

New Scientist

WEEKLY October 12–18, 2019

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THE BIG BANG**

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But where are they?

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THE UNDERWORLD

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The startling things you reveal to other people
without even saying a word



TURTLES THAT DON'T BREATHE

And other animals with survival superpowers

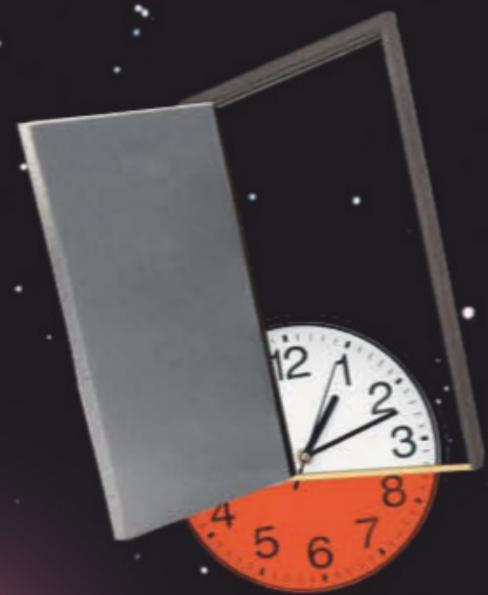
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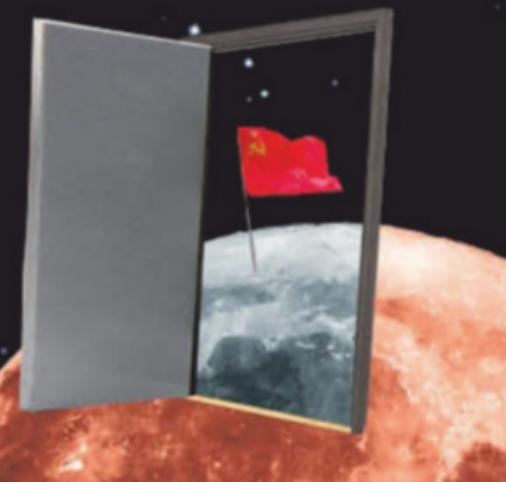


**WHAT IF TIME STARTED
FLOWING BACKWARDS?**



**WHAT
IF THE
RUSSIANS
GOT TO
THE MOON
FIRST?**

**WHAT IF DINOSAURS
STILL RULED THE EARTH?**



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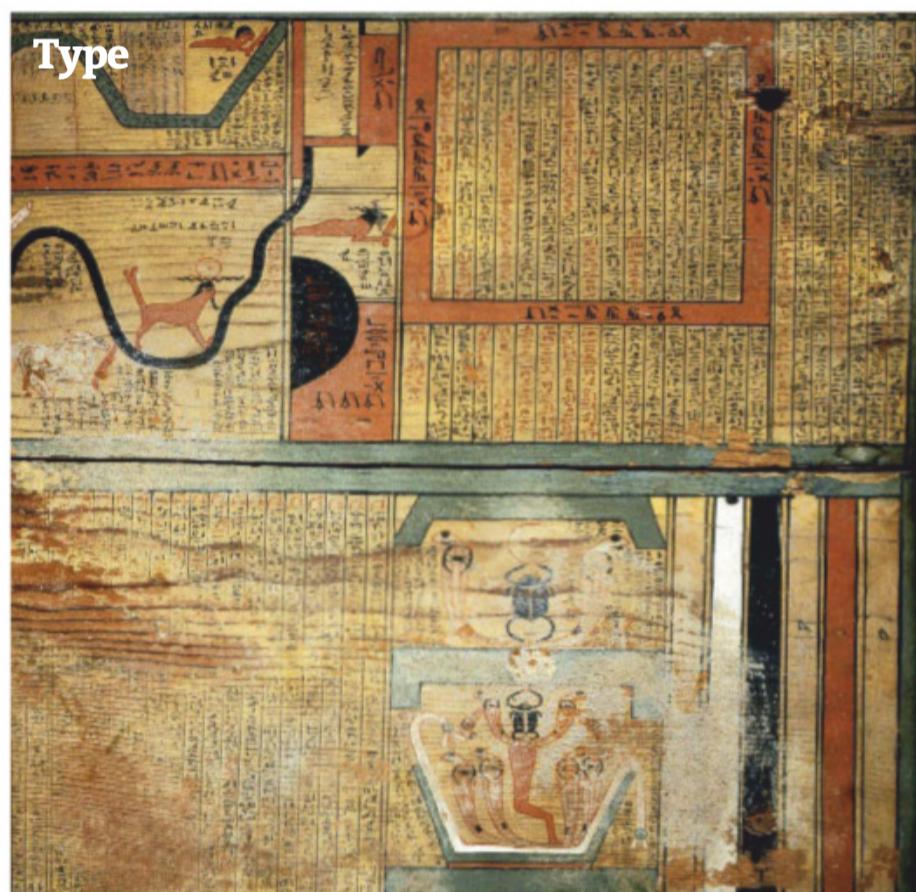
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The minds of others

Are experiments on how animals think justified?

AS A primate with sophisticated cognitive abilities, you may remember a recent story we ran about experiments on macaques. It showed that these monkeys can understand the logical process of transitive inference. In other words, if a macaque learns that A comes before B, and B comes before C, it can then deduce that A must come before C.

To get the animals to take part in the tests, they were put on what the paper in *Science Advances* called a “fluid-restricted” diet. Water became a reward for doing the puzzles. The study’s findings are interesting – but are they interesting enough to justify the method?

The debate about the merits of experiments on animals usually centres on those done for medical purposes. Many people are willing to accept drug testing on rodents or studies involving



Experiments have shown that macaques can grasp a certain type of logic

As our Insight on page 18 explores, there are still various reasons to carry out this sort of work. One is that it may help us look after animals in our care better, including those in laboratories. Experiments have shown, for example, that rats don’t want bigger cages, they want ones with places to hide.

Another argument for this research is the pursuit of knowledge for its own sake. It is now scientific dogma that open-ended questions with no immediate application should be pursued, partly because they could lead to discoveries that one day prove vitally useful.

Yet as experiments increasingly reveal similarities between the human experience and that of many animals, this principle may become harder for some people to support. ■

primates if such efforts are in pursuit of new treatments for our most unpleasant diseases. Last year, a poll suggested that two-thirds of people in the UK accept animal experiments being carried out for the purposes of medical or scientific research provided there is no alternative.

But when investigating questions such as “do monkeys have logic” or “can we implant memories in birds’ brains” (see page 17) there clearly is an alternative – not asking them at all.

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JONATHAN NACKSTRAND/GETTY

The Nobel prize goes to...

Discoveries of an alien world orbiting a sun-like star and how cells detect oxygen are hailed. **Jessica Hamzelou** and **Donna Lu** report

NOBEL prizes in medicine and in physics were announced this week for advances in our understanding of how cells sense oxygen and the first discovery of an exoplanet around a sun-like star.

On Monday, the Nobel prize in physiology or medicine was announced (pictured). It went to William Kaelin at Harvard, Gregg Semenza at Johns Hopkins, Maryland, and Peter Ratcliffe at the University of Oxford.

Semenza identified a protein that appears in the blood when oxygen levels are low, and Ratcliffe and Kaelin identified a protein that destroys it when oxygen levels are high. Together, these proteins form a molecular switch that controls how cells respond to

varying levels of oxygen. This not only helps explain how the body responds to change, but has implications for treating a range of disorders, from anaemia to heart attack and cancer.

On Tuesday, the physics prize honoured two advances. James Peebles at Princeton University and the astronomers Michel Mayor at the University of Geneva in Switzerland and Didier Queloz at Geneva and the University of Cambridge were the recipients.

Peebles's research formed the basis for our understanding of the universe's history after the big

bang. He made predictions about the shape of the universe and the matter and energy it contains, later validated by experiments.

In October 1995, Mayor and Queloz were the first to discover a planet orbiting a sun-like star outside our system: the exoplanet 51 Pegasi b. This kick-started a revolution: since then more than 4000 exoplanets have been discovered, including worlds with the potential to host life.

Several more Nobel prizes, including for chemistry, were due to be announced as *New Scientist* went to print. ■

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Environment

Vote hinders action on airline emissions

THE UN agency tasked with limiting aviation emissions has effectively voted to block meaningful action. Although the vote has no legal force itself, it could make it harder to cap emissions from flights.

Few effective measures are in place to stop aviation emissions rising. Jet fuel on international flights isn't taxed. And there are doubts over the international CORSIA scheme, which requires nations to offset growth in aviation emissions after 2020 – for instance, by paying for tree planting. This is widely seen as ineffective, as we can't be sure the trees wouldn't have been planted anyway or will still be growing and absorbing CO₂ for decades.

Delegates at the UN's International Civil Aviation Organization discussed a range of issues related to reducing emissions. They also voted that CORSIA "should be the only market-based measure applied to international flights". That threatens other measures, such as a scheme that requires airlines to buy carbon allowances to cover emissions of flights within the European Union.

The UN vote won't immediately affect the EU scheme. But it could lead to airlines suing the EU over their inclusion in it, says Andrew Murphy at the campaign group Transport & Environment. If the EU lost, it would be a green light for airline business as usual, he says. ■ Michael Le Page

We can visit comet from alien star

As comet Borisov nears Earth, we are learning a lot about the second-ever interstellar object seen – including how to travel to it, says **Jonathan O'Callaghan**

RUMOURS began to circulate in early September that an object from another solar system had been spotted. Now its status as only the second interstellar visitor ever seen has been confirmed.

With this, the race is on to find out as much about the comet as we can. We know it would be possible to send a spacecraft to visit – and there is plenty more excitement on the way.

The object, officially known as 2I/Borisov, was first spotted by Gennady Borisov, an astronomer from Crimea, using a homemade 0.65-metre telescope. At first, its trajectory left some doubt as to whether it really came from outside the solar system.

"It wasn't quite as obvious as being hyperbolic as the first one was, so there was some caution," says Robert Weryk at

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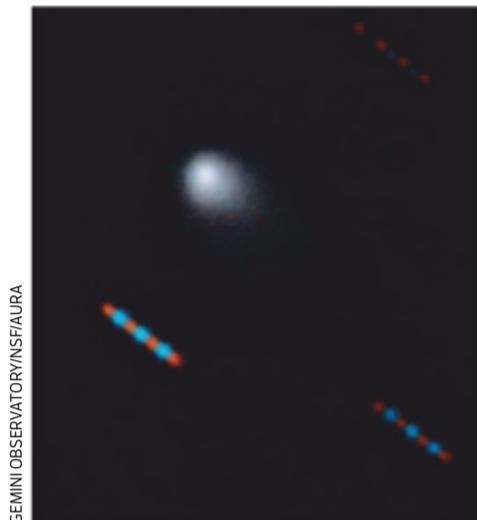
Best estimate of comet Borisov's minimum width, in metres

the University of Hawaii at Manoa, who discovered the first interstellar object, the asteroid 'Oumuamua, in 2017. Calculations from NASA's solar system dynamics group have now confirmed that comet Borisov is from outside the solar system.

Borisov himself has taken a back seat since he found the object. "The last four weeks have been just crazy," he says. "When the big telescopes came in, I took a break."

With the comet set to reach its closest point to us – at twice the Earth-sun distance – on 7 December, other astronomers are gearing up for a major observing campaign.

The William Herschel Telescope has found that comet Borisov emits cyanide



GEMINI OBSERVATORY/NSF/AURA

Unlike 'Oumuamua, comet Borisov was spotted approaching the solar system rather than leaving it. This gives us more time to study it – probably about a year. Another difference is that the comet appears to be spewing dust and gas into space.

Astronomers led by Alan Fitzsimmons at Queen's University Belfast, UK, looked at the trail of gas using the William Herschel Telescope on the Spanish island of La Palma. This showed that it contained cyanide gas (arxiv.org/abs/1909.12144). We see this in comets from our solar system, suggesting that Borisov may have been formed in a similar way. This matters because astronomers want to know more

This composite image shows Borisov streaking towards us

about whether our system is relatively typical or unique.

Over the coming weeks, the comet should continue melting as it nears the sun, releasing more of its inner substances for us to observe. One important question we should be able to answer is about the comet's balance of water and carbon monoxide. "Usually in typical comets of the solar system, there is about 75 per cent water, nearly 20 per cent carbon monoxide and the rest is mostly carbon dioxide," says Emmanuel Jehin at the University of Liège in Belgium. He plans to use the TRAPPIST telescopes in Chile and Morocco to study whether that is true of Borisov.

We should soon also know the comet's shape. 'Oumuamua had an unusual shape – like that of a long, thin cigar – and was rapidly tumbling end over end through space. Several telescopes, including the Hubble Space Telescope, will be trained on Borisov in the next few weeks so we can work out its size and deduce its shape by observing how it reflects sunlight. Our

best current estimate is that it is between 700 metres and 3 kilometres wide.

Attempts have also been made to work out where the comet came from. By tracing back its trajectory, Piotr Dybczyński at the Adam Mickiewicz University in Poland and his colleagues suggest that it may have come from a pair of red dwarfs called Kruger 60 that lie 13 light years from us, although Dybczyński is far from certain about it. "Probably we will never know for sure," he says. However, measuring the isotopes of carbon in the comet could tell us which region of the galaxy it came from.

Slingshot manoeuvre

Andreas Hein at the Initiative for Interstellar Studies in the UK and his colleagues looked at how a spacecraft could be dispatched to Borisov. We have already sent craft to comets, so it isn't unthinkable.

Getting to the object would involve slingshotting a craft around the sun and possibly Jupiter. This can only be done when the planets are aligned a certain way. Hein found that the optimal launch window would have been July 2018. But he also found that we could launch in 2030 and get to Borisov by 2045 using a large rocket such as NASA's upcoming Space Launch System (arxiv.org/abs/1909.06348). "It's possible from a technical point of view," says Hein.

Michele Bannister at Queen's University Belfast says astronomers are working to get as much information as possible before the comet waves goodbye. "We have most of the major facilities sorted out that will be able to observe it," she says.

We are about to get a better glimpse into an alien solar system than ever before. ■



NIK SZYMANEK

Longevity

The key to a long life may be genes that protect against stress

Jessica Hamzelou

GREY whales are one of the longest-lived mammals in existence. The secret to their long lives? A resilience to stress, according to the first genetic sequencing of the animals.

The genes for stress resistance are also shared by other long-lived animals, like naked mole rats, which can outlive mice by 25 years, give or take, and humans. It is this stress resistance that protects most long-lived animals from cancer, says Dmitri Toren, now at the Romanian Academy in Bucharest.

Toren and his colleagues are investigating ageing and why some animals are able to live long lives. The team decided to study the grey whale because it can live into its 70s, and is considered to be the eighth longest-lived mammal.

In order to study cells taken from grey whales, a member of the team had to travel to Chukotka, an autonomous area of Russia, where annual whale hunts are regulated by the International Whaling Commission. "It was challenging to get a biopsy," says Toren. "He had to fly there and wait for half a year."

Once the team had liver and

kidney tissue from two grey whales, the researchers looked at the genes that were switched on in each sample. They sorted these "expressed" genes into categories based on their functions, and focused on those that had previously been linked to ageing. These included those that code for proteins that affect how well the

Grey whales can live long lives, surviving well into their 70s

body can get rid of faulty proteins and maintain and repair DNA, as well as others involved in the workings of the immune system.

Toren and his colleagues then compared the levels of gene expression to that of two other long-lived whales – the bowhead and minke – as well as the relatively short-lived mouse, the cow and the relatively long-lived human and naked mole rat. All of the animals were young adults.

It is difficult to compare

individual genes across species, so instead, the team ranked the expression of genes based on their functions for each species.

When they compared these rankings between species, they found that long-lived animals had higher levels of gene expression associated with the maintenance of DNA and immune cells, and the flushing out of damaged proteins. This may explain why whales are thought to be protected from cancer (*bioRxiv*, doi.org/dcfr).

"That stress resilience is important is a very plausible hypothesis," says Lorna Harries at the University of Exeter, UK. "We know that your molecular stress response tends to decline with age... if you can maintain your stress responses, the chances are you're going to age better."

Harries points out that the researchers may have missed some differences between the animal species, and that, given the team were only able to study two grey whales, more research is needed to confirm the findings. ■
For more animals that combat ageing see page 34



CLAUDIO CONTRERAS/NATURE PICTURE LIBRARY

Computing

Supercomputer simulates key brain centre in real time

A BRAIN-inspired computer can now simulate part of the sensory cortex in real time, using tens of thousands of virtual neurons. It is the first time such a complex simulation has run this fast and could be used to help build better brains for robots.

The SpiNNaker supercomputer at the University of Manchester, UK, features 57,000 specialised chips with a total of 1 million processing units, known as cores. It is designed

to run programs that simulate how biological neurons behave.

The computer shuttles information around in a similar way to the brain, says Oliver Rhodes, who led the research. Standard supercomputers send big blocks of data at set times, but SpiNNaker's cores can transmit small blocks to hundreds of other cores simultaneously whenever required.

Now Rhodes's team has shown that SpiNNaker can simulate the behaviour of 77,000 neurons in the sensory cortex, equivalent to about 1 square millimetre's worth, as fast as it happens in the

brain and for up to 12 hours (arxiv.org/abs/1909.08665).

"We can run this at the same speed as biology, which is quite a big achievement," he says.

This is a stepping stone to more complex models of things like sensory processing, says Rhodes.

The research is a big step towards large-scale simulations of brain processes, says Brad Aimone at Sandia National Laboratories in

New Mexico. Researchers will have to run hundreds of simulations to confirm results, so making them fast is crucial. "Now the burden is back on to the neuroscientists to actually build models that can scale to this level," he says.

Markus Diesmann at the Jülich Research Centre in Germany, who designed the model used by SpiNNaker, says real-time operation means the chips could also be useful in robotics. "You can really transfer principles and algorithms that you've uncovered in nature into this artificial brain living in a robot." ■

Edd Gent

"SpiNNaker can simulate the behaviour of 77,000 neurons in the sensory cortex"

Space

Life could drift in the clouds of brown dwarfs

Chelsea Whyte

THE search for life beyond Earth has an unlikely new target: the atmospheres of brown dwarfs.

Brown dwarfs are gaseous objects that are too big to be planets but too small to be stars. They aren't massive enough to sustain the type of nuclear fusion that powers stars, but they do produce a lot of heat early in their lives. Once their fuel is gone, they begin to cool.

"One reason we're interested in brown dwarfs is that they're much bigger than Earth, and the volume of the atmosphere is much bigger," says Manasvi Lingam at Harvard University. They also cool very gradually, he says, which means they can sustain temperatures suitable for life for a long period.

He and his Harvard colleague Avi Loeb calculated that the habitable volume of the atmosphere of a typical brown dwarf—that is, all those places that remain at temperatures and pressures conducive to life—may exceed the habitable volume of Earth-like planets by a factor of 100 (*The Astrophysical Journal*, doi.org/dcdg).

This includes zones where the temperatures are between -23°C and 76°C. In such zones, where the atmosphere allows water clouds to form, Lingam says the pressure would be about 0.1 to 1 bar. The high end of that range is roughly the pressure of Earth's atmosphere at sea level.

We know bacteria exist high in Earth's atmosphere, where they can seed the formation of cloud droplets, but that doesn't necessarily mean the atmosphere is a good biosphere. Paul Byrne at North Carolina

State University says these bacteria come from the ground or the lowest reaches of the atmosphere. "When they're up there, the bacteria don't do much. They're in a dormant state or they're dead," he says. It is hard for life to persist there principally because of the lack of water vapour and exposure to damaging ultraviolet rays.

"There could be as many habitable worlds orbiting brown dwarfs as there are orbiting stars"

Rory Barnes at the University of Washington is sceptical about finding life in brown dwarf atmospheres. "I think the prospects for life to originate and survive in a fairly gaseous environment is pretty close to nil," he says. "A freak event could occur where life is able to hop from raindrop to raindrop, but we have to ask ourselves, what is the likelihood of seeing that?"

Lingam also says the key chemical ingredients for life as we know it can be found in brown dwarfs. This includes carbon, hydrogen, oxygen, nitrogen and more. But Abel

Méndez at the University of Puerto Rico in Arecibo says there may be too little of these: "You wouldn't have the concentrations needed to maintain a full cycle of life."

Aside from looking at whether life could crop up on brown dwarfs, we know some of these objects have planets. It may be more likely that life could exist on these. Lingam and his team have also investigated this.

They found that such worlds are unlikely to host conditions conducive to life if the brown dwarf they circle is less than 30 times the mass of Jupiter (arxiv.org/abs/1909.08791). Despite this, they calculate there may be as many planets that could host life orbiting brown dwarfs as there are potentially habitable worlds orbiting stars. So these environments could still be a target for finding an exoplanet with signs of life.

"This is far more likely," says Méndez. "Terrestrial planets around brown dwarfs have a more stable surface. At least for maintaining microbial life, it's more stable than the atmosphere of any planet." ■



MARK GARLICK/SCIENCE PHOTO LIBRARY

A depiction of a brown dwarf, in this case orbiting a star

Oncology

Anti-evolution drug may help treat resistant cancers

Michael Le Page

MANY cancer treatments work well in the beginning, only to fail later as tumours evolve resistance. Now a new generation of therapies is being developed to prevent this.

One, called BOS172722, seems to restore the effectiveness of paclitaxel, the main chemotherapy that is used to treat so-called triple-negative breast cancer, according to recent trials in animals.

Like other chemotherapies, paclitaxel targets tumours by homing in on cancer's rapid rate of cell division. It interferes with the process of cell division, resulting in chromosomal abnormalities that often kill cancer cells. But the tumour cells that do survive can end up becoming resistant, meaning the drug no longer works.

"Resistance is pure Darwinian evolution," says Spiros Linardopoulos at the Institute of Cancer Research in the UK. He and his team have been trying to find new drugs, or new ways of using drugs, that prevent resistance.

They have tested BOS172722, which also interferes with cell division, but in a different way to paclitaxel. It binds to and blocks a protein called MPS1 that plays a key role in division. The combination of the two drugs together causes such severe chromosomal abnormalities that none of the cancer cells survive. And if no cells survive, there can be no resistance (*Molecular Cancer Therapeutics*, doi.org/dcdf).

There are some side effects, and the initial aim of an ongoing human trial is to establish the maximum safe dose. But the findings are potential good news, as at the moment there is no effective treatment option for triple-negative breast cancer when paclitaxel fails.

"We urgently need to find new options to stop more women dying," said Delyth Morgan of charity Breast Cancer Now in a statement. The group helped fund the work. ■

Plant genetics

Natural transgenic plants

Bacteria may have modified the genomes of thousands of plants

Michael Le Page

ABOUT one in 20 flowering plants are naturally transgenic, carrying bacterial DNA within their genomes. The added genes can make them produce unusual chemicals, and the species they have been found in include tea, bananas and peanuts.

Other plants that carry bacterial genes include sweet potatoes, yams, American cranberries, Surinam cherries and the hops used to flavour beer. What effect the added genes have on the plants that contain them is still far from clear. "We are only at the start of this," says Léon Otten at the Institute of Molecular Biology of Plants in Strasbourg, France.

The culprit is a microbe called *Agrobacterium* that infects plants. When this bacterium gets inside a plant cell, it inserts a "cassette" of DNA containing hundreds of genes into the genome of the cell. These genes include ones that encode hormones that make plants grow tumour-like lumps called crown gall (pictured, below right) and enzymes that make chemicals the bacteria feed on.

Agrobacterium is the main tool used to create the genetically engineered crops grown globally. Biologists swap out the microbe's cassette of genes for whatever DNA they want the bacterium to splice in for them. "*Agrobacterium* is nature's own genetic engineer," Mary-Dell Chilton, once wrote. In 1980, she was the first to use it to modify plants.

In the wild, though, it was thought that the genes added by *Agrobacterium* hardly ever got passed on to the next generation. For this to happen, an infected cell has to grow into an entire new plant, says Otten. That plant then has to flower and produce offspring, and those offspring have to thrive despite harbouring alien genes meant to hijack them.



IMAGINE CHINA/SHUTTERSTOCK

Until now, the only known examples of *Agrobacterium* DNA persisting in a plant genome were in tobacco and the sweet potato. Otten and Tatiana Matveeva of St Petersburg State University in Russia have now found dozens more by analysing the genomes of hundreds of plants (*Plant Molecular Biology*, doi.org/dcdn).

5%
of flowering plants may carry
DNA inserted by bacteria

Their results suggest that about 5 per cent of the hundreds of thousands of species of flowering plants carry *Agrobacterium* DNA. "They did a good job," says Jan Kreuze at the International Potato Center in Lima, Peru, who found in 2015 that sweet potatoes are transgenic. "I think it's true."

This has only just been discovered because no one had looked before, says Otten. Of the *Agrobacterium* genes identified by Otten and Matveeva, most contained mutations that should disable them, but some are still likely to be active.

Plants that are transgenic in this way don't count as genetically modified under European Union regulations, which specifically exclude organisms modified by "natural" processes.

The discovery is good news for Henrik Lütken at the University of Copenhagen in Denmark, who plans to test the limits of this definition.

He is creating new plant varieties using natural strains of *Agrobacterium*. For instance, he has created a compact variety of a house plant called *Kalanchoe blossfeldiana*, which is now ready for commercial sale. He thinks these plants shouldn't count as GM and the latest findings will bolster his case.

Because the genes inserted into plants by *Agrobacterium* can produce big changes, Otten thinks



A tree with
a crown gall
caused by
infection with
Agrobacterium

**Some tea plants have
been found to contain
genes from a bacterium**

this process could drive the evolution of new plant species. His research suggests that tobacco plants have been modified by *Agrobacterium* several times in the past few million years, and these events seem to have coincided with the emergence of new species.

Infection by *Agrobacterium* isn't the only way that transgenic organisms can be created naturally. Viruses often move genes between species. For instance, monarch butterflies have acquired genes from wasps in this way, and gonorrhoea bacteria have some human DNA inside them.

It has also been discovered that the horticultural process of grafting different plants together can lead to the exchange of genes, meaning humans have inadvertently been creating transgenic plants for millennia. From genome studies, we can see that gene swapping has been going on since the dawn of life. ■

Zoology

Hobbyists are saving rare species of fish from extinction

Michael Le Page

DEDICATED aquarium enthusiasts are keeping alive dozens of fish species now believed to be extinct in the wild and helping to preserve hundreds more.

The CARES Fish Preservation Program, founded by enthusiast Claudia Dickinson in 2004, encourages fish-keepers to keep, breed and exchange endangered fish to help preserve viable populations. It has compiled a priority list of nearly 600 freshwater fish, which has now been assessed and compared with official lists of endangered species. Jose Valdez at Aarhus University in Denmark and Kapil Mandrekar at the State University of New York found 80 of the species on the CARES list have yet to be formally described by scientists (*Fishes*, doi.org/dcgp).



KAPIL MANDREKAR
The blue tail goodeid is critically endangered, but kept going by aquarium enthusiasts

There are also 30 species CARES says are extinct in the wild. Members of the programme are keeping populations of these alive. Many of the species on the CARES list have no commercial value as pets, and aren't charismatic enough for many conservation organisations, says Mandrekar. If they weren't on the list, no one would be doing anything to preserve them.

Valdez says many of the hobbyists dedicate their time to certain fish and even go on field trips to study them in the wild. "Since they are passionate and are directly involved with these fish, they are more knowledgeable than scientists," says Valdez. ■

Egyptology

Guide to the underworld is earliest illustrated book

Colin Barras



ARCHAEOLOGISTS have found remains of the oldest known copy of the Book of Two Ways, a guide to the Ancient Egyptian underworld.

About a century ago, Egyptologists began finding annotated drawings inside 4000-year-old wooden coffins buried in a necropolis called Dayr al-Barshā. Among the drawings was a panel on which there were two long, meandering lines (pictured above) that seemed to be described as roads in the surrounding hieroglyphic text. Elsewhere, the text appeared to offer instructions for travelling through the underworld towards the resting place of the god Osiris – a journey that, if successful, would secure a happy afterlife.

This suggested to researchers that the illustrations were a map of the underworld, with the meandering lines representing two paths the dead could take on their travels.

Only a few dozen copies of the book survive today. Now, one more has been added by Gina Criscenzo-Laycock at the University of Liverpool, UK, and Hanne Creelman and Harco Willems at the KU Leuven in

Belgium. In 2012, they led a team that excavated a burial shaft at Dayr al-Barshā that had previously been ignored. At the very bottom, they found the remains of a coffin covered in hieroglyphs. "To my amazement it was a Book of Two Ways," says Willems.

From nearby inscriptions, it was possible to date the coffin to the time of Pharaoh Mentuhotep II, who reigned until 2010 BC (*The Journal of Egyptian Archaeology*, doi.org/db8p). This suggests this copy of the book is about 40 years older than any other we know of, says Willems.

Other archaeologists agree with this conclusion, although Foy Scalf at the University of Chicago says complete

4000

The age in years of the decorated coffins

confidence in the dating will be possible only after the team publishes its final excavation report.

Burkhard Backes at the University of Tübingen in Germany says there are a few earlier, simpler visual

A Book of Two Ways painted in a coffin from 1800 BC

depictions of the Egyptian underworld, but the Book of Two Ways appears to be far more elaborate. Scalf says it could be described as the "first illustrated 'book' in history".

This means that the new discovery slightly extends our record of such works of literature, and also suggests the Ancient Egyptians began producing detailed maps to help the dead reach the afterlife earlier than we thought.

Or, at least, it might do. While most archaeologists still consider the Book of Two Ways to be a visual guide to the underworld, a few – including Willems – have their doubts.

"It definitely looks like a map," he says, but he adds that it is very difficult to know that the Ancient Egyptians intended it to be seen in those terms. While the arrangement of lines, monstrous figures, doors and ships looks map-like to us, it might not have done to them.

Willems speculates that the Book of Two Ways was initially developed by the cult of Osiris, the ruler of the underworld, as a set of rituals to bring him back to life. These rituals might later have been painted on coffins in the belief they could help restore an occupant to life.

Whatever its purpose, the Book of Two Ways shows the Ancient Egyptians were fascinated by the underworld. It is also clear that both men and women could hope to obtain a favourable afterlife: the newly discovered copy of the Book of Two Ways was in the coffin of a high-ranking woman called Ankh. ■

New Scientist Discovery Tours

USA

Cruise Hawaii with Richard Dawkins

Accompany the evolutionary biologist and highly-regarded author Richard Dawkins on this cruise around the fascinating island of Hawaii

From the Volcanic National Park to abundant rare wildlife and stunning landscapes, this is a truly unique expedition. Discover Hawaii's unique culture and history whilst cruising aboard the Safari Explorer, a rugged expedition yacht small enough to explore where larger ships can't. Then in the evenings, thought provoking seminars from Richard.

DAY 1: ARRIVE BIG ISLAND

Check-in to the Marriott King Kamehameha's Kona Beach Hotel in Kailua-Kona for a day at leisure to visit the Hulihee Palace and Mokuauika Church.

DAY 2: VOLCANOES AND DEPART TO SEA

Explore Hawaii Volcanoes National Park then board your yacht, the Safari Explorer, a nimble 36-passenger yacht with a 2:1 crew to guest ratio.

DAY 3: BIG ISLAND

Throughout the cruise, Professor Richard Dawkins will be talking about the evolutionary principles that volcanic island chains illustrate. The evolutionary story in Hawaii is similar to the Galapagos – both young, volcanic archipelagos.

Snorkel in the protected marine reserve and reefs of Pawai and a thrilling night-time adventure swimming with giant manta rays.

DAY 4: HONOKOHAU NATIONAL PARK

Kaloko-Honokohau is the site of an ancient Hawaiian settlement, comprising of historic temples, fishponds and petroglyphs. The park is also renowned for its walking trails, geological features and opportunity to observe turtles.

DAY 5: MAUI

Explore one of the most unique ocean reef systems in Hawaii. Snorkel in this known sea turtle habitat among hundred-year-old coral gardens and sail through the Humpback Whale National Marine Sanctuary, spotting humpback whales, spinner dolphins, Hawaiian monk seals and reef fish.

DAY 6: LANAI

Wake up to views of the tranquil island of Lanai and prepare for a full day of water and land-based excursions. Hike to Puu Pehe, an

ocean rock formation steeped in folklore that rises majestically out of the sea and learn about Lanai's historical plantation days.

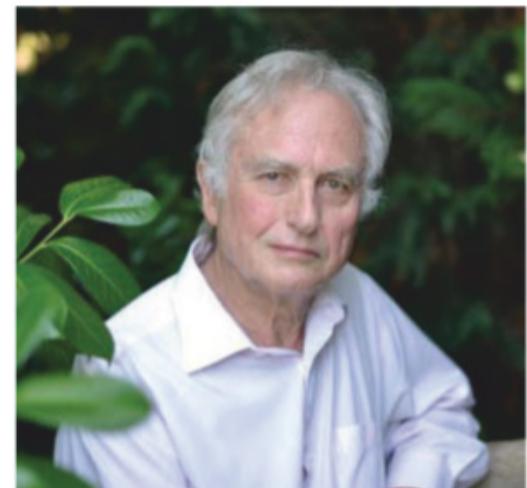
DAY 7: CAPTAINS CHOICE EXPLORATION DAY

The captain will purposefully navigate to a site that uncovers more of what the Hawaiian Islands have to offer based on local conditions and current wildlife sightings

DAY 8: MOLOKAI

Spend the day on Molokai learning about the traditions of the Hawaiian people. In the evening, enjoy one of Hawaii's cultural treasures, a pa'ina (feast) held at the Molokai Museum.

DAY 9: DISEMBARK FOR YOUR HOMEWARD JOURNEY



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Psychology

The power of common sense

It is easy to guess whether a psychology study will stand up to further testing

Leo Benedictus

AFTER an embarrassing decade in which the results of many classic psychology and social science studies couldn't be repeated, now there seems to be a simple solution: common sense.

The “replication crisis” has seen many eye-catching studies fail to be verified. We now know, for example, that children who can resist marshmallows and hold out for a bigger reward later don’t reliably become successful adults, despite what the classic Stanford marshmallow experiment found.

To see if we should have been able to guess as much, Alexandra Sarafoglu at the University of Amsterdam, the Netherlands, and her colleagues recruited 233 volunteers. About half of them were first-year psychology students, but none were experts in the field. After reading a quick explanation of what replicating an experiment means, participants were shown 27 short descriptions of well-known findings from social science and psychology.

Of these, 14 had recently been replicated successfully, including a 2008 study that found that

students think they are more likely to be questioned in class if they arrive unprepared. Attempts to replicate the other 13 studies hadn’t worked, including a 2013 study that suggested people are better at recognising emotions after reading some literary fiction.

After reading about each study, participants were asked to predict whether repeating it was likely to validate its findings. When shown

The results of the famous “marshmallow test” haven’t been replicated

just the description, participants guessed correctly 58 per cent of the time. When also shown a simple statistical measure of the strength of the study’s evidence, this rose to 67 per cent.

Pooling these predictions made the results even clearer. When most of the group confidently guessed the same, their prediction was almost always right. Among the 10 most confident predictions that a study wouldn’t replicate and the 10 most confident that it would, the group was wrong just twice.

The finding implies that scientists shouldn’t let surprising findings override their common sense. “We are in this crisis for a reason,” Sarafoglu says. “There is a strong incentive in science in

“We are in this crisis for a reason. There is a strong incentive to publish sexy findings”

general to publish sexy findings. So implicitly, people get pushed towards finding effects that are counter-intuitive.”

“I find it very interesting that laypeople are pretty successful in predicting replication outcomes,” says Anna Dreber Almenberg at the Stockholm School of Economics in Sweden.

Sarafoglu accepts that the picture might change if her study were repeated with a different selection of studies, or with differently written descriptions, but she predicts that people will be able to replicate this research. However, the team hasn’t asked a group of laypeople whether they agree. What do you reckon? ■



PETER CADE/GETTY

Microbiome

A few days in hospital changes your gut bacteria

HARMFUL bacteria have been found to rapidly colonise the guts of people treated for several days in an intensive care unit. Heavy use of broad-spectrum antibiotics, feeding people through a tube and using a ventilator could all contribute to changes in the microbiome, says the team that carried out the study.

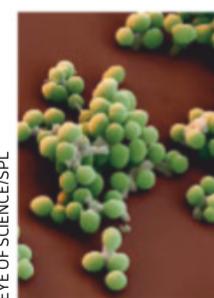
“It’s quite disconcerting,” says Mark Pallen at the Quadram Institute, UK, who led the research.

“I suspected that something like this was going on, but I was quite taken aback at the scale of the changes.”

Pallen and his colleagues tracked 24 people admitted for trauma, heart attacks, cancer and other emergencies to Queen Elizabeth Hospital Birmingham, UK. Many were unconscious or sedated. After getting permission from family members, the scientists took stool samples from these individuals.

The team then sequenced DNA from the samples to identify which microbes were present – and how that changed during treatment.

Two-thirds of the patients



EYE OF SCIENCE/SPL
Enterococcus faecium can spread from the gut to other parts of the body

showed a marked reduction in microbial diversity at some stage. The biggest changes were associated with intravenous use of the antibiotic meropenem.

Many of the patients’ guts became dominated by *Enterococcus faecium*, a common pathogen

that can be fatal if it reaches the bloodstream (*Microbial Genomics*, doi.org/dcc9).

It is a small number of people to draw conclusions from, but the results align with other studies, says Joost Wiersinga at the Academic Medical Centre in Amsterdam, the Netherlands. While the priority in intensive care is to save lives, Wiersinga says medics could do more to minimise disruption to gut bacteria. “If you need to give antibiotics then give them. But think about which antibiotic, for how long and if you can stop earlier.” ■

David Adam



New Scientist Discovery Tours

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Darwin's Galapagos with Jo Ruxton

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A paradise for natural history, animal and geology lovers, we have curated a distinctive trip which includes the UNESCO World Cultural Heritage Site of Quito followed by 8 days exploring at sea and exclusive behind the scenes access at the Galapagos Science Centre. The spacious and stylish yacht Natural Paradise is small enough to get into bays that larger expedition ships cannot go near, so you get to experience Galapagos as Darwin did.

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- » Explore eight varied islands including Isabela, Espanola and Fernandina
- » Exclusive behind the scenes access at the Galapagos Science Centre
- » Jo Ruxton will give talks on board covering her marine conservation as well as accompanying the daily excursions
- » Plus local naturalist guides will accompany the voyage and give seminars at sea and on land
- » Lots of opportunities to visit the many islands by panga boat and snorkel in these amazing waters
- » Observe a wide variety of wildlife including reef sharks, nazca, blue-footed boobies, sea lions, Galapagos penguins, seahorses, sea turtles, and the strange yet fascinating mola.
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The Natural Paradise yacht only accommodates 15 people, so enquire early to avoid missing out.



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Environment

Giant boom collects plastic

Device for cleaning up the oceans begins its work

Adam Vaughan

A PIONEERING effort to collect plastic rubbish from the seas has caught floating debris for the first time.

Boyan Slat, founder of The Ocean Cleanup, said that after a failed effort last year, his giant V-shaped boom system has started removing waste. "We now have a self-contained system in the Great Pacific Garbage Patch that is using the natural forces of the ocean to passively catch and concentrate plastics," he told a press conference.

Slat says the system caught all sizes of plastic, from microplastics to ghost nets for fishing, as well as other rubbish. "Anyone missing a wheel?" he joked on Twitter.

However, animals have also been captured, including by-the-wind-sailors and blue-buttons, relatives of jellyfish that are eaten by birds, fish and turtles. The Ocean Cleanup says it isn't happy about this but it expects the impact to be minimal. ■



THE OCEAN CLEANUP

Medical technology

Mind-controlled suit helps man walk again

A MAN who is almost completely paralysed from the neck down was able to walk using an exoskeleton suit he controls with his mind. It can't yet let him walk independently – the suit hangs from an overhead harness to stop him falling – but the advance is a step towards this goal.

Several groups are working on ways to let people with spinal cord injuries regain control over their bodies by reading their thoughts. So far, the most common method has been to insert ultra-thin electrodes into the brain.

But this entails wires entering the skull, which could let in an infection. The functioning of the electrodes also gradually

deteriorates over the following months as they get covered with cells that form a kind of scar tissue.

To get round these problems, Alim Louis Benabid at the University of Grenoble Alpes in France and his colleagues replaced two 5-centimetre discs of skull, one on either side of his head, with brain sensors that have electrodes on their underside.

The researchers started by asking the man, known as Thibault, to have several brain scans so they could map which areas became active when he thought about walking or moving his arms.

After inserting the sensors, Thibault practised using them,

first by trying to move an avatar shaped like the exoskeleton on a computer. After this, he was strapped into the suit and he learned to make it start walking forwards, while supported from overhead. "I felt like the first man on the moon," says Thibault.

He also learned to use the suit's arms for increasingly complex tasks, such as rotating his wrists, reaching out to targets and using both hands simultaneously (*The Lancet Neurology*, doi.org/dcbh). The team's next goal is to make the

"Thibault also learned to use the suit's arms for tasks like operating both hands simultaneously"

exoskeleton self-balancing. This will require faster computation speed, says Benabid.

However, not all of the project has gone smoothly. Before Thibault, another person was given the implants, but they stopped working within a few seconds of being turned on, due to a technical fault. This has now been fixed and three more people are set to test the system.

It is highly promising that Thibault's implants are still working after 27 months, says Ravi Vaidyanathan of Imperial College London. "Obviously it has a long way to go before it can be generally used, but this is a pivotal step." ■

Clare Wilson

Astronomy

Mystery space signals could come from starquakes

Chelsea Whyte

STRANGE blasts of radiation from space called fast radio bursts (FRBs) may sometimes be sparked when two stars collide and then vibrate in reverberating aftershocks.

The origins of FRBs have puzzled astronomers for years. Most of the nearly 100 FRBs we have detected consist of a single burst, but a few of them flash repeatedly, which makes it easier to find where they are coming from and determine what might be causing them.

One such source, known as FRB 171019, was first detected in 2017, when a bright burst was seen with the Australian Square Kilometre Array Pathfinder. It was followed by three more flashes over a year, some of which were nearly 600 times fainter than the first.

Jincheng Jiang at Peking University in China and his colleagues have now created a model to account for the successively dimmer bursts seen from FRB 171019. They suggest that the first bright burst may have been created when two neutron stars collided (arxiv.org/abs/1909.10961).

Neutron stars are extremely dense objects. When two spin closer and eventually collide, the result can be a more massive neutron star, which would potentially have different rates of rotation in its layers. This could create powerful oscillations in the body of the star – starquakes – that would throw out radiation that we see as faint bursts.

"This is one of many proposals for how FRBs form," says Bing Zhang at the University of Nevada, Las Vegas. "Personally, I wouldn't bet on it, but it's a possibility of course."

Zhang says he is sceptical because FRB 171019 has only been observed for a few years. "Suppose in the future, there is another brighter burst detected from this source. In that case, this model is dead," he says. ■

Engineering

Solar-powered airship could make freight green

Donna Lu

AIRSHIPS were once considered the future of flight. Now, they are being touted as a greener method of transport. A solar-powered craft being built by UK-based firm Varialift Airships could eventually be used as a low-emissions way to freight cargo internationally.

On a transatlantic flight between the UK and the US, the airship would use 8 per cent of the fuel of a conventional jet aeroplane, says Varialift CEO Alan Handley.

Airships – lighter-than-air vehicles that rely on gas to lift them into flight – were common until the 1940s, when they were supplanted by jet engine aeroplanes.

The advantage of airships is that they don't require dedicated runways to take off and land, meaning they can travel to areas with poor infrastructure. "We can take it from point A to point B where it's required, without any transfer from aircraft to lorries," says Handley.

They are, however, far slower than jet engines. Handley says

the Varialift airship would travel at roughly half the speed of a Boeing 747, which has a cruising speed of around 900 kilometres per hour. Made from a solid aluminium exterior, it could carry 50 tonnes of cargo.

The airship will contain tanks filled with compressed helium, which it will use for buoyancy. When the helium is transferred from the tanks into a larger chamber, it will expand and push air out, generating lift.

Once the airship reached a height of around 10,000 metres, it would be propelled forward by a combination of two solar-powered and two conventional jet engines. Because there would be no on-board battery, the solar-powered engines would be limited to daylight hours.

At an airfield near Châteaudun, France, Varialift is building a prototype for training pilots that is 140 metres long, 26 metres wide and 26 metres high. It is set to be completed in the next nine months.

Manoeuvring an airship of this size poses significant challenges, says Robert Hewson

at Imperial College London.

Elsewhere, UK manufacturer Hybrid Air Vehicles has been developing Airlander, a hybrid airship combining lighter-than-air lift and aerodynamic lift (pictured). It uses four diesel engine-powered propellers. Global aerospace firm Lockheed Martin has also been developing a hybrid airship for several years, but hasn't yet started production.

"The airship would use 8 per cent of the fuel of a conventional jet aeroplane"

A team at the University of the Highlands and Islands, UK, has developed a solar-powered aircraft that is propelled by changes in buoyancy. The aircraft alternates its buoyancy between positive and negative, propelling itself forward on each descent by compressing air.

For the moment, airships remain a niche industry, says Hewson. They may be useful for transporting oversized cargo and large structures, such as gas turbines and nuclear reactors, to inaccessible places, he says. Surveillance and broadcasting are two other possible uses.

But it is unlikely that we will see the return of airships as a means of transporting passengers on commercial flights. The significant speed disadvantage would be a deterrent, says Hewson. "It would take days to fly to Australia, for example," he says. "I think it's just not feasible." ■

Airlander is a diesel-powered airship under development



HYBRID AIR VEHICLES



TERRY WHITTAKER/NATURE PICTURE LIBRARY

Health

Drug may ease fatty liver disease

AN EXPERIMENTAL drug has reversed the build-up of fat in the livers of monkeys and lowers levels of fatty substances in their blood. Known as non-alcoholic fatty liver disease, the build-up of fat in the liver affects 1 in 3 people and can lead to type 2 diabetes and heart and kidney disease.

Gerald Shulman at the Yale School of Medicine and his team are developing the fat-busting drug to get at what he believes "is the root cause of diabetes".

Called CRMP, the drug works by making the liver waste energy. The energy that powers cells relies on structures called mitochondria. As protons flow out of mitochondria, they drive molecular turbines that produce an energy-rich chemical called ATP. The new drug lets protons flow out of mitochondria without generating ATP. It is a bit like opening a bypass gate on a

hydroelectric dam, letting water out without generating power.

However, that lost energy ends up as waste heat. A drug called dinitrophenol, used for weight loss from the 1930s, worked via the same mechanism. Its use was discontinued after people died when they overheated. But CRMP affects mainly liver cells, not the entire body. "That's important for safety," says Shulman.

Tests in two types of macaque suggest CRMP is safe and effective at reversing fat build-up in the liver. But it causes no weight loss, which means it is less likely to be misused as a diet drug (*Science Translational Medicine*, doi.org/db96). Unpublished results from tests in mice suggest the drug also cuts the risk of heart disease by reducing blood cholesterol and triglyceride levels, says Shulman.

Given how dangerous dinitrophenol was, Shulman wants to carry out further animal tests of CRMP before moving on to human trials. **Michael Le Page**

Biodiversity

No let up in the worrying decline of nature in UK

THE loss of wildlife and plants in the UK shows no sign of slowing. This year's State of Nature report, the most comprehensive assessment yet, found that the area occupied by more than 6500 species has shrunk by 5 per cent since 1970.

Of the species with detailed data, nearly 700 saw numbers fall by 13 per cent. The declines have left 15 per cent of species facing extinction, including the turtle dove. "We have this pattern of ongoing loss, which is showing no slowing in the rate of decline," says Daniel Hayhow at the Royal Society for the Protection of Birds.

While the 5 per cent fall in distribution of species may sound small, Hayhow calls it a "canary in the coal mine signal" because changes in distribution usually happen much more slowly than

changes in abundance of wildlife.

This year's report, produced by the National Biodiversity Network, was, for the first time, able to draw on figures on less well-studied species, such as lacewings, hoverflies and lichens, after biases in the data were adjusted for.

For moths and butterflies, the picture is one of steep declines. Mammals and birds show a slight increase since 1970, which masks dramatic falls in some species such as hen harriers. There is a flicker of good news for hedgehogs – classed as vulnerable to extinction due to long-term decline, since 2012 their numbers seem to have grown.

The biggest drivers of change are intensified farming and climate change. The report notes the UK will miss most of its biodiversity targets for 2020. **Adam Vaughan**

Astronomy

Hidden structure of the cosmos spotted

A VAST spider's web of matter is thought to stretch across the whole universe and astronomers have just got the best view of it yet.

Hideki Umehata at the RIKEN institute in Japan and his team used the Very Large Telescope (VLT) in Chile to observe a young cluster of galaxies 12 billion light years from Earth, called SSA22. They spotted wispy filaments of hydrogen gas, shown in blue here,

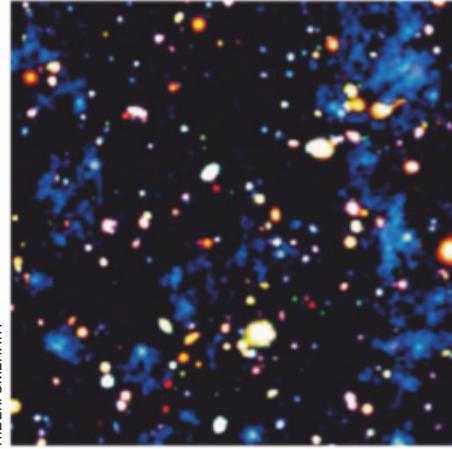
spanning the space between the galaxies. These seem to be filaments of the cosmic web.

Cosmologists assume that as the universe grew, gravity pulled matter into strands, creating a structure of voids and stringy areas filled with matter. We have glimpsed this web before, but never on such a large scale.

It is thought that the web arose several hundred million years after the big bang along with the first galaxies, with gravity helping to form rivers of hydrogen flowing between them. At the point where filaments cross, star and galaxy formation would occur.

The filaments seen by Umehata and his team stretch for 3 million light years, but are just a small portion of the web. Until now the filaments have remained elusive, but Umehata says they were able to see them using a fairly new instrument called the Multi Unit Spectroscopic Explorer on the VLT (*Science*, doi.org/dcdh).

Jonathan O'Callaghan



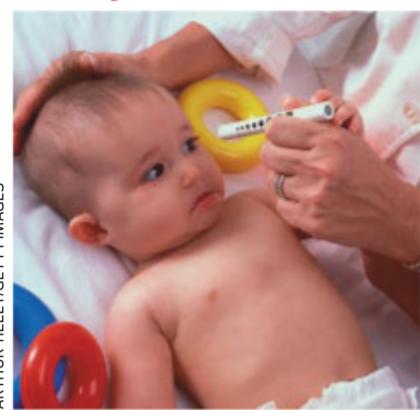


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Really brief



Cancer screening

Yet more doubts over cancer checks

BOWEL cancer screening should be recommended only for people at high risk due to their age, family history or other factors, according to new guidelines.

Checks for this cancer have been introduced in many countries, usually from around the age of 50. Doctors can look at the bowel with a camera on a flexible tube or people can send in a stool sample.

But a review of the evidence suggests that, in most cases, the

benefits are small and uncertain and outweighed by potential harms from false positives, anxiety and bowel perforation. Screening is worth it only in those whose risk of bowel cancer in the next 15 years is 3 per cent or more, say Lise Helsingør of Oslo University Hospital in Norway and her team.

They don't suggest a firm age cut-off. Instead, doctors should calculate people's risk with software that uses their age and other factors such as sex, family history and whether they smoke or drink – but age is the most important (*BMJ*, doi.org/dcbl).

"The 3 per cent threshold represents the cumulative risk above which the balance of benefits and harms tilts in favour of screening," said Philippe Autier at the International Prevention Research Institute in Lyon, France, in an accompanying editorial.

Concerns have also been raised about screening for other cancers, such as PSA blood tests for prostate tumours and mammograms for breast cancer. The fear is that these programmes may do more harm than good by finding tiny tumours that are unlikely to carry on growing. **Clare Wilson**

App spots signs of disease in photos

An app can detect "white eye" in photos of children, a possible sign of health problems, over a year before it would normally be picked up. White eye occurs when a camera flash makes a pupil appear white. Normally this is nothing to worry about, but it can be a sign of disease, including cancer (*Science Advances*, doi.org/db97).

Wildlife trade is far bigger than thought

More than 5000 species of wild animal are being traded, according to the most comprehensive global estimate yet (*Science Advances*, doi.org/dcdb). That is 40 to 60 per cent higher than previously thought. Large or distinctive species are most likely to be traded.

Artificial limb attaches to nerves

A new prosthetic leg tested by three people felt like an extension of their own bodies and helped them avoid tripping over. Sensors in the foot and knee of the prosthesis were directly connected to the participants by implanting electrodes into their nerves (*Science Translational Medicine*, doi.org/dccl).

Neuroscience



Bird brains retuned with the help of fake memories

YOUNG zebra finches have had memories implanted in their brains that change the length of the notes they sing.

The birds usually learn a series of notes by memorising their father's song. Now Todd Roberts at the University of Texas Southwestern Medical Center and his team have manipulated the brains of young finches, making it seem like they had a memory of a song despite never hearing an adult sing it.

Previous work had shown that a region of the brain in birds called HVC is important for learning songs. This gets input from another brain area called NIf, and neurons in this

structure fire at the beginning and end of notes. That suggested these neurons have a role in coding the length of notes, or syllables.

Roberts and his colleagues used optogenetics – a genetic technique that enables neurons to be activated by light – to manipulate this pathway and make the birds learn to sing longer notes (*Science*, doi.org/gf9f4f).

"We identified a pathway in the brain that, if we activate it, can implant false memories for the duration of the syllables, without the bird having experience with another bird," says Roberts. **Sam Wong**

Space

Andromeda had a two-course meal

OUR nearest major galactic neighbour has feasted on several galaxies in its lifetime. Now it seems it had two distinct courses.

We know Andromeda ate other galaxies because it has a large halo of stars on the periphery, caught in its orbit during collisions with smaller, dwarf galaxies.

To see when this happened, a team led by Geraint Lewis at the University of Sydney, Australia, studied data on the halo. They focused on groups of millions of stars packed in spheres known as globular clusters. These clusters would have retained a degree of structure from their parent dwarf galaxy for a while after they were captured by Andromeda. Lewis and his colleagues traced what remains of these structures.

They found that half of the clusters were orbiting one way around Andromeda's core and the other half in a perpendicular orientation. The former still have some substructure intact, so the collision that created them was relatively recent, probably a few billion years ago. The second group of clusters retain less of their original structure, suggesting they were swallowed 7 to 10 billion years ago (*Nature*, doi.org/db95).

Ruby Prosser Scully

The animal-testing paradox

Experiments involving animals can provide great insights into how to treat them, but should they be done at all? **Chelsea Whyte** investigates

AYUMU the chimpanzee sits behind a glass wall taking a memory test. He sees a sequence of numbers randomly set out on a touchscreen, memorises them and, when they disappear, taps out a pattern to indicate where they were. For a correct answer, he is given a small reward of food.

The ape featured in a 2012 documentary, *Super Smart Animals*, and the research he was involved in at Kyoto University in Japan revealed that young

"You might assume that giving lab rats larger cages is a good thing, but that's not necessarily true"

chimpanzees have a better working memory for numbers than human adults. The experiment with Ayumu is just one example of research that is confirming how sophisticated animal minds can be.

The trouble is, many studies like these involve housing animals in laboratory conditions or incentivising them to do a test by restricting their food or water. In recent months, *New Scientist* has reported on findings that chimps bond after watching films together, macaque monkeys can use logical reasoning to solve puzzles and that implanting memories in the brains of zebra finches can alter their songs (see page 17). All these studies involved manipulating animals in unnatural ways.

There has long been a debate about the merits of animal experiments, especially in medical research. But when animal behaviour or cognition experiments are unlikely to lead to medical advances, the purpose of such studies can seem less immediately clear.

In the US, the total number



Can lab experiments really help us conserve chimps in the wild?

us what proportion of these experiments are done to find out about animal cognition.

The purpose of animal cognition research can seem less obvious than medical experiments. One driver is to learn about ourselves. "I want to understand how brains evolve," says Tom Smulders at Newcastle University in the UK. "From my perspective, just studying humans doesn't get you anywhere. To understand evolutionary patterns and processes, you need a wide range of species."

Cognitive research is also conducted in the pursuit of basic knowledge. In the early 17th century, René Descartes thought that animals didn't feel pain or experience emotions – that they were a kind of unconscious organic mechanism. But experiments have shown that some creatures seem to have cognitive abilities that begin to approach our own (see "Minds of the beasts", below).

Learning more about how animals tick can also boost conservation efforts by

of animal studies under way is difficult to come by because there is no requirement to record experiments involving mice, rats and fish. However, the US Department of Agriculture does report the use of cats, dogs, farm animals, non-human primates and a few other species. In 2017, its records show that more than 250,000 animals were used

in research that involved pain and being given pain-relieving drugs. Some 30,000 of these were non-human primates.

In Great Britain, we know that, in 2018, there were 3.52 million scientific procedures performed on animals, as well as how this breaks down by animal and type of experiment (see statistics, far right). Still, the figures don't tell

Minds of the beasts

Logic

In July, a study confirmed that macaques are capable of deductive reasoning. The animals were trained to view a few images in a specified order, and then shown them out of order and asked to identify the image that belonged earliest in the sequence. They were first put on a water-restricted diet and rewarded with drops of water for correct answers.

Empathy

Contagious yawning is thought to be part of a tendency to synchronise with others, and may be linked to empathy. Budgerigars are known to be mimics, but a study also demonstrated that they will yawn when budgies in nearby cages do so, and also when shown a video of other birds yawning. They are the first non-mammals found to do this.

Theory of mind

Apes have been shown to understand that others can think differently to them based on the information they have, an idea called theory of mind. In one study, a person put an object in a box and left the room before a second person moved it to another box. When the first person re-entered, chimps, gorillas and orangutans will show them where the object is.

assisting captive breeding projects and subsequent releases.

Opinions as to whether these are good enough justifications for animal experiments are split. "It's a dilemma, and I struggle with it a little bit myself," says Smulders.

One thing is for sure: if the overall goal is conservation, lab experiments on animals can't tell us much in isolation.

Playing chess

Think, for example, of the 1950s studies in which chimps played chess, says Ludwig Huber at the University of Veterinary Medicine Vienna in Austria. They told us that chimps had the curiosity to try out the game. That knowledge couldn't be used for conservation, though, because the setting was so far removed from the animals' natural environment.

Huber says we should instead be doing lab experiments and field observations in conjunction. "We need to know what is the real problem the animal is solving in the wild," he says.

To conserve birds, it may be reasonable to do systematic lab experiments to get rigorous evidence on how they remember where they have stored food, for instance. But we would also need to study them in the wild to see how that translates into real behaviour.

Deciding whether animal experiments of any kind are worthwhile also involves balancing potential harm to the animal with the wider benefits. For example, testing drugs on animals may hurt them, but the medical benefits to people might be seen to outweigh that harm.

Studies of animal cognition are a far greyer area, however. Public opinion is already divided on the wider issue. A 2018 Pew

Research Center poll found that 52 per cent of adults in the US oppose the use of animals in scientific research, generally.

We do have ways of trying to ensure that animal research leads to benefits. In the US, the National Academies of Sciences, Engineering, and Medicine states that all such research should show "relevance to human or animal health, advancement of knowledge, or the good of society". That may sound generic, but there are also specific rules that lay out the physical environments required for laboratory animals. These include everything from heat and humidity to how much vibration an animal can experience.

In fact, those guidelines were informed by the very research they are designed to oversee.

3.52 million
Number of scientific procedures carried out on animals in Great Britain in 2018

51%
of these were experiments – the rest involved breeding

93%
of all procedures involved mice, rats or fish

56%
of all procedures were for the purposes of basic science, including medical research

1%
of experimental procedures involved cats, dogs, horses or primates

Source: UK Home Office

Experiments on animals that tell us about their minds and how they experience the world can also tell us how best to keep those animals content. It is a positive feedback loop.

This has led to real improvements in rodent research. Rats and mice used to be housed in stark cages on their own. "That's illegal now," says Smulders. "It's required and routine to give them bedding materials, places to hide, chewing tubes. These things have changed precisely because there's more of an understanding now that these animals do have feelings of their own."

But shouldn't it be possible to treat animals well without having to experiment on them to find out what they need? It isn't necessarily that simple. You might assume, for instance, that it would be a good thing to give rats larger cages, but that may not be true. Studies have shown that rats' stress levels are lowered by having places to hide and being housed with other rats. It isn't more space that's important, but the right kind of space.

Ultimately, finding out the best way to improve the lives of animals comes down to evidence. Here's the paradox: to treat animals – whether on farms, in labs or even in the wild – with the respect many feel they deserve, we must understand the ways we affect their lived experience, and to do that in a detailed way we may need to study them closely in the lab.

"We keep animals in zoos and circuses, use them for our meat. We do lots of harm to animals. Is this justified?" says Smulders. The only way to answer that question, he says, is to do experiments. "It's not enough to sit in an armchair and think about it. You have to investigate it and prove it." ■

Working hypothesis

Sorting the week's supernovae from the absolute zeros



▲ Fat bears

It's the heavyweight battle of the year. The public are voting on which bear is the fattest of them all in an Alaskan national park.

▲ Typing

Smartphone typing speeds are catching up with those on keyboards. Combined with predictive text, mobile could soon reign The Supremes (damn you autocorrect!).

▲ Bins

It's rubbish tech that's actually quite good. A smart bin autonomously puts itself on the roadside ready for collection.

▼ DNA tests

Even sailing can't escape swabbing. A cruise ship is offering on-board DNA tests for people to trace their ancestry.

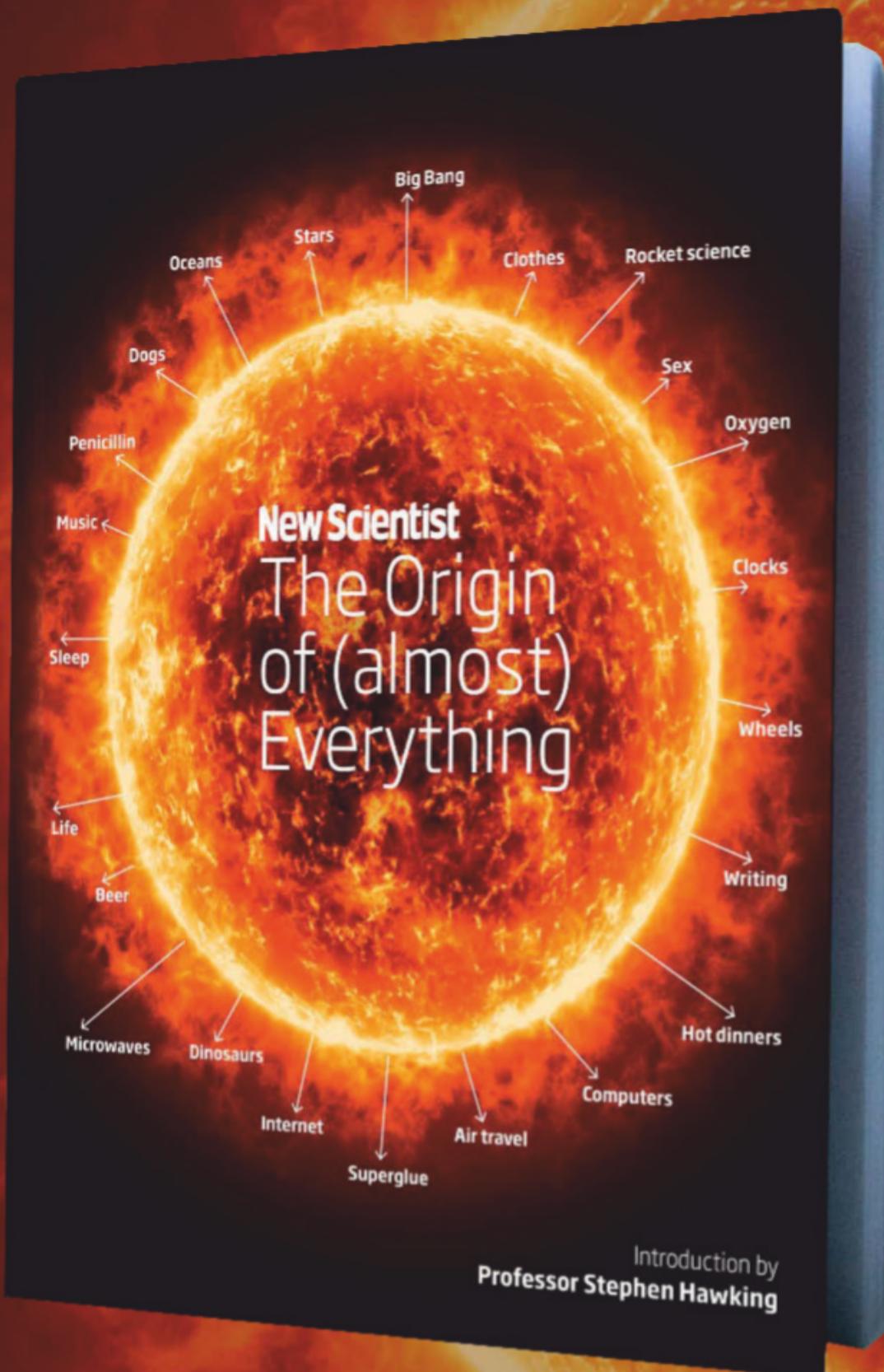
▼ Toxic fungus

The poison fire coral could be the world's least fun fungus. Its dangerous toxins can be absorbed through the skin and it has now spread from Asia to Australia.

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Introduction by **Professor Stephen Hawking**

**New
Scientist**

The columnist

Graham Lawton has “eco-anxiety”, but he’s OK with that **p22**

Letters

Combining bad algorithms will lead to injustice **p26**

Aperture

The beautiful puddles left behind by mining machinery **p28**

Culture

Photo exhibition reveals how prejudice taints AI **p30**

Culture columnist

Chelsea Whyte enjoys a pared-down whodunnit **p32**

Comment

The future from the past

A 17th-century wish list shows the importance of blue-sky research, and of building cooperation between science and the humanities, says historian **David Cannadine**

MORE than 300 years ago, philosopher and scientist Robert Boyle compiled a list of breakthroughs that he hoped future scientists would make. The list is a fascinating glimpse into 17th-century society: its desires, the limits of its technology and the boundlessness of imagination.

Some items on Boyle’s list remain largely outside the bounds of science: “The Attaining Gigantick Dimensions”, or “The Transmutation of Species in Mineralls, Animals, and Vegetables”. But many now exist in some form or another: “The Prolongation of Life”, “The Art of Flying”, “The Cure of Diseases at a distance or at least by Transplantation” or “Potent Druggs to alter or Exalt Imagination”. The list shows the power of blue-sky thinking and the importance of scientific research in making ideas reality.

This summer, the UK national academies started a public conversation to develop a new “people’s list” of things we would like to be able to do, or better understand, through research and innovation. The results are as varied as you would expect, from tackling climate change and cancer to the colonisation of planets outside our solar system and communicating with pets.

Similar items would probably feature on such a list anywhere in the world. But the list carries particular lessons for the UK as it grapples with its future global role.



Boyle’s list shows how seemingly pie-in-the-sky dreams can become the future norm. For that to happen today requires investment from government and industry in creative research. The UK government is committed to 2.4 per cent of GDP being invested in research from public and private sources by 2027. But it is some way off this target, and the country lags behind international competitors. The likes of Germany, Israel, South Korea and Japan already invest more than 3 per cent of GDP.

The UK has a great deal to build on. The country is at the forefront of climate science, as the second largest contributor of expertise to the Intergovernmental Panel on Climate Change, behind the US; it has discovered and developed a quarter of the world’s top prescription medicines; and it leads the world in machine learning and artificial intelligence.

Scientific advances don’t exist in a vacuum, and the UK can play to the well-developed cooperation between the sciences and the humanities. Humanities

researchers are busy developing ethical and regulatory frameworks for new technologies: the University of Oxford recently received a record £150 million from US investor Stephen Schwarzman to tackle the ethical questions of AI.

UK anthropologists use their expertise to engage sensitively to strengthen medical interventions around the world, for example in vaccination campaigns and in the Ebola crisis in West Africa in 2014.

With a general election in the UK potentially around the corner, backing research is also a vote-winner. According to the UK Public Attitudes to Science Survey, 79 per cent of those surveyed agree that even if it brings no immediate benefits, research that advances knowledge should be publicly funded.

Boyle’s list and the people’s list prove that in our capacity to dream of a better, safer and more exciting world, we are just like our predecessors and, indeed, our successors. The UK government has an opportunity now to set an example by committing fully to research for a common global future. ■



David Cannadine is president of the British Academy, the UK’s national academy for the humanities and social sciences

No planet B

I have eco-anxiety but that's normal The UK media reports widespread eco-anxiety in kids. If we accept it is a mental health condition, climate denialists will have won, writes **Graham Lawton**



Graham Lawton is a staff writer at New Scientist and author of *The Origin of (Almost) Everything*. You can follow him @grahamlawton

Graham's week

What I'm reading

I'm much better at starting books than finishing them, so all of the ones in my past columns.

What I'm watching

Nothing very memorable. But I'm listening to a great BBC podcast called The Missing Cryptoqueen.

What I'm working on

I'm preparing to interview the brilliant Naomi Oreskes, a leading expert on science denial. I haven't had enough of experts.

This column appears monthly. Up next week: Annalee Newitz

LAST week I had a sobering conversation with an editor from one of the BBC's flagship science programmes. He had been reading my column and wanted to pick my brains about emerging environmental issues. After half an hour chewing over the dire state of the climate and biodiversity, he asked me: how do you cope? How do you sleep at night knowing all of this?

I admit that I sometimes lose sleep, usually when I'm working on a story that brings me face to face with the realities of climate breakdown or biodiversity loss. I worry for my sons' future and I feel a profound sense of loss, guilt, anger and helplessness.

Recently I have come to suspect that I have eco-anxiety. In fact, a psychotherapist has told me I almost certainly do. But I'm not seeking help and I'm not worried about it, because I know there is no such condition – although not for the reason you might think.

The concept of eco-anxiety has been discussed in academic circles for years but burst into the wider world last month when sections of the UK media reported a "tsunami" of eco-anxiety in children.

Apparently, they are increasingly asking doctors, therapists and teachers for help coping with their fears. Some are even being prescribed psychiatric drugs.

The response to this story was predictable. Many commentators saw the opportunity for an anti-green pile-on. Instead of calling for action on climate change, they shot the messengers. Greta Thunberg, Extinction Rebellion, the youth climate strikes and the teachers who encourage them were accused of stoking panic. Take-home message: eco-anxiety is a made-up condition.

I have a shred of sympathy with the view that warnings of

imminent catastrophe can be exaggerated. The oft-repeated "fact" that we have 12 years (now 11) to save the planet – one of Thunberg's go-to claims – is a subtle misrepresentation of the science. It makes it sound as if the climate will have collapsed by then. What the Intergovernmental Panel on Climate Change said was that to avoid dangerous warming later this century, greenhouse gas emissions must peak before 2030.

I have less sympathy for the idea that children's fears are being cynically stoked. We have more than 12 years but there is no doubt the natural world is in trouble.

"Eco-anxiety is not an illness but a perfectly rational response to the enormity of our problems"



And although friends tell me that their kids have exaggerated fears of environmental disaster, children also have exaggerated fears about kidnap, fire, dogs and plane crashes. Just because they are overblown is no reason to dismiss them as baseless.

Which brings us back to the supposed tsunami of eco-anxiety. I called the source of the story, Caroline Hickman at the University of Bath, UK, a member of the Climate Psychology Alliance. She confirmed that, in her experience as a researcher and psychotherapist, children and their parents are becoming more anxious about the state of

the environment and increasingly asking for help. Health professionals are waking up too: this month, the UK Council for Psychotherapy will dedicate its annual meeting to the topic. Some children have indeed been put on medication.

But she absolutely denied there was an epidemic. Eco-anxiety is real, but it isn't an illness. Quite the opposite, she said. The last thing the world needs is for it to be recognised and treated as a mental health problem – a nuance you may have missed from the media coverage of the findings.

I missed it, so let me spell it out. Eco-anxiety is not an illness but a perfectly rational response to the enormity of our problems. If it becomes pathologised, the forces of denial will have won, because normal feelings will officially be recognised as an abnormal state of mind. Putting kids on medication sounds drastic but only a tiny number have been prescribed drugs, says Hickman.

Hickman and her colleagues don't even like the term "eco-anxiety" because it insinuates mental illness and conceals that people also experience feelings including grief, depression, rage, despair and injustice. They prefer to call it what it is: eco-awareness. So that is what is wrong with me: I'm normal.

And forget the idea of a "cure". People will need help dealing with their fears, including having them put into perspective, but they also need to know that they are legitimate, shared by a growing number of people, and, above all, rational. And look on the bright side: eco-anxiety could be a great motivator for action. What we are witnessing isn't a tsunami of mental illness, but a long-overdue outbreak of sanity. ■

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Editor's pick

Combining bad algorithms will lead to injustice

7 September, p 14

From Ramon Lopez de Mantaras, Artificial Intelligence Research Institute, Sant Cugat de Vallès, Spain

Many ethical questions need to be answered before facial recognition technologies can be used as part of criminal investigations, as Donna Lu rightly points out. She notes that combining inaccurate facial recognition algorithms with the new algorithm to deblur faces leads to the possibility of the wrong person being identified.

This will certainly happen. Combining two inaccurate algorithms dramatically increases the false positive rate – which, in the case of the best face-recognition algorithms working with clear faces, is over 80 per cent.

People's choices are already being led by AI

24 August, p 38

From John Hockaday, Canberra, Australia

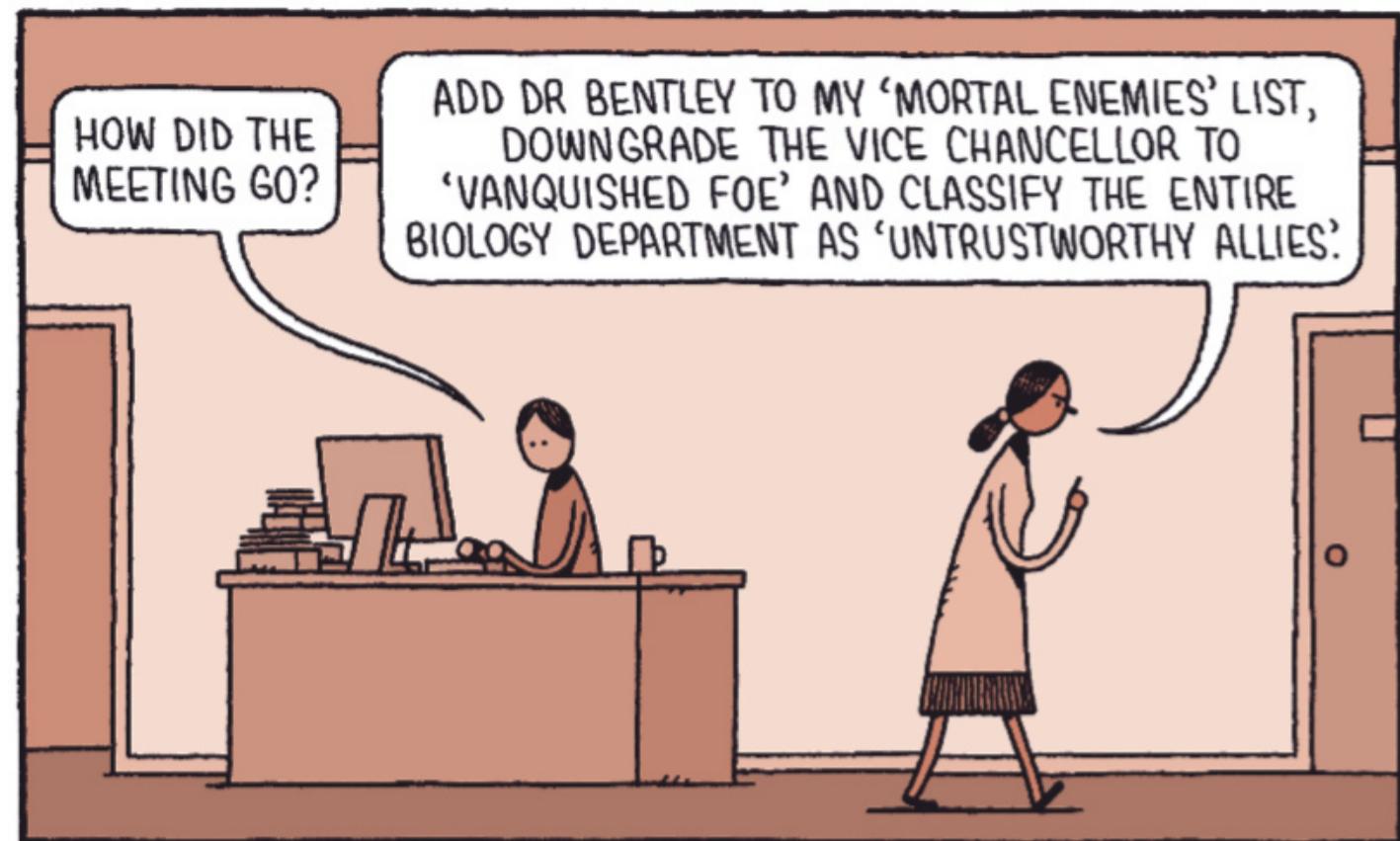
You suggest that humans are less likely to accept a choice attributed to an artificial intelligence when it concerns a social problem. Many people make decisions that are influenced by their social media interactions, which are governed by AI. Fake news spreads between users on Facebook, who may change their vote because of it. YouTube's algorithm has been shown to recommend more extreme videos, affecting people's attitudes (13 July, p 14).

It appears that humans already make decisions suggested – perhaps covertly – by AI.

Richard Dawkins, history and lived experience

21 September, p 38

From Ian Stewart, Sutton Coldfield, West Midlands, UK
Richard Dawkins tells Graham Lawton that he doesn't comment on topics such as fake news and



TOM GAULD for NEW SCIENTIST

the promotion of gut feelings over facts, or issues relating to the environmental crisis, because none of these are in his area of expertise and his amateur opinion would be no more interesting than anyone else's. I am familiar with Dawkins's studies in zoology and his eminent career in evolutionary biology and ethnology, but I seem to have missed learning of the period in which he studied theology and religious history.

From Gerald Coles, Bristol, UK
Dawkins has usefully promoted scientific truth through his writing on evolution. We need to remember, however, that there is also historical truth, which differs from scientific truth in that history can't be repeated.

It is important because it helps us to understand the cultures and countries around us and, we hope, to avoid serious future political mistakes and wars.

There is also a third form of truth: that of experience. The best example is love, a vital ingredient in families, which can't be measured, only given and received. Enough people experience it that it is significant.

A bigger study shows no benefit of organic food

Letters, 14 September

From Anthony Trewavas, Penicuik, Midlothian, UK

Ann Wills mentions a study that compared consumption of organic food with cancer rates in a sample of nearly 70,000 people. She doesn't mention a much larger UK study of 625,000 women (*British Journal of Cancer*, doi.org/gb9qwj). This compared those who only ever ate organic food with those who never did and reported on the incidence of 16 different cancers over a nine-year period.

In that time, 50,000 women developed cancer, but there was no statistically significant difference between the groups, except for small increases in breast cancer. There was a lower rate of lymphoma in the organic eaters, although the number of lymphomas was too small to judge statistical significance. As with the breast cancer, this may be due to chance variations. Organic associations promote the idea that their food is healthier, which isn't scientifically sustainable. Trying to get people to eat their five-a-day

by recommending more expensive organic produce is inevitably counterproductive.

ET lacks the time, space and persistence to reach us

31 August, p 42

From Martin Greenwood, Perth, Western Australia

There are many suggested solutions to the Fermi paradox (there is a high probability of alien civilisations existing, so where are they?) that Sarah Rugheimer discusses. A glaring omission from the list you present is also one of the simplest: space is too big. A journey by a biological organism to another inhabited world would take an implausible amount of time or energy.

Some assume aliens possess technologies beyond our current understanding. These would require at least one gaping hole in our understanding of physics. What if our physics is essentially correct and no such holes exist?

From Peter Basford, Potters Bar, Hertfordshire, UK
The Drake equation that estimates how many alien civilisations exist

that are capable of signalling their presence includes the period in which each actually transmits across the galaxy.

We have existed for several hundred thousand years, but have broadcast in this way for only about 100 years. We are now moving to less noisy laser and cable signals, so that period is unlikely to be much greater than 1000 years.

A circle with a radius of 1000 light years covers less than 0.04 per cent of the area of the disc of our galaxy; 1000 years is a tiny fraction of its 13-billion-year age and it is likely that it will exist for as long again.

We have been looking for these signals for less than 100 years. This is like shining a tiny torch into the Grand Canyon on a pitch-black night. The probability of seeing anything is surely very low, however much has been, is and will be out there.

*From Harold Worby,
Wheaton, Illinois, US*

To answer the question "where is everybody?" we must consider the time period in which a technologically advanced civilisation maintains a broad coalition with the desire to put an immense amount of resources into interstellar travel. I can't see anything in human history that indicates we are capable of that kind of long-term commitment. If the course of human development to date is a model of how other civilisations develop, then we will never meet any others.

Prospecting for metal with plants goes way back

17 August, p 12

*From Brian King,
Barton on Sea, Hampshire, UK*
David Hambling reports that a company is using trees to find gold deep underground in Australia. Plants have been used for such purposes at least since modern metal prospecting began. Possibly the best known is *Ocimum centraliafricanum*, the copper flower, which has been used in the

Central African Copperbelt since the 1920s to confirm the presence of copper in soil in clearings where the absence of trees is thought to be due to the poisoning of their seeds by copper.

More recently, there have been attempts to recover nickel from the ash of trees that concentrate it (22 March 2014, p 46).

Keep those fossil fuels until we really need them

10 August, p 34

*From Andrew Scott,
Perth, UK*

Tom Chivers discusses solar technologies that could be used instead of fossil fuels, which would help address the increasingly urgent requirement to control global warming. There is a second reason to do this.

All understanding of Earth's long-term cycling tells us that, on a much longer timescale than the current warming phase, a new colder spell within our present ice age will eventually loom.

If humanity is still around then, it may need fossil fuel reserves to burn to counter that threat. Long-term atmospheric management in both directions of temperature will be necessary for a truly long-term future for our species.

Engineering obstacles to electrolysing seawater

Letters, 21 September

*From Clive Semmens,
Ely, Cambridgeshire, UK*

Why can't we use seawater to make hydrogen, asks Albert Lightfoot. We can, but corrosion of the anode by chloride ions in seawater is a problem. It isn't insurmountable: you could use anode materials like gold or platinum, but they are expensive. Researchers at Stanford University are working on exactly this issue: see bit.ly/NS-brine.

I wonder whether we could use graphite for the electrodes. I don't think it would be corroded, but its relatively low conductivity would mean the cells would have to be bigger for a given rate of hydrogen generation.

Lightfoot suggests that there might be useful by-products, but sadly, rare earth metals and cobalt aren't present in significant amounts in seawater. Lithium only forms 160 parts per billion by weight of seawater and the hydrogen production process wouldn't help much in its extraction from that water.

Stroppy teenagers are just how they should be

14 September, p 56

*From Richard Hambly,
Sydney, Australia*

It was good to read your interview with neuroscientist Dean Burnett and his conclusion that teenagers are how they are because it was evolutionarily useful.

I've been going on about our adventurous species and the drive of the young towards risky behaviour and exciting experiences – looking to see what is over the next hill and so on. Now, I can quote Burnett as an authority on the subject when my listeners' eyes glaze over.

How can my circadian rhythm be so precise?

21 September, p 15

*From Howard Owens,
Stoke Canon, Devon, UK*

Jessica Hamzelou reports that boosting circadian rhythms can help relieve perinatal depression. This prompts me to wonder how such rhythms work. How is it that I always wake at 7.20 am, plus or minus 30 seconds? How can the wetware of the mind be so precise? I get no external cues, visual or

aural, and this routine has survived three house moves. It even resets for daylight saving time after about three weeks.

Do take into account the effects of the effects

24 August, p 17

*From Mike and Linda Hutchinson,
Pamber Heath, Hampshire, UK*
We read with interest your snippet reporting that sleep loss is worse for young people's mental health than social media. Taking into account sleep, physical activity and cyberbullying, the effect of frequent social media use in causing unhappiness and anxiety was found to be insignificant.

We suggest a story along similar lines. Cancer is worse for you than tobacco: people who smoke tobacco frequently tend to be more prone to breathlessness and lung cancer than those who smoke less. But taking into account tar, nicotine and carbon monoxide, the effect of frequent smoking was found to be insignificant.

A proposition about the use of the word 'theorem'

21 September, p 6

*From Doug Clark,
Edinburgh, UK*

Leah Crane says that because an estimate by physicist Maximiliano Isi of the mass and spin of a black hole is based on the no-hair theorem, which holds that no information about a black hole beyond its mass, spin and electrical charge is visible beyond its event horizon, this suggests that the theorem is correct.

A theorem is a mathematical proposition not self-evident but proved by a chain of reasoning, a truth established by reason and based on accepted axioms.

I suggest that this "theorem" would more accurately be called a conjecture.

The editor writes:

We have to call things what they are universally called and this is the language cosmologists use. █



Want to get in touch?

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Scar tissue



Photographer **J. Henry Fair**

THESE vibrant pools of water may look inviting, but they are part of a sad story unfolding at the heart of Hambach Forest: that very little of the woodland remains.

The nearly 12,000-year-old forest, which lies between Cologne and Aachen in western Germany, was once the size of Manhattan. Energy company RWE bought the forest in 1978, and felled 90 per cent of it to create the largest opencast mine in the country.

The little that survives of the original forest is home to 142 species considered important for conservation, and is the subject of furious protests and legal actions. By the time the mine is exhausted in around 2040, nearly 20 cubic kilometres of soil and coal will have been removed from the site.

The enormous, colourful puddles are the result of acid water flowing to the surface and filling the depressions left behind by the mine's machinery. They had long eluded the lens of J. Henry Fair, a New York-based photographer and activist, until one day "the colours were vibrant, we were able to get in the right place, and the light was perfect", he says.

Fair, an environmentalist who runs a wolf conservation centre, divides his photography between portrait work (his portfolio includes world-renowned musicians like Yo-Yo Ma) and images of rusting machines, ancient ruins and environmental degradation. The picture here, *Remains of the Forest*, won the Climate Action and Energy prize at this year's CIWEM Environmental Photographer of the Year awards. ■

Simon Ings

Impaired visions

Trevor Paglen's latest installation reveals the ethical gulf that yawns when we leave computers to organise the world for us, says **Simon Ings**



Exhibition

Trevor Paglen: From "Apple" to "Anomaly"

Barbican Centre, London

Until 16 February 2020

A COUPLE of days before the opening of Trevor Paglen's latest photographic installation, *From "Apple" to "Anomaly"*, a related project by the artist found itself splashed all over the papers.

ImageNet Roulette is an online collaboration with artificial intelligence researcher Kate Crawford at New York University. The website invites you to provide an image of your face. An algorithm will then compare your face against a database called ImageNet and assign you to one or two of its 21,000 categories.

ImageNet has become one of the most influential visual data sets in the fields of deep learning and AI. Its creators at Stanford, Princeton and other US universities harvested more than 14 million photographs from photo upload sites and other internet sources, then had them manually categorised by some 25,000 workers on Amazon's crowdsourcing labour site Mechanical Turk. *ImageNet* is widely used as a training data set for image-based AI systems and is the secret sauce within many key applications, from phone filters to medical imaging, biometrics and autonomous cars.

According to *ImageNet Roulette*, I look like a "political scientist" and a "historian". Both descriptions are sort-of-accurate and highly flattering. I was impressed. Mind you, I'm a white man. We are all over the internet, and the neural net had plenty of "my sort" to go on.

Spare a thought for *Guardian*



TIM P. WHITBY/GETTY IMAGES FOR BARBICAN CENTRE

journalist Julia Carrie Wong, however. According to *ImageNet Roulette* she was a "gook" and a "slant-eye". In its attempt to identify Wong's "sort", *ImageNet Roulette* had innocently turned up some racist labels.

From "Apple" to "Anomaly" also takes *ImageNet* to task. Paglen took a selection of 35,000 photos from *ImageNet*'s archive, printed them out and stuck them to the wall of the Curve

From "Apple" to "Anomaly" has photos arranged in intriguing categories

gallery at the Barbican in London in a 50-metre-long collage.

The entry point is images labelled "apple" – a category that, unsurprisingly, yields mostly pictures of apples – but the piece then works through increasingly abstract and controversial categories such as "sister" and "racist". (Among the "racists" are Roger Moore and Barack Obama; my guess is that being over-represented in a data set carries its own set of risks.) Paglen explains: "We can all look at an apple and call it by its name. An apple is an apple. But what about a noun like 'sister', which is a relational concept? What might seem like a simple idea – categorising objects or naming pictures – quickly becomes a process of judgement."

The final category in the show is "anomaly". There is, of course, no such thing as an anomaly in nature. Anomalies are simply things that don't conform to the classification systems we set up.

Halfway along the vast, gallery-spanning collage of photographs, the slew of predominantly natural and environmental images peters out, replaced by human faces. Discrete labels here and there indicate which of *ImageNet*'s categories are being illustrated. At one point of transition, the group labelled "bottom feeder" consists entirely of headshots of media figures – there isn't one aquatic creature in evidence.

Scanning *From "Apple" to "Anomaly"* gives gallery-goers many such unexpected, disconcerting insights into the way language parcels up the world. Sometimes, these threaten to undermine the piece itself. Passing seamlessly from "android" to "minibar", one might suppose that we are passing from category to category according to the logic of a visual algorithm.

Find out the role of people in an age of AI from Joanna Bryson on 13 October at New Scientist Live newscientistlive.com

After all, a metal man and a minibar are not so dissimilar. At other times – crossing from “coffee” to “poultry”, for example – the division between categories is sharp, leaving me unsure how we moved from one to another, and whose decision it was. Was some algorithm making an obscure connection between hens and beans?

Well, no: the categories were chosen and arranged by Paglen. Only the choice of images within each category was made by a trained neural network.

This set me wondering whether the ImageNet data set wasn’t simply being used as a foil for Paglen’s sense of mischief. Why else would a cheerleader dominate the “saboteur” category? And do all “divorce lawyers” really wear red ties?

This is a problem for art built around artificial intelligence: it can be hard to tell where the algorithm ends and the artist begins. Mind you, you could say the same about the entire AI field.

“The group labelled ‘bottom feeder’ consists entirely of headshots, there isn’t one aquatic creature in evidence”

“A lot of the ideology around AI, and what people imagine it can do, has to do with that simple word ‘intelligence’,” says Paglen, a US artist now based in Berlin, whose interest in computer vision and surveillance culture sprung from his academic career as a geographer. “Intelligence is the wrong metaphor for what we’ve built, but it’s one we’ve inherited from the 1960s.”

Paglen fears the way the word intelligence implies some kind of superhuman agency and



TREVOR PAGLEN/GETTY IMAGES FOR BARCICAN CENTRE

Trevor Paglen chose photo categories, but an AI chose the pictures to fill them

infallibility to what are in essence giant statistical engines. “This is terribly dangerous,” he says, “and also very convenient for people trying to raise money to build all sorts of shoddy, ill-advised applications with it.”

Asked what concerns him more, intelligent machines or the people who use them, Paglen answers: “I worry about the people who make money from them. Artificial intelligence is not about making computers smart. It’s about extracting value from data, from images, from patterns of life. The point is not seeing. The point is to make money or to amplify power.”

It is a point by no means lost on a creator of ImageNet itself, Fei-Fei Li at Stanford University in California, who, when I spoke to Paglen, was in London to celebrate ImageNet’s 10th birthday at the Photographers’ Gallery. Far from being the face of predatory surveillance capitalism, Li leads efforts to correct the malevolent biases lurking in her creation. Wong, incidentally, won’t get that

racist slur again, following ImageNet’s announcement that it was removing more than half of the 1.2 million pictures of people in its collection.

Paglen is sympathetic to the challenge Li faces. “We’re not normally aware of the very narrow parameters that are built into computer vision and artificial intelligence systems,” he says. His job as artist-cum-investigative reporter is, he says, to help reveal the failures and biases and forms of politics built into such systems.

Some might feel that such work feeds an easy and unexamined public paranoia. Peter Skomoroch, former principal data scientist at LinkedIn, thinks so. He calls ImageNet Roulette junk science, and wrote on Twitter: “Intentionally building a broken demo that gives bad results for shock value reminds me of Edison’s war of the currents.”

Paglen believes, on the contrary, that we have a long way to go before we are paranoid enough about the world we are creating.

Fifty years ago it was very difficult for marketing companies to get information about what kind of television shows you watched, what kinds of drinking habits you might have or how you drove your car. Now giant companies are trying to extract value from that information. “I think,” says Paglen, “that we’re going through something akin to England and Wales’s Inclosure Acts, when what had been *de facto* public spaces were fenced off by the state and by capital.”

The happy bit about this story is how, time and again, the scandals thrown up by “AI” turn out to have a simple human origin. Boredom, carelessness, malignity: we know what to do about this. And even as I was writing this, ImageNet Roulette was taken down. ■

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predicted the internet in baffling, alluring art. More than 200 of his works, from robot sculptures to giant installations, are on show at this eponymous exhibition at London’s Tate Modern from 17 October.



Watch

Living With Yourself, a new sci-fi comedy on Netflix from 18 October, finds Paul Rudd (Marvel’s Ant-Man) struggling to wrest his life and family away from a better version of himself, after a spa treatment over-delivers on its promise of a “new you”.



Read

The Consequential Frontier: Challenging the privatization of space by Peter Ward (Melville House) casts a critical eye over the commercial works of today’s space tycoons and argues for public ownership of space.

The TV column

A battle of words The stripped-down, laboratory-like setting of Netflix's international whodunnit series *Criminal* is the perfect foil for scripts that focus with clinical precision on the mind, says **Chelsea Whyte**



Chelsea Whyte is a reporter for *New Scientist*, based in Boston, Massachusetts. Follow her on Twitter @chelswhyte



THANKFULLY, I've never seen the inside of a police interrogation room – not in the UK, Spain, France or Germany – but I can tell you that government buildings can't be as similar in those nations, or as well-lit, as they appear in Netflix's new drama series.

Criminal, created by George Kay and Jim Field Smith, is a crime procedural that strips away all the flashy stuff. You won't see a car chase or enter a murder scene. There's no DNA lab, no courtroom drama. Just a room, a suspect and a handful of police, either asking questions or observing behind a two-way mirror. (Admittedly, there's a coffee machine in the hallway – that changes up the scenery a bit.)

Four countries, with three stories in each. Twelve tales, then, enacted on the same limited set. A back-to-back viewing of all the episodes isn't something I would recommend.

Each story is performed in the country's native language with subtitles. This is television worth actually watching, not focusing half your attention on while

scrolling through your phone. Although each country's episodes have a different director, any disjointedness is overcome by the shared set design and visual tone. Despite being set in four European countries, all the episodes were filmed at Netflix's production hub at Ciudad de la Tele in Madrid.

"It's a crime procedural that strips away all the flashy stuff. You won't see a car chase or enter a murder scene"

I was surprised to see how each director had framed the action, finding countless new angles on the same space. If future episodes continue in this vein, this interest, I imagine, will be hard to maintain.

But it is here that psychology itself becomes another character in the television show as we see manipulation play out in real time, both from the investigators and their suspects. Some of the most intriguing views into the art of interrogation come in snippets

A highly charged silence: Lolita Chakrabarti and David Tennant in *Criminal*

of conversation between the various police crews, who swap in and out of the room to better intimidate, empathise with or stonewall their suspects.

The weakest set of stories is the one from Spain, which made caricatures of some of the characters and had twist endings I could see coming a mile away. These episodes included investigators who routinely lied to the suspects, as well as forging a warrant and threatening to harm their loved ones. Yet it wasn't presented in a way that felt like a commentary on police corruption, but more as a way to create drama within the show's tight format.

It wasn't necessary. The UK series includes two performances that are so compelling I couldn't look away. In its first episode, David Tennant plays the stepfather of a 14-year-old girl, and is being questioned about her rape and murder. For the first 15 minutes he says nothing but "No comment", each a masterclass in restraint.

The moments that stayed with me longest were from Hayley Atwell, who plays a woman being questioned about the death of her sister's boyfriend. She was by turns brash, pained, defensive and utterly wrecked. Her every lip quiver was perfectly judged.

We get only glimpses of the lives of the investigators, whether they are arguing in the hall or watching from behind a two-way mirror as their colleagues psychologically break down a suspect. But I quite liked not really being able to tell where things might go in the future between these co-workers as they angled for advantage, stabbed each other in the back and fell in love. ■



TV

Criminal

Created by George Kay and Jim Field Smith

Netflix

Chelsea also recommends...

TV

Broadchurch

Created by Chris Chibnall
ITV

David Tennant's brilliant turn as a detective investigating the death of a young boy in a seaside town.

Podcast

Crimetown

Hosted by Marc Smerling and Zac Stuart-Pontier

Gimlet Media

Dive into US organised crime. Each season focuses on one city – Providence in Rhode Island and Detroit, Michigan – and the peculiar characters who make up its criminal underbelly.

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Fantastic beasts

Some animals have superpowers that seem to defy nature. Can we unlock their secrets and emulate them?

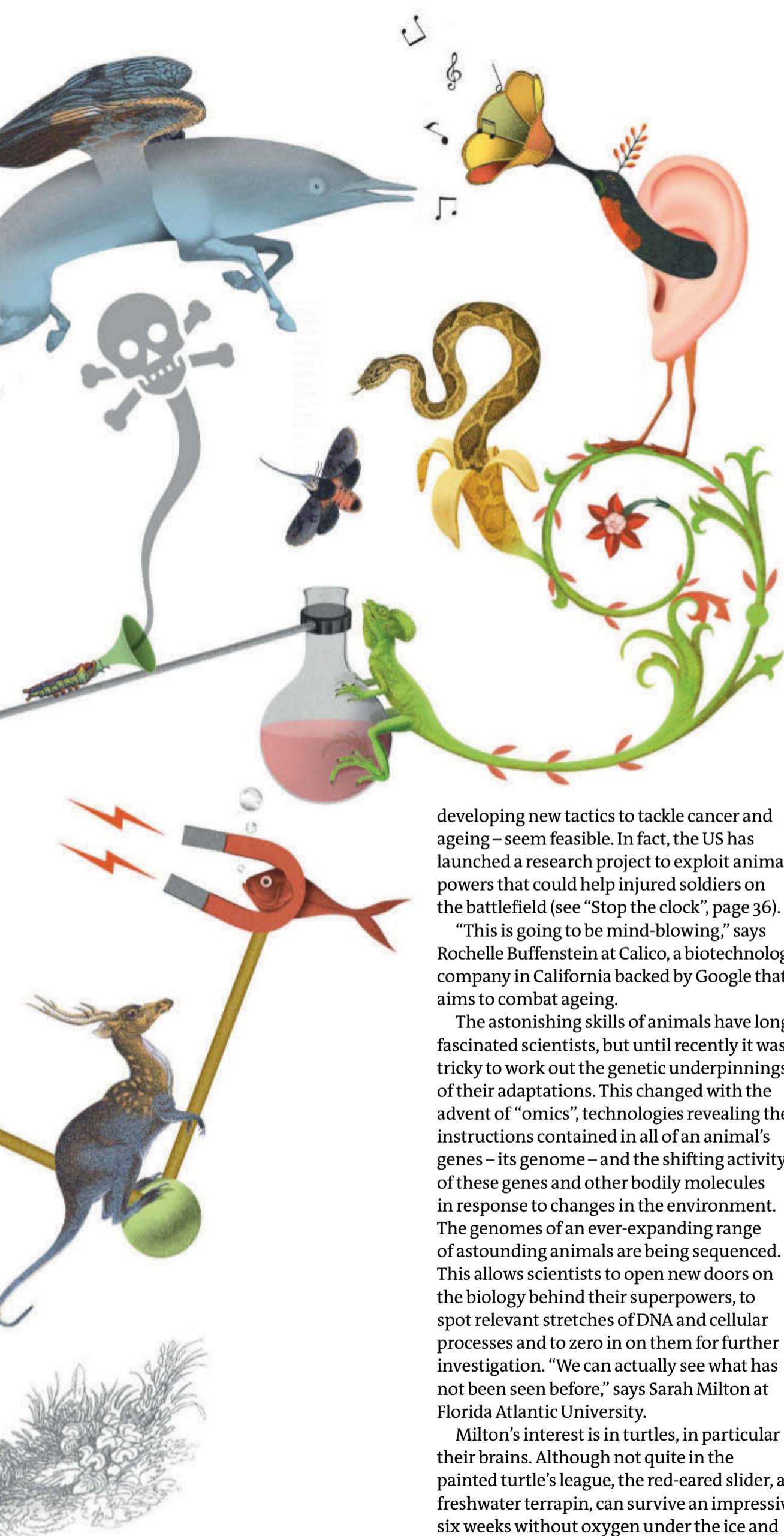
Claire Ainsworth investigates

IT HAS been holding its breath for months. Locked under an airless seal of ice, the extraordinary animal waits. At last, the warmth of spring brings relief. Claws twitch, a brain rouses and a beak pushes through the lake's thawing slush to take a lungful of air. Incredibly, the western painted turtle is none the worse for having endured the kind of oxygen starvation that would normally kill a human in minutes.

At more than 100 days, the turtle holds the record among four-legged animals for surviving without oxygen. It is by no means the only creature to boast jaw-dropping talents. The constellation of powers found across the animal kingdom seems fantastical: the ability to almost completely regenerate innards, to dodge ageing or cancer, to slumber immobile for months without bone or muscle wasting, to slow biological time or even enter a state of suspended animation that can withstand all manner of trials, from freezing to bombardment with gamma rays.

Almost as implausible-sounding is the idea that humans might be able to borrow some of these abilities. Yet the discovery that these powers are underpinned by genes and biological processes we too possess makes this a distinct possibility. Some potential applications – such as putting people into a sort of hibernation for space travel – remain distant goals. But others – including keeping transplant organs fresh without cooling and





developing new tactics to tackle cancer and ageing – seem feasible. In fact, the US has launched a research project to exploit animal powers that could help injured soldiers on the battlefield (see “Stop the clock”, page 36).

“This is going to be mind-blowing,” says Rochelle Buffenstein at Calico, a biotechnology company in California backed by Google that aims to combat ageing.

The astonishing skills of animals have long fascinated scientists, but until recently it was tricky to work out the genetic underpinnings of their adaptations. This changed with the advent of “omics”, technologies revealing the instructions contained in all of an animal’s genes – its genome – and the shifting activity of these genes and other bodily molecules in response to changes in the environment. The genomes of an ever-expanding range of astounding animals are being sequenced. This allows scientists to open new doors on the biology behind their superpowers, to spot relevant stretches of DNA and cellular processes and to zero in on them for further investigation. “We can actually see what has not been seen before,” says Sarah Milton at Florida Atlantic University.

Milton’s interest is in turtles, in particular their brains. Although not quite in the painted turtle’s league, the red-eared slider, a freshwater terrapin, can survive an impressive six weeks without oxygen under the ice and two days at room temperature. This is a

remarkable feat of brain preservation. Brains guzzle energy to keep the electrical charges on the inside and outside of their cells properly balanced. Stifle the oxygen supply in humans – for example, in a stroke – and there is a catastrophic power cut: the pumps that bail electrical charge across cell membranes fail, upsetting the electrical balance inside neurons. This makes them dump toxic quantities of chemical signals known as neurotransmitters onto their neighbours, triggering further electrical mayhem and cell death.

Paradoxically, restoring oxygen makes things worse. As energy-depleted cells resume power generation, they create harmful by-products, known as reactive oxygen species, which damage and kill yet more cells.

To survive this last step, red-eared sliders have several tricks. One is to modify their metabolism so that they produce fewer reactive oxygen species. Another is to make specialised proteins that defend cells against damage. Humans have similar defences, but we deploy them differently. For example, we ramp up production of some of these proteins after damage has occurred, whereas turtles are constantly making them. The similarities are good news because they suggest we could tweak our biology to make it more like that of the turtles, says Milton. Potential medical applications extend to any condition where oxygen starvation is a problem, including stroke and heart attack.

Frozen frogs

Other animals have superpowers that allow them to endure freezing and thawing. The poster beast for this is the wood frog, which survives harsh Canadian winters by letting up to two-thirds of its body freeze – so solidly that it makes a clinking noise if gently tapped. “Biochemistry still goes on at -5°C, but at one 10,000th the normal rate,” says Ken Storey at Carleton University in Canada. The animal’s secret is producing a chemical that stops moisture being sucked from its cells as ice forms in the spaces around them. This ability suggests a possible solution to a pressing medical problem.

At the moment, preserving human organs for transplant operations is difficult because conventional freezing would destroy them. Two-thirds of all donated hearts go to waste every year. A team at Harvard University is now trying to harness the wood frog’s “partial freezing” strategy to better preserve organs. ➤



STOP THE CLOCK

No animal goes to such extremes as the tardigrade, a creature so preposterously resilient that it can almost stop time. When faced with dehydration, these tiny six-legged beasts, also known as water bears, slow their metabolisms to a point at which signs of life are barely detectable, a state known as cryptobiosis. Like this, they can survive bombardment with gamma radiation, extremes of temperature and the vacuum of outer space. They may have even survived crash-landing on the moon. The tardigrade's ability to slow biological time has inspired scientists at the US Defense Advanced Research Projects Agency (DARPA) to set up a research programme called Biostasis. Its aim is to buy time for soldiers injured in battle, where it is a challenge to administer treatments within the "golden hour", the window that maximises their chances of survival.

DARPA's scientists wanted to find biological processes shared by a wide range of animals able to slow down biological time, from tardigrades to hibernating bears. They homed in on the ability to hinder the activity of proteins that drive metabolism within cells. Then they identified three ways animals do this, and challenged other researchers to mimic these processes.

As a result, a team at Harvard University is trying to create drugs that reversibly lock proteins into an inactive state, copying the natural

behaviour of so-called chaperone proteins. A second team is developing molecules that would link together inside cells to form lattices, crowding out proteins and hence slowing their metabolic activity. Other teams are pursuing a third approach: aiming to produce designer versions of "disordered proteins", which stressed tardigrades churn out in vast quantities to both act as chaperones and crowd out other proteins.

BATTLEFIELD BOON

Translating these developments into medicines will be a tall order. The Biostasis programme is taking it step by step and is aiming to get a usable technology out of each stage. The first step – stabilising individual proteins at room temperature – could aid the development of vaccines and antibody therapies that don't need to be kept chilled, which would be a real boon in remote locations. Next, slowing the biology of whole cells could increase the shelf life of donated blood.

Finally, the ability to slow biological processes in tissues or whole animals could be used to reduce bleeding, tissue death and sepsis on the battlefield. It could also have civilian applications such as reducing damage from heart attacks and strokes. "I'm fascinated to see how far they can get with the tools that they build," says Tristan McClure-Begley, who heads the Biostasis programme.



GLENDA CHRISTINA/DESIGNPICS/GETTY IMAGES

Storey is taking a different approach to this problem. His inspiration comes from animals that slow biological time without freezing. "That's the new horizon: staying warm while turning everything off," he says. Creatures that hibernate at warmer temperatures include mammals, among them primates, our close relatives. This raises the possibility that we have retained at least some of the biological machinery needed to drastically slow our metabolic rate as they do. Storey and his team have found that there is indeed a general "blueprint" – a shared set of biochemical responses in cells – for slowing metabolic rate.

To awaken these processes in humans, we need to pinpoint what switches them on and off. That is a challenge, but researchers are making progress. Being able to slow biological time in this way could be used to delay harmful processes such as those caused by injury, sepsis, stroke and heart disease. Ultimately, it might even make it possible for humans to travel into deep space.

An intriguing aspect of extraordinary adaptations is that they often have knock-on effects on the rest of an animal's physiology. Many creatures that can survive without oxygen or that can lower their metabolic rates, for example, have unusually long, seemingly ageing-free lives. A case in point are naked mole rats, small rodents that should, based on body size, live for a mere five years, but instead can survive for 30. Even then, the cause of their demise is a mystery. "I don't know what they die of," says Buffenstein, who studies them.

A naked mole rat's life is long but unenviable. The animals live underground in stifling tunnels where oxygen levels are extremely low. The earth they dig through is laced with toxic heavy metals and the tubers they eat are poisonous. On the bright side, living underground means they avoid predators and disease. This, it has been

"The red-eared terrapin can survive without oxygen below the ice for six weeks"



STOCK/GETTY IMAGES PLUS

Don't miss Rebecca Nesbit discuss which animals we should save from extinction on 13 October at New Scientist Live
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suggested, means they don't have to race to reproduce and so have evolved to devote more of their resources to combating the cellular damage caused by their stressful environment. Over the years, scientists have tested this resilience by exposing them (or their cells in a dish) to a range of challenges including UV light, toxic compounds and high doses of chemotherapy drugs. The naked mole rat simply shrugs them off. "Most of the time they just put their little third finger up at you and say, 'I don't care,'" says Buffenstein.

This resilience means they don't seem to age. As they get older, their heart function, bone density, muscle mass and metabolism stay healthy. A 30-year-old female mole rat is still highly fertile. What's more, their resistance to developing cancer is legendary. In three decades of study, Buffenstein's team has encountered only five cases of the disease when examining more than 2000 dead animals. They have also inserted versions of genes known to cause cancer into naked mole rat cells in a lab dish. In other mammals, this causes aggressive tumours to grow, but not in these little rodents.

To fully explore the naked mole rat's remarkable capabilities, we will need a complete version of its genome – our best

effort currently has several gaps. But clues are emerging. Unlike red-eared sliders, naked mole rats don't bother producing lots of antioxidants and so end up with bizarrely high levels of cellular damage from an early age. They seem to protect themselves from the consequences of this damage by boosting the activity of genes that stop damaged cells from dividing. These are genes that humans also possess. The rodent's metabolism is unusual too – resembling that of animals on a calorie-restricted diet, which is associated with longevity.

Regenerating pythons

Interest in naked mole rats is high, but only time will tell whether we can tap into their powers to combat ageing and cancer. Meanwhile, another remarkable animal holds the promise of an even more futuristic capability. The python's special power is extreme regeneration. These snakes starve for months before gobbling an entire animal in one sitting. So, to conserve energy, they let their internal organs shrivel between meals. "In a fasting python, the intestine looks like a little tube that's empty," says Todd Castoe at the University of Texas at Arlington. But when

Tardigrades (left)
are capable of suspended animation and wood frogs (far left) can survive freeze-thawing

it does eat, a python rebuilds with explosive speed. Within a day, the small intestine has more than doubled its mass and other organs, including the liver, pancreas, heart and kidneys all swell by a half or more. Then, between 24 and 48 hours after eating, its innards start withering back to starvation mode, and the whole process is reversed in just two weeks.

Underlying this dramatic transformation is an equally dramatic burst of gene activity. Castoe's team compared this activity in different organs at different times before and after feeding. Predictably, many of the genes are involved in growth. But what intrigues Castoe are other genes that usually help protect cells against stress and were previously only associated with cancer and ageing. Turning these stress-response genes off while the growth ones remain on seems to trigger the organs to shrink back down again. "We think we've discovered a kind of back-door switch for how to modulate regenerative growth in a vertebrate," says Castoe.

The big question is what controls this dramatic response. The answer seems to be something in the snake's blood. Add plasma – the liquid part of blood – from a recently fed snake to rat cells in a dish, and they undergo a burst of growth, switching on a similar suite of genes to those the snake cells activate. This suggests that whatever is signalling to the python's organs can talk to mammalian cells too. Castoe's team is now hot on the trail of the mysterious signal. "I don't think you'd ever want a drug that made every one of your organs freak out and grow," he says. But the possibility of using insights from pythons to regenerate specific organs or block the growth of tumours is tantalising.

There is more to this research than mimicking animal superpowers. Extreme adaptations also offer a unique window into our own biology. For example, researchers are investigating pythons to better understand how our physiology changes after eating, in a bid to learn more about conditions such as diabetes and obesity.

Nature's fantastic beasts can help us see what life is capable of, too. "What we're learning about basic biology from such a weird perspective is so valuable," says Castoe. "It's almost like looking at a mountain from 90 degrees to one side." ■



Claire Ainsworth is a freelance writer based in Hampshire, UK

Dark secrets

Tiny, ancient black holes could solve cosmology's biggest puzzles, says **Leah Crane**





IN THE beginning, there was light. Then, perhaps, a point of darkness. More dark spots appeared, the light circling them before falling in like water down a drain. These would have been our universe's first inhabitants, strange baby black holes gorging on the radiation that flooded out of the big bang. As the cosmos expanded and cooled, their feasting slowed.

Millions of years passed, some of the radiation that filled the cosmos giving way to matter, which eventually clumped together to form the first stars, planets and galaxies. Over time, some stars grew so large that when they ran out of fuel and collapsed, they turned into black holes themselves. But what happened to their distant ancestors from the dawn of time? Maybe those very first, primordial black holes faded away or perhaps they were big enough to survive to the present. Either way, they could help solve some of the biggest problems in cosmology. If they were ever there.

The concept of black holes, objects so enormously dense that not even light can escape their gravitational pull, has haunted cosmology for decades. Until recently, we had no direct evidence they existed. That changed in 2015, when the Laser Interferometer Gravitational-Wave Observatory (LIGO) detected the aftershock of a pair of black holes colliding 1.3 billion light years away.

Experiments such as LIGO could be our best shot at finding evidence of primordial black holes too. In fact, some people think we have already spotted them. That would be a monumental discovery because these cosmic ancients wouldn't only be our universe's first black holes, but also its most interesting.

The universe's earliest moments saw a period of rapid expansion called inflation. Areas of space-time that once sat side by side

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shot apart faster than the speed of light, never to come into contact again. In some models of this process, tiny fluctuations in the universe's density prior to inflation would have resulted in small areas of extreme density immediately afterwards. In those moments, a fraction of a second after the big bang, these areas could have pulled in beams of ambient light before collapsing into black holes. Any that formed from this primeval radiation would rank as primordial black holes.

In 1975, the possible existence of these cosmic old-timers sparked widespread interest when Stephen Hawking published a landmark paper on the properties of black holes. He calculated that black holes should emit particles in a process called Hawking radiation, causing them to slowly shrink and – eventually – evaporate.

Hawking radiation would be a particularly significant factor for primordial black holes. Regular, or astrophysical, black holes form from the collapse of dense stars, with a minimum mass of about 1.4 times that of our sun. But primordial black holes are created via the direct collapse of lots of radiation, so they can be as small as you like. That is bad news for their longevity. "How long a black hole lives depends on its mass: the smaller it is, the shorter it lives," says Francesca Vidotto at the University of the Basque Country in Spain. Accelerated evaporation of primordial black holes makes them an obvious place to look for traces of Hawking radiation.

More than 40 years on, no such traces have been spotted. And as primordial black holes remained equally invisible, interest in them waned. Lately, though, that is changing. "The really exciting thing about primordial black holes is that there are so many mysteries that in principle they could explain," says Bernard Carr at Queen Mary, University of London, who worked on these objects with Hawking.

Cosmic clean-up

For one thing, they might make up the mysterious substance we call dark matter. For decades, galaxies have been observed rotating faster than they should given all the visible stuff within them. That has led cosmologists to believe that an invisible "dark" matter lurks within these galaxies too, giving them the gravitational heft they need to spin at the speeds we see without flying apart. "We're pretty sure dark matter exists, but we have no idea what it is," says Anne Green at the University of Nottingham in the UK.

The preferred candidate has long been ➤

vast numbers of tiny particles, each possessing mass but lacking the capacity to interact with ordinary matter. Yet although these weakly interacting massive particles, or WIMPs, remain the theoretical front runners, they have yet to show up in experiments. "That's why primordial black holes are getting more interest lately," says Green.

If WIMPs don't make up dark matter, there are a host of rivals waiting to take their place. On the other end of the spectrum, appropriately enough, are MACHOs: massive compact halo objects. These are large objects that float freely through space and emit little if any radiation, which would explain why we haven't seen them. Neutron stars and starless planets have been proposed as MACHOs, as have primordial black holes.

"Primordial black holes are my favourite explanation for dark matter," says Vidotto. Astronomical observations, however, have concluded that they are unlikely to account for all of dark matter, which means there must be something else out there to pick up the slack. If WIMPs made up the other part, we would expect them to surround every primordial black hole, drawn in by its gravitational pull. That higher density of WIMPs would increase the probability of WIMP-WIMP collisions, generating a distinctive shower of gamma rays that has never been seen.

"If one day we discovered even a few primordial black holes, you just have to concede that whatever dark matter is, not all of it is made of WIMPs," says Dan Hooper, head of the theoretical astrophysics group at Fermilab in Illinois.

Another, more intriguing, option is that the primordial black holes could be creating the dark matter particles themselves through the medium of Hawking radiation. Calculations predict that the bigger one of these black holes is, the lower its temperature, meaning it emits fewer and lighter particles. As it shrinks, it heats up, radiating more and more energy. That means small primordial black holes can spew more massive, complex particles.

"The kinds of particles that are generated by Hawking radiation don't depend on the stuff that falls into a black hole," says Hooper. "The black hole doesn't care what kind of particle you are, you're just as likely to be made. That includes dark matter and everything else." Whatever particles exist, whether they are predicted by the standard model of particle physics or not, should be emitted by primordial black holes as they evaporate.

That includes massive dark matter particles that are too big for us to create in the Large

LIGO may have spotted the universe's first black holes

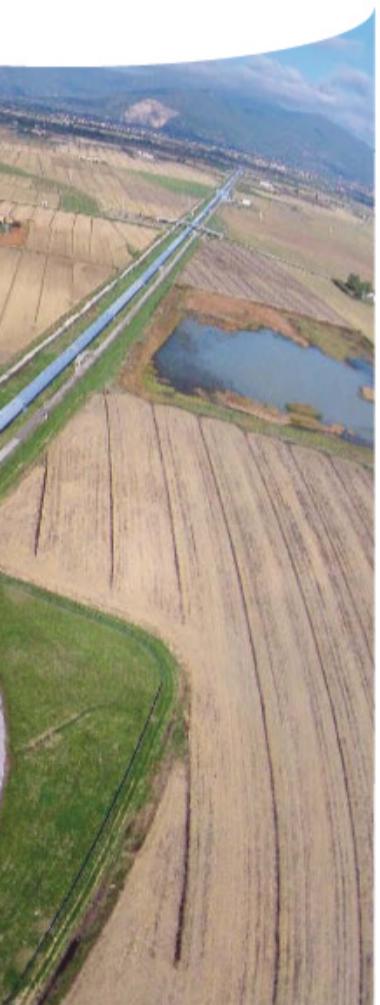
// Ancient black holes would give us access to physics we would never otherwise be able to do"



Hadron Collider or any experiments planned on Earth. "If we can find primordial black holes and observe them in their last few seconds as they get to those high temperatures, it gives us access to physics that we'd never otherwise be able to do," says Jane MacGibbon at the University of North Florida. If those massive particles do exist, they could turn the standard model on its head.

Primordial black holes could clear up other cosmological conundrums too. One of the biggest puzzles in the universe today is the mystery surrounding its present rate of expansion. At the moment, we have two ways of measuring it: one involves flashing a speed gun at nearby objects to detect their acceleration away from us, the other extrapolates data from ancient light to work out a current value.

The trouble is, the two methods produce conflicting results – they are in tension. "One thing that is known to relax this tension is if there was some extra 'dark' radiation earlier in the universe's history," says Hooper. So-called dark radiation – particles that move close to the speed of light and can travel straight through matter without stopping – could be emitted by primordial black holes as they evaporate away. If enough of these black holes existed in the early universe, that extra



"I definitely think that primordial black holes are out there. I am convinced that we will find one"

radiation could have given a little oomph to its expansion, explaining the discrepancy in our cosmological measurements.

That isn't all. Most large galaxies have supermassive black holes at their centres that are up to tens of billions of times the mass of the sun. Based on our understanding of how standard black holes form, these enormous objects are impossible – there just hasn't been enough time for a star to grow big enough to collapse into a black hole that can get anywhere near that large. But if supermassive black holes have been there since moments after the big bang, there's no problem. "If you start out with a million-solar-mass black hole in the early universe, it's easy to get to a billion," says Carr.

Where are they then?

For all the excitement surrounding black holes, until recently, the evidence for their existence was pretty thin. Then LIGO switched on. An enormous international collaboration, LIGO searches for ripples in the fabric of space-time caused by the movement of massive objects. Since it spotted its first black hole collisions in 2015, the experiment has turned up evidence for about 30 more, ranging in size from just a few times the mass of the sun to more than 50 times bigger.

In the intervening years, some physicists have suggested that LIGO may actually have detected primordial black holes colliding, rather than standard stellar black holes. The idea isn't widely accepted by astrophysicists, but remains tantalisingly plausible.

One reason to suspect the LIGO black holes may actually be primordial is that most don't seem to be spinning. "If the black holes which are detected by LIGO come from stars, those stars are in binary systems so you tend to get black holes that form with some spin," says Carr. "But primordial black holes born in the early universe don't tend to have spin."

Another hint comes from calculations of when primordial black holes were most likely to have formed – when the pressure in the universe dipped slightly and allowed for more intense gravitational collapse. When they formed can tell us what their masses would probably be today. One of these dips lines up with a primordial black hole mass about 30 times that of the sun, similar to the masses of most of the LIGO black holes. "We predicted before the LIGO detections that black holes of this size should have formed in the early universe," says Juan García-Bellido at the Autonomous University of Madrid, Spain. "Most astronomers did not expect LIGO's first black holes to be this massive, but they were."

The easiest way to catch primordial black holes red-handed is probably with LIGO. We could alternatively look for radiation emitted by matter falling into them, or use gravitational lensing, a phenomenon whereby massive objects stretch and distort the light passing near them. Some researchers, such as Carr and García-Bellido, suspect we may already have seen primordial black holes acting as lenses, but other objects could have been responsible.

So how do we know for sure if we have spotted a primordial black hole? A small size is one obvious sign, but some could be just as big as regular black holes – or, indeed, supermassive. Looking at how much energy they emit over time could help, says MacGibbon. "With most objects in astrophysics, you see the energy decaying with time, whereas an evaporating black hole would be rising higher and higher in temperature and energy," she says.

We could also look extraordinarily far away. By doing so, we would be peering back billions of years, into the first few hundred million years of the universe. "A pretty definitive way you could know you're looking at primordial black holes would be to see a black hole binary system really far away, at a very early time in the universe," says Adam Coogan at the University of Amsterdam in the Netherlands, as such systems with non-primordial black holes wouldn't have been possible then.

Beyond finding a small, evaporating black hole or spotting one in the early universe, though, there are very few ways to prove that an observed black hole is primordial. And the lack of evidence even has those who study them unsure. Carr, who has devoted his career to these black holes, puts the probability that they are real at between 20 and 50 per cent.

The promise of these early universe relics to explain so many cosmic phenomena is a powerful motivation to keep up the hunt. "I definitely think that primordial black holes are out there," says García-Bellido. "I am convinced that we will find one." Carr says the search must go on. "We had to wait 100 years after gravitational waves were predicted before we found them, for black holes we had to wait 50 years, and if primordial black holes exist, we shouldn't be too surprised if we have to wait another 50 years to find them." If he is right, then the wait will have been worth it. ■



Leah Crane is a reporter at New Scientist. She tweets @downhereonearth

The scent of you

Human smells evolved to be a rich channel of communication, so why do we work so hard to hide them, asks **Kate Douglas**



IAM standing in a bright and airy converted barn in the English countryside sniffing vials of pure armpit odour. The contents of these five tiny bottles are so pungent they actually knock me back. I'm getting top notes of cheeses – stinky as they come – lots of sulphurous onion and a hit of ammonia. The least offensive has a citrusy undertone. The bottles are provided by Camille Ferenzi of the French National Centre for Scientific Research (CNRS) in Lyon, whose work includes recruiting volunteers to sniff sweaty T-shirts. Clearly, studying human smells isn't for the squeamish.

Our bodily scents provide a channel of communication that evolved to help us survive and thrive, and in recent years Ferenzi and others have revealed this language to be far richer than we realised. We have now discovered that each person's scent is unique – not even identical twins smell exactly alike. Each of us also has a one-of-a-kind nose for smells. What's more, we have learned that scents wafting from our bodies and wisping into our nostrils help us to forge family bonds and draw us to partners, divert us from danger, illness and aggression, and even allow us to sniff other people's happiness.

Yet throughout history and across cultures, people have scrubbed, perfumed and deodorised to disguise their natural smells – perhaps never more than today. "Every day, we control our olfactory image," says Ferenzi. If these smells are such a powerful form of communication, our aversion to them is puzzling. And recent evidence

suggests we are getting less stinky and losing the ability to detect certain scents. What the smell is going on?

The role of smell in our lives begins before we are born. Many odour chemicals from foods can cross the placenta, says Benoist Schaal at CNRS in Dijon, giving fetuses a taste of what their mother is eating. That may help explain why, after birth, babies find the smell of human milk – also flavoured by their mother's diet – intrinsically attractive. Schaal's team has even found that a mother's odour helps her newborn's brain to identify faces, suggesting that from an early age, even mainly visual processes incorporate smell. He speculates that babies may have an early sensitive period for their mother's smell, which fortifies the

drive to bond, like the "imprinting" we see in birds and some other mammals.

The scent of newborns makes quite an impression on other people too. The smell of a new baby's head activates reward circuitry in adult brains, similar to when we receive a treat or even take a drug. That is a potent way for babies to remind us to look after them.

Newborn smell evaporates away by about 6 weeks of age, but as we get older, a vast range of things influence our personal bouquets: diet, age, fertility, illness, even state of mind. So individual are our scents that some have tried to use "odourprints" to identify criminals, or "nose witnesses" to sniff out suspects in a line-up. And it isn't just how you smell to others that is unique, but your sense of smell too (see "Can you smell that?", page 46).

But what exactly constitutes your particular aroma, the scent of you? The realm of human smells is vast, and most of our knowledge about it is confined to the underarms. That is what we generally negatively think of as body odour (BO), although armpit odour is unlike other noxious smells. "It is not a typical bad or 'off' odour, even if we perceive it as such," says Andreas Natsch, a scientist at fragrance firm Givaudan. In other words, it doesn't contain the small volatile chemicals associated with things like sour milk, decay and faeces – although our breath and foot smells may.

Instead, armpit odour has three key components: thiols, steroids and a diverse set of acids. All three are secreted as odourless precursors and then converted into smelly

"There is no doubt that we can smell fear, stress and anxiety in others"

compounds by microbes living on our bodies, says Natsch. We know genetics plays some part, and that it is the microbes, not the precursors, that determine how ripe you get. But we still don't know all the steps in the process.

Getting sniffy

In general, people with lots of bacteria in the genus *Corynebacterium*, which are more common in men, tend to smell pungent, whereas those with lots of *Staphylococcus* are less smelly. Men also tend to sweat more, releasing more precursors to feed those musky microbes – another reason they are generally the stinkier sex.

It may come across as rude, but recoiling from someone's oniony underarms is a long-evolved reaction. "There's a high sensitivity of the human nose to these odorants," says Natsch. "This indicates that they had some function in human history, even if today they are just malodours."

Until recently, it was thought that we could detect only about 10,000 scents. In 2017, this idea was exposed as a myth by John McGann at Rutgers University in New Jersey. Comparing the neuroanatomy of 24 mammals, he found that humans can smell up to a trillion different odours – similar to a dog or a rat.

Still, the notion that smell is less important for us persists. "We humans don't typically walk up to strangers and overtly sniff them," says Noam Sobel at the Weizmann Institute of Science, Israel. "Or do we?" His team has shown that we sniff our hands a lot and are twice as likely to do so after shaking hands

with a stranger. Handshaking is just one of the subtle ways we sample someone else's scent. "People constantly sniff themselves and others," says Sobel.

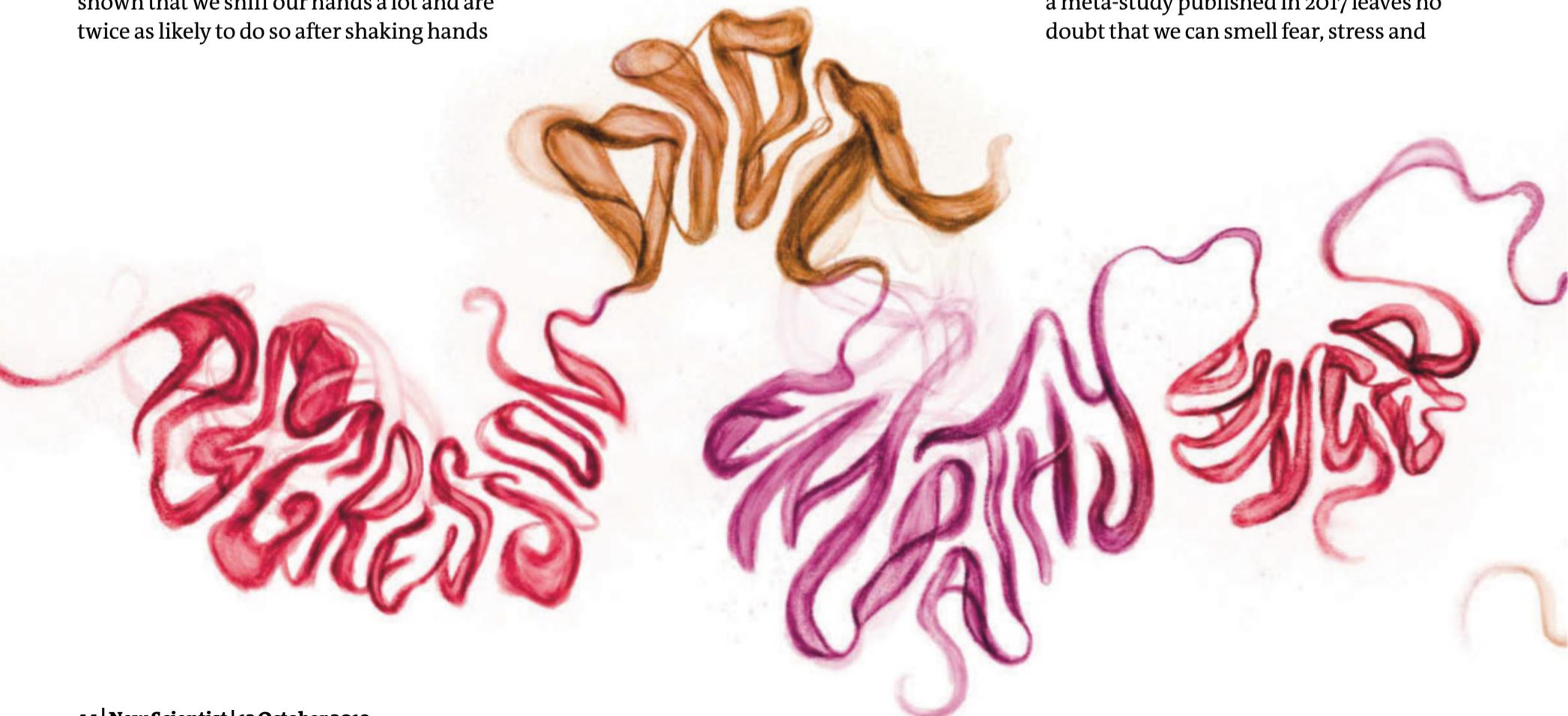
What are we trying to suss out with all of this sniffing? Despite popular enthusiasm for the idea, there is still no good evidence for specific pheromones that drive sexual attraction (see "Love potion", opposite). But many researchers, including Tristram Wyatt at the University of Oxford, think we probably do produce pheromones – chemicals that have evolved to trigger a specific behaviour in the individual who smells them. He believes the first will be discovered between mothers and their babies, where we already know scent plays a role in bonding and that mothers can recognise their infant's smell minutes after birth.

"Handshaking is just one of the subtle ways we sample someone else's scent. We constantly sniff each other"

Body odour undoubtedly plays a broader role in kin recognition, but studies show surprisingly inconsistent results. "Kin recognition is based on both familiarity and a genetic component," says Ilona Croy at the Technical University of Dresden, Germany. She notes that not all mothers recognise the smell of their children but, if they do, they much prefer it to the smell of other kids. "Familiarity seems to be more important," she says.

The genetic component of kin recognition by smell is puzzling. It is thought to rest on the human leukocyte antigen (HLA) set of genes, which varies a lot between individuals and codes for proteins associated with immunity. It has been assumed that humans are sexually attracted to the smell of people whose HLA is dissimilar to our own, based on reams of research suggesting this is the case for many animals. That would be an evolutionary boon for offspring because the more diverse a person's HLA, the stronger their immune system. But studies in humans have been disparate and controversial, and a 2017 meta-analysis failed to confirm that HLA drives sexual attraction, even though it did show that we prefer people with high HLA diversity. "This is just a small part of partner choice," says Jan Havlíček at Charles University, Czech Republic, whose own studies reveal that the HLAs of real couples are actually more similar than those of randomly chosen ones.

Beyond bonding, our bodily odours convey a whole other world of meaning, particularly where emotions are concerned. For example, a meta-study published in 2017 leaves no doubt that we can smell fear, stress and



anxiety in the body odours of others. Recently, researchers from Sobel's lab analysed skydivers' sweat during their first jump and found it contained 29 volatile compounds not present before. Similarly, using sweat from cage fighters, Havlíček and his colleagues discovered that people can identify winners and losers, suggesting that smell helps us recognise dominance.

Sobel's team has also found that sniffing tears resulting from negative emotions lowers testosterone in men, possibly through a volatile chemical called hexadecanal, which modulates aggression in mammals. Some work has even shown that smelling someone else's anxiety can promote empathy.

Less research has been done on whether body odour conveys positive emotions, but it has been shown that the scent of a loved one can reduce stress. Ferdenzi believes that the smell of positive emotions, even in strangers, may help explain why happiness is contagious. In not-yet-published work, her team has shown that the smell of happy people produces feel-good physiological responses in others.

Clearly BO evolved over millennia to be a subtle and multifaceted channel of communication, but the fact remains that it often grosses us out. Why? One reason is obvious: certain bodily odours are intended to repel. This is true of smells connected with disease. We can't all be super-sniffers like Joy Milne, the woman who can detect the scent of Parkinson's disease, but anyone can learn to recognise a range of illnesses including diabetes, pneumonia, cholera and certain cancers from specific smells given

LOVE POTION

A host of online products claim to offer sexual allure in a bottle. They tend to contain steroids found in armpit odours, including androstadienone and estratetraenol, suggested as the first human pheromones in 1991.

They are no such thing, says Tristram Wyatt at the University of Oxford. Pheromones trigger specific behaviour when smelled, but as yet there is no robust evidence for any particular ones with a role in human sexual attraction.

"They were plucked out of thin air," says Wyatt, then patented by a fragrance company to add to perfumes. Many papers have been published since, but the research is like an echo chamber. "There's no more evidence now than there was then," he says.

off in sweat, breath, urine and faeces.

Even without medical training, we find an individual's sweat more intense and less pleasant when they are ill, says Mats Olsson at the Karolinska Institute in Sweden. His experiments reveal that, via sweat, we subconsciously detect when someone else's immune system is ramped up in response to an infection, and our own leaps into action.

Being repulsed by particular body odours can help us avoid other dangers too. "Kin recognition serves two main purposes: one is bonding, the other is incest avoidance," says Croy. That would explain the finding that parents come to dislike the smell of their opposite-sex children when they reach puberty. The scent of aggression may put us on alert too. Bettina Pause at Heinrich Heine University Dusseldorf, Germany, has found a distinctive response in the sensory processing part of women's brains when they sniff sweat from aggressive men, something she believes evolved to help women avoid violence.

Sickly smell

An obvious reason why, unlike other mammals, we work hard to wash away our smells is that we understand the link between poor personal hygiene and disease – we know that washing can increase our chances of survival. In fact, anthropologists argue that our changing attitudes towards personal hygiene coincided with the rise of urbanisation around the industrial revolution, says Asifa Majid at the University of York, UK.

Natsch points out that there is a much longer history of personal hygiene in East Asia, which might help explain the curious fact that many Asian people have naturally odourless armpits. Thanks to a one-off genetic mutation of the *ABCC11* gene, 95 per cent of ethnic Chinese people and some 70 per cent of East Asians don't produce chemical precursors of armpit odours. We don't know when the mutation happened, says Natsch, but an aversion to BO would have helped it succeed.

All this goes some way to explaining our distaste for bodily odours. However, there are plenty of scents that we love – and not just from those irresistible babies. In the right circumstances, we appreciate even the most pungent human odours. We are less disgusted by the nasty odours of our nearest and dearest – the so-called source effect, for example. And we positively enjoy the smell of someone we are sexually attracted to when dancing with them. Sometimes context doesn't even matter, says Ferdenzi, recalling that, after her first study, ➤



CAN YOU SMELL THAT?

Our noses are home to about 6 million smell receptors of some 400 different types – compared with just three kinds for vision. Genetic variations affect the way these work, and there are five such variations, on average, per receptor. Most odours activate several receptors, but a change in a single receptor is often enough to alter the way we perceive particular smells, including their pleasantness.

It isn't easy to measure something as subjective as smell. Having people describe aspects of certain odours such as strength, pleasantness and quality has revealed that we can perceive similar compounds very differently.

"There's a lot of variation among people in odours that have been tested," says Casey Trimmer, a scientist at fragrance company Firmenich.

That's just the first level of smell perception. "A whole other level happens in the brain," says Trimmer. How you perceive smells depends on exposure, expectations and associations, but there are probably some universals. Asifa Majid at the University of York, UK, has found that Westerners and hunter-gatherers from Malaysia display similar facial expressions in response to particular smelly compounds. "That suggests there may be some shared element to what we find pleasant and unpleasant," she says.

Having a particularly acute sense of smell – which is more common in women than men – also influences our perceptions. "As you find an odour more intense, you tend to find it less pleasant," says Trimmer. She thinks that may be caused by overstimulation, but notes that some odours, such as vanillin, don't offend even at high concentrations.

IG/TOM GRILL/GETTY IMAGES



Mothers can identify their babies by scent within minutes of giving birth

one of the volunteers asked if she could have the contact details for sweaty T-shirt No6.

Even as we are learning more about the subtle scent cues we send and receive, genetic studies now indicate that humanity as a whole is losing touch with its olfactory communication channel – and not just because we are evolving to stink less. A significant proportion of people have a selective anosmia, or loss of smell, for the major compounds found in armpit odour, says Natsch. For example, up to 40 per cent are unable to smell androstenone, a putative sex pheromone. "There seems to be an accelerated evolutionary loss of the ability to smell body odours," he says.

Missed messages

Intriguingly, modern languages may reflect this loss. Most, like English, lack a decent lexicon for smell. We have relatively few words to describe specific scents compared with languages such as Umpila, which is spoken by a traditionally hunter-gatherer community in Australia. "Maybe in that kind of environment smell is a much more salient signal. That's why you end up with a language for it," says Majid. Hunter-gatherers also don't share our enthusiasm for disguising their bodily smells, she notes.

That loss goes both ways. Having a lexicon of smell enhances people's appreciation of this unsung sense. "Once you have it in language, it's more part of your conscious awareness," says Majid. Without this awareness, we are probably missing out on some of the subtle

signals that body odour transmits about others. On the other hand, with the evolution of language, perhaps humans didn't need to rely on smell as much as other mammals because we could verbalise some of the messages it carries. But Ferenzi, for one, is unconvinced. "Language and body odour are totally different ways of communicating," she says. "There is this subliminal effect of olfaction that we absolutely cannot control."

Whatever the reasons for our changing relationship with human smells, we may be paying a price. Anosmia – which affects around 5 per cent of people – is an extreme version, but we know that it can undermine quality of life and increase risk for depression. And smell fortifies our relationships in ways we may only appreciate once the people, or their scents, are gone. When Thomas Hummel at the Technical University Dresden asked anosmics which odours they missed most, many said it was the smell of their loved ones.

But there are things we can do. We can all learn to smell more "mindfully", according to Hummel. In his efforts to help people with anosmia, he found that simply sniffing odours consciously and regularly radically improves anyone's ability to smell. "It alerts people to smell smells," he says.

Even if we could do more to appreciate their influence or stop taking them for granted, sometimes the power of human scents is undeniable. "It's not just an ancient sense we don't use anymore," says Ferenzi. Just ask sweaty T-shirt No6. ■

Kate Douglas is a features editor at New Scientist

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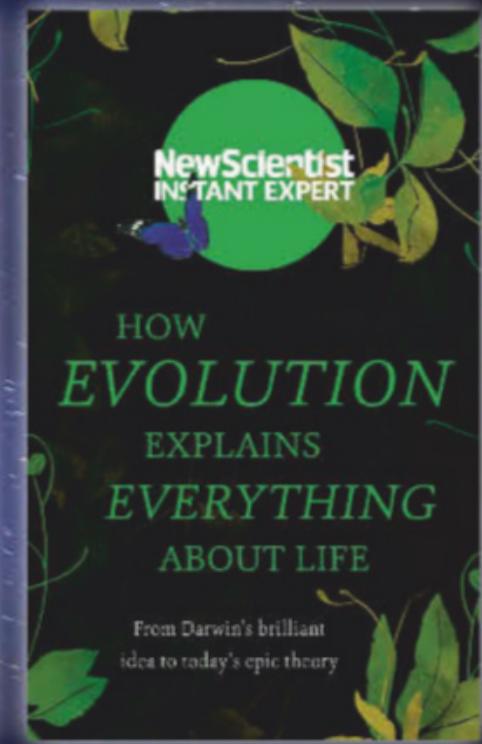
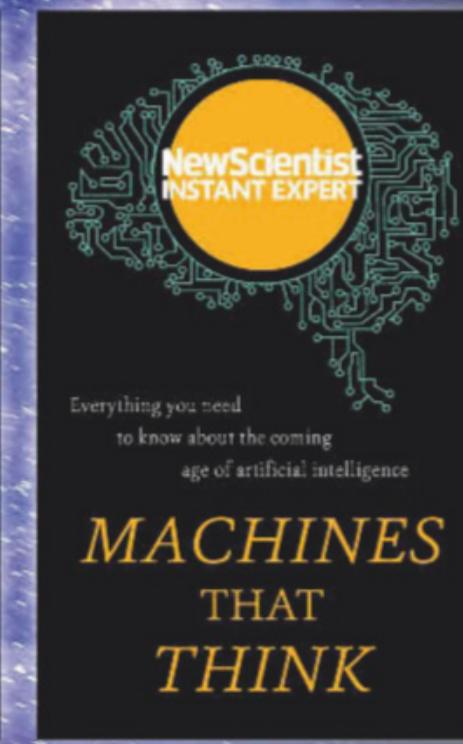
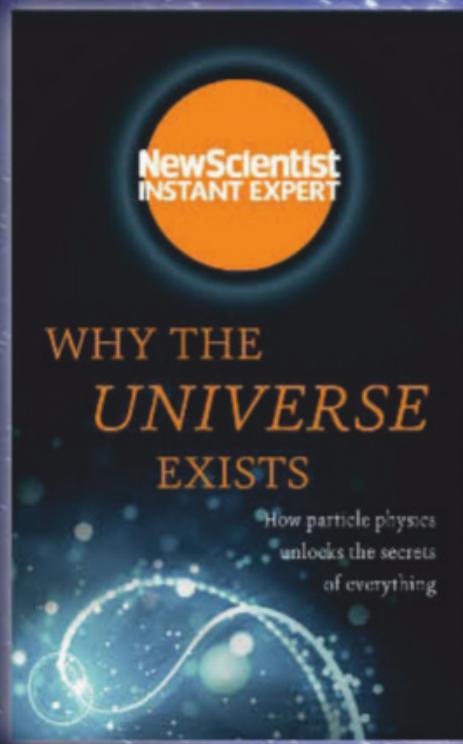
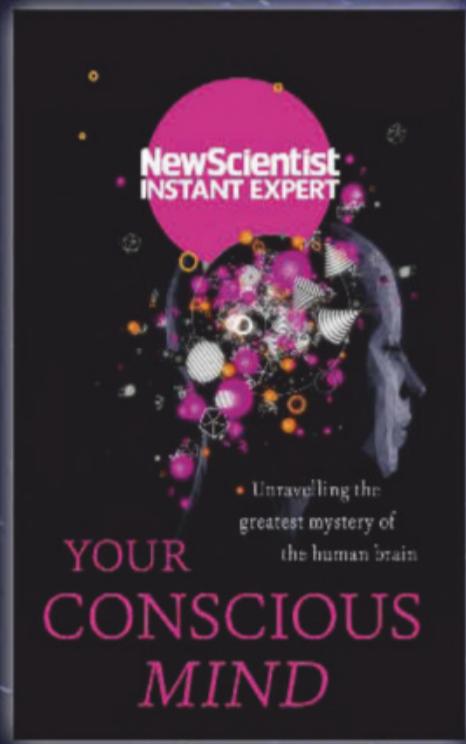
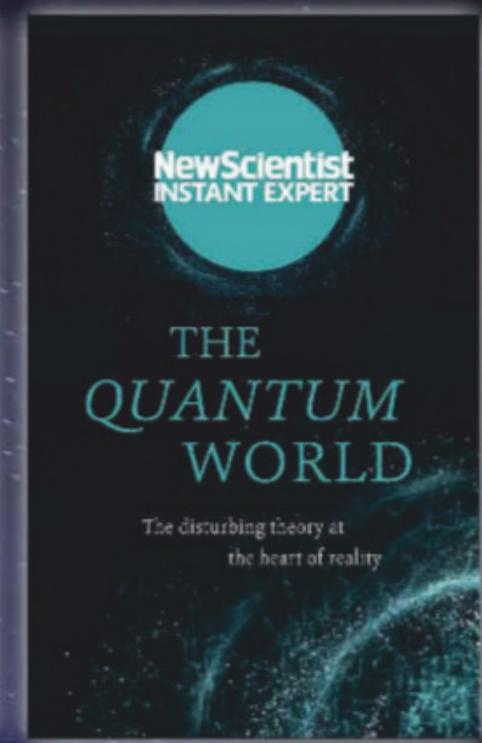
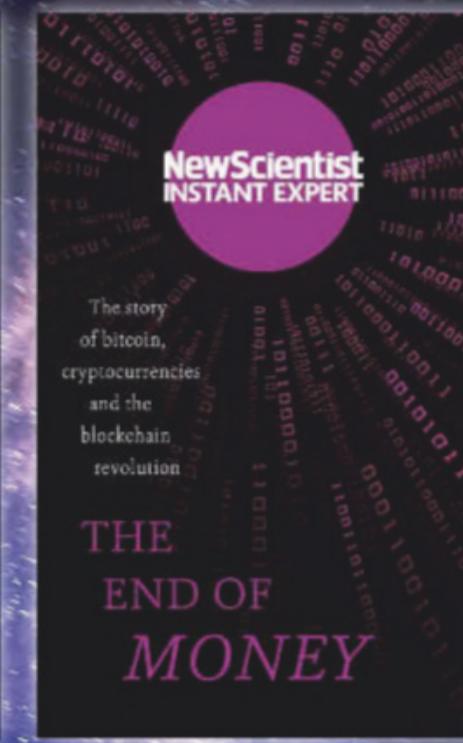
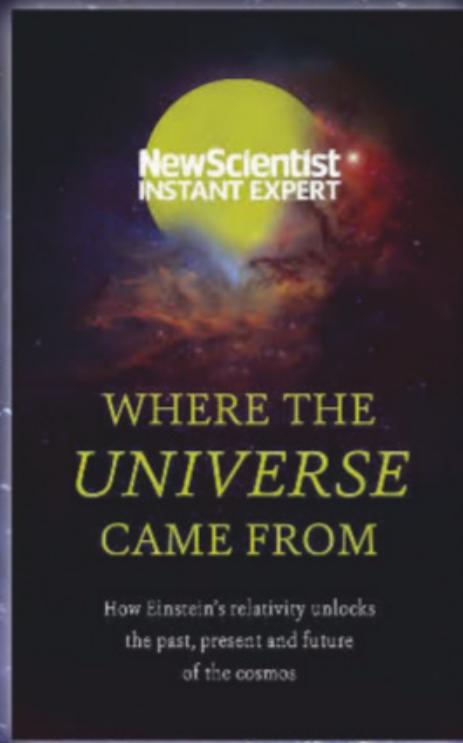
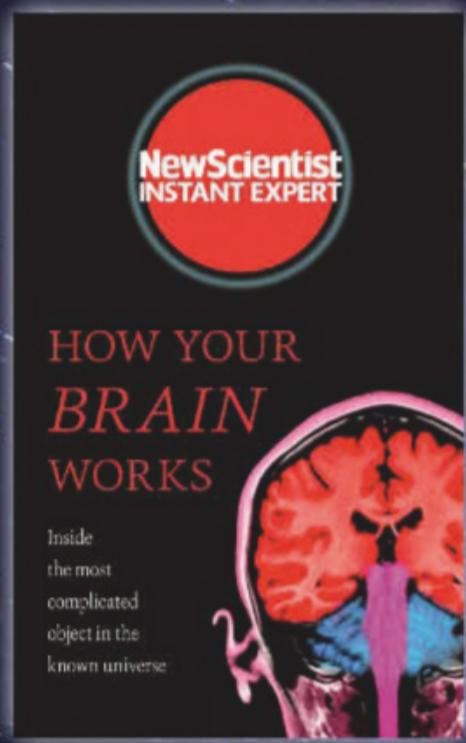
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Stargazing at home **Week 4**

Land of a million craters

Discover the moon's fascinating history – and ours – by spotting lunar craters with **Abigail Beall**



Abigail Beall is a science writer in Leeds, UK. This series is based on her book *The Art of Urban Astronomy* @abbybeall

What you need

Binoculars

For next week

You don't need anything

THE moon is our closest celestial neighbour. It is just 385,000 kilometres away, which means it is easy to see surface features using binoculars, and so get a glimpse into its history – and our own.

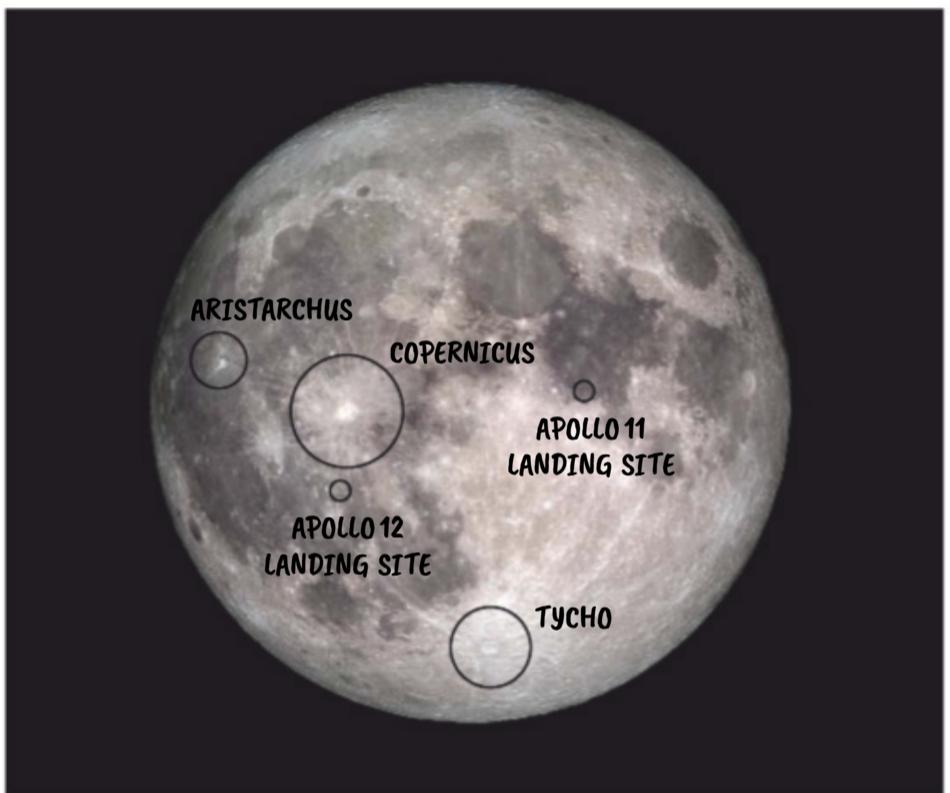
Unlike Earth, the moon has almost no atmosphere. This means there is nothing to slow down or burn up incoming rocks and dust, so everything hits the surface. You would never see a shooting star from the surface of the moon.

And because the moon isn't geologically active, the signs of those impacts aren't erased as they are on Earth. The moon is entirely covered in craters, some billions of years old, and studying them can tell us about the history of the solar system.

The best time to spot craters is two days either side of a full moon, when light from the sun highlights them clearly. The next full moon is on 13 or 14 October, depending where you live.

That's true despite the moon being dimmer than normal right now. The moon's orbit is elliptical, and on 10 October it reached its furthest point, or apogee, from Earth. At its closest point, or perigee, it is 50,000 kilometres nearer and appears 30 per cent brighter and 14 per cent larger than an average full moon.

The first thing to notice when looking at the moon are the dark and light areas. The dark parts are maria, basalt plains that formed from lava flows – and evidence that the moon was once volcanic. The lighter parts are the highlands, made of lighter-coloured rock.



Stargazing at home online

Projects will be posted online each week at newscientist.com/maker Email: maker@newscientist.com

Next in the series

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2 Find the North Star and Southern Cross

3 Test your area's light pollution

4 Identify the craters of the moon

5 Orion and Sirius: how to star-hop
A handy trick for stargazers

6 Planet spotting: Mars, Mercury and Uranus

7 Taurus and the zodiacal constellations

In the middle of the big mare to the left is Copernicus, a crater 93 kilometres wide. You might see long streaks radiating out from it. These were formed by material thrown out by an impact 800 million years ago. We know the age because Apollo 12 astronauts took samples of this material; the landing site is just to the south.

You can also use Copernicus to find the Apollo 11 landing site. Look about a third of the moon's width to its right and you can imagine Neil Armstrong stepping out of Apollo 11's lunar module, Eagle, 50 years ago.

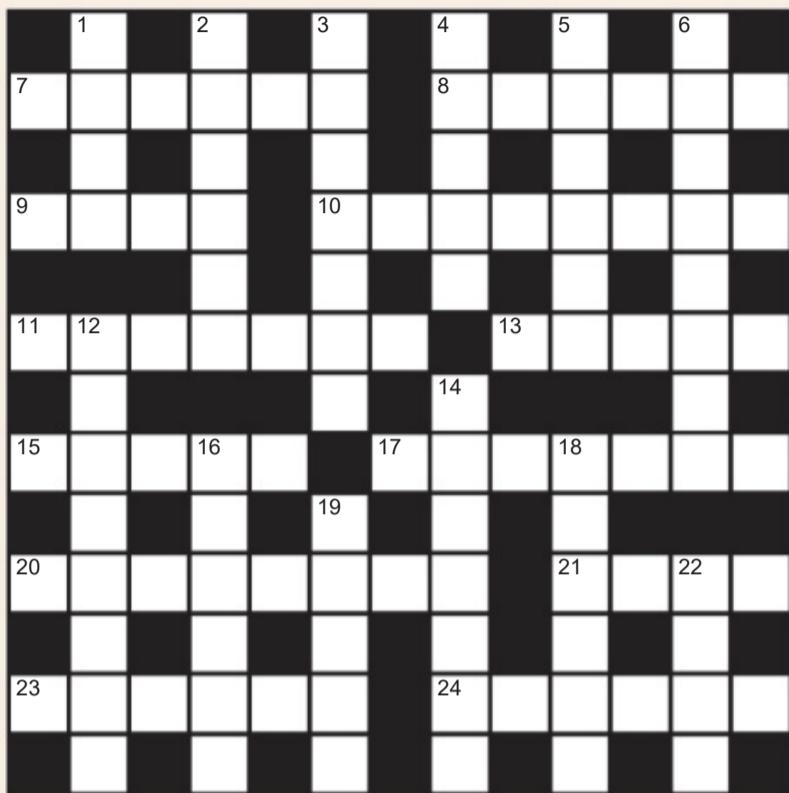
To the left of Copernicus is Aristarchus, the moon's brightest

crater. It is bright because the pale rock of its steep, 2.7-kilometre sides reflect a lot of sunlight.

Now look at the south of the moon to find Tycho, a giant crater nearly 5 kilometres deep. In 1968, the uncrewed Surveyor 7 mission landed on its edge and analysis of its samples tell us the crater is just 108 million years old.

We always see the same side of the moon, thanks to the timing of its orbit. The so-called dark side of the moon looks quite different. Aside from the fact that it gets just as much sun as the side we see, so "dark" is a misnomer, maria cover just 2 per cent of the surface here, so it looks even lighter overall. ■

Cryptic crossword #16 set by Sparticle



In this Tectonic crossword, every answer is formed by the subduction of one word under another. For example, CLIFF might subduct under ROCK to form CROCK. The traditional definition is always at one end of the clue, and clues to the two subducting words appear in the same order as their answers.

ACROSS

- 7** One who fishes can be obtuse medic (6)
- 8** Overly sentimental morally suspect beetle (6)
- 9** Wager indigenous wildlife, inferior in pack life (4)
- 10** Geological period concealed Monty Python's alternative Messiah (8)
- 11** Unpredictable task, a sudden movement (7)
- 13** Fool Armageddon trial (5)
- 15** Cordon off a wetland love affair (5)
- 17** Natural material belongs to me, the Queen's Scottish residence (7)
- 20** Stick to mature geological splitting (8)
- 21** Portable surface intended for beam (4)
- 23** Meet poem to conceal messages (6)
- 24** Rubbish used for fishing gemstone (6)

DOWN

- 1** Bet worker or queen, for example, Indian currency (4)
- 2** European mountain, destination of the Odyssey's star South American mammal (6)
- 3** Rock playwright Bertolt's intelligence service (7)
- 4** Did the breaststroke, not down marshland (5)
- 5** Support fathers' facial hair (6)
- 6** The almighty New Orleans dish mountain (8)
- 12** Mathematician Bernhard: "throw out white wine!" (8)
- 14** Pretend to have been fouled, push, go separate ways (7)
- 16** Stable part of the Earth's crust splits a lot (6)
- 18** Complete doorway anger (6)
- 19** Gemstone surface confronts 1982 alien (5)
- 22** Top primate fornication (4)

Answers and the next quick crossword next week.

Quick quiz #24

1 What name is given to the sudden appearance of most animal lineages in the fossil record starting around 541 million years ago?

2 Soft body parts fossilised in which rock formation in the Canadian Rockies are crucial to understanding that sudden shift in life on Earth?

3 Which US palaeontologist and science populariser's 1989 book *Wonderful Life* brought those Canadian fossils to wider attention?

4 What name, referring to their three major body sections, is given to an extinct group of marine arthropods characteristic of the period in question?

5 What dismissive name is sometimes given to a long period of apparent stasis in evolution, starting around 1.8 billion years ago, before the emergence of animals?

Answers below

Quick Crossword #42

Answers

ACROSS **1** Altered States, **8** Yeti, **9** Betelgeuse, **10** Foetus, **11** HackBook, **12** Westworld, **14** Sine, **15** Tank, **16** Eddington, **20** Pumpkins, **21** Oil rig, **23** Branestawm, **24** Thaw, **25** Bernstein test

DOWN **1** Anemone, **2** Twist, **3** RuBisCO, **4** Dutch elm disease, **5** Telica, **6** Trembling, **7** Systole, **13** Tin opener, **15** True rib, **17** Iron man, **18** Oxidant, **19** Miosis, **22** Litre

Quick quiz #24

Answers

- 5** The boring billion
- 4** Trilobites
- 3** Stephen Jay Gould
- 2** The Burgess Shale
- 1** The Cambrian explosion

Puzzle set by Ben Sparks

#25 Car crash maths



Two cars of the same model, one blue, one yellow, are on a motorway in the UK. The blue car is in the inside lane travelling at 70 miles per hour*, which is the speed limit. The yellow one is speeding in the outside lane at 100mph.

At the instant when they are neck and neck, both drivers see a fallen tree across the road some distance ahead. Both immediately brake, each applying the same constant braking force. The blue car manages to stop centimetres short of the tree. To the nearest 10mph, at what speed does the yellow car hit the tree?

- a) 10mph
- b) 30mph
- c) 50mph
- d) 70mph

Use your intuition (particularly if you are a driver) to have a guess. Then work out the answer to see if you were right.

* Alternatively, call the starting speeds 70 kilometres per hour and 100km/h, the number in the solution will be the same.

Answer next week

#24 Three stamps

Solution

- a) To allow all postage values up to 15 cents using no more than three stamps, the choice of 1¢ and 5¢ stamps is obvious. That leaves the values 4, 8, 9, 12, 13 and 14 unaccounted for, which can be solved by choosing 4¢ as the third stamp. So you need to choose 1¢, 4¢ and 5¢ stamps.
- b) To make all postage values to 24¢ with four stamps or less, choosing 1¢, 4¢ and 8¢ stamps is sensible. To cover the values not possible with those, the fourth stamp must be 7¢.



Get in touch

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Heartbreaking sushi

Can sushi break your heart? That's the question posed by doctors writing in *The BMJ*, after a 60-year-old woman ate a mouthful of wasabi and went into cardiac arrest. The unnamed woman was attending a wedding in Israel when she mistook a bowl of the peppery horseradish paste for avocado.

She experienced pain in her limbs and went to hospital some time later, where doctors diagnosed her with takotsubo cardiomyopathy, also known as broken heart syndrome. The condition arises when the heart's left ventricle, responsible for pumping blood around the body, becomes enlarged and weakened. It is most often seen in older women experiencing emotional distress, such as the death of a loved one. Though serious, the condition is usually temporary. Following treatment, the wasabi-addled woman made a full recovery within a month.

Buying limbs

Looking to get rich quick? The US military has a unique opportunity for you to net a cool \$2 million. One catch: it will cost you an arm and a leg. Left or right, you choose. According to a procurement ad posted to the Federal Business Opportunities website, the US Army Medical Command needs fresh frozen limbs, presumably for use in ballistics testing or for training combat medics.

Either way, it is a once in a lifetime opportunity to serve president and country – or possibly twice in a lifetime, if you are feeling particularly generous. The solicitation requests 16 arms (shoulder included) and 16 legs (pelvis to toe, sacrum included), so get a local rugby union team involved to really maximise your reward. We should specify that the ad does insist limbs should be taken from cadavers rather than volunteers, but if they really cared about getting a quality product, they wouldn't have advertised online.

Gluten tag

"The coconut oil hand cream I bought recently smells good enough to eat," writes Christine Duncan. "I hope that's why the information on the tube tells me that the product doesn't contain gluten, because otherwise I would have to conclude that the world is taking leave of its collective senses."

Before you raid the bathroom cabinet to whip up a batch of macaroons, Christine, be aware: our investigations tell us that the warning exists because topical applications of gluten can still prove irritating to coeliacs.

Nonetheless, Feedback has noticed a proliferation of "gluten free" labels in the local supermarket, often on items that have no obvious connection to wheatgerm. While it is technically true that steak is gluten free, advertising this fact only serves to cast doubt on the coeliac-friendliness of the adjacent chicken breasts that sport no such label.

Which is, perhaps, the intention, as food sellers try to snatch some of the "conscious consumption" aura that a gluten free sticker bestows. Your most egregious examples of this labelling chicanery to the usual address, please.

Contra-noms

John Davies chides our faltering resolve when it comes to swearing off nominative determinism (we have a problem, this much is clear). He suggests a suitable prophylactic: dismantle our hypothesis by collecting names that work in the opposite way.

"For a start," says John, "I give you David Pannick," the barrister who challenged the UK government's prorogation of parliament. "In his recent appearance before the Supreme Court, his performance was widely seen as the epitome of calm control."

Indeed, such anti-nominative determinism (or should that be nominative anti-determinism?) isn't so hard to find. K Bundell

Twisteddoodles for New Scientist



flushes out Sarah Dry, author of the recently published *Waters of the World*. Meanwhile, Danielle Outlaw is a frequent fixture of the Feedback inbox, thanks to her role as chief of the Portland Police Bureau in Oregon. We are sure you have more – help wean us off this terrible addiction for good.

Dog days

"As someone with a very soft spot for rabbits and hares, I enjoyed your report of Peter Duffell's testimony about literate lagomorphs in Northumberland," says Nigel Sinnott (31 August).

"There are literate dogs too, a little further south."

Walking in the outskirts of Sutton-in-Craven in Aire valley, UK, Nigel came across a cattle trough, above which was a notice

with the stern message: "Dogs not allowed to drink at this trough".

"I don't imagine Airedale's literate canines took the slightest heed of the prohibition," he says.

Basket case

The perils of automation: Paul Huggett's online search for the laxative CosmoCol returns the following advert at the top of his results: "Get Quality Constipation, Diarrhoea, IBS & Wind at Tesco." Is there nothing you can't pick up at the supermarket these days?

Foreseeable errors

A colleague tells Feedback that New Scientist's content editing system "offers the option to search for stories that were modified next week". That should make spotting corrections easier. ■

Got a story for Feedback?

Send it to New Scientist, 25 Bedford Street, London WC2E 9ES or you can email us at feedback@newscientist.com



End of an era

Dinosaurs went extinct 66 million years ago, apparently as a result of an asteroid impact. How much time elapsed between that event and the death of the very last dinosaur?

Mike Follows

Sutton Coldfield, West Midlands, UK

The theropod dinosaurs evolved into birds and survive to this day. But the Chicxulub asteroid that rammed into Earth just off the Yucatán peninsula in Mexico 66 million years ago led to the extinction of 75 per cent of all species living at the time.

It isn't possible to be certain of conditions after the impact but it seems likely that it would have created a massive plume of vaporised rock. Within hours, this probably condensed into a rain of molten rock. This in turn could have killed most organisms out in the open and ignited global wildfires. That means animals in caves, underground or in water stood a better chance of surviving the first few hours.

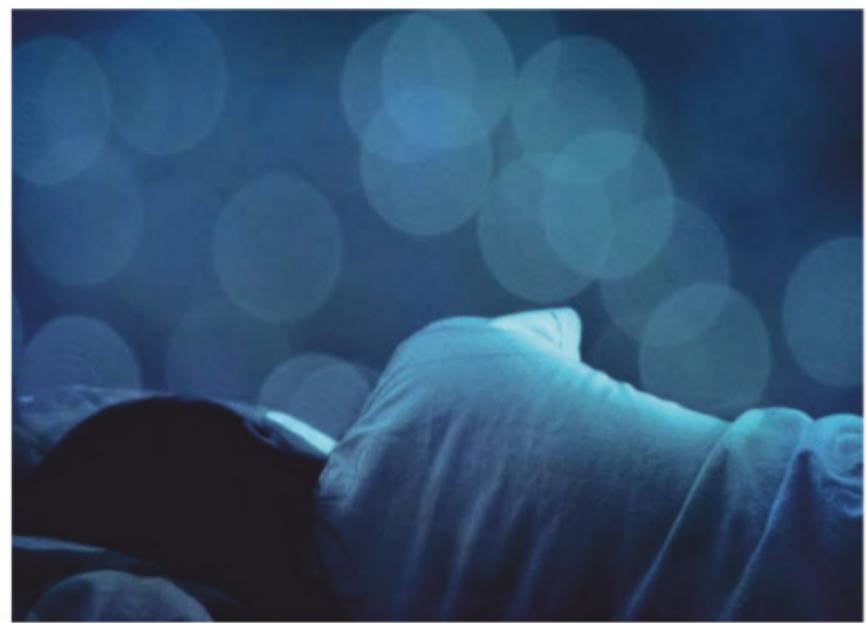
For many, surviving simply prolonged their demise because the dust that was lofted into the stratosphere blocked out sunlight, cooling the globe and reducing photosynthesis, leading to the collapse of food chains.

Once the dust settled, Earth would have experienced global warming because of the release of carbon dioxide into the atmosphere from the wildfires. It is possible that most of the extinctions may have happened within months of the impact.

J. David Archibald

Professor emeritus of biology, San Diego State University, California
The more than 10,000 species of living birds are descendants of the survivors of the asteroid impact.

But dinosaurs were already in decline. In the 10 million years before the impact, the number of species almost halved. A likely cause is the loss of habitats due to the retreat of inland seas and climate change caused by



LESLIE MAGNO/GETTY IMAGES

This week's new questions

Dreamy looks Strangers appear in my dreams. Their features are clear, but none are familiar, not even from an earlier dream. What is going on in my brain, and do others experience the same? **Andrew Ferrier, Eardiston, Worcestershire, UK**

New for old The roll-out of low-emission zones in the UK encourages us to replace cars with newer, lower-emission models. Taking manufacturing into account, how long would it be before reduced emissions make a new car less polluting than keeping the old one? **Karen Pearson, Edinburgh, UK**

volcanism in the Deccan Traps on the Indian subcontinent.

Remaining species of dinosaurs appear to have been doing fine until the Chicxulub asteroid struck. For scale, the Pinatubo eruption in 2001, which injected large amounts of ash and gas high into the atmosphere that spread worldwide, caused an average global cooling of 0.6 °C. The asteroid impact had a cooling effect many magnitudes greater.

Brian King

Barton on Sea, Hampshire, UK
As the author Mark Twain once said, reports of my death are greatly exaggerated. Dinosaurs are alive and well in a chicken coop near you.

Seth Paddle

Melbourne, Australia
In New Zealand, a region that was far from Chicxulub at the time of the impact, a full ecological suite of dinosaurs survived for another million years. Jeffrey Stilwell at

Monash University in Australia and colleagues have found three herbivorous and two carnivorous species. It is interesting to reflect on what prevented the resurgence of dinosaurs from this base.

Fresh fruit

Most fruit and vegetables sold in supermarkets come with a label saying "wash before eating". What are the risks of eating unwashed produce and does a quick sluice under the tap reduce them significantly?

Simon Goodman

Griesheim, Germany
Fruit and vegetables can have contaminants from three sources on their surface: soil, human handling and their own

Why do unfamiliar faces feature in some dreams?

microbiome. All are a potential source of pathogens for us, but those with a compromised immune system, such as older people and pregnant women, are most likely to be affected.

It is possible that some microbes on fruit and veg are helpful, especially those of the plant's microbiome, which may help boost our immune system.

A minority of bacteria and fungi in soil are potentially harmful, including those causing botulism, tetanus, listeriosis and histoplasmosis. Meanwhile, the vegetable microbiome is complex, and in one German study 4 per cent of sampled lettuces were found to be colonised by *E. coli*.

Washing lettuce, including using detergents or disinfectants, was reported not to help remove such contamination – but might get rid of soil and bacteria left by people during handling.

Chris Daniel

Glan Conwy, Conwy, UK
The UK National Health Service advice is to rinse fruit and veg in running water for 30 seconds and rub the surface gently in a bowl of water, using a soft brush if needed to remove any soil. This is claimed to remove most bacteria and pesticides. More effective methods are to soak produce in a 10 per cent salt water solution, vinegar or a 1 per cent solution of sodium bicarbonate, then rinse.

Washing your hands before and after preparing fruit and veg and cleaning chopping boards are also advised. And it is recommended that fruit is washed only as it is used, not as soon as it is brought home, because increased moisture can itself be a breeding ground for bacteria and mould. ■

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The back pages Q&A



Maggie Aderin-Pocock has always been fascinated by space, and sees our future there – even though it would take thousands of years to reach our neighbouring solar systems

As a child, what did you want to do when you grew up?

I wanted to go into space and find out as much about it as I could.

Explain what you do in one easy paragraph.

For many years, I worked as a space scientist. I also do lots of science communication. This year, I have worked on a project involving Stonehenge, helped set up the science behind a TV drama and I am working on a new children's TV programme.

What do you love most about what you do? And what's the worst part?

I love applying scientific knowledge to different situations, and I have set up my own company so I work for myself, which I really enjoy. The flip side is there is lots of paperwork. As a dyslexic, I find this quite hard work, but definitely worth it.

Sum up your life in a one-sentence elevator pitch...

A space scientist who likes to bring the excitement of the amazing things in the universe to the general public, releasing the inner scientist in everyone.

What's the most exciting thing you're working on right now?

I was inspired by the programme *The Clangers* as a child, and this helped me become a space scientist. Now I am part of a team developing a new TV show, which is cosmology for tots.

What achievement or discovery are you most proud of?

I visit schools where I try to reach the children who are disillusioned, to see if I can excite them with the wonders of space. To date, I have met around 350,000 kids around the world.

How has your field of study changed in the time you have been working in it?

Astronomy has changed so much since I was a child. We have bigger telescopes than I would have ever thought possible and are discovering planets travelling around distant stars. The detection of gravitational waves gives us a whole new way of doing astronomy and investigating objects such as black holes and neutron stars.

Were you good at science at school?

Not at first because the dyslexia got in the way, but then I found the benefits of dyslexia, such as good 3D spatial awareness and a strong logical sense, which were ideal for a career as a space scientist.

What scientific development do you hope to see in your lifetime?

Space travel for everyone, fusion to solve the energy crises and medication based on our genes.

Which discovery do you wish you'd made yourself?

Cheap and accessible space travel. I truly believe our destiny is out there.

If you could have a long conversation with any scientist, living or dead, who would it be?

Albert Einstein. He was so ahead of his time. I loved the way he did thought experiments, and as he was dyslexic, we would have lots to talk about.

What's the best thing you've read or seen in the past 12 months?

The film *Armstrong* stood out as it made me see Neil Armstrong as a different person from what I had assumed – a lot quieter and more reflective.

"As I got older I found some of the benefits of dyslexia, such as good 3D spatial awareness"



How useful will your skills be after the apocalypse?

My good general science knowledge could be useful. Also, I am quite hands-on.

OK, one last thing: tell us something that will blow our minds...

Our galaxy, the Milky Way, has around 300 billion stars, many with planets orbiting them. There are around 100 billion galaxies, so a lot of planets for life to potentially exist on. But using our fastest space tech, it would take around 76,000 years to get to the nearest solar system, Proxima Centauri. The universe is mind-bogglingly big. ■

Maggie Aderin-Pocock is a space scientist, author and broadcaster. Her latest book *Dr Maggie's Grand Tour of the Solar System* is out now

CAPITAL PICTURES

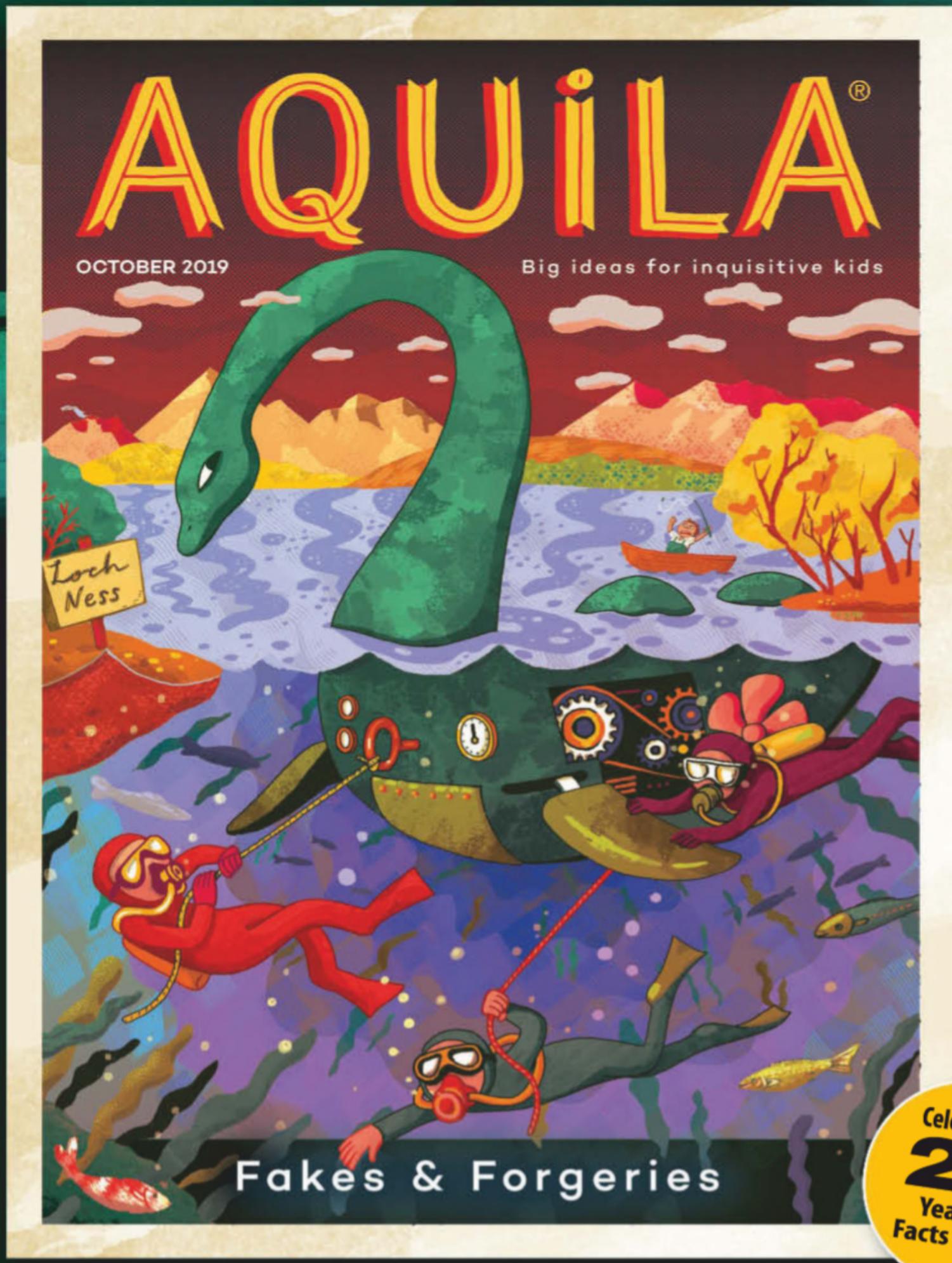


What has the moon ever done for us?

Maggie Aderin-Pocock will be speaking at New Scientist Live on 12 October
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