossil fuels. It claims 80 per cent of the value of oil and gas companies depends on reserves

that they will be able to sell in the next 10 to 15 years.

However, the issue for fossil fuel companies isn't just whether they will be able to sell their products in future; it's whether they can make a profit.

The US is still using lots of coal, but since 2010, three of the top five coal companies have filed for bankruptcy. Cheap gas is killing coal's profits in the US, and cheap renewables could do the same to fossil fuel profits globally – even if they are only supplying a small proportion of overall energy.

"The oil majors clearly have a vested interest in the status quo not being changed as far as disclosure is concerned," says Wilkins. But pretending the problem doesn't exist will lead to far greater shocks down the line.

"The risk of panic is far greater, as we have seen with the credit crunch, when there is no information out there," says Waygood.

Disclosing companies' exposure to climate-related risks is just the first step, however. Investors and companies need to act on these disclosures by taking steps to minimise the risks.

Oil companies have already found more reserves than future climate laws may allow them to sell. These firms must accept that they cannot keep growing and instead focus on downsizing to maximise revenue from their existing reserves, says Anthony Hobley of the Carbon Tracker Initiative, a think tank set up to highlight financial risks from climate change.

If they do, they could remain profitable and valuable for decades to come. "They have to go ex-growth," says Hobley. "The growth mentality no longer applies in this new world."

Instead, fossil fuel companies are borrowing to find further reserves. According to a report in June, banks are pouring about \$100 billion a year into "extreme" fossil fuel projects – those most likely to be targeted by climate



Is worse to come?

SPENCER PLATT/GETTY IMAGES

\$100 billion

Money lent annually by banks to fund "extreme" fossil fuel projects

SOURCE: RAINFOREST ACTION NETWORK

action. These include coal mining and power plants, and oil from tar sands, the Arctic and deep offshore.

These sectors are already high risk. In 2015, Shell had to write off \$2.6 billion after withdrawing from the Arctic, and another \$2 billion on a suspended tar sands project, for instance. China has suspended more than 100 planned coal power plants.

"They are betting on an increasingly risky house," says Johan Rockström of the Stockholm Resilience Centre, who studies sustainable development.

Then there is Donald the denier. President Trump's attempt to turn back the tide on climate action in the US will probably have little effect on the country's emissions, but it could delay the transition to a low-carbon global economy if lots of the developing countries that signed up to the Paris climate agreement scale back action too.

Any delay is bad news. A late and abrupt transition away from fossil fuels is much more likely to trigger a financial crash than a

gradual one, according to a report last year from the European Systemic Risk Board, set up in 2010 to try to avert financial crashes. "The adverse scenario for the EU financial system is one of late adjustment, resulting in a 'hard landing,'" the report says.

Despite all these issues, Waygood thinks we can avoid another big crash. Few people predicted the credit crunch, he says, but this time lots of big institutions are saying there is a problem. The task force's recommendations should smooth the transition, if widely adopted.

But investors still have to bet on what they think are the most plausible scenarios. There could be trouble ahead if lots of them get it wrong – perhaps because of an unexpected technological revolution, like turning solar power into petrol, or some climate tipping point kicking in early, such as the Gulf Stream grinding to a halt.

Rockström is optimistic, though. "There may be a sudden shock, no doubt, but there's growing global preparedness," he says. "There will be a quick bounceback."

But by a quick bounceback he means a recovery like the one after the 2007 crisis. To the millions of austerity-hit people around the world who are still suffering as a result of that crash, that's not exactly comforting. ■

\$19.2 trillion

Cost of the 2007–2009 financial crisis to US households
SOURCE: US TREASURY

Enough to get you down

Talking up the idea that women need to get optimistic to live longer is patronising in an age of stubborn inequality, says **Lara Williams**

NOW we know and presumably we should be grateful: Women who remain “optimistic” have a lower risk of heart and respiratory disease, cancer and stroke – and as a result, live longer.

This is from a US study of 70,000 female nurses. Those who identified as most optimistic had a 31 per cent reduced mortality risk compared with the least upbeat.

This message may seem OK at first glance – who doesn’t want to live longer? But beyond the actual science, there is a problem. Why were women singled out, both as subjects for the study and as the recipients of this message?

Why not determine whether people, irrespective of gender, could enjoy the health benefits of positivity? Was the gendering tied to an existing expectation for women to remain sanguine?

This exists on the same spectrum as men who feel



compelled to shout “smile” at passing female strangers, should they not seem visibly cheered – there is a peculiar pressure on women to appear pleasant.

The messaging around this study feels particularly hampered by these problems, insinuating an almost moral and personal imperative to be optimistic, aimed at just one half of society.

For example, Richa Sood of US medical research group Mayo Clinic commented: “Women have a lot of self-doubt... But if we could focus on ‘I tried my best, pat on the back, I will do better next time,’ that’s optimism, and we are caring for ourselves.”

There is a lot to decode, from the flippancy of invoking “self-doubt” through to the patronising obligation to care for ourselves. It is reductive language.

Unfortunately, the onus is being placed on women to remain

See no evil

Trump’s smoke-screen strategy is clear, say **Gretchen Goldman** and **Andrew Rosenberg**

JUST a few months into the Trump era, the White House and Congress have truly shown their disdain for science and science-based policy. The president’s proposed budget is the latest example showing how the role of research in decision-making is being sidelined.

Perhaps most disturbing is the emerging philosophy behind

all this: don’t measure, so you don’t have to manage.

Proposed funding cuts for science agencies offer an alarming window on this philosophy. They would kill funding of the National Oceanic and Atmospheric Administration’s Air Resources Laboratory, which tracks and forecasts the release of radioactive

material, volcanic ash, wildfire smoke and hazardous chemicals.

The public health preparedness programmes of the Centers for Disease Control and Prevention’s are also targeted. So is the entire research and development arm of the Environmental Protection Agency, which is responsible for collecting, analysing and disseminating air and water quality data. The cuts would end four NASA Earth Science missions set to make measurements that

“Most disturbing is the emerging philosophy: don’t measure so you don’t have to manage”

improve greenhouse gas estimates; detect harmful algal blooms, volcanic ash and oil spills; and improve air pollution checks.

This is being done in the name of state flexibility. The Trump administration argues that states should manage these public health and environmental challenges. But how could a state be expected to compensate for a lack of federal leadership and resources? Will they launch their own satellites? Will they be able to track and prepare for infectious disease outbreaks?

It is likely that such a strategy will fail to adequately protect public health and safety in the

optimistic at a time of enduring gender inequality, in which their fundamental rights are under threat. The pay gap persists, partner violence is worryingly high and reproductive rights are being challenged. Remaining optimistic requires an active disengagement with the facts.

"Optimism is about 25 to 30 per cent genetic," Sood states. "That means... it can be learned." A state of mind to aspire towards, a bit like a stereotypical feminine ideal. Optimism is surely more the product of circumstance than a simple shift of mindset.

Charmingly cantankerous and curmudgeonly men are a cultural mainstay, often a codified means of communicating depth or intelligence. Women exhibiting similar tendencies are characterised as boorish or bitches, if made visible at all.

To portray optimism as an expressly female requirement is an expansion of the myriad ways women are pressured to modify behaviour: to take up less space, to present in a certain manner.

If you want us to look on the sunny side, at least give us a little something to be optimistic about. ■

Lara Williams is a writer based in Manchester, UK

face of emerging threats. The research community must not allow this. The scientific enterprise depends on it.

But it is much more than that. We must also articulate the great benefits to society that monitoring provides. We must make clear that this goes beyond scientists' livelihoods. It is about the vitality of our nation and its ability to make the evidence-based decisions that keep us all safe and healthy. ■

Gretchen Goldman is research director at the Center for Science and Democracy at the Union of Concerned Scientists. Andrew Rosenberg is the centre's director

INSIGHT EU competition law

EMMANUEL DUNAND/AFP/GETTY IMAGES



Antitrust: Google Shopping

The EU is taking on the tech giants

Google's €2.4bn fine is the least of its worries

Matt Reynolds

WHEN it comes to the European Commission's decision to fine Google €2.42 billion for breaking competition law, the cash is just a distraction. The EU's larger goal is to position itself as an antidote to Silicon Valley's winner-takes-all attitude, and reshape our interactions with the tech giants.

The hefty sum, announced by Margrethe Vestager on 27 June (pictured), will sting in the short term, but Google can handle it. Alphabet, Google's parent company, made a profit of \$2.5 billion (€2.2 billion) in the first six weeks of 2017. The real impact of the ruling is that Google must stop using its dominance as a search engine to give itself the edge in another market: online price comparisons.

Google disputes the ruling, but the evidence is quite clear. The higher up a search result is, the more people click on it. Links on the first page of search results get 95 per cent of all clicks.

Search for a product on Google and you will see boxes offering places to buy. Click, and Google may get a cut of your purchase. The ruling says that in doing this, Google deliberately

promotes its own price comparison results over those of its competitors.

The impact is significant. The EU commission found that since 2008, Google's price comparison service has increased its UK traffic 45-fold. Traffic to competitors, however, dropped by 85 per cent. It's a similar story in many other European countries.

The EU doesn't find fault with Google dominating in search, says Ariel Ezrachi, director of the University of Oxford Centre for Competition Law and Policy. But it does object to Google

"Google must stop using its dominance as a search engine to give itself the edge in another market"

leveraging that power to gain an unfair advantage in price comparison.

As such, the EU says Google has 90 days to start giving equal prominence to rival price comparison services, or it may face fines of up to 5 per cent of Alphabet's daily worldwide turnover, totalling about \$14 million per day.

The ruling sets out a principle that companies cannot use their position in one industry to give themselves a leg

up in another. It's better for consumers, the EU argues, if competitors aren't unfairly forced from the marketplace.

This is a direct challenge to the Silicon Valley ethos that says anyone can create their own website and compete against the big companies. Consumers will flock to the best one, the story goes, and they will rightly claim their crown as market disrupters.

But this is a myth. In reality, the online world is dominated by a handful of gatekeepers that decide which companies survive. If Google doesn't promote your website, you are dead in the water. In the long term, one company ends up dominating in each marketplace and consumers suffer.

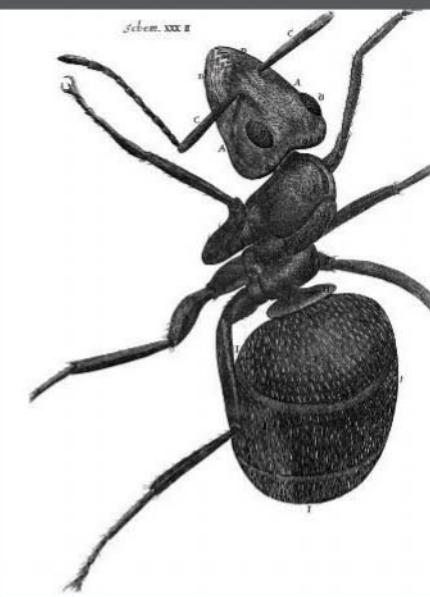
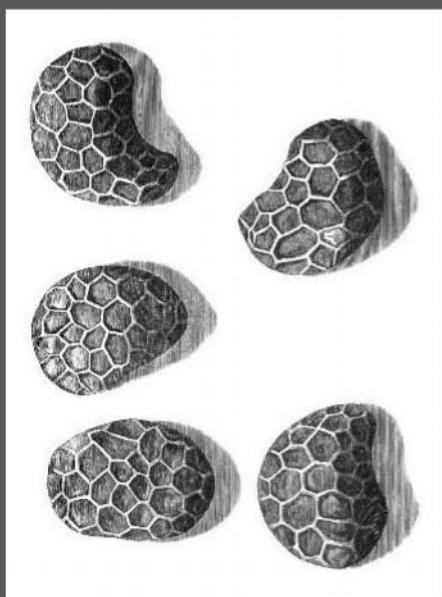
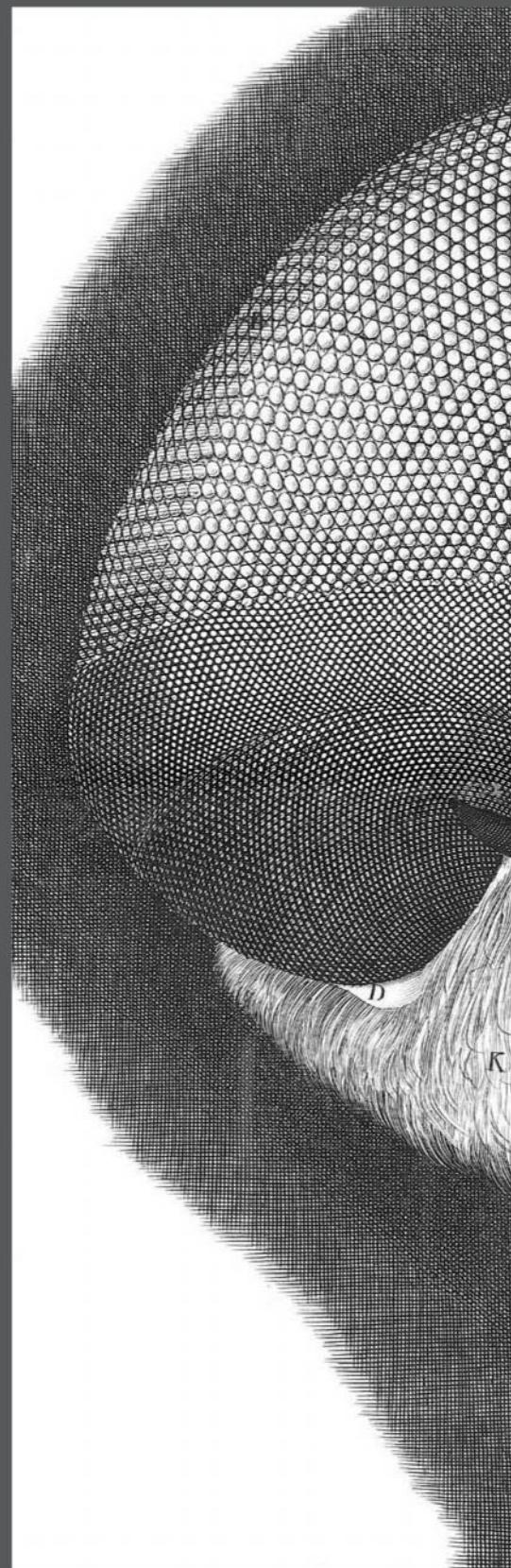
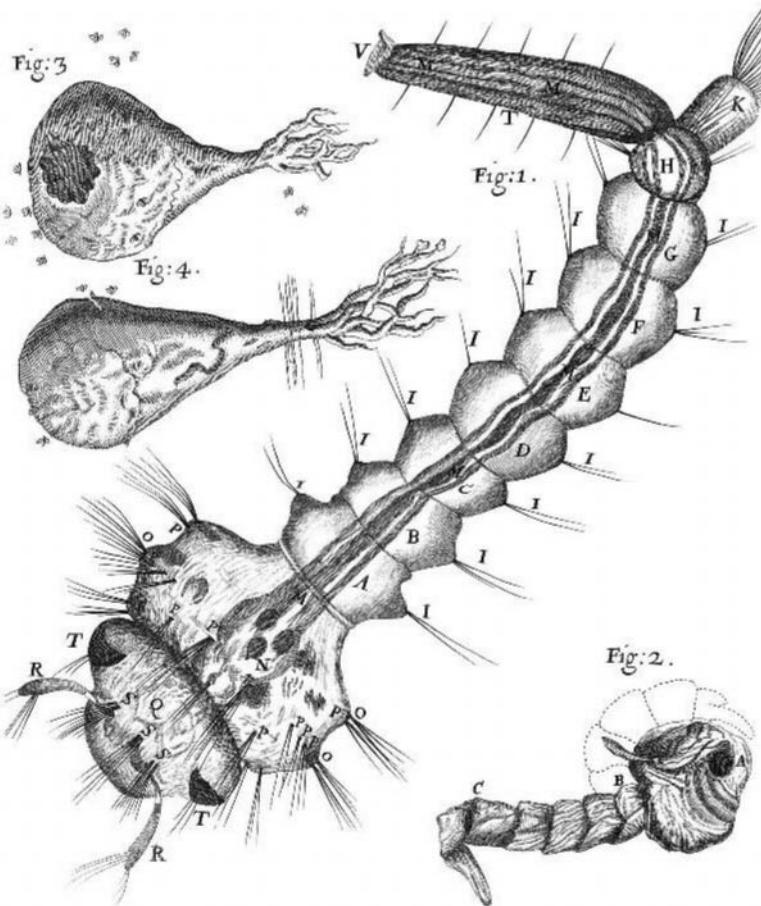
Now the EU is writing a new rulebook and forcing Google to take note. "It will have to compete by making its services better," says Ezrachi. The ruling should encourage Google to innovate, now that it can't rely on search to give itself the edge.

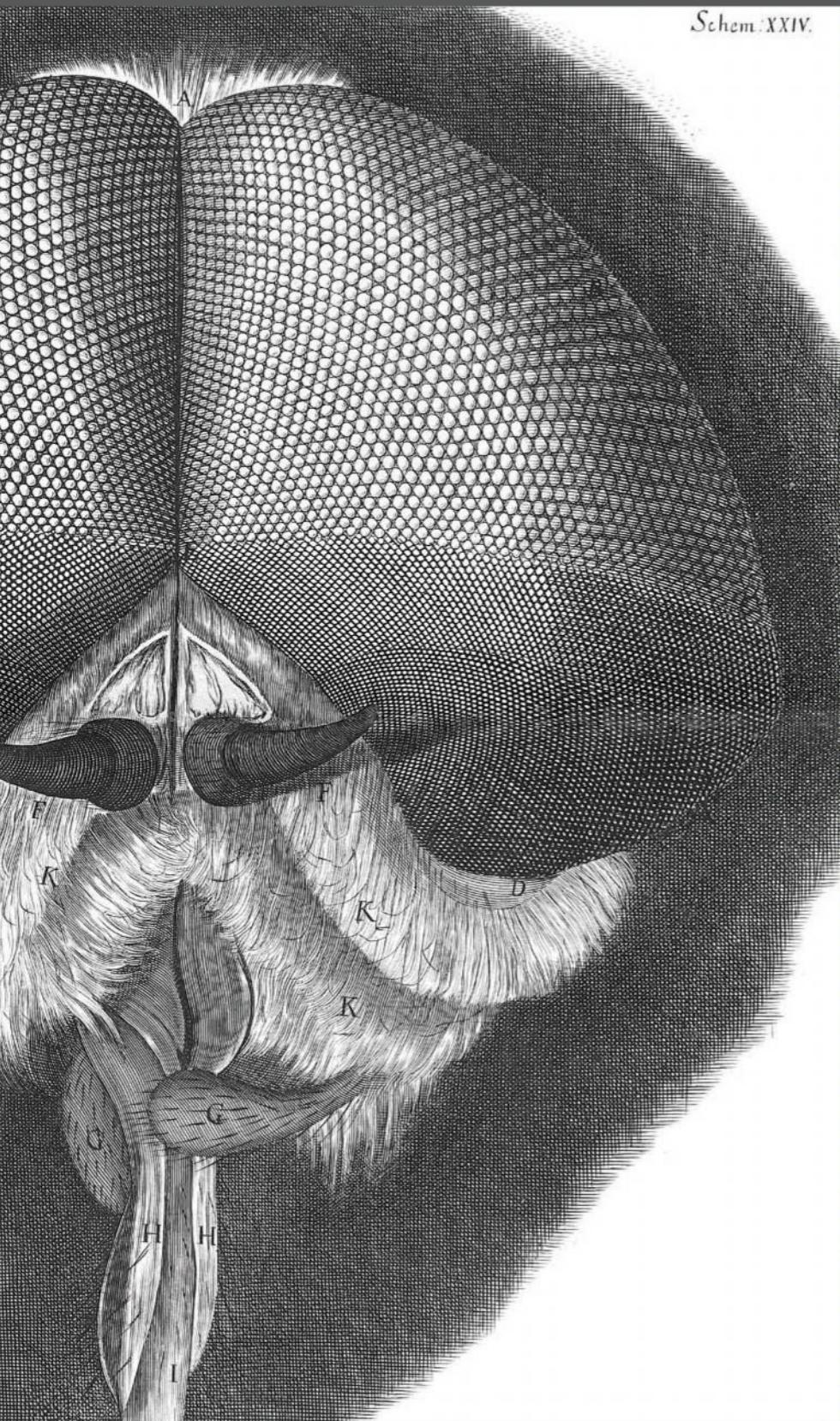
But the EU may struggle to keep up with the tech giants. The legal system often lags behind the ever-changing business practices of the digital era; Google's promotion of its own price comparison service had been going on for nearly a decade before the ruling.

That's too slow given that the next battle over search is already warming up. The rise of voice-activated home assistants such as Amazon's Alexa and Google Home, which only return a single search result, means the fight to be first is more critical than ever. ■

APERTURE

Schem. XXVII.





Schem. XXIV.

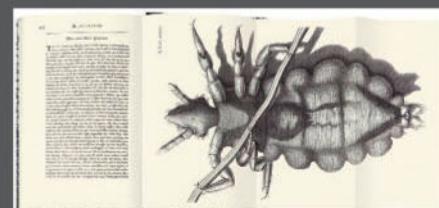
Drawing the invisible

THIS was our first look at the realm of the invisible. In 1665, Robert Hooke's *Micrographia* brought microscopic observations out of his laboratory to a wider world.

Hooke believed that, through the lens of a microscope, nothing could be "so small as to escape our inquiry". The 38 copper engravings from his book, now republished by The Folio Society, detail many objects smaller than a grain of sand, in the manner of the diaries of travelling contemporaries who sketched rare exotic specimens on their travels around the New World.

Hooke chose subjects he thought looked attractive for his idealised and ordered catalogue of the microworld, including poppy seeds (bottom left), an insect larva (top left), and a louse clinging to a human hair (below). Before drawing the head of a fly (main picture), Hooke first detached it so he could observe the organs inside the animal's abdomen.

But he showed more tenderness to a tiny ant (pictured to the right of the poppy seeds). Fearing that killing the insect would squash its miniature parts and destroy their beauty, he instead submerged it in alcohol so it would revive after the study was over "as if it had been awoken out of a drunken sleep". Luisa Mostert



Photograph

The Bodleian Library, University of Oxford
from The Folio Society's edition of
Micrographia by Robert Hooke
foliosociety.com/micrographia

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Should we...?

Ten scientific dilemmas
that will shape our future



DAVID DE LAS HERAS

Minimising suffering. Maximising happiness. Saving the planet. Looking after future generations. Worthy goals all, but what happens when they come into conflict?

Science and technology are constantly pitting our values against each other. In this special feature, we've selected 10 particularly burning dilemmas. What makes them so thorny, what ethical principles are at stake – and what should we do?

SHOULD WE... GIVE OTHER ANIMALS RIGHTS?

Minimise suffering of other life forms

VS

Maximise human well-being

For centuries, if not millennia, ethical debates have centred on the notion that human beings have certain fundamental, inalienable rights. No matter what you do, or how evilly you behave, those rights cannot be stripped away. Even if violating your rights would turn out to be for the common good, tough luck – they're there to stay.

But the question of what other animals should benefit from such blanket protections is an open one. Last November, an Argentine court endowed a chimp called Cecilia with the right to live in her natural habitat and ordered her release from Mendoza zoo. Six months later, a Canadian court upheld the notion that pigs are property that can be denied food, water or rest in transit for up to 36 hours.

So what should qualify? If our objective is to minimise suffering in any fellow creature, is it time to give non-human animals rights on a par with our own? Should the intelligence of an octopus exempt it from being hunted and eaten by humans? Does the same go for pigs? Are mice entitled to freedom of movement?

The short answer is, it's complicated. "There are different kinds of rights," says Andrew

Knight, who studies animal welfare and ethics at the University of Winchester, UK. "Although sentient animals should have key moral rights respected, it makes no sense to give them the same legal rights as humans."

Chimpanzees provide a salient example of the problem. They have had their rights championed more than most: it is now illegal in many countries to do scientific experiments on them, and efforts are under way to grant them personhood – effectively, human rights. But Jennifer Mather, an animal behaviour expert at the University of Lethbridge, Canada, sees no reason why chimps should receive such privileged status. "Animals from all taxa deserve consideration," says Mather, although she admits others may disagree.

"I am all for working towards improved welfare of animals, but that doesn't mean ascribing them rights," says Steven Cooke at Carleton University in Canada. "I care far more about ensuring that we properly manage populations and habitats to ensure resilience and enable appropriate human use," he says (see "Should we colonise other planets?", page 35).

The truth is that most of modern life, from clothing manufacture to agriculture, relies on exploiting animals and treating them with less regard than humans – especially if they invade our space.

The calculus is a complex one. Would mosquito rights lead to the end of eradication programmes and thus the spread of malaria? Would horse or cattle rights force humans to take up gruelling physical labour? "It's a moral and ethical dilemma – my view is that we have the right to use animals but should do it humanely," says Lynne Sneddon, an animal welfare researcher at the University of Liverpool, UK.

Wider education about animals' experience is the primary way forward, Mather says. She thinks an understanding of animal sentience, such as the problem-solving skills of crows, the self-awareness of elephants and the theory of mind demonstrated by chimps, will help us achieve a more sophisticated stance. "As we discover more and more about how animals are smart, it is going to be easier to see that they should have some basic consideration."

Michael Brooks

SHOULD WE...

GENETICALLY ENGINEER OUR CHILDREN?

Maximise human well-being

VS

Respect difference

The thought of shaping future generations to fit some pre-imagined ideal of strength and beauty is one that should make us uncomfortable. Once a fashionable field of enquiry, the study of eugenics remains associated with some of the worst excesses of the 20th century, from forced sterilisation to genocide. The lesson we might be tempted to draw from this is to let nature proceed unchecked, free from human meddling, and embrace the diversity it engenders.

But as ethically comforting as that sounds, deciding to do nothing is a decision in itself. We may like to think of humans as perfect, finished natural products that should not be interfered with, but nature's creations are botch jobs, full of mindless mistakes. And evolution's way of getting rid of the worst mistakes is to let children suffer horribly and die young.

In the interests of human well-being, then, should we head back down the slippery slope?

Actually, we already have. In most countries, it is already legal to shape the genomes of our children in various ways, from the abortion of fetuses with Down's syndrome to the screening of embryos during IVF. Last year, the thin end of the wedge got that little bit thicker when the UK gave the go-ahead for what have been called "three-parent babies", whose mitochondrial DNA is supplied by a third-party donor.

And now, thanks to the revolutionary genome-editing method known as CRISPR, we can directly edit the main genome of cells. In theory, CRISPR could be used to weed out the hundreds of mutations that make us more likely to suffer from disorders ranging from heart attacks to cancer to Alzheimer's to schizophrenia, greatly improving the health of future generations.

From this perspective, it appears immoral not to genetically improve our descendants in every way we can. "There is a moral imperative," says ethicist Julian Savulescu of the University of Oxford. "We would be

horrified if a child went deaf because the parents refused drugs or surgery. It is just as wrong, argues Savulescu, not to use gene editing once it is safe to do so.

Some see it very differently. Gene editing could be a way of "disappearing" certain types of people, suggested actress Kiruna Stamell, who has a rare form of dwarfism, at a recent debate. "By eradicating individuals with the condition, we are not beating the condition, we are not curing it."

The issue is whether some states we regard as disabilities are just differences that are only a problem because the rest of society treats them as such (see "Should we make everyone 'normal?'", right). For Savulescu, conditions like deafness, blindness and paraplegia are disadvantageous no matter what. "If you can correct them, then you should."

These are questions our descendants may grapple with for millennia to come. Barring scenarios in which we merge with machines to become superhuman cyborgs, it seems certain we will increasingly shape the genomes of our children. The only question is how. **Michael Le Page**

"Gene-editing could be a way of 'disappearing' certain types of people"

MAKE EVERYONE 'NORMAL'?

Respect difference

VS

Maximise human happiness

Imagine a pill or therapy capable of rewiring your neural circuitry so as to make you more empathetic: one that decreases aggression, and causes your capacity for moral reasoning and tendency to forgive to go through the roof. Wouldn't the world be a better place if we were all encouraged to have it? In fact, if human happiness lay on the other side of a tablet, why not embrace utopia and prescribe it by force?

Such a scenario may not be as far away as you suppose. Technologies to read and manipulate thought patterns are growing. Elon Musk's Neuralink project is attempting to establish direct communication between our brains and computers, while Kernel, a company in California, has invested \$100 million to develop intelligence-boosting brain implants. Electric shocks delivered to the brain have been found to combat depression, and certain chemicals can help us make more moral decisions.

But even if weeding out aberrant thought patterns and enforcing social conformity through technological or pharmacological means could be made to work in practice, would it be the right thing to do? Or do people have an inalienable right to be themselves, provided they pose no immediate risk to themselves or others?

"This is a topic we need to be talking more about right now," says Chris Danforth, co-director of the Computational Story Lab at the University of Vermont. Letting the majority of the population redesign the outliers in the interests of their own safety might seem to do the greatest good for the greatest number of people, but opens the door to some terrifying possibilities. Historically, those who challenged the status quo saw their motivations recast as mental deviancy - such as Victorian women confined to asylums for rebelling against patriarchal society, or gay men like Alan Turing who were given the "choice" of chemical castration.

"Being normal is a dangerous concept," says Mark Slater, a consultant psychiatrist and spokesperson for the Royal College of Psychiatrists in London. "How can we evaluate happiness or contentment, or a specific blood pressure come to that, as normal?" Not only is "normality" an illusory concept, but our conception of it is ever-changing. If we began to optimise people for the qualities we wished to see

SHOULD WE...

in society, who gets to choose what those are? Perhaps conformity isn't as good for society as we suppose. In 2015, psychologist Jesse Harrington at the University of Maryland published a study showing that highly restrictive societies fared worse in measures of overall happiness, rates of depression and suicide than moderate ones – but then again, so did highly permissive cultures. When it comes to how much abnormality we should tolerate, then, it seems we would be best off having the normal amount. Frank Swain

"Conformity may not be so good for society as we suppose"



CHRISTOPHER ANDERSON / MAGNUM PHOTOS

ABANDON PRIVACY ONLINE?

Maximise human happiness

VS

Maximise human safety

Those who would give up essential Liberty to purchase a little temporary Safety," Benjamin Franklin once said, "deserve neither Liberty nor Safety." But if Franklin were alive today, where would he draw the line? Is the freedom to send an encrypted text message essential? How about the right to keep our browsing history private? What is the sweet spot between our need to be left alone and our desire to keep potential criminals from communicating in secret?

In an age where fear of terrorism is high in the public consciousness, governments are likely to err on the side of safety. Over the past decade, the authorities have been pushing for – and getting – greater powers of surveillance than they have ever had, all in the name of national security.

The downsides are not immediately obvious. After all, you might think you have nothing to hide. But most of us have perfectly legal secrets we'd rather someone else didn't see. And although the chances of the authorities turning up to take you away in a black SUV on the basis of your WhatsApp messages are small in free societies, the chances of insurance companies raising your premiums are not.

The Faustian bargain taking place in our interactions with tech companies has gone more or less unnoticed. We hand over our data and in return get to use apps and websites without charge, with virtually no insight into how our information gets used, or who it gets sold on to. People have been declaring the privacy debate over for 20 years, says Paul Bernal at the University of East Anglia Law School in Norwich, UK. In fact, it's a debate we've never actually had. And the ethical issues at its heart are getting more urgent, not less. "What this is really about is interfering with people's lives," says Bernal.

Recent allegations of political manipulation in the Brexit and Trump campaigns give a glimpse of the dangers. According to reports, UK company Cambridge Analytica used psychometric profiling based on publicly ➤

GIVE ROBOTS THE RIGHT TO KILL?

Maximise human safety

VS

Keep technology under control

available data, including Facebook “likes”, to present finely tuned personalised ads to undecided voters. It’s not clear they had any effect, but the method is based on research that shows you can profile people surprisingly accurately using just public social media activity.

And while we don’t have to use any of these services, the likes of Facebook, Google and Amazon are so dominant that it has become hard to find alternatives. In many newly connected countries there aren’t any. Myanmar, for example, was largely offline until a few years ago; now it has one of the highest proportions of Facebook users in the world. For most people there, Facebook is the internet and its approach to privacy the norm. “Ethically, it’s a critical issue,” says Bernal.

Of course, data-fuelled technology could also bring enormous benefits, improving the way we treat disease, manage energy use and run communities. But the issue is who gets our data, and what do we want them to do with it? Personal data is knowledge and knowledge is power. “In the end, it comes down to a slow erosion of our autonomy,” says Bernal. “We need to step back and talk about what kind of control we’re giving away. What are the final consequences and are they acceptable?”

Douglas Heaven

“It is morally wrong to give autonomy to robots that cannot think morally”

Hot-headed, irrational and swayed by emotion - who’d want a human in control? If we could build machines capable of making tough choices for us, surely we should. That’s the line taken by people like roboticist Ron Arkin at the Georgia Institute of Technology in Atlanta. For Arkin, autonomous weapons - or killer robots - that remain rational under fire and behave exactly as they were trained to would be more humane than human soldiers in a war situation, and would save lives. We therefore have a moral imperative to create them.

The same reasoning can be applied to many scenarios where human nature may stop us doing the right thing, from driving to making life-or-death decisions in hospitals to criminal sentencing. Computers are already moving into all these areas, and in many cases surpass humans where it counts. But how much autonomy should we give them?

The problem with fully autonomous machines from a moral point of view is that they cannot take responsibility for their actions. Human ethics is built on the assumption that actions are done by agents with the capacity to make a call between right and wrong. If we offload those actions on to machines, who do we blame when something goes wrong?

Filippo Santoni de Sio, a philosopher and ethicist at the Delft University of Technology in the Netherlands, calls this the “responsibility gap”. For him, it is crucial that a human always takes responsibility. This might be the machine’s designers or a designated human handler, much as a parent takes responsibility for their child or an owner for their pit bull. “It is morally wrong to give autonomy to machines because they cannot perform moral thinking,” says Santoni de Sio.

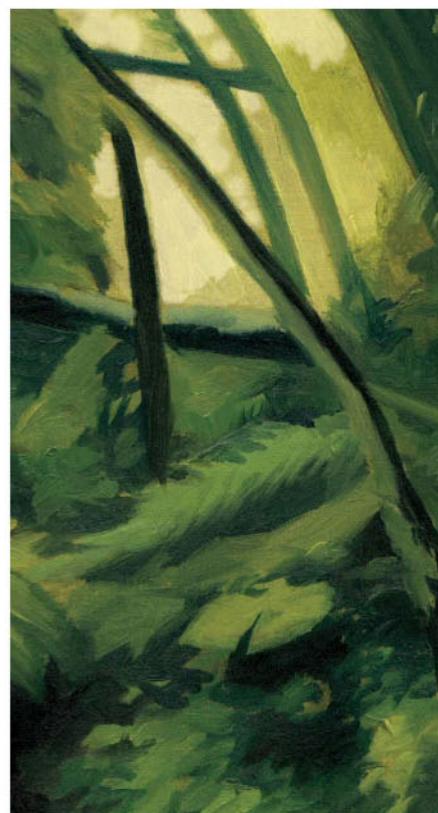
Arkin and others have suggested that at some point in the distant future machines capable of moral reasoning could be built. But even in such a case, many will still feel it is wrong to delegate such decisions to a machine. With people, we don’t just want them to do the right thing; we also have a need to understand why they act the way they do.

Blame is as much about explanation as it is compensation or retribution, says Santoni de Sio. “This is the main idea behind moral responsibility - we want to blame people not necessarily because

we want to punish them, but because we want to understand. We want to see the person’s face, we want to ask questions.”

So where do we go from here? Where the stakes are highest, many are calling for an outright ban. Campaigners are pushing the UN to draw up a treaty curbing development of autonomous weapons, for example. Legislation is on its way for autonomous vehicles too. Germany has proposed a highway code for driverless cars, laying down guidelines for who is ultimately responsible in an accident. And similar regulations will be drawn up for medical robots.

Attitudes may change as we work through the moral maze surrounding autonomous machines. But for now, at least, we will be keeping them on very short reins. Douglas Heaven



SHOULD WE...

RELEASE SYNTHETIC LIFE FORMS INTO THE WILD?

Keep technology under control

VS

Save the planet

Biologist George Church is making forms of life that could never arise naturally. He and his team are changing the genetic code of *E. coli* bacteria used in drug manufacture so as to make them immune to all viruses: a giant step forward for the industry. But the very immunity that serves us so well in a vat in the lab could come back to bite us if those bacteria wound up in our bodies.

Church's team at Harvard University is just one of hundreds around the world creating "synthetic life", some kinds meant for labs and factories, others for farms. Can we really control these creations? Can we ensure they remain where we want them? Or do the potential risks

to us and to wildlife mean it would be better not to meddle with synthetic life at all?

"Biocontainment is our number one priority," Church told *New Scientist* last year when he unveiled his latest creation. To ensure his recoded organisms cannot go feral, he has altered them so they are dependent on chemicals that don't occur naturally.

Others want to go much further, creating forms of life based on molecules not used by any other organism. With an entirely different biochemistry, such truly synthetic life would pose little risk – at least in theory.

But less alien forms of synthetic life are already common. Many drugs are now produced by modified cells, for instance, and more than a tenth of arable land is planted with genetically modified crops.

Such technology is still in its infancy, but the potential benefits are huge. For instance, creating plants better at photosynthesising would let us grow more food on less land. That means more land could be set aside for wildlife, or used for capturing carbon (see "Should we geoengineer the planet?", page 34). This could be crucial in a world where land is in increasingly short supply.

But plants that can capture more of the sun's energy would be able to outcompete ordinary ones. Supercrops that combine several beneficial traits, such as enhanced photosynthesis, and resistance to salt, droughts, viruses and pests, would be even more likely to turn into rogue superweeds.

And our track record on biosafety is not exactly reassuring. Genetically modified plants and products keep being found in places they are not meant to be, and lab accidents are still distressingly commonplace.

In an ideal world, perhaps it might be better not to take the risk. But in our world, with looming crises from population growth to climate change, it looks as if we have no choice.

If we lose that gamble and synthetic life does take over the world, who knows: it might do a better job of caring for the planet than we have. **Michael Le Page**

HELP! WHAT SHOULD WE DO?

At times, making the ethically right decision can seem impossible. Every course of action is bound to benefit one group at the expense of another, whether it's people on the other side of the world or future life forms on a distant planet. So how do we decide what to do?

For Elinor Mason, an ethicist at the University of Edinburgh, UK, the key is to not let ourselves get distracted by the quest for the perfect answer. Imagine we are repainting our house and have to decide on a single colour, says Mason. "We're not going to interrupt ourselves halfway through and say, 'isn't this all just a matter of opinion?' We have to decide and move forward."

For Andrew Stirling, a science policy researcher at the University of Sussex, UK, making the best possible decision depends on three key principles: responsibility, precaution and participation. First, experts have a responsibility to drop the pretence that they can be perfectly impartial. We all have a moral perspective, and our collective decision-making only benefits if those perspectives are shared freely.

Second, we have to proceed with caution, as the uncertainties surrounding alternative futures are far too complex to be easily comparable. The fiction that one scenario can be deemed superior to another on the basis of the facts alone is reassuring to policy-makers, but does the rest of us a disservice.

And finally, all members of society should have the chance to participate in debates like the ones outlined on these pages. "We shouldn't be scared about involving ordinary people in decisions about science and technology," says Stirling. "The technologies we pursue, the innovations we support, the sciences we prioritise, are as genuine matters for democratic discussion as anything else."



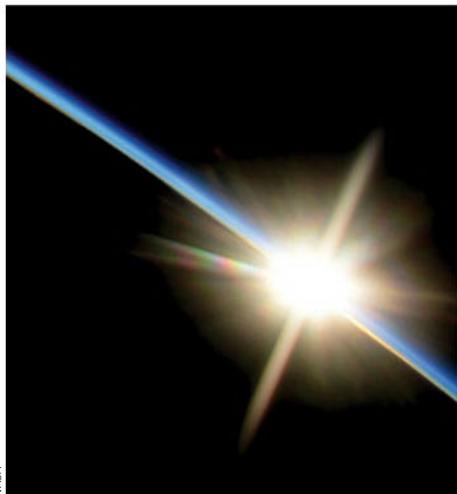
SHOULD WE...

ENGINEER EARTH?

Save the planet

VS

Look after future generations



NASA

The pressure is on. If we want to save the planet from the worst effects of climate change, we need to get our greenhouse gas emissions to zero by 2070 – a target that requires immediate and drastic action. But our unbreakable addiction to fossil fuels makes this goal seem more and more unreachable. So what if there were another solution, some quick techno-fix that could let us burn our fuel but not our planet?

Enter geoengineering: large-scale manipulations of the planet designed to clean up our mess. The ideas range from sucking carbon dioxide out of the atmosphere to deploying a stratospheric parasol that would bounce the sun's warming rays back out into space. Some have been field-tested, or soon will be. But while most climate researchers agree geoengineering makes sense as a last resort, we need to ask: do we have the right to interfere with the planet on this scale?

The answer might seem obvious: we've already done it. By chucking billions of tonnes of greenhouse gases into the atmosphere, humanity has put the planet's thermostat on turbo-boost, melted the Arctic, and altered the seasons, large-scale weather systems and the ocean's acidity. Why should reversing that be any different?

Opinions vary. "A strict consequentialist would argue that there is no ethical difference because

what is right is determined solely by the outcome," says Steve Rayner, a climate policy researcher at the University of Oxford. "However for most other ethical viewpoints, motives matter. They certainly matter in law."

To John Shepherd of the University of Southampton, UK, who led a Royal Society working group on geoengineering, the risks need to be put in context: "I find it hard to see that attempting to ameliorate climate change deliberately should be unacceptable in principle, so long as it was done carefully and cautiously, and with an exit strategy in place".

The various proposals carry different risks for different people. One contender involves covering vast areas with vegetation in order to suck CO₂ out of the skies and then be burned as fuel – with the resulting emissions buried deep underground. It may sound promising, but the new forests would have to compete for land with food crops, probably in tropical countries that have contributed least to global warming and will suffer most from it.

Sunshades also come with risks. Kevin Trenberth and Aiguo Dai of the US National Center for Atmospheric Research in Colorado looked at past mega-volcano eruptions, which release particles that reflect light in a similar way to proposed sunshades. They found that these events caused a marked decrease in precipitation, particularly in the tropics. Computer models have since confirmed that artificial sunshades would rapidly lower regional temperatures but also change rainfall patterns, resulting in poor harvests and the risk of drought.

Legacy is another major ethical concern. What goes up must come down and sunshades, like volcanic dust, will eventually be rained out. In the meantime, our continued appetite for fossil fuels would cause greenhouse gases to pile up in the atmosphere. If a future generation decided to stop maintaining the sunshade, the world would be hit with the full force of the resulting climate change. In the space of a few years, global temperatures would shoot up to where they should have been all along. The consequences for humanity could be disastrous.

Silver bullet, then, or Russian roulette? It may be that the only real solution is to find another one.

Catherine Brahic

IMPOSE POPULATION CONTROLS?

Look after future generations

VS

Realise human potential

Fears that we are too many are nothing new. As long ago as 1798, the English writer Thomas Malthus warned that a growing population would eat its way through the planet's finite resources, condemning millions to die of starvation.

We haven't exhausted our supplies quite yet, but seven billion people later our planet's ability to support us all comfortably does appear to be under threat. If we all lived like affluent Americans, say, resource consumption and carbon emissions would be at unsustainable levels. Given the clear and present dangers posed by climate change, how can we look after future generations without keeping half of the world's population in poverty?

For Travis Rieder, a bioethicist at Johns Hopkins University in Baltimore, the answer is reducing birth rates – and not in the places you might expect. When it comes to climate change, says Rieder, "my American kid is way more problematic than the many children a family might have in poor, high-birth-rate countries". And should the worst consequences of climate change come to pass, it will be the poorest that suffer most severely. So let's assume that the West is incapable of slashing carbon emissions or finding a technological silver bullet

"If we all lived like affluent Americans, the impact would be unsustainable"

COLONISE OTHER PLANETS?

Realise human potential

VS

Minimise suffering of other life forms

(see "Should we geoengineer the planet?", left). In this case, we are obliged to explore all options, including the taboo subject of population control. "It's the one variable we haven't been prepared to talk about, but if we could reduce fertility, it would have a powerful effect on emissions," says Rieder.

Most people are uneasy about any intrusion on people's right to choose how many kids they have. Rieder points out, though, our rights get limited by the interests of others all the time. Why should procreative rights be any different?

Historically, however, attempts to limit our numbers have often led to abuses. The stain of forced sterilisations and abortions performed to satisfy China's one-child policy is hard to shift. But there are other, less extreme ways to encourage people to have fewer children, such as giving everyone access to the education and resources they need to make informed decisions. Few would argue against that.

More interesting is the middle ground. How about a tax on families with more than two kids, for example, incentivising people to change their preference? You would have to tread carefully, says Rieder, given the harm you could cause children by removing resources. And while public information campaigns sound less problematic in theory, the reality is not so clear-cut. As Rebecca Kukla at Georgetown University in Washington DC has pointed out, women are already widely held responsible for family size, so making it a moral issue would only add to their burden. If norms on family size shift, she says, you will see a backlash against women who have more children than is deemed responsible.

Then again, maybe we're missing the point. If the problem is too many of us living at the same time, why not limit lifespan instead of birth rate? Billions of dollars are spent each year on research aimed at extending our lives, but those golden years are only making things worse for others. Perhaps the ethical thing to do would be to divert those funds elsewhere.

Daniel Cossins

Next stop, Mars. Space agencies and private companies alike plan to send humans to the Red Planet in the next decade, with the idea of permanent settlements twinkling in the future. As the technical challenges of such missions are conquered one by one, it's past time to ask: is taking over another world the right thing to do?

This question, like so many ethical quandaries, comes down to rights: does life on other worlds have the same rights as Earth life? What if it's just microbes? And what if there is no life at all? Do humans have the right to leave muddy bootprints on pristine planets, potentially stamping out future civilisations before they arise?

"There's this idea lurking behind all of this that the universe has a natural way of doing things and that humans come in and mess it up," says Kelly Smith, a philosopher at Clemson University in South Carolina. But, Smith says, humans are also part of the natural world, and not everything we do is bad, so a human settlement might enhance nature's pristine splendour rather than ruin it.

That's not to say we shouldn't tread carefully. Even now, when we send spacecraft to hover near other worlds, we take great pains to ensure they are as clean as possible to avoid contaminating the planet or moon with Earth life. Of course, this consideration doesn't arise out of respect for other worlds so much as the fear that it could render them useless for scientific study.

But settling humans on another planet would be a big step - make that a giant leap. Rather than mere contamination, it would probably mean overrunning or exterminating any native organisms outright.

Would that give us pause? On Mars, say, the most probable life forms are microbes. And when it comes to microbes on Earth, says Margaret Race, a biologist with the SETI institute in California, "we are killers, and deliberately so", murdering them with pesticides, antibiotics and soap every day.

Once the excitement surrounding any discovery of extraterrestrial microbes had faded, their eradication would seem a small price to pay for an expansion of human civilisation. "If we did destroy Martian microbes to create a new human society on Mars, I would argue that what we created is a whole lot more valuable than what we lost," says Smith.

That means we would have a responsibility to create a successful society, forcing us to take a hard look at the way we have changed and maintained our own world. "The idea that we could just take a whole planet and massively transform it to make it habitable for ourselves - gosh, we just did that and it's not going so well," says Maria Lane at the University of New Mexico.

If Earth becomes so uninhabitable that we need another planet as a lifeboat, what's to say we won't do the same again? Colonising the universe is all well and good, but not if we leave a trail of pillaged worlds in our wake. Leah Crane

Mind those microbes



COREY FORD/STOCKTRK IMAGES/GETTY

SHOULD WE...

STOP DOING SCIENCE?

Realise human potential

VS

Everything else

Science has the capacity to cure diseases, improve crop yields, reshape the planet and carry us into the cosmos, but is any of that worth the risks? The march of science has improved the lives of some, but not all. And it has inadvertently precipitated a problematic population explosion (see "Should we impose population controls", page 34) and an unfolding environmental catastrophe. As Winston Churchill once said, "It is arguable whether the human race have been gainers by the march of science beyond the steam engine... Give me the horse."

Add to that the development of weapons of mass destruction, disgraceful research such as the Tuskegee syphilis experiments on African Americans, and a few accidents such as the 1978 release of smallpox in Birmingham, UK, and perhaps the ethical thing to do would be to quit while we're ahead. We have enough knowledge, surely?

Not according to Lewis Dartnell at the University of Leicester, UK. Having spent years assembling *The Knowledge*, a detailed handbook for rebuilding a scientific civilisation after an apocalypse, he thinks there is still plenty of room for more insight. Scientific exploration of the world around us is just what we do – and it has been the making of us, he reckons.

"Through it we serendipitously discover whole new areas of understanding, which then offers the means to build fundamental new kinds of technology," Dartnell says. "I don't think that anyone would argue that we would want to give up now and stop making these fundamental leaps in our understanding that are so helpful to the world."

But philosopher Massimo Pigliucci of the City University of New York is willing to make that argument. He admits that a lot of applied science – medical research, for example – results in social benefit (see "Should we genetically engineer our children?", page 30). But not all science can be applied, and maybe it shouldn't all be funded, he suggests. The idea that scientists ought to pursue whatever



stimulates their curiosity because no one knows where the next practical application will come from is "really nothing more than a convenient just-so story", Pigliucci says. "It is odd that a bunch of empirically minded people will not actually be able to produce empirical evidence supporting the idea of unqualified benefits of basic scientific research."

The elephant in the room, Pigliucci says, is that scientific and technological advances have allowed us to group into vast nations, and the biggest winner from that seems to have been the military complexes designed to keep one scientifically armed nation from massacring another. The money we spend on military science and its applications far outweighs all other "public interest" science spending, he points out. "Maybe, before questioning the relatively small amounts we spend on basic science, we should ask ourselves what on earth are we doing with such an oversized military?"

Whatever the pros and cons, we certainly won't stop science at this stage of our civilisation, according to Jerry de Groot of the University of St Andrews in the UK. "It's an intriguing idea, but I can't see how it would remotely work in practice," he says. What's more, he adds, any forced scaling back would open science up to potentially disastrous manipulations. "Funding would be even more subject to political whim than it is now." **Michael Brooks**

"The biggest winner from science has been the military"



Aboriginal Australian knowledge could be an effective weapon against wildfires, finds Kate Douglas

Flame resistance

SHAUN LOWE/GETTY

"LIVE in a city that can be completely destroyed by fire," says David Bowman. Fifty years ago, the Tasmanian capital, Hobart, came within a whisker of being burned to the ground as flames raked in from the surrounding hills. Some 3000 buildings and 80 bridges were destroyed; more than 60 people died.

When wildfires hit the news, they tend to be in tinderbox lands in south-eastern Australia and the western US, or perhaps in southern Europe, as with last month's catastrophic fires in Portugal. But wildfires are a truly global concern. They consume an area the size of India each year, and their economic and social impacts are felt far beyond their scorched boundaries. They release huge amounts of carbon dioxide into the atmosphere – and as Earth warms, they are on the increase.

Yet we know surprisingly little about them. For many, fire is just about oxygen, fuel and

heat for ignition. For Bowman, an ecologist at the University of Tasmania who has been researching wildfires for 40 years, those bald chemical facts aren't enough. "I'm not a guru," he says. "Gurus tempt people with simple solutions, and fire is complicated."

Specifically, we tend to ignore some crucial elements that determine how wildfires play out: landscape, people and the interaction between the two. And for effective solutions to the problem of wildfire, says Bowman, we should look to those people who have lived alongside fire the longest.

Fires have raged on Earth ever since there was vegetation to burn. Long before our species existed, natural wildfires caused by lightning or lava were shaping the planet. Fire has shaped us, too: our ancestors were manipulating it as much as 790,000 years ago, and domesticated it between 100,000

and 50,000 years ago. Food cooked over fire may have given our forebears the energy needed to feed their expanding brains. Later, burning facilitated our shift from a hunter-gatherer to settled lifestyle, as fire converted forests to agricultural land. "Humans learned to use and live with fire over long generations, with knowledge encoded in rituals, myths and tradition," says Stephen Pyne, a fire historian at Arizona State University.

Yet modern approaches to wildfire have tended to ignore that history. They emerged from the science of forestry, and were largely developed in the damp forests of central Europe – not a natural breeding ground for wildfires. "Foresters condemned fire, and considered fire control the first task of any effort to rationalise landscapes," says Pyne.

That ignored the crucial role fire can play in adapted ecosystems. In the 1960s, for ➤

"Australia is Earth's most fire-prone continent - a land shaped by fire"

example, it was found that strategies of fire suppression were damaging the health of California's iconic giant sequoias. The trees relied on natural fires that swept through the forests every decade or so to release their seeds, restore nutrients to the soil, and open up gaps in the canopy that would allow sunlight to fall on germinating seedlings.

Big wildfires cannot be stopped in their tracks, anyway. All firefighters can do is guide their path until they are eventually extinguished by rain. So Western practice has settled on rigid schemes of pre-emptive

burning, almost always involving big fires set at the start of the dry season to reduce the amount of combustible material.

This strategy has significant problems. Large-scale, pre-emptive burning can itself get out of control: in 2012, a fire set by the Colorado State Forest Service in Lower North Fork, south-west of Denver, destroyed more than 20 homes and killed three people. Annual burning also favours the growth of flammable grasses adapted to the environment. This is an expanding problem as more people move into highly combustible areas and the risk of

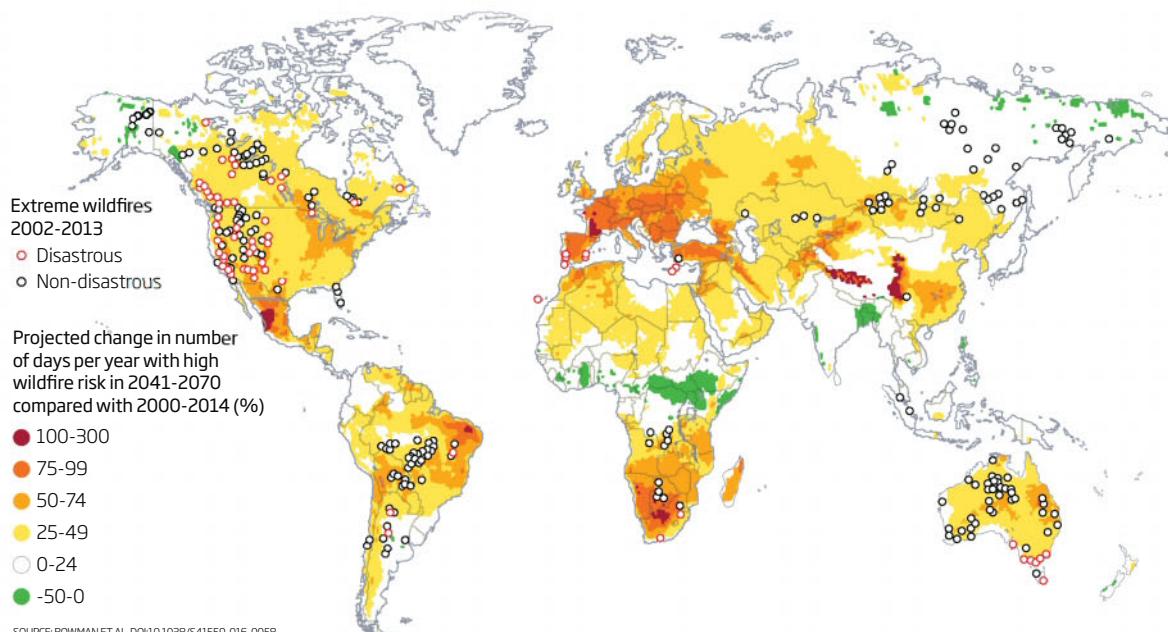
arson and accidental wildfires increases (see "Spreading like...", below).

A one-size-fits-all approach also fails to take account of local ecological differences, says Clay Trauernicht, a fire ecologist at the University of Hawaii. "Wildfire risk assessment tools in places like the continental US often don't work here due to the novel fuel types and different fire-climate relationships we have observed on the ground," he says.

Nowhere is the need for better answers more acute than in Australia, the most fire-prone continent on Earth. "It's a land shaped

Spreading like...

Disastrous wildfires with substantial economic, political or social impacts are currently concentrated in a few areas, notably western North America and southern Australia. As the climate warms, other areas are expected to become more at risk



ABOUT 400 million hectares of Earth's surface are burned every year through human activity and natural factors. The cost can be huge in destroyed infrastructure, degraded ecosystems, smoke-related disease and loss of life. Fires in South-East Asia's tropical forest sparked by conditions related to the 1997/98 El Niño-Southern Oscillation event are estimated to have cost the region \$9 billion.

Globally, carbon dioxide emissions from wildfires equal half those from burning fossil

fuel, a warming effect compounded by heat-absorbing black-carbon aerosols. As Earth warms and weather extremes become more extreme, wet periods that promote vegetation growth are followed by heat waves and droughts that turn landscapes into tinderboxes. An increasing wildfire frequency in Canada also risks releasing carbon stored in permafrost.

Earlier this year, David Bowman at the University of Tasmania and his colleagues

revealed the first global picture of human exposure to wildfires, present and future. The greatest risk occurs where human habitation encroaches into flammable landscapes in south-eastern Australia and the western US. Despite its similar climate and vegetation, southern Europe historically has had fewer extreme fires. But as people migrate from the countryside into cities, creating urban sprawl and leaving fallow land that was once intensively worked, that picture is changing.

The study suggests that susceptible landscapes could see an increase of between 20 and 50 per cent in the number of fire weather days, with the worst-affected areas being on the Australian east coast, including Brisbane, and across the Mediterranean.

"Our results suggest that extreme wildfires impacting southern European communities may simply be a matter of time," says Bowman - a point underscored by the deadly wildfires that engulfed central Portugal last month.

by fire," says Bowman. Fires set by the first human colonisers at least 40,000 years ago may have precipitated the extinction of Australia's megafauna; there seems little doubt that it killed off some fire-sensitive plants and animals. And burning must have contributed to the wide-open savannah grasslands and the prevalence of fire-adapted species, such as eucalyptus.

Today, Aboriginal Australians burn land for a range of practical reasons, from clearing land for habitation to hunting fires used to catch small mammals, large lizards or to drive turtles from a swamp. Fires are also used to generate new grass shoots to attract game. The Kunei people of Arnhem Land in Australia's Northern Territory burn patches on drainage lines to promote habitat for kangaroos.

Land is also burned pre-emptively to reduce the risk of large wildfires – but not in the way it is in the US, say. Strategies vary in between different Aboriginal groups, but have several features in common: the fires are relatively frequent, small-scale and low-intensity. This reduces the amount of flammable grass while sparing the tree canopy, and produces a fine mosaic of burned and unburned patches.

Patch burning seems to have two major benefits. It reduces the risk of uncontrolled fires; wildfires ignited by lightning are much smaller in areas where patch burning has occurred. And it promotes biodiversity, by creating a range of different habitats suitable for a wide range of animals and plants.

Feel the burn

Aboriginal burning practices are also adaptable. Around Kakadu National Park in the Northern Territory – a UNESCO world heritage site thanks to its many endemic species and vast tracts of tropical savannah – the Gundjeihmi burn early in the dry season when vegetation is still moist, using low, creeping fires to protect the canopies of fruit trees. Their neighbours the Kunei, by contrast, tend to hold off burning until the middle of the dry season when the winds keep flames below 3 metres.

But when that happens varies from year to year. Dividing the year into wet and dry seasons is a Western convention. Aboriginal Australians recognise six seasons marked by cues such as thunderstorm activity, the summer monsoon, temperature, humidity and changes in wind direction, plants and animals. These seasons form a reliable sequence whose timing varies, meaning burning is adapted to suit local conditions.

Aboriginal burning practices may help reduce wildfire threat to surrounding cities



Until recently, Aboriginal burning practices were largely charted through proxies such as charcoal particles in lake sediments, or "eloquent narratives" recorded by 19th century ethnographers. The core of Bowman's "pyrogeographic" work over four decades has been to observe Aboriginal practices and translate them into a Western scientific vocabulary of distinct "fire regimes". These are characterised by measurable factors, such as what type of vegetation burns, whether the fire flames or smoulders, how fast a fire spreads, when and how regularly fires are lit, how big they are, patchiness, and impact on vegetation and soils.

Bowman is now working in Tasmania's Bass Strait islands, where Aboriginal communities have lost much of the ancient know-how and are keen to adopt practices used in the Northern Territory. "There's a great interest in rekindling their traditions," he says. But it's a case of hasten slowly, he adds. The patch-burning approach must be modified to account for climate change and suburban sprawl into bushland, for example. "Tasmania has a very fire-sensitive ecology and we don't want it to go up in flames," he says.

That caution is echoed by Pyne. "There is no single driver, there is no universal algorithm", for wildfires, he says. Nevertheless, Bowman's

approach of looking back at long-established interactions between peoples and their landscapes can be useful, he says.

Trauernicht agrees. "It's important to keep in mind that we have a deep, collective heritage of proactively managing fire," he says. He is developing a wildfire model for Hawaii grounded in the principles of pyrogeography to help landscape managers take effective steps to protect fire-prone areas.

For Bowman, it's not just an academic project, but also a personal and political one. Back when he started, the Aboriginal Land Rights Act, passed in the Northern Territory in 1976, had recently given Aboriginal groups a claim to their traditional lands for the first time, and there was friction with incomers. "People were saying, 'Aboriginal culture is irrelevant,'" says Bowman.

He thought otherwise – and 40 years on, feels the wind is finally changing. Traditional knowledge could be one of the most effective weapons to beat back wildfire – as long as we learn to use the methods the right way. "The likelihood of major fires is increasing and the consequences are horrendous," he says. "It's exciting. But I'm conflicted about it. We mustn't set them up to fail." ■

Kate Douglas is a feature editor for *New Scientist*



FRANÇOIS WAVRE

Exoplanet hunter number one

The idea of finding worlds outside our solar system was considered borderline crazy until a few decades ago, when **Didier Queloz** ran headlong into the first one

ASTRONOMERS can barely look up these days without detecting yet another crop of alien worlds circling distant stars. It's a thrilling time to have eyes on the skies, and hard to recall that just over two decades ago, the only known planets in the universe were the nine – back in Pluto's glory days – orbiting the sun.

Many people suspected that our solar system, with its numerous and varied planets, was one of a kind. And there was no evidence

to suggest otherwise. Even if there were alien worlds out there, it was thought they would be too small and dark to be detectable, and lost in the glare of the stars they orbit. Anyone with the nerve to explicitly hunt for exoplanets risked not only their reputation but also their funding, so few astronomers tried. Even the man who would bag the first one thought it was far-fetched. "It would have been considered a really silly topic for my thesis," says Didier Queloz, who was a PhD student at

the University of Geneva at the time.

So how did Queloz, now primarily at the University of Cambridge, make such a landmark discovery? It began with his PhD advisor, Michel Mayor. Mayor was an authority on analysing the spectrum of light coming from stars. Two decades earlier, he had developed CORAVEL, a type of spectrograph that could detect the shifts in a star's light caused by a nearby massive object. For example, in a binary star system, in which

two stars orbit around their common centre of gravity, the gravitational pull of one star affects the radial velocity of its partner star, causing it to wobble slightly in its orbit. That wobble creates Doppler shifts in the spectrum of starlight that CORAVEL could detect. Mayor was involved with building a more sensitive instrument. "Michel was looking for someone to take on this project, and I liked the style of the guy," Queloz says. "I also really like building stuff. That was how it all started."

The anomaly

At first, the new instrument, ELODIE, could discern changes in radial velocities as low as 50 metres per second. "But I had built the software and I knew it could do much better," Queloz says. They improved the sensitivity to 10 metres per second – able to detect subtler stellar wobbles than ever before. They knew this level of sensitivity was a potential game-changer: it might allow for the detection of giant planets. So they decided to start looking.

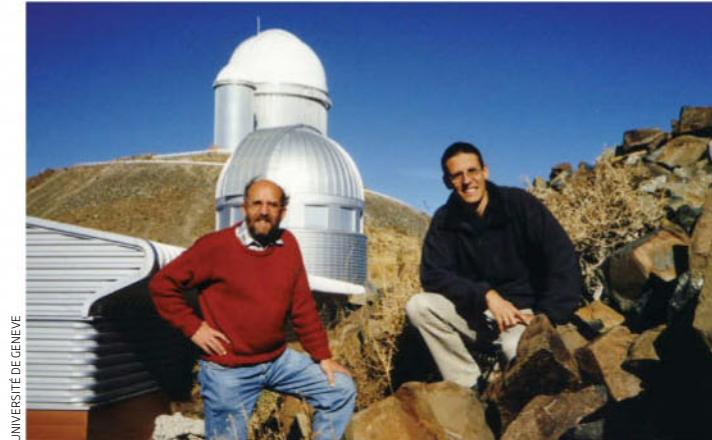
Mayor and Queloz picked 100 stars that no one had paid much attention to and settled in for what they thought would be a decade of data gathering. "Michel told me to start looking at the radial velocities, then he went on a sabbatical to Hawaii." That was in May 1994.

It was July when Queloz first looked at 51 Pegasi, a star 50 light years away. By September, he realised the data didn't make sense. The star's radial velocity kept changing in ways Queloz didn't understand: the wobbles were too small for a binary star system, but the value was changing way too fast to be caused by a planet. "I was really worried. For a week, I tried to find a bug in the software, but couldn't find one," he says. Further observations continued to throw out inexplicable results. "I was in total panic at that point," Queloz says. But he kept it all to himself: family, friends and Mayor had no idea of his turmoil.

Quietly, doggedly, Queloz kept up a programme of observations, looking at other stars to see whether ELODIE also did something inexplicable to their radial velocities. It didn't. "That's when I started to think, 'OK, this must be real!'" Queloz says, but he still couldn't bring himself to confide in Mayor. "I was worried he would laugh at me."

By January 1995, Queloz in desperation reached for what he thought was a far-fetched solution. If he was seeing the gravitational effects of a giant planet, it would have to be orbiting disturbingly close to the star to make it wobble so rapidly. This went against three

Michel Mayor and Didier Queloz at La Silla Observatory in Chile



decades of space exploration programmes, billions of dollars of investment in probes sent to Jupiter, Saturn and the other planets. "They all said a Jupiter-scale planet couldn't form and orbit so close to a star," Queloz says. For comparison, Jupiter, the closest gas giant to the sun, takes 12 years to complete an orbit.

He developed a computer program in an attempt to fit the data with a possible orbit, and finally cracked the puzzle in March. "I got an observation, and it was right on the curve," he says. "And then I did another one, and that was on the curve, too." Queloz decided it must be a giant planet whizzing around 51 Pegasi once every 4.2 days, and it seemed to be orbiting

"That's it. Wow. It's a planet. It really shouldn't be, but it is"

more closely than Mercury orbits the sun. It was a conclusion bordering on scientific heresy.

A thrilled Queloz sent a fax to Mayor. It read: "I think I've found a Jupiter-mass planet of four days' period." But Mayor's reply was non-committal. "He told me to keep it to myself until he got back," Queloz says. "He said afterwards that initially he didn't believe it."

Mayor returned from Hawaii in April, but by then 51 Pegasi wasn't in the right part of the sky, so the pair had to wait until July to resume monitoring. "Then, for four nights it was exactly on the curve. I said: 'We're Swiss; let's be sure.' And on the fifth night, we said, 'That's it. Wow. It's a planet. It really shouldn't be, but it is,'" says Queloz.

Then came paranoia about being scooped. "We kept quiet and drafted a paper," he says. At the end of August, they submitted it to *Nature*. Queloz remembers the terror: he knew a single mistake in the data would have crippled

his career before it had even begun. "It was my data, and as a PhD student with no reputation to fall back on, I'd be dead if we'd got it wrong."

In October, *Nature* still hadn't accepted the paper, but regardless the pair presented their results at a conference in Florence, Italy. An audience member phoned astronomer Geoff Marcy at the University of California, Los Angeles, who had been looking for exoplanets. Marcy observed 51 Pegasi for five nights and was able to gather data to support the exoplanet's existence. When Queloz and Mayor's paper was finally published that November, there were still doubters aplenty. Many astronomers later admitted to Queloz that they didn't believe in his discovery for years afterwards. It wasn't until 1999, when David Charbonneau, then at Harvard University, saw a star's light dim as a planet crossed in front of it that the scientific tide turned. And it turned decisively.

Today, exoplanets are commonplace and include many "hot Jupiters" like the one Queloz spotted. The haul of confirmed worlds is more than 3500 and climbing – NASA's Kepler space telescope alone discovered more than 2300. Some, such as the TRAPPIST-1 system with its seven Earth-scale planets, have truly captured the popular imagination. "We didn't realise that the discovery of other worlds would mean so much to the public," says Queloz, who remains at the forefront of exoplanet discovery.

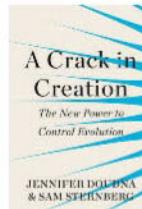
It turns out that our solar system is nothing special in planetary terms. But it is unique, at least, in boasting the only known life in the universe. But with hunters now scouring exoplanet atmospheres for signs of alien life, how long before we realise we're not so special after all? ■

By Michael Brooks

This changes everything

Hype? What hype? CRISPR has been delivering on every promise, finds **Adam Rutherford**

A Crack in Creation: Gene editing and the unthinkable power to control evolution by Jennifer Doudna and Samuel Sternberg, Houghton Mifflin



KAKPOS are fat New Zealand ground parrots that have stared into the abyss of extinction for decades.

Conservationists have laboured to raise numbers from the moribund low 50s to a still ultra-critical 160 or so today.

Once a species becomes so depleted, however, a lack of genetic diversity can hinder its long-term salvation. A geneticist once told me of a crazy idea that might save the kakapo. He said that there are more stuffed kakapos in European museums than there are living birds. If we could extract DNA from those dead parrots, from a time when their numbers were large, we could genetically engineer the living birds to mimic the once healthy species by changing single letters of genetic code.

There are a lot of “ifs” here, but the modification of DNA itself – even at the level of precision this mad scheme would require – is eminently possible, thanks to a technology known by the acronym CRISPR. Ten years ago, identifying, characterising and modifying a gene then getting it back into an organism was a process that took weeks, months or years. With CRISPR you can perform the same process in days.

Incredibly, it looks as though CRISPR will live up to its hype, transforming every aspect of biology as genetic engineering did from the 1970s on. Tweaking individual letters of genetic code, it takes just hours to finely edit what evolution fashioned over billions of years. All aspects of the science of life are within CRISPR’s reach: disease, conservation, synthetic cellular manufacture.

CRISPR’s complex origins as a gene editing tool can reasonably be credited to a few key players: Jennifer Doudna is one of them. With her former colleague Samuel Sternberg, she has written a detailed account of the story so far. It may well end up being compared with the book that inspired a 12-year old Doudna in the first place: James Watson’s *The Double Helix*.

But while Watson’s iconic account of his and Francis Crick’s discovery of the structure of DNA is dramatic and myth-making, bitchy and sexist, *A Crack in*

“Concern about genetically modifying people may once have seemed overheated. That’s about to change”

Creation is thoughtful and thorough. Packed with amazing female scientists, it is thrilling, generous and no less personal. It’s a good tale of how science works, tracing all the meandering paths that lead to discovery: meetings, chance encounters, ceaseless discussions, and the endless beavering of lab life.



FRANS LANTING/NATIONAL GEOGRAPHIC CREATIVE

CRISPR has ruffled feathers, but it may be capable of saving species

A Crack in Creation is quite technical at times, and a touch bogged down with the clinical specifics of the many diseases that CRISPR may one day fix. The journey from the days of gene therapy to the first human CRISPR studies in China is no amble, either. Following these early Chinese studies, Doudna recommended an instant moratorium on human CRISPR experimentation. Similar moratoriums were called for in the first days of genetic engineering in the 1970s, and in recent years, following the experimental modification of virulent flu viruses.

Public concern about the genetic modification of people may have seemed overheated while we lacked the scientific chops to do anything significant.

But that is about to change: CRISPR is powerful and potentially scary. Doudna’s own ethical position comes into focus in the final chapter. It’s a nuanced account, but she definitely inclines towards excising conditions like cystic fibrosis and Huntington’s disease from the human germ line.

A Crack in Creation touches the surface of these issues. It doesn’t delve deep, but one book cannot do everything. Genetics has been in perpetual revolution for several decades now. Since the 1990s, when the Human Genome Project ground into action, there have been so many advances in our understanding of genetics and our ability to manipulate DNA that it’s hard to keep up. Doudna accounts for the many cracks in creation in the 21st century: developing RNAi, where genes can be silenced with tiny bits of ingested genetic code; the



building of giant chromosomes to help us clone larger genes; and the manipulation of stem cells. All of these achievements resulted in Nobel prizes – Doudna's must surely come soon.

We need scientifically informed public conversations about what we should do next with these powers, and Doudna's book is a good place to begin. The first gene engineers of the 1970s framed their discoveries by actively engaging with the ethical, legal and political ramifications of genetic engineering. So must we. "As I write this," says Doudna, "the world around us is being revolutionized by CRISPR, whether we're ready for it or not." So strap in and get up to speed, because these days, the science of modifying life moves pretty fast. ■

Adam Rutherford is a geneticist, author and broadcaster

Plane speaking

Analogue tech powers a futuristic artwork, finds **Simon Ings**

DX17 at IWM Duxford, UK, to 30 September

THERE are many stories at the Duxford airfield, Cambridgeshire. How it served British and American military interests for 100 years. Why Alexander Graham Bell wanted to call his daughter Photophone. How a technologist in Tasmania came half way round the world to the UK, only to discover that the technology he was developing was being used to send messages between mountaintops in – of all places – Tasmania.

Luckily for me, I'm being shown around *DX17*, Duxford's new sound sculpture, by its creator Nick Ryan, a sound artist who is good at making sense of complicated stories. It was Ryan who recreated the soundscapes of the Yangtze river and spread them along a pedestrian bridge at Gatwick Airport's Skybridge. He also incorporated the orbits of 27,000 pieces of space junk into a musical instrument called *Machine 9*.

DX17 is made of netting stretched over a steel skeleton. It's an aerodynamic abstract with protrusions that suggest design elements from iconic aircraft.

The first thing you notice are the lights: the sculpture is filled with 100 spotlights, their beams playing through the mesh of the sculpture and onto the floor. Yet *DX17* contains more sound than vision. Hidden in each beam is a sound recording selected by the Imperial War Museum – some originals, others documents read

by Duxford staff and volunteers. Together, they celebrate the base's 100 years of aeronautical activity.

Weaving these recordings comprehensibly through an object no bigger than a Spitfire was a technical challenge. Ryan and his project partner Sean Malikides opted to use light after deciding that digital solutions were clunky and historically inappropriate.

"Visitors press their 'light-catchers' to the sculpture, or catch beams projected onto the floor"

Each light shines a flickering beam through the mesh of the sculpture – a sound signal carried on light. 3D-printed handsets with a lens at one end turn the signal back to audio, and play it through headphones.

Visitors can press their "light-catchers" to illuminated spots on the sculpture, or catch beams projected from the sculpture onto

the floor. Here and there, two beams intersect, and through your headphones, two audio samples blend. As you step away from a light source, the voice in your headphones – an airman's memoir, instructions to ground staff, a loved one's letter, a child's recollections – slowly fade.

It wasn't until they were testing their system that Malikides came across the pre-history of this "li-fi" tech. Alexander Graham Bell invented it, using sunlight and a deformable mirror to send sound information across space. In 2005, enthusiasts in Tasmania used a similar system to signal between mountaintops some 160 kilometres apart.

Bell considered the photophone more important than the telephone and wanted to name his daughter after the invention. His wife persuaded him that Daisy would be kinder.

There are many stories here. Good hunting. Fade to black. Transmission ends. ■

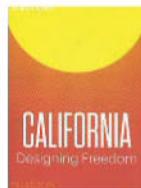


Chasing rainbows: Duxford's history is conveyed on beams of light

California dreaming tools

The idea of design shaping societies connects us to the 1960s, finds **Jonathon Keats**

California: Designing freedom by Justin McGuirk and Brendan McGetrick, Phaidon Press



IN 1971, a group of San Francisco renegades set up a collective banning lazy hippies. Based in a warehouse, the Project One commune was heavily stocked with tools and technologies, including a mainframe computer, all directed toward community-building and radical activism. While it hardly conformed to counterculture back-to-the-land clichés, this hyperactive, tech-savvy collective embodied many qualities and values that connect the 1960s to Silicon Valley today.

The relationship between these seemingly disparate realms is one of the main themes of *California: Designing freedom*, an illustrated book that would look chic on any Californian coffee table, yet one that packs an impressive heft with five original essays by design scholars and practitioners.

Timed to coincide with the London Design Museum's exhibition, the book sets out to show California design as a phenomenon, from Los Angeles to San Francisco, and from Hollywood's golden age to the tech present. It's about "selling freedom", says Justin McGuirk, a curator at the Design Museum. "It is about putting tools in your hands, so you can go where you want, say what you want, make what you want, see what you want and join who you want."

Each essayist takes one of

McGuirk's five freedoms to elucidate facets of California's access-to-tools mentality. In the process, they cover an impressive range, from geodesic domes and desktop publishing to augmented reality and design theory.

As absorbing as these topics are on their own, it is especially interesting to note those that reappear, since their recurrence highlights a particular significance. Two stand-outs are the *Whole Earth Catalog* and the graphical user interface (GUI).

First published out of a shopfront in Menlo Park in 1968, with "access to tools" as a motto, the *Whole Earth Catalog* was a sort of self-sufficiency encyclopedia to

help you design your entire life. In addition to articles describing DIY projects, there were addresses for ordering everything from potters' wheels to computer books.

As designer Brendan McGetrick writes in his essay, the *Catalog* offered those tools, and itself, as "prototypes of a new relationship between the individual, information and technology" – a relationship he traces to today's makers and to Silicon Valley's design-based philosophy, especially the idea of design

as a tool for changing society. Elsewhere in the book, architectural historian Simon Sadler makes a lateral move, presenting Project One as "the *Catalog*'s vision of community become real".

The graphical user interface, developed by Xerox at what is now PARC, was equally pivotal since intuitive visual interaction made the most powerful tool of all – the computer – accessible to everyone. Starting with the Xerox Alto but really taking off with the Apple Mac, the GUI facilitated desktop publishing and the World Wide Web, making the PC nothing less than, in McGuirk's words, "a tool... of personal liberation".

If this book has a flaw, it is overemphasising northern California at the expense of the state's south. With that comes an overdose of Silicon Valley's personal-liberation Kool-Aid. McGuirk gamely tries to plot a role for Los Angeles, writing that "Hollywood has been the tech industry's perfect counterpart. Films like *Minority Report* reveal a feedback loop... Hollywood visualizes nascent innovations such as augmented reality in ways that become self-fulfilling".

That may be true, occasionally, but Hollywood has also offered up a counterpoint to the north's tech obsessions with dystopian movies (*Minority Report* included). In the end, though, California is a place of contradictions, and that's not a problem. The lack of consensus and freedom to undermine its image are key to the Golden State's eternal design vitality. ■



Finding freedom, through geodesic domes and the *Whole Earth Catalog*

LUKE HAYES
Jonathon Keats wrote *You Belong to the Universe: Buckminster Fuller and the future*, Oxford University Press



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Lindsay Catherine Burrage, M.D., Ph.D.
Baylor College of Medicine

Aaron Foster Carlin, M.D., Ph.D.
UC San Diego

Alejandro Chavez, M.D., Ph.D.
Harvard Medical School

Whitney Elizabeth Harrington, M.D., Ph.D.
University of Washington

Tamia Alisha Harris-Tryon, M.D., Ph.D.
UT Southwestern Medical Center-Dallas

Kara Noelle Maxwell, M.D., Ph.D.
University of Pennsylvania

Kent William Mouw, M.D., Ph.D.
Harvard Medical School

Anoop Patel, M.D.
University of Washington

Tamer Sallam, M.D., Ph.D.
UCLA

Zuzana Tothova, M.D., Ph.D.
Harvard Medical School

Craig Brian Wilen, M.D., Ph.D.
Washington University in St. Louis

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Brian Aguado, Ph.D.
University of Colorado-Boulder

Christopher Barnes, Ph.D.
Caltech

Daniel Dominguez, Ph.D.
MIT

Nicholas Gomez, Ph.D.
Rockefeller University

Theanne Griffith, Ph.D.
Columbia University

Antenor Hinton, Jr., Ph.D.
University of Iowa

Kellie Jurado, Ph.D.
Yale University

Christopher Lopez, Ph.D.
Vanderbilt University Medical Center

Ciera Martinez, Ph.D.
UC Berkeley

Derrick Morton, Ph.D.
Emory University

Shamsideen Ojelade, Ph.D.
Baylor College of Medicine

Manuel Ortega, D.Phil., Ph.D.
MIT

Melody Smith, M.D.
Memorial Sloan-Kettering Cancer Center

Max Staller, Ph.D.
Washington University in St. Louis

Tomeka Suber, M.D., Ph.D.
University of Pittsburgh

Bryan Wilson, Ph.D.
University of North Carolina-Chapel Hill

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MY WORK IS A STORY OF FLOURISHING.

A photograph of a woman jogging on a paved path in a park. She is wearing a purple t-shirt, black leggings, and a pink smartwatch. She has white earbuds in her ears. In the background, there is a large, multi-jet fountain spraying water into the air. The scene is bright and sunny.

I'm helping children avoid asthma attacks. We produce a blood test that identifies allergens that can cause breathing problems—giving people around the world vital information to avoid asthma triggers. As an avid runner myself, I have a particular interest in helping all of us to breathe well. I've made it my mission to encourage pediatricians to order our tests for their young asthma patients. I'm grateful that I can use my position to make a difference for children in my community—and beyond.

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EDITOR'S PICK

I am your perfect test subject on smell effect

*From Anne Sproule,
Ottawa, Canada*

Clare Pain reports research on the effects of exposure to fragrances, including the suspicion of some that they trigger migraines (10 June, p 34). I've had migraines most of my life, and have noticed an increased sensitivity to smells, but was never sure whether

the smells were triggering a migraine or my migraine made me more sensitive to smells. However, as I age, I'm starting to lose my sense of smell: for example, I can no longer smell lilacs and lily of the valley (sigh), or boys' washrooms (hooray!).

I was recently participating in a parent-teacher interview and felt a migraine starting up. I was waiting for the interview to end before fetching my medication and the migraine was gradually getting worse. Then the parent went away, and my co-worker said, "you don't often see people who wear that much cologne any more." I'd had no idea the air was permeated with scents, so I guess I made a fairly good blind test subject. I suppose my question is answered – the scent was triggering the migraine, even though I couldn't smell it.

Monkey see, monkey steal, all over the place

*From Jo Darlington,
Cambourne, Cambridgeshire, UK*
Brian Owens reports an investigation into monkey criminality (3 June, p 14). This reminded me of an incident at Mzima Springs in Kenya some decades ago.

Two American women were sitting on a rug to eat their picnic lunch. A female vervet monkey came and sat down about 3 metres in front of them, in full view, and started to play prettily with her baby – not something she would normally do. While the women were thus delightedly distracted, a male vervet that had wandered up behind them suddenly darted out, grabbed their sandwiches and made off at speed.

The mother vervet immediately picked up her baby and bolted

after him. The two adult verves appeared to have colluded in this little ambush.

No one knows whether iron fertilisation works

*From Paul Broady,
Christchurch, New Zealand*
Olive Heffernan mentions John Martin talking, in an informal seminar at Woods Hole Oceanographic Institution in 1988, about stimulating an ice age with half a tanker of iron (10 June, p 24). This gives the impression of extreme confidence.

In contrast, in a 1990 article Martin expressed doubts by stating: "Clearly, the reasons for glacial-interglacial CO₂ change are complex. Iron availability appears to have been a player; however, whether it had a lead role or a bit part remains to be determined." This is still the case. Claims that

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"I still wouldn't want to go head-to-head. They go for your genitals when they attack"

Natalie Robinson is not entirely reassured by news that chimpanzees' strength has been exaggerated (1 July, p 9)

we could biogeengineer climate by fertilisation of the oceans are equivocal. Attempting it in ignorance of its effects could be disastrous.

Language games and generalisation in the crib

From Jane Henderson,
London, UK

Your discussion of the importance for language development of the human ability to generalise was fascinating (3 June, p 38). It brought to mind my eldest son's early forays into speech.

With a limited vocabulary – barely half a dozen words – his favourite utterance was “me-mill”, a mispronunciation of “windmill”. He applied this to anything that showed circular motion: concrete mixers, windmills, hoops – and pictures of these. He could clearly both

generalise and recognise symbolic representation from a very early age. This led to a game where he would spot a “me-mill” and I would spend the next little while working out what he had seen.

He is now a research scientist.

It takes a fiction writer to say the unsayable

From Fred White,
Keyworth, Nottinghamshire, UK
At last you report a voice speaking the seemingly unspeakable, with Kim Stanley Robinson noting that “capitalism is the system we have agreed to live by. Its rules... are ... destroying the world” (10 June, p 44). An economic system in which the planetary “capital” of mineral reserves, fossil fuels, clean air and water can be used up for apparently profitable activity would normally be recognised as a Ponzi scheme, selling our

descendants’ inheritance for our short-term gain.

The environmental crisis we face is down to bad bookkeeping. We need to correct the balance sheet, not dump iron into the oceans and deflect the sun (10 June, p 24) for the benefit of mega corporations. Stanley Robinson’s *New York 2140* looks like a must-read.

Does Stephen Hawking propose abandoning us?

From Iain Murdoch,
Marton, Warwickshire, UK
Stephen Hawking proposes sending colonists to other worlds (20 May, p 22). How will this contribute to the future of our species or our current civilisation?

Sending a privileged few to try to build a sustainable existence elsewhere seems rather pointless when we haven’t yet learned how

to do it on Earth. Is there also a sub-plot that the rest of us are being abandoned to perish?

If the collapse of civilisation and perhaps the extinction of our species is regarded as inevitable, that is surely a self-fulfilling prophecy. Instead, the resources required for colonies could be well spent learning how to sustain our planet’s ecology and the civilisation it supports.

Can't the scientists and the politicians get along?

From Steve Haines, Bishop's Waltham, Hampshire, UK
David Willetts sets out the deep mutual incomprehension between scientists and politicians (3 June, p 24). This is ironic given the difficulty some conservative politicians have accepting scientific evidence (see, for example, 29 October 2011, p 38). ➤

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The rain gets in and stops my mind from wandering

From Leopold Faltin,
Vienna, Austria

I agree with Caroline Williams that the best strategy against mind-wandering is to make use of it (20 May, p 26). But what should one do when the mind resists by simply continuing to wander?

To my knowledge, the best trick when you notice that your mind is wandering is to ask yourself: "What will be my next thought?" This not only stops mind-wandering at once, but gives you the (usually much wanted) opportunity to choose the next topic yourself.

The roles of radars in the Battle of Britain

From Sean Waddingham,
Golden Green, Kent, UK

Chris Baraniuk, recalling the invention by Russell and Sigurd Varian of the klystron radio amplifier tube, writes that the British won the Battle of Britain thanks in some measure to it (27 May, p 40). But that air battle

was fought in daylight, with help from ground-based radar powered by other technology.

British historians date the Battle from 10 July to 31 October 1940. The first time a klystron-powered Air Intercept radar in a plane enabled the shooting down of an enemy plane was on 22/23 July 1940, but this technology wasn't crucial in the battle thus defined. Beaufighter night fighters with radar systems (using magnetron devices, developed in the UK, rather than klystrons) entered service at the beginning of 1942.

You shall know us by our thin layer of polythene

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Andrew Sanderson, discussing a possible Anthropocene Age, wondered whether concrete would be identifiable in 10 million years (Letters, 10 June). This put me in mind of articles a while ago in *New Scientist* referring to the strange thin layer of iridium that can be seen in a number of sedimentary rocks dating from

the end of the Cretaceous period and the demise of the dinosaurs (for example, 2 June 1990, p 30).

I recall one of these articles going on to speculate about how geologists 65 million years in the future (of whatever species they might be) would explain the microscopically thin layer of polythene that would probably appear in a similar layer across the entire planet, as they investigated the epoch we now call our own.

Fears about Fukushima are not at all allayed

From Judy Kendall,
Todmorden, Lancashire, UK

The picture Shunichi Yamashita gives of the situation around the Fukushima nuclear power station conflicted with what I have been hearing (13 May, p 40). I wrote to a friend in Japan, who said Yamashita has been criticised and that she feels little on Fukushima is reported in Japanese news.

Her worries include contaminated soil, waste from the area being transferred across Japan, and cows being transported

to other prefectures and their milk not being tested for contamination, outside very limited areas.

She still avoids buying food products from Fukushima and five surrounding prefectures because the Citizens' Nuclear Information Center reports they were contaminated.

New Zealand can take pride in this rocket

From Greg Billington,
Auckland, New Zealand

Readers of your story about a rocket launch from New Zealand might assume that Rocket Lab is a US enterprise and that the launch site was simply chosen for clearer skies (3 June, p 5). This is far from the case.

Rocket Lab was founded in 2006 by New Zealand scientist Peter Beck, who still leads the company. It did become a US company, with US as well as New Zealand shareholders for legal reasons, but does retain the wholly owned subsidiary Rocket Lab New Zealand.

Readers may also be interested to know that the rocket is largely and unusually built from carbon composites, and that its main engine, the Rutherford – named for another significant Kiwi – was developed under the leadership of Rocket Lab's Head of Propulsion, NZ engineer Lachlan Matchett.

TOM GAULD



For the record

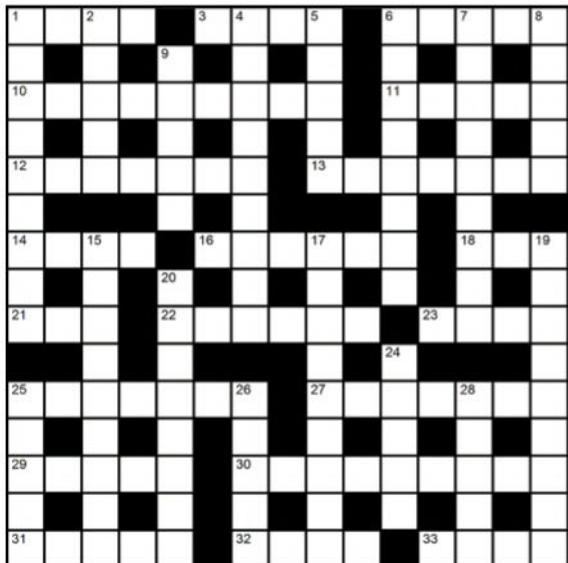
■ **Stub it out:** the proportion of smokers among adults in the UK fell from 20.1 per cent in 2010 to 15.5 per cent in 2016 (24 June, p 6).

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CROSSWORD

Compiled by Richard Smyth



Crossword No8

ACROSS

- 1/14 The ___ of DNA, 2003 biography of Rosalind Franklin by Brenda Maddox (4,4)
3 Toxic clouds of air pollutants (4)
6 General-purpose AC power (5)
10 Island group west of Ecuador, visited by Charles Darwin in 1835 (9)
11 Chemical element, atomic number 54 (5)
12 Endocrine gland in the neck (7)
13 Herbert ___ (1820-1903), English scientist who coined the term "survival of the fittest" (7)
16 Producing an effect (distinct from "correlative") (6)
18 Viscous, often flammable substance of animal, vegetable
- 21 The result of the addition of a sequence of numbers (3)
22 ___ Committee, considers moral aspects of scientific trials (6)
23 Probability (4)
25 A computer's output device (7)
27 Ernst ___ (1834-1919), German naturalist and biologist (7)
29 Pungent vegetable of the genus *Allium* (5)
30 Transition metal, atomic number 40 (9)
31 Relating to sound waves (5)
32 Structure in which benzene's carbon atoms are depicted (4)
33 + (4)

DOWN

- 1 Genus of plant from which the drug digoxin, used to treat heart conditions, is derived (9)
2 Electrically operated switch (5)
4 Term for a million human fatalities, usually in relation to nuclear warfare (9)
5 Helium, hydrogen and oxygen, for example (5)
6/24 Thought experiment concerning the second law of thermodynamics (8,5)
7 Chemical attraction between oppositely charged particles (5,4)
8 Sound Navigation and Ranging (5)
9 Acronym for a kind of memory
- 15 Length, breadth or height? (9)
17 Artificial sweetener first produced in 1879 (9)
19 New Mexico location used as a base for the Manhattan Project (3,6)
20 Relating to the structure of Earth's crust (8)
25 Natural satellites such as Phobos and Titan (5)
26 Occam's___, medieval problem-solving principle (5)
28 Tiny marine crustaceans (5)

Answers to crossword No7

ACROSS: 8 LOVELL, 9 DNA, 10 YONG, 11 WILLOWHERB, 12 OTIC, 13 ICE AGE, 16 ANALEMMA, 17 RUBELLA, 18 RHOMBUS, 22 SONOGRAM, 25 MACULA, 26 BLUE, 27 AMINO ACIDS, 30 SINE, 31 DDT, 32 DYNAMO. **DOWN:** 1 LOC, 2 BELL, 3 FLYWHEEL, 4 ADRENAL, 5 LAMBDA, 6 HYPODERMIC, 7 INDIUM, 14 CPU, 15 ANEMOMETER, 19 HUMBOLDT, 20 URL, 21 AMIOTA, 23 OIL RIG, 24 RWANDA, 28 CONE, 29 DOME

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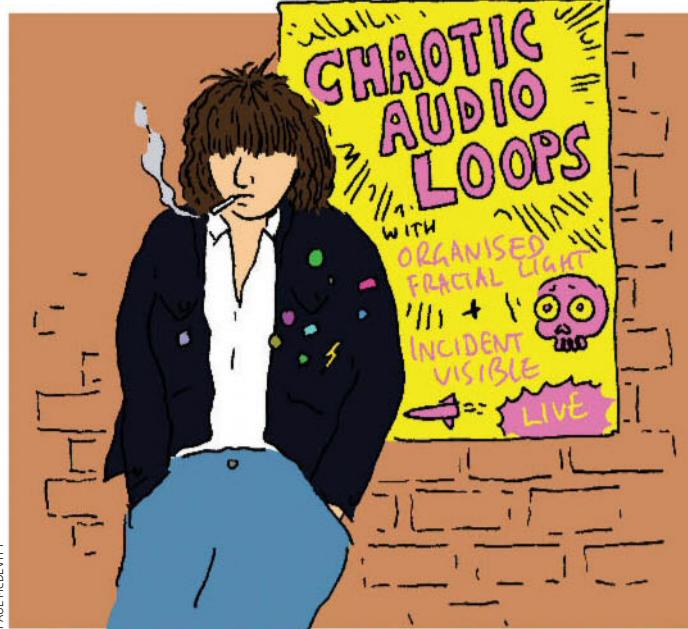
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SILENT alarms keeping you up at night? Unfortunately nobody is quite sure what causes tinnitus, the mysterious ringing in the ears that only you can hear. Consequently, it's not for Feedback to say if any of the remedies on offer are effective.

Nonetheless, something about the latest offering, forwarded by Paul Holmstrom, doesn't ring true. The Antinnitus sticky patches, designed to be glued behind the ear, "contain a unique microscopic raster, which, with the help of incident visible and thermal light, creates a regular and organised fractal light". But of course!

You may ask how that helps with the subjective perception of noise. "In contact with fractal light, water molecules in biological tissues adopt a more coherent state... The hypothesis is that an elevated reorganisation of water in the biological environment may modulate the chaotic audio loops in the auditory system that represent the various conscious sound experiences that we call tinnitus and hence provide relief."

Yes, chaotic audio loops are no longer just a feature of the bands which might have caused your tinnitus in the first place. Feedback's hand is poised over the "Order" button, but one niggling question remains: do the patches still work at night, when there's no light, fractal or otherwise, to fall on our raster-plastered skin?

PERHAPS with hopes of entering the market for trendy cold brew beverages, Tefal have a new kettle that Michael Harrison has seen, advertised with the claim that it "boils at different temperatures for the perfect cup of tea".

"It may boil at different temperatures depending on altitude and solutes," says Michael, "but whether this results in the perfect cup of tea is open to dispute."

FORGET Beethoven for babies. If you really want to raise a genius, we suggest buying them a certain pack

of building blocks from the Wicked Uncle website. David Love found his attention drawn to the Smartmax Start Magnetic Discovery pack, aimed at 1-year-olds, which contains "rods and balls to build fun shapes and structures".

"The cold coloured bars (green & blue) have North poles and the warm coloured bars (red & yellow) have South poles," the website reveals. Yes, after decades of searching, it seems magnetic monopoles were under our noses all along.

Reject boring wooden blocks and get your infant playing with these quantum toys, says Feedback. In no time at all, they'll be building flux tubes from pasta shells and sketching grand unified theories in crayon.

ANDY BEBINGTON writes: "Ian Gordon's tale of being given precise GPS coordinates to a site 5 miles away from the holiday cottage reminds me of a customer who called by appointment at our London office" (24 June). The fellow was in the UK because his company was providing the timing equipment for the Commonwealth games, says Andy, and proudly boasted that he could time sprinters to within 1/100th of a second. However, "he arrived an hour late for his appointment, as he was working on Central European Time".

DESPITE our protests, readers keep emailing us about Nazis (24 June). "I burst out laughing reading John King's fanciful explanation of the term," writes Anja Nohlen. "The Socialists were commonly called 'Sozis' and to distinguish them, the National Socialists were called 'Nazis' as both terms are quite a mouthful, even for Germans."

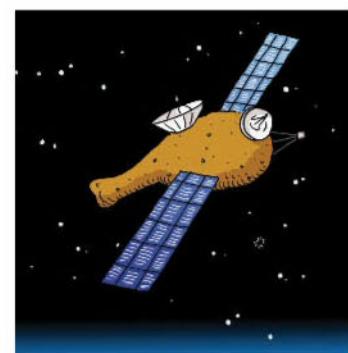
Roger Savidge adds that previous correspondents have failed to point out that the term was also "a derisory pun coined by its opponents". This was to ridicule the party's origins in Bavaria, a place "regarded as a backwater populated by half-witted peasants whose stereotype was a Natsie, short for Ignatius, a common name in Bavaria".

IT'S one small flight for a chicken breast, but one giant leap for chickenkind. Fast-food giant KFC has announced plans to launch a piece of deep-fried poultry to the edge of space by balloon. The chicken sandwich will drift in the stratosphere for several days before returning to Earth.

The exact rationale for this epic endeavour remains a mystery, but it's safe to say the journey time means KFC isn't planning a new method of home delivery.

The launch vehicle is provided by World View, a company hoping to fly communications "satellites" on high-altitude winds to provide connectivity to users below.

Feedback can only speculate about this delicious twist in the privatisation of spaceflight. The confectionery world already boasts a host of products that could maximise brand synergy



with off-Earth exploration: Mars, Milky Way and Galaxy chocolate bars are three in the running. Watch this mouth-watering space.

PREVIOUSLY Feedback scratched its head over the existence of scentless perfume (3 June). Ian Napier writes: "My entrepreneurial tendencies have me considering the repackaging of sparkling water as 'flavourless cola'." Don't forget to remind customers that it's low in fat and sugar-free.

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.

Spider shroud

I went on holiday for two weeks and returned to find this ghostly impression of a spider on our toilet roll (see photo below), but no spider or spider body anywhere around. How did the spider cause this pattern? (Continued)

■ I take issue with a previous correspondent's description of studying loo rolls as being "several orders of interest below watching paint dry" (25 March). The highly respected computer scientist Donald Knuth devoted a paper to the topic of which roll is more likely to run out first in a dual-roll dispenser, and there have been many studies of the social stratification of toilet paper orientation, as evidenced by the scores of references in the Wikipedia entry on the topic.

Need I continue?

*Richard Miller
London, UK*



Rock and hole

While holidaying on the Greek island of Paxos, I came upon a pebble beach where many of the stones had apparently been "engraved" by some type of creature. This example (see photo above) is roughly 50 by 60 millimetres, but the same sort of pattern was also present on much larger stones. What type of creature made these, and how and why?

■ Although the marks may appear to have been made by recent burrowing, they are the result of much older biology. The rock retains the pattern of the marine creatures that laid down the limestone, but mildly acidic rainwater has dissolved the softest parts and expanded the marks. The same chemistry creates cave complexes throughout the world.

*Keith Reid
Soil Scientist
Agriculture and Agri-Food Canada
Ottawa, Canada*

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quickly. How do they suddenly produce this? They must be drawing on stored material and energy, but where are these stores?

*Howard Bobry
Nehalem, Oregon, US*

RUNNING BATTLE

Runners have long debated the difference between training on a treadmill and training on solid ground. "Belt turnover" is commonly cited as a factor that helps to move your foot backwards and thereby makes running on a treadmill easier than running on the road. At constant velocity, is this a real effect? If so, wouldn't it be felt on any "moving" surface you walk on, such as a train or plane – or even Earth?

*Dan Bruestle
North York, Ontario, Canada*

IN NEED OF A FIX

Why do the automated bus stop announcements (presumably based on GPS) on some London bus routes get their location quite wrong? I notice that buses passing Tottenham Court Road station, for example, sometimes announce that they are at the "Petersham, Fox and Duck" pub. I'm guessing this probably has nothing to do with the ongoing excavation there as part of the Crossrail transport project, which has meant buses in the vicinity being subjected to some diversions.

*Alan Hunt
London, UK*

This week's questions

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