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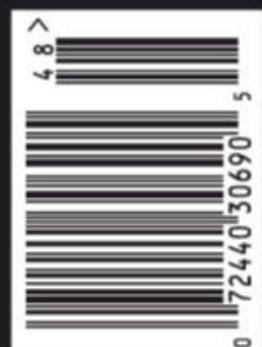
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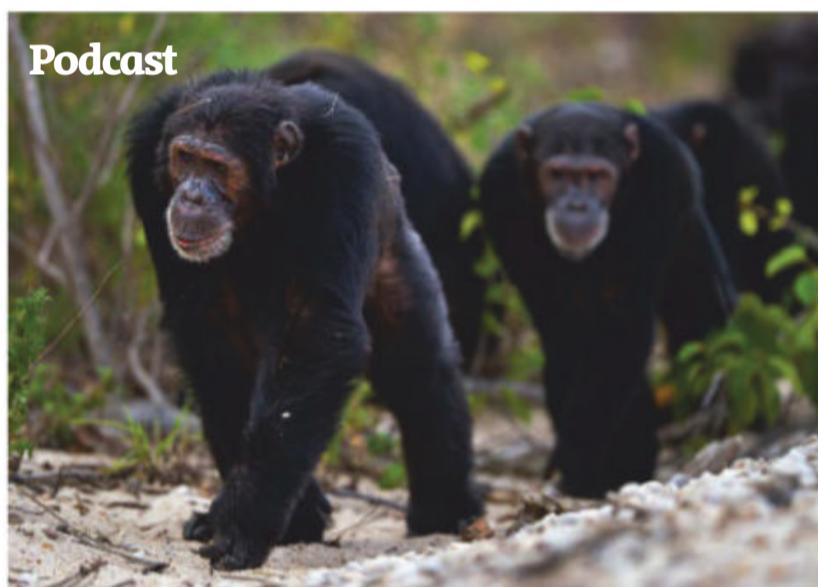
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Shooting for the moon

China's Chang'e 5 lunar mission is an ambitious step towards a crewed landing

WHEN it comes to space exploration, China has long taken third place. The cold war's space race saw the US and the Soviet Union vying for firsts – satellite, human in orbit, landing on the moon – and left few records for China to claim.

That changed last year, when its uncrewed Chang'e 4 spacecraft made the first landing on the far side of the moon. Among other experiments, it contained a "lunar garden" of seedlings that went on to host the first plants (that we know of) to germinate on another world.

The Chang'e missions, named after the Chinese goddess of the moon, have seen the country orbit, land and rove – all important, but fairly common. But Chang'e 5, launched this week, is attempting something that hasn't been done in more than 40 years – bringing moon rocks back to Earth (see page 8).

The US claimed this "first" with the Apollo missions, in which astronauts collected samples directly from the lunar surface. The Soviet Union did it last, with a robotic sample return mission in 1976.

Yet China isn't just playing for bronze now. Chang'e 5, an uncrewed, multi-part

"Chang'e 5 is trying something that hasn't been done in more than 40 years – bringing moon rocks back to Earth"

spacecraft capable of landing on and launching from the surface of the moon, is essentially a dress rehearsal for a crewed landing. After all, if you can bring rocks home safely, you are one step closer to making the same trip in person.

A Chinese crewed mission to the moon wouldn't be a first, but it would bump

the nation firmly into second place. While Russia is arguably the current leader in sending humans to low Earth orbit – the US only regained the ability to do so this year, thanks to SpaceX – few people take its claims of attempting a crewed lunar landing in the near future seriously.

China, meanwhile, has kept up a steady drumbeat of lunar missions, each more ambitious than the last, and there is no reason to believe it won't continue to succeed. Chang'e 6 will see a second sample-return mission in 2023 or 2024, followed swiftly by Chang'e 7, which will involve five spacecraft, including a flying probe. Chang'e 8, pencilled in for 2027, will be the most ambitious yet, aiming to test a 3D-printer capable of building a structure out of the lunar soil. If that succeeds, things on the moon may begin to get very interesting indeed. ■

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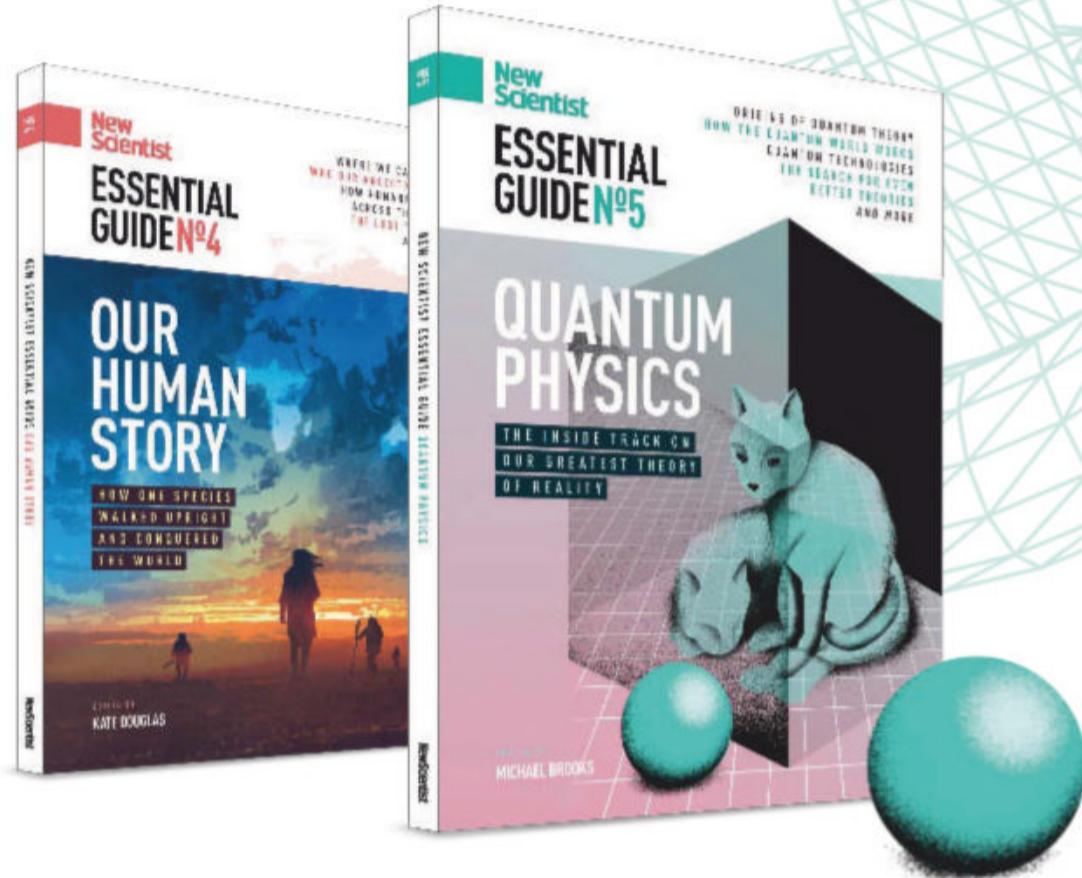
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UNIVERSITY OF OXFORD/JOHN CAIRNS

Coronavirus

More vaccine hope

Promising early results are in for the covid-19 vaccine developed by AstraZeneca and the University of Oxford, reports Adam Vaughan

A COVID-19 vaccine that doesn't need to be kept at very low temperatures has been found to be 70 per cent effective on average, with potential for that to rise to 90 per cent depending on how the doses are given.

In large-scale trials of more than 20,000 people in the UK and Brazil, 131 people became infected by the disease, according to preliminary results published this week by the vaccine's developers, AstraZeneca and the University of Oxford. "We have a vaccine for the world. We've got a vaccine that's highly effective: it prevents severe disease and hospitalisation," Andrew Pollard at the University of Oxford told an online press conference.

The vaccine's 70 per cent effectiveness is much lower than the 90-plus per cent reported in

recent weeks for Pfizer and BioNTech's and Moderna's vaccines. However, in a subgroup of more than 3000 people given a half dose followed by a full dose a month later, the figure jumped to 90 per cent.

Sarah Gilbert, also at the University of Oxford, said at the press event that more research was needed to work out why the half dose seems to prime the body to respond better to the coronavirus. "It could be that by giving a small amount of the vaccine to start with and following up with a big amount, that's a better way of kicking the biggest and most effective immune system response," she said.

The trial results show that the vaccine prevents mild and severe disease. There is some evidence that it curbs transmission too, said Pollard and Gilbert, although a full analysis is still being carried out on this. The results are "hugely encouraging", research charity Wellcome said in a statement.

Crucially, the vaccine can be stored in a fridge rather than in a freezer as required for Pfizer and BioNTech's vaccine, simplifying supply chain logistics. A half-dosing regimen also offers the prospect of far more initial doses being made available.

Pam Cheng at AstraZeneca said at the press conference that the firm would have more than

The vaccine developed by the University of Oxford and AstraZeneca

300 million full doses available globally by the end of March 2021, a number that could double for the first doses, given the promise shown by a half dose. She added that the company can produce around 200 million doses a month. The UK has ordered 100 million doses of the vaccine.

Even combining AstraZeneca's vaccine production capacity with

"We've got a vaccine that's highly effective: it prevents severe disease and hospitalisation"

Pfizer and BioNTech's and Moderna's, there aren't enough doses for the world, so capacity must be increased, Pascal Soriot, AstraZeneca's chief executive, told the press event.

Research is still under way on how long immunity provided by the AstraZeneca and University of Oxford vaccine lasts. However, Gilbert said she was optimistic it would have "good durability", pointing out that related vaccines developed for the coronavirus that causes MERS conferred about a year's protection.

Asked about the side effects of taking the covid-19 vaccine, she said that during earlier, smaller phases of its development, people reported sore arms, fever and headache. "It's quite short-lived," she said. "It's nothing unusual after vaccination."

On Tuesday, the Russian government announced new trial results, saying its Sputnik V vaccine has been found to be more than 95 per cent effective after a second dose, up from the 92 per cent it reported earlier this month.

The country's sovereign wealth fund said each dose would cost less than \$10, noting that this is cheaper than "foreign vaccines" based on messenger RNA. These include Pfizer and BioNTech's and Moderna's. The AstraZeneca and University of Oxford vaccine is due to cost about \$3 to \$4 a dose. ■

Daily coronavirus news round-up
Online every weekday at 6pm GMT
newscientist.com/coronavirus-latest

To the moon and back

China's most advanced lunar mission yet will fill gaps in the moon's history and could be a dry run for sending humans, reports **Donna Lu**

CHINA has launched its Chang'e 5 spacecraft, the first mission designed to bring moon rocks back to Earth in more than four decades.

The uncrewed Chang'e 5 probe will attempt to collect at least 2 kilograms of lunar dust and debris from the northern region of Oceanus Procellarum, a previously unvisited area on the near side of the moon.

If successful, the Chang'e 5 return mission will make China only the third country, after the US and the Soviet Union, to have retrieved samples from the moon. The last sample return mission was carried out in 1976 by the Soviet Union's Luna 24 robotic probe, which brought back around 170 grams of rocks to Earth.

Chang'e 5 launched early on 24 November, Beijing time, from a Long March 5 rocket at a site in Wenchang on Hainan Island in the South China Sea. The spacecraft consists of an orbiter, re-entry capsule, lander and ascent stage (see diagram, right). It is set to reach lunar orbit later this month, at which point the lander and ascent stage will separate from the main spacecraft in order to touch down on the moon.

Given that many factors can affect the probe's actual landing point, the China National Space Administration selected a large potential landing area near Mons Rümker, a 1300-metre-high volcanic formation, says Long Xiao at the China University of Geosciences in Wuhan, who helped propose candidate sites for the mission.

"The landing site covers two different geological units," says Xiao. To the west, the basalts – rock formed from the rapid cooling of lava – resemble those sampled in the Apollo missions. Chang'e 5 is aiming to land east of Mons Rümker in an area that contains



XINHUA/SHUTTERSTOCK

China's Chang'e 5 lunar probe blasted off on 24 November local time from Hainan Island in the South China Sea

2 kg

Amount of lunar rock that the Chang'e 5 mission aims to collect

what appears to be much younger rock, around 1.2 billion to 2 billion years old.

"These would be the youngest volcanic samples to ever be returned from the moon," says Catherine Neish at Western University in Canada. "This is an extremely exciting mission."

In the Apollo missions, which consisted of six lunar landings between 1969 and 1972, astronauts brought back 382 kilograms of lunar rocks to Earth. The samples returned from the Apollo missions are between 3.1 and 4.4 billion years old.

Once Chang'e 5 lands, it will use two sampling methods, a major improvement on Luna 24, says James Head at Brown University in Providence, Rhode Island. First, the lander will drill and collect a core of regolith – loose soil and broken rocks – around 2 metres deep. A robotic arm will also scoop up shallow soils on the surface.

While the aim is to collect at least 2 kilograms of samples, Chang'e 5 has a maximum sample capacity of around 4 kilograms.

The lander is also equipped with a visible near-infrared spectrometer, as well as ground-penetrating radar to help it assess the make-up of the soil beneath it. "Lunar ground-penetrating radar is critical in correlating the structure and layers of the lunar soil and understanding its origin," says Head.

All in a day's work

Unlike the previous Chang'e spacecraft, Chang'e 5 isn't equipped with heating units to help it weather the extreme cold of the lunar night, so sampling will need to take place during a single lunar day – roughly 14 Earth days.

Once Chang'e 5 completes its surface operations, the samples will be stored in its ascent stage, which will lift off from the moon and make contact with the orbiter again. The samples will then be transferred to the re-entry capsule and the spacecraft will depart lunar orbit. It is expected to land in Inner Mongolia in mid-December.

"Any time you are landing on another planet's surface, it is challenging, but this mission is more complex in nature because a sample will be collected, stowed and then lifted off the lunar surface for its return to Earth," says Kerri Donaldson Hanna at the University of Central Florida. "This is something that has not been done in the modern era of space exploration."

If the Chang'e 5 mission is successful, the return of new samples will fill a major gap in our understanding of how the moon developed.

"This will be a really key piece of information to understanding the

Astronomy

Earth's minimoon has drifted away beyond our reach

Leah Crane

CHINA might have its sights set on the moon (see left), but astronomers are on the look out for alternatives. Earlier this year, they spotted a minimoon orbiting Earth. It has now drifted away, but we should soon be able to detect more of these miniature companions.

When astronomers at the Catalina Sky Survey in Arizona spotted a dim object they called **2020 CD3** hurtling across the sky in February, they couldn't be sure whether it was a minimoon or an artificial object like a rocket booster. Over the following few months, Grigori Fedorets at Queen's University Belfast in the UK and his colleagues used a series of telescopes around the world to take more measurements of the object and figure out what it was.

They found that it had a diameter of about 1.2 metres. Based on its colour and brightness, it was probably made of silicate rock, like many rocks in the asteroid belt. The researchers also traced back its orbit in an effort to find out where it might have come from before it was caught in Earth's orbit about 2.7 years earlier (*The Astronomical Journal*, doi.org/fj42).

"Based on simulations, the average capture time for minimoons is only nine months, so this was captured for a longer time than is expected," says Fedorets. "But this object flew very close to the [regular] moon, and that put it into a more stable orbit."

2020 CD3 drifted out of Earth's orbit in March, but the researchers predict that once the Vera C. Rubin Observatory – under construction in Chile – is finished, we should be able to find many more objects like it.

"We could detect a minimoon once every two or three months in the best-case scenario," says Fedorets. "In the worst-case scenario, maybe once a year." ■

Oceanus Procellarum (the central dark region) is an unexplored lunar plain

thermal evolution of the moon's interior," says Marc Norman at the Australian National University in Canberra.

If analysis shows that the samples are as young as we think they are – 2 billion years or younger – it would shed light on what happened on the moon at a time when it was cooling down and also shutting down its magnetic field, says Neish.

The samples will also help researchers better calibrate the age of surfaces on the moon based on the density of impact craters. Older surfaces tend to have more and larger craters than younger surfaces.

"If we can tie an absolute age to crater densities in that vicinity on the moon, that will give us a really useful data point for doing geological mapping on other planets in the solar system," says Norman.

Once the samples are returned to Earth, they will be stored at the National Astronomical Observatories of China in Beijing.



"As part of the safekeeping strategy, some samples will be stored permanently at Hunan University to avoid any potential loss due to natural disasters," says Head.

Because of the limited amount of lunar material, research laboratories that are successfully granted samples may be restricted to certain kinds of analysis, such as mineralogy or isotope studies, with non-destructive research methods to be used first, says Xiao.

Chang'e 5 is part of the four-phase Chinese Lunar Exploration Program run by the Chinese government, and is probably a preparatory step towards sending taikonauts to the moon in future, perhaps around 2030. "The Chinese are thinking very long

term about this and very strategically about what they want to accomplish by going to the moon and going to Mars," says Norman.

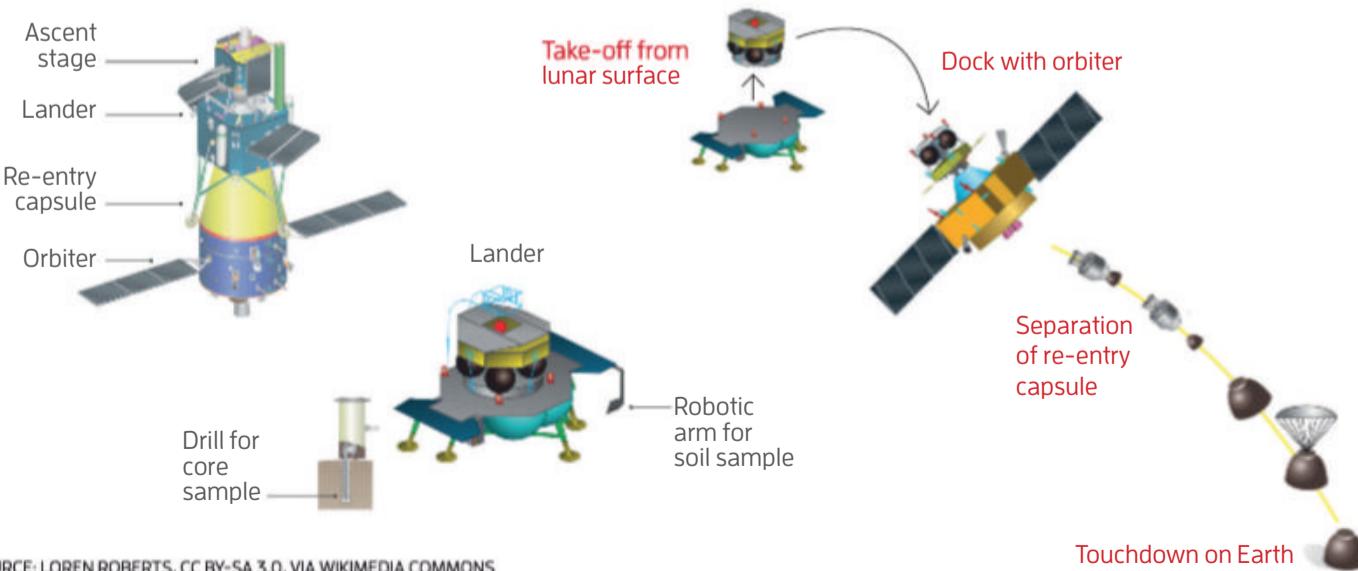
Phase one – Chang'e 1 and Chang'e 2 – involved orbital missions, while the Chang'e 3 and Chang'e 4 missions in phase two used soft landers and rovers. Phase three, sample return, is comprised of Chang'e 5 and Chang'e 6, which is planned for launch in 2023 or 2024. Phase four will involve exploration at the moon's south pole.

"The Chinese have had a good success rate for their Chang'e missions so far," says Lionel Wilson at Lancaster University in the UK.

"This is something that has not been done in the modern era of space exploration"

"The Chang'e 4 landing was on the lunar far side where there was absolutely no possibility of any realistic last-minute corrections to the landing process from Earth, thus confirming that they have a robust landing system, so I expect they will land successfully." ■

How Chang'e 5 will bring moon rocks back to Earth



SOURCE: LOREN ROBERTS, CC BY-SA 3.0, VIA WIKIMEDIA COMMONS

Infectious disease

The DRC is free of Ebola

Ultracold devices for vaccine distribution helped end epidemic

Peter Yeung

THE Democratic Republic of the Congo (DRC) has declared an end to its 11th Ebola outbreak, marking the first time in years the central African country has been free of the deadly viral disease.

Eteni Longondo, the DRC's minister of health, and the World Health Organization (WHO) made the announcement on 18 November after no new cases were recorded in the country's western Équateur province for 42 days, or twice the disease's maximum incubation period. There were 55 deaths in the outbreak, with 75 people recovering out of 119 confirmed and 11 probable cases.

Announced on 1 June, the outbreak surfaced shortly before the DRC called an end to a separate Ebola epidemic in the east of the country that killed 2280 people over nearly two years. Genetic sequencing showed that the two virus strains were unrelated.

The latest outbreak stretched across dense rainforests and remote waterways as well as busy urban areas. It was halted thanks to "cold chain" vaccine storage and

community-based health workers who vaccinated 40,000 people deemed at high risk of contracting the disease, according to experts.

"The geography was very difficult in terms of accessibility," says Ngoy Nsenga at the WHO. "It required serious logistics and so this ultracold-chain technology was very important."

To meet the temperature requirements of the Merck Ebola

vaccine, it was placed in cylinder-shaped "super thermos" devices called Arkteks that were developed by US social enterprise the Global Good Fund. Each can store 500 vaccine doses at -80°C for up to a week with no external power source. This is also cold enough to store Pfizer and BioNTech's new covid-19 vaccine, which bodes well for vaccination in countries with less-developed infrastructure.

"There were so many factors in the management of the outbreak," says Nsenga. "The DRC is gaining experience in stopping epidemics

and the WHO has learned to react as quickly as we can."

Bob Ghosn at the International Federation of Red Cross and Red Crescent Societies (IFRC) says working with local people was crucial to the success.

"Community engagement is key to stopping any outbreak," says Ghosn, who helped deploy a team of 1000 IFRC community workers in Équateur. "Top-down messaging doesn't work on its own – covid-19 has proved that."

However, experts warn that the risk remains of another Ebola outbreak in the DRC. The disease can be caught from animals and is believed to derive from bats.

Natalie Roberts at humanitarian organisation Médecins sans Frontières says future efforts are likely to improve with the use of monoclonal antibodies, lab-made molecules that can boost immune response.

"Due to the remote nature of this outbreak and other constraints, we weren't able to use them as much as we wanted," she says. "But they are very effective in the early stages of the disease." ■



ALEXIS HUGUET/AFP VIA GETTY IMAGES

Palaeontology

'Zombie' dinosaur had open wounds and bone disease

BONE disease discovered in the leg of a titanosaur from 83 million years ago may have been caused by the first parasites seen in a dinosaur bone. Titanosaurs were among the largest ever land animals and this one probably had open wounds.

"It's a new kind of parasite," says Aline Ghilardi at the Federal University of Rio Grande do Norte in Brazil. "We don't have anything similar to it."

This fossilised parasite was seen in a sample from a dwarf titanosaur, a species first identified from a leg bone found in a deposit near São Paulo, Brazil, in 2009 that dated to the late Cretaceous period. The dwarf titanosaur species, dubbed "Bilbo", would have been 5 or 6 metres long, a little smaller than most titanosaurs.

"It's our hobbit titanosaur," says Ghilardi. She and her team analysed a sample of the leg bone, cutting thin sections of the fossil and analysing them using a CT scanner.

The researchers also found that the dinosaur was old and infirm.

They analysed strange, spongy bumps on its bones, and found that they were probably due to an aggressive form of osteomyelitis, a type of bone infection often spread by fungi, bacteria or protozoa (*Cretaceous Research*, doi.org/fjrt).

Based on the way the infection typically works in animals or humans today, they deduced that it was so advanced that this dwarf titanosaur would have been covered

"The dwarf titanosaur species, dubbed 'Bilbo', would have been 5 or 6 metres long"

in open wounds. The team gave it another nickname: Dino Zombie.

Further analysis also revealed microorganisms that were present in the dwarf titanosaur's blood when it died. Ghilardi says these might be large protozoans or nematode worms, and could even have been the cause of the bone infection, although it is difficult to say for sure.

The parasite seems to be something we have never seen before, she says, and learning more about it could teach us about how modern related diseases evolved. ■

Joshua Rapp Learn

Tiny worm makes milk to feed its offspring

Michael Marshall

A MICROSCOPIC worm that has been studied by biologists for decades has been hiding a secret: it can make milk to feed its young, and it does so in a way that supports the idea that ageing is programmed by evolution, rather than simply being an accident.

The nematode worm *Caenorhabditis elegans* is used in many biological studies every year, but David Gems at University College London and his colleagues are the first to investigate why the worms, some of which are egg-laying hermaphrodites, leave smears of brown liquid in their wake after depositing eggs. The liquid came out of the worms' vulvas, the orifice through which they lay eggs, and contains yolk protein.

Experiments showed that the offspring consumed the liquid and grew better as a result. Gems and his colleagues say it serves the same function as mammalian milk. They propose calling it "yolk milk" (*bioRxiv*, doi.org/fjx8).

"We had no idea that *C. elegans*, has this primitive form of lactation," says Marina Ezcurra at the University of Kent in Canterbury, UK.

True milk is unique to mammals. However, other animals, from spiders to pigeons, secrete nutritious liquids for their young.

The *C. elegans* milk production was triggered by a biochemical pathway called the insulin-like signalling pathway, which is known to promote ageing in many species.

Gems and his colleagues argue that, after laying hundreds of eggs in a few days, *C. elegans* adults sacrifice themselves by breaking down their bodies to make yolk milk. The implication, they say, is that this form of ageing has been favoured by evolution because it allows parents to support their young.

"What this paper is saying is: ageing has a biological purpose," says Ezcurra. ■

Illegal bushmeat found for sale in Belgium

Donna Lu

THE meat of several protected African animals has been illegally imported into and sold in Belgium. Sophie Gombeer at the Royal Belgian Institute of Natural Sciences and her colleagues have identified wild animal meat, known as bushmeat, being sold in several markets in Brussels.

They identified the meat of three species listed as protected according to CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora: the red-tailed monkey, De Brazza's monkey and a species of small antelope called the blue duiker. Under European Union law, importing wild meat products is illegal without specific authorisation.

In 2017 and 2018, the research team visited five vendors and purchased a total of 15 pieces of bushmeat. According to the vendors, the meat originated from the Democratic Republic of the Congo. It wasn't directly advertised, but was available on request at €40 per kilogram.

The team used DNA sequencing to identify

the species that the meat came from. In addition to the three CITES-listed species, the team identified meat from species including the greater cane rat and domestic cattle, which had been sold as African buffalo (*Biodiversity and Conservation*, doi.org/fjx7).

€40

Cost per kilogram of bushmeat on sale in Brussels, Belgium

The researchers had heard anecdotal reports of bushmeat being imported into Brussels, but existing research was scant. "Because there is no [existing] data, it's easy to ignore the problem," says Gombeer.

To better understand the drivers of bushmeat consumption, the team spoke to expatriates from seven African countries who had been living in Belgium for the past 10 years. Of the 16 interviewees, 15 said they often imported African food items, including bushmeat, primarily driven by a desire to stay connected to their countries of origin.

In certain regions with tropical forests, wild animals are hunted as a source of protein, particularly when meat from domesticated animals is unavailable or unaffordable.

"It's very much a practice that's just embedded in everyday life," says Liana Chua at Brunel University London, who has studied wildlife hunting in Borneo. A challenge for conservationists when trying to reduce wild meat hunting, she says, is to take into account the social and nutritional role that hunting plays in people's lives.

Local and Indigenous people living in and around forest areas should have the right to continue traditional practices and hunt sustainably, says Julia Fa at Manchester Metropolitan University in the UK.

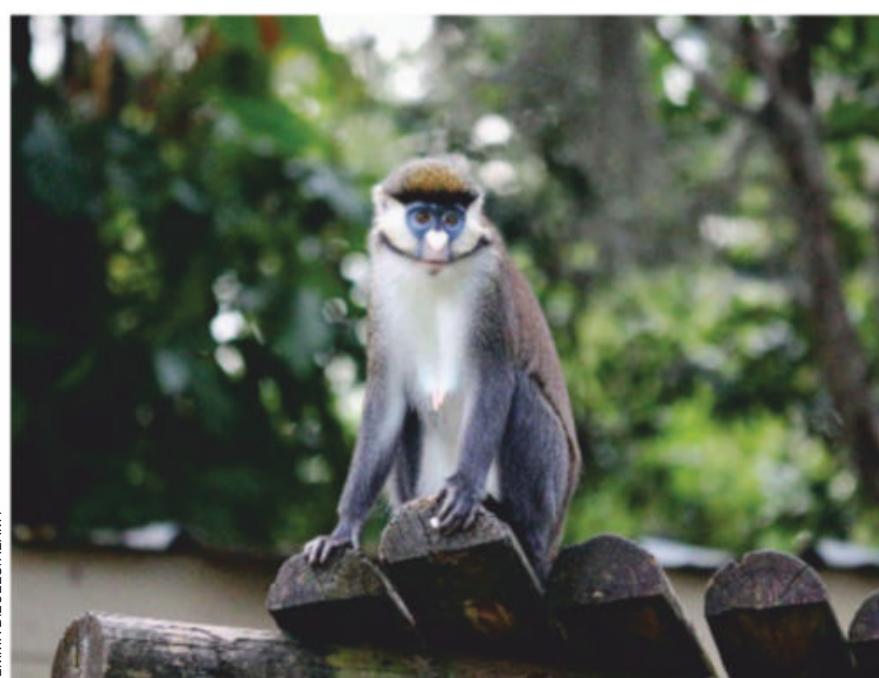
"You have to make the distinction between eating wild meats really to survive... and the market that has grown in the past decade in big cities where there are alternative proteins available and it's more of a delicacy," says Gombeer.

She suggests that stricter enforcement of meat importation laws could help reduce sales, while Fa favours social campaigns in Brussels to reduce demand.

"There shouldn't be any consumption of wild meat in urban centres," says Fa.

She estimates that 5 million metric tonnes of mammal meat is hunted and extracted from the Congo basin each year – a rate two to three times higher than hunted animal populations can sustainably support. ■

Meat from a red-tailed monkey has been sold in Belgium



GEMMA DILUO/ALAMY

Geology

Plate tectonics may have got a very early start

Michael Marshall

EARTH'S tectonic plates may have begun moving 4 billion years ago, almost a billion years earlier than thought, according to an analysis of ancient rocks.

The claim has earned a mixed response from geologists. Many argue that Earth was too hot at the time for plate tectonics in its modern form.

Today, Earth's crust is divided into several dozen rigid plates that move slowly. Where two plates meet, one can be forced under the other and destroyed inside the planet, a process called subduction.

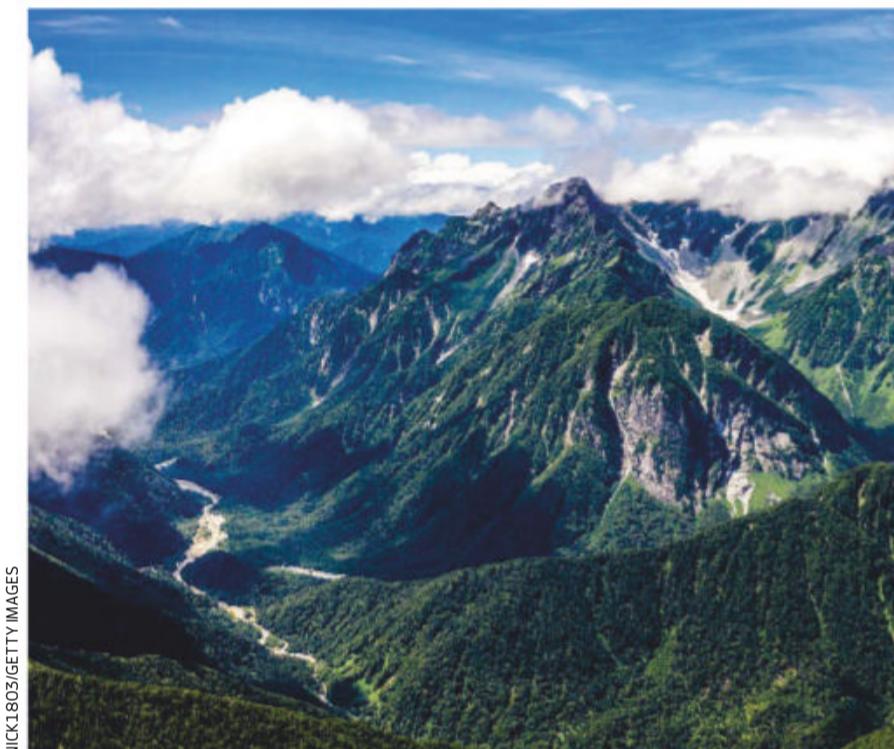
There is a growing consensus that plate tectonics started about 3.2 billion years ago. But according to Brian Windley at the University of Leicester in the UK, that is wrong. "It really is a great misunderstanding of so many things," he says.

Instead, Windley and his colleagues argue that tectonics began at least 4 billion years ago. The evidence of a shift 3.2 billion years ago, they say, merely reflects a change in the way the plates were behaving.

The researchers re-examined data from rocks laid down between 4 and 3.2 billion years ago. They argue that many of them contain evidence of mountain-building, but of a particular kind seen today in a few places, including Japan and the Caribbean.

When two tectonic plates meet, if one gets subducted, the volcanic activity this generates can sometimes lead to the formation of a chain of volcanically active islands.

Crucially, the rocks of these mountains are chemically distinct from those that form when continents collide – like the Himalayas, which were thrust up when India hit Asia.



NICK1803/GETTY IMAGES

Windley and his colleagues argue that before 3.2 billion years ago, the only mountains on Earth were formed by subducting oceanic plates. Big continents only started to form about 3.2 billion years ago, once the crust was thick enough. This explains the shift in the chemistry of rocks at that time, says Windley (*Precambrian Research*, doi.org/fjqr).

Not everyone is convinced by the claim. "Plate tectonics requires rigid plates," says Nicholas Gardiner at the University of St Andrews, UK.

"When two tectonic plates meet, if one is subducted, it can lead to formation of volcanic islands"

However, billions of years ago, Earth's interior was hotter, so the crust was probably less rigid. If it was divided into plates, he says, they wouldn't have behaved as they do today. Instead most of the motion may have been vertical, as less dense rocks rose and denser

The mountains of Japan have a distinctive rock chemistry

rocks sank. Overall the system would have looked different to today, says Gardiner.

"There are really strongly held views on either side of this debate," says Kathryn Goodenough at the British Geological Survey in Edinburgh, UK.

Some researchers, like Windley, have long argued for an early start to plate tectonics, while at the other end of the spectrum, others argue that modern plate tectonics began only 700 million years ago.

Either way, it is becoming clear that there was exposed land as early as 3.5 billion years ago, says Gardiner.

Sediments, which can only be produced when rocks on land are weathered, are known from that time. The oldest confirmed fossil organisms come from the same rocks, and life may have emerged in small bodies of water on the first land. ■

Technology

Uncrewed US Navy ship passes through Panama Canal

David Hambling

A ROBOTIC cargo vessel has passed through the Panama Canal for the first time.

The ship, an Overlord uncrewed surface vessel belonging to the US Navy, made a 4700-nautical-mile (8700 kilometre) journey, including passage from the Atlantic Ocean to the Pacific, almost entirely without human assistance.

Pentagon spokesperson Josh Frey says the vessel was in autonomous mode for more than 97 per cent of the trip's length. A remote crew assisted when needed.

The US Navy has two of the 59-metre Overlord vessels, modified from crewed fast transport ships. The modification to uncrewed operations cost more than \$100 million for each vessel.

While the technology to guide the large vessels may not be novel, the willingness of the canal authorities to allow the robotic ship to pass through indicates growing acceptance by the shipping industry.

"This is a significant achievement that definitely shows it is possible to undertake such passages and operations," says Jon Downes at the University of Southampton, UK.

Smaller uncrewed vessels have made extended journeys, including a surfboard-sized Wave Glider, which voyaged 14,700 kilometres across the Pacific Ocean in 2013. However, the Overlord trip including the Panama transit was the longest for a robot vessel of this size.

The Overlords are part of the US Navy's Ghost Fleet project, which will supplement the crewed fleet with many smaller uncrewed ships for less demanding roles, such as transport, clearing mines and submarine-hunting patrols.

The civil sector is also developing crewless vessels. Just as DARPA's Grand Challenge advanced the technology for driverless cars in the early 2000s, the US Navy may pave the way for uncrewed ships. ■

The eyes have it

Your pupils can help reveal your decisions before you are conscious of making them

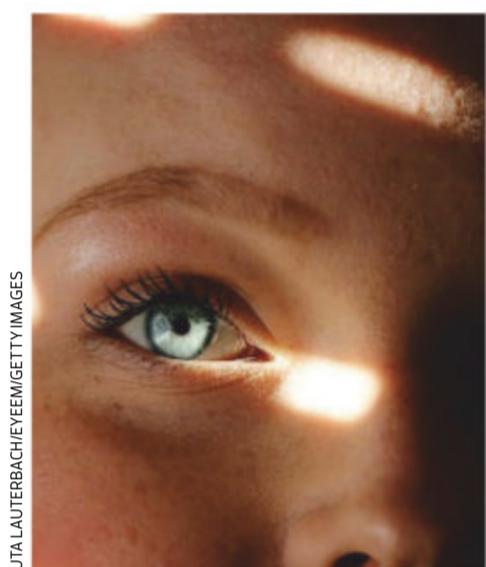
Gege Li

CHOOSING between going out for a run or staying slumped on your sofa in front of the TV can be tricky, but it turns out your decision can be seen in your eyes before you have even made it.

When we do something that requires physical effort, our pupils can dilate and activity heightens in the prefrontal cortex, part of the brain that is vital to cognition. Now, it seems that these two reactions may also guide our decisions about activities that we are thinking about doing.

To investigate this idea, Irma Kurniawan and her colleagues at the University of Zurich in Switzerland asked 49 people to choose between different tasks that varied by the level of effort involved.

The researchers first got the participants to do hand squeezes using a handheld device at varying degrees of physical difficulty. Each person was then placed inside a functional MRI scanner to record their brain activity



Whether you intend to exercise may be shown in your eyes

while an eye-tracker also monitored their pupil size.

While in the scanner, participants were asked to choose between doing more strenuous or effortless hand contractions later on, with a greater cash reward for choosing the more difficult exercises. Once

outside, 30 minutes to an hour later, they completed a random selection of hand squeezes at their chosen levels of effort.

The team saw changes in pupil size and prefrontal cortex activity as people made their decision in the scanner. Because these changes occurred before doing the exercises, it suggests that the participants were anticipating the amount of effort that would be required.

What's more, if someone chose the most difficult activity, this was revealed by specific pupil dilation and brain activity patterns. The team suggests that these signals influence the outcome of people's decisions, by helping to predict the amount of energy required, and this reveals whether they will end up doing a higher effort task (bioRxiv, doi.org/fjp6).

"It's a very interesting proposal," says Tobias Hauser at University College London. However, pupil size and the prefrontal cortex signal are known to reflect

different things, he says. "[They] have been linked to different aspects of cognition, be it effort, be it surprise, be it difficulty, so it's not a unitary thing," says Hauser.

As to whether pupil dilation and prefrontal cortex activity really play a role in our decision-making about future exertion,

"Changes in pupil size seemed to anticipate the amount of effort exercises would require"

"it's a long shot, but long shots are worth pursuing", says Hauser.

Follow-up studies would need to establish whether these two factors directly affect our behaviour and if they might act differently in people with low motivation, he says. If that holds true, Hauser thinks "it's definitely an interesting new perspective on effort and decision-making which could in part reformulate what we understand". ■

Computing

Software estimates calorie content of food from an image

YOU can now estimate how many calories are in a meal simply by taking a photo of it.

Calorie counting is one of the ways many people try to control their weight, but manually entering nutritional information about ingredients into apps is time-consuming. Cooking meals muddles things further, making it difficult to get accurate calorie counts.

Robin Rueude and his colleagues at the Karlsruhe Institute of Technology, Germany, might be able to help. They have harnessed

a commonly used neural network called DenseNet to cross-reference images of meals with a database of 308,000 photographs taken from 70,000 recipes on a German cooking website. A neural network is a software system modelled on the architecture of a brain.

"We adapted the architecture and made it predict the macronutrients – such as fat and protein content – from the ingredients," says Rueude. "We assume they cooked the recipe correctly, take the nutritional values and make the model learn the correlation between the nutritional information and that image."

The model is far from perfect: on average, its estimate of calories



One photograph is now enough to estimate a meal's calorie content

loaf of bread at 229kcal (arxiv.org/abs/2011.01082).

"The whole paper is a big step forward in our ability to determine the nutritional value of food from pictures," says Dane Bell, co-founder of Lum Al, a natural language processing company. "This data set directly bears on what we want to know: how much protein, carbs and fat this food has."

The model falls down when confronted with items that aren't in the list of recipes or when recipes use unusual ingredients or methods. But even so, says Rueude, "it's pretty clear it can distinguish between categories of high-calorie and low-calorie foods". ■

Chris Stokel-Walker

Controlling the spread

Does mass testing work?

Widespread testing can help contain the coronavirus, but only when combined with other measures, reports **Michael Le Page**

IT LOOKS likely that some countries will soon be able to vaccinate at least some people against the coronavirus (see page 7), but until vaccines are widely available, mass testing is seen as a route back to normal life. For example, UK prime minister Boris Johnson announced on 23 November that daily coronavirus tests will be given to people who have come into contact with anyone who has tested positive for the coronavirus, in an attempt to limit the number of days they have to self-isolate. The measure will be trialled in Liverpool, which began mass testing earlier this month.

But while extensive testing has helped places such as China and Singapore keep the spread of coronavirus low, it won't work on its own. Many other policies are needed to make testing successful at containing the spread of the coronavirus. "Just testing people does not get rid of covid," says Christina Pagel at University College London (UCL).

People need incentives to get tested, for example, and it must be easy for them to do so. Those who test positive need to self-isolate, and they need financial support

"There is no country, not a single one, that controlled covid-19 with testing alone"

to do so. Their contacts need to be quickly traced, isolated and tested too. Once a region has eliminated the spread of coronavirus within a community, strict border controls can prevent it entering again from outside the region. And all this needs to be combined with wider measures to limit exposure, such as wearing face coverings and social distancing.

"All those things have to work and if they don't work, if one of

People queue at a coronavirus testing centre in Liverpool, UK

them is leaky, you get problems," says Pagel. "That's what's been happening in Europe."

This is why some researchers think the UK government is making a mistake in rushing to do mass testing without rigorously implementing these other measures. "The way [England is] going about it means it will fail miserably," says Angela Raffle at the University of Bristol in the UK.

Countries cannot simply pin all their hopes on vaccination and ignore testing, as it could take years to vaccinate entire populations. "We have a long process before we can roll out the vaccine," says Jasmina Panovska-Griffiths, who is also at UCL. "[England] still needs to get test and trace right."

Here is what is needed to make a testing scheme succeed:

People must have an incentive to get tested

The first step in using testing to help control the spread of covid-19 is to detect as many cases as possible. In many countries, everyone who has potential covid-19 symptoms is meant to get tested. However, there are good reasons to think many are not.

In Australia, for instance, one recent survey found that just 15 per cent of people with cold or flu-like symptoms were getting tested for covid-19. The most common reason for not doing so was that they didn't think they had covid-19, which is reasonable – just 0.4 per cent of UK users of the COVID Symptom Study app reporting symptoms of illness had a positive coronavirus test as of August – but misses the point.

Some people may not get tested because of the time and



REUTERS/CARL RECINE

effort involved, or because being swabbed is unpleasant. And for others it is because they or other members of their household could lose income or their jobs if they have to isolate after a positive test.

"We have to give people an incentive to do it," says Pagel. This is even more important with mass-testing programmes. People who feel fine may be less likely to get tested than those with symptoms. In Liverpool, less than a fifth of the

population came forward for a test in the first week of mass testing.

What's more, this and other mass-testing programmes being launched in England will attempt to provide weekly testing for everyone. Asking venues to demand evidence that people have been tested recently could encourage take-up, says Julian Peto at the London School of Hygiene & Tropical Medicine. "If you can't get into a pub or go to a



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a marker of your status at the time of the test. The fear is that many people don't understand this and will stop taking precautions if they get a negative result. "Do they get false reassurance and engage in behaviours that are harmful?" says Sian Taylor-Phillips at the

40%

Proportion of cases in Taiwan due to pre-symptomatic spread

University of Warwick, UK. "Do they go and see their grandmother? Do they stop wearing masks?"

If so, there is a risk that mass-testing programmes, such as the £100 billion England-wide testing scheme, dubbed Operation Moonshot, could actually increase transmission, she says.

There are particular concerns about the rapid tests being used for mass testing in England and Slovakia, which are less sensitive than standard tests. "This test is not good enough to pick out people in the first part of an infection," says Jon Deeks at the University of Birmingham, UK.

People exposed to those who test positive must be traced quickly
If the aim of testing is to stop the coronavirus spreading further, it will work only if positive results are followed up – and fast.

First, those who test positive have to be told to self-isolate as soon as possible. Then, everyone they have come into contact with needs to be found quickly, told to isolate and tested too.

What makes this difficult with the coronavirus is that people become infectious before they develop symptoms, so even if

football match without it, that's a wonderful way to encourage people to participate," he says.

People who test negative should still take precautions, especially after rapid tests, which can be less accurate

Getting a negative test result doesn't mean that you can't or won't still be able to pass on the coronavirus, as tests can return false negatives, and they are only

A woman posting a sign requiring face coverings in a shop window in Wales

infected people self-isolate and get tested as soon as they become ill, they may already have passed on the virus. In Taiwan, around 40 per cent of cases have been due to pre-symptomatic spread, says Hsien-Ho Lin at the National Taiwan University in Taipei.

This means that even the most efficient testing system can't prevent all secondary cases. But if contacts are traced fast enough – ideally within 24 hours – these people can isolate in time to stop further spread.

Unfortunately, the test-and-trace systems in many countries aren't efficient enough to achieve this. England's system has repeatedly missed its own targets. Germany's system did better but was overwhelmed as case numbers rose in the autumn. "The capacity of local health authorities was exceeded," says Ralf Reintjes at the Hamburg University of Applied Sciences in Germany.

We must ensure that people asked to self-isolate actually do so

In some countries, such as China, people with covid-19 have been quarantined in special facilities. But in most countries, people are merely required to self-isolate at home. This works only if they and the other members of their

household really do isolate.

Some countries in Asia have taken a carrot-and-stick approach. For instance, Taiwan tracks people in isolation using their phones. Police check on any apparent violations, with fines for those who have left home. But there is also financial compensation and support, such as the delivery of bags of food and other essentials.

In Europe, there has been less enforcement and less support. "Europe is not handling the isolation part well. This needs to be managed isolation with

"If you can't go to a pub or a football match without a test, that can encourage people to take one"

support financially, emotionally and practically," says Devi Sridhar at the University of Edinburgh, UK. "European countries seem to just expect people to isolate without thinking through how to ensure this happens."

A study in May found that only 1 in 5 people in the UK were self-isolating after developing symptoms (medRxiv, doi.org/gg9n24). Surveys in early September showed that 54 per cent of people in England asked to isolate were staying at home, the head of England's test-and-trace programme, Dido Harding, told a committee of MPs on 10 November, though the figures aren't publicly available and she said they hadn't been quality checked.

The rise could be because England has introduced fines of up to £10,000 for not self-isolating, as well as compensation of £500 for people on low income who are asked to isolate. But there is still no systematic enforcement.

"One of the biggest differences compared with Asia is we have ➤



MATTHEW HORWOOD/GETTY IMAGES

much more relaxed isolation," says Pagel. "No one checks up on you and makes sure you are doing it." She fears that the fines will deter people from coming forward for testing in the first place.

Border controls can prevent reintroductions of the virus from outside a region

Many of the countries that have been successful in controlling the virus have used strict border controls to prevent it being brought in from other countries.

Travellers to Australia, for example, have to quarantine in a hotel room for two weeks upon arriving in the country – and even this hasn't been enough to prevent a couple of outbreaks.

Most countries in Europe relaxed border controls during their summer to help the tourism industry. In August, Sridhar warned that summer holidays would lead to winter lockdowns, and there is some evidence that she is right. Several European countries have imposed restrictions in October and November.

Genetic studies have revealed that a variant of the coronavirus called 20A.EU1 emerged in Spain in June and spread to many other European countries, probably carried by returning tourists (medRxiv, doi.org/fjrv).

"Our study looking at the 20A.EU1 variant highlights that travel did play a role in spreading this variant around Europe in the summer," says Emma Hodcroft at the University of Basel, Switzerland. "Few countries screened returning travellers. Most relied on 'honour system' quarantines that may not have worked as well in practice as we might have liked it to in theory."

The UK could introduce tougher border controls together with the Republic of Ireland, says Pagel.

"Use of face coverings, physical distancing and handwashing had a bigger impact than test and trace"

£10,000

Maximum fine in England for failure to comply with orders to self-isolate

An airport terminal in Sydney, Australia, where travellers must quarantine after arrival



ISA MAREE WILLIAMS/GETTY IMAGES

Even with mass testing, we still need tried-and-true methods such as face coverings and social distancing

South Korea is sometimes portrayed as having controlled the coronavirus mostly with its test-and-trace programme, but it has implemented many other measures, too, including shutting schools very early on.

"In South Korea, testing was one of several measures that allowed them to control the epidemic," says Francois Balloux at UCL.

In Taiwan, another country that has been successful at controlling the coronavirus, an analysis by Lin found that the widespread use of face coverings, physical distancing and handwashing had a bigger impact than test, trace and quarantine (medRxiv, doi.org/fjrw).

It is the combination of the two approaches that has worked to control the outbreak in Taiwan, says Lin. This combination may have failed in other countries because these measures haven't been implemented as effectively.

"There is no country, not a

single one, that controlled [covid-19] by testing alone or even mainly by testing," says Balloux.

Effective contact tracing and mass testing aren't enough. Sometimes we must use lockdowns too

In China, entire cities – including Wuhan, Qingdao and Kashgar – have experienced strict lockdowns after small outbreaks, with every resident tested in just days. The idea was to stop infected people spreading the coronavirus beyond their household, making contact tracing easier.

In Slovakia, mass testing was also done as part of a lockdown. The country tested two-thirds of its population of 5 million people over two days at the start of November, and then did follow-up tests in the worst regions a week later. It is now easing restrictions.

The UK government, however, seems to view mass testing as an alternative to lockdowns. "If it works, we should be able to offer those who test negative the prospect of fewer restrictions, for example meeting up in certain places with others who have also tested negative," said Johnson during the 23 November press conference.

But without a lockdown, efficient contact tracing is even more vital if mass testing is to make any difference.

"In England, we really need to get the contact-tracing element working," says Allyson Pollock at Newcastle University in the UK. "We were very concerned when the government decided to ramp up the test-and-trace system without fixing it, and to extend it to mass testing of the whole population."

She thinks England's mass-testing programme needs to be paused and rethought in order to be effective. ■

Fatality rates

What are your chances of dying if you catch the coronavirus?

Michael Le Page

THE proportion of people who die after being infected by the coronavirus has become a highly controversial subject. Some have claimed that death rates aren't as high as thought and that governments are overreacting by imposing measures such as lockdowns. But a recent meta-analysis confirms earlier estimates, finding that the death rate can be as high as 16 per cent for people over 90, but is 0 per cent for children under 4.

This study concludes that in high-income countries, more than 1 in 100 people infected by the coronavirus died in the first wave. "The death rate is at least 10 or 20 times higher than flu," says Nicholas Brazeau at Imperial College London.

More of the people admitted to hospital with covid-19 are surviving now, suggesting that the death rate has fallen slightly. However, if hospitals in some countries are overwhelmed during the surge of infections now hitting Europe and the US, that might not continue to be the case.

Estimating the real death rate is hard for two reasons. First, the odds of dying from covid-19 vary greatly depending on a person's age, sex, health and the standard of care received. This means death rates will vary from place to place and at different times.

Care home cases

For instance, the death rate is greatest in care homes: as high as 73 per cent in nursing homes in Belgium, one study estimated (medRxiv, doi.org/fjnh). In places such as South Korea that have largely prevented outbreaks in care homes, the overall death rate is lower. Similarly, vaccines that prevent severe disease in older people should reduce death rates.



NEIL HALL/EP/A/BLOOMBERG VIA GETTY IMAGES

The second reason it is hard to estimate the real death rate is that there is great uncertainty about the numbers used to calculate it. What we want to know is how many people who get infected with the virus actually die: the infection fatality rate.

The best way to work out how many people have been infected is to test the blood of thousands of people to see how many have antibodies to the coronavirus, and then extrapolate the results to entire countries. But antibody surveys can produce a misleading picture because of false positive and false negative results.

The number of confirmed cases that countries report can't be used to calculate the infection fatality rate because most cases aren't detected – not everyone has symptoms, and not all who do get tested. Estimates suggest that about 250,000 people were infected daily at the peak of the first wave in the UK, when only 5000 daily cases were being reported by the government.

A medical worker in an intensive care unit in Cambridge, UK

For high-income countries, we do have a fair idea of how many people have died of covid-19 but there are uncertainties. In the UK, for instance, many deaths weren't counted because of an early lack of testing, so the official estimate of about 44,000 in the first wave is too low, says Paul Hunter at the University of East Anglia in the UK.

"The 44,000 number underestimates the total mortality quite substantially," he says. "A lot of deaths were not diagnosed early on." Looking at the number of deaths above what was seen under "normal" conditions in previous years suggests that 10,000 or even 20,000 deaths were missed.

In lower-income countries, most covid-19 deaths are probably unreported. For instance, it is estimated that just 1 per cent of deaths due to covid-19 were reported in Damascus, Syria, according to that country's data.

For all these reasons, reported infection fatality rates have varied. To get a better estimate, Brazeau and his team looked at 175 studies, finding just 10 they regarded as reliable. They adjusted for confounding factors and calculated the death rate for each age group, including 0 per cent for under 4s, less than 0.1 per cent for people

16%

Estimated coronavirus infection fatality rate for people over 90

under 40, 0.36 per cent if 50 to 54, 2.17 if 70 to 74, 5 per cent if 80 to 84 and 16 per cent for those over 90.

During the first wave, the infection fatality rate in high-income countries, which tend to have a high proportion of older people, was just over 1 per cent, the findings suggest. For countries with younger populations, it would have been 0.2 per cent, assuming the same age-specific death rates – which may not be the case given the poorer healthcare in many of these countries.

The death rate should be lower now because healthcare workers have more experience treating covid-19, and trials have revealed which treatments are effective. Figures from hospitals in England, Wales and Northern Ireland show that people admitted with covid-19 after 1 September were about 10 per cent less likely to die than those admitted before then.

"There is evidence that fatality rates in hospital have been improving over time, but more work is needed to fully understand these patterns," says Robert Verity at Imperial College London. Fewer people infected during the current waves in the US and Europe are expected to die, but this won't be clear for a while, because most of the deaths haven't happened yet. ■

Must ~~Nice~~ to have this Christmas

The coming year will see the fight against coronavirus continue, make-or-break international agreements on climate change and biodiversity, and nations continuing to vie for supremacy in space.

And that's just the stuff we know about.



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Animal behaviour



KEENE ET AL.

Caterpillars lash out when they get hangry

VERY hungry monarch butterfly caterpillars get hangry, resulting in them headbutting and lunging at each other in an attempt to secure food.

"The less food that is present, the higher their level of aggression," says Elizabeth Brown at Florida Atlantic University.

Monarch caterpillars (pictured) are found across North and Central America. They only eat milkweed leaves. Brown and her team gave the caterpillars three different amounts of food and found they attacked each other significantly more when the leaves were scarce.

Larger monarch caterpillars – those in the final stages before starting to transform into butterflies – often showed the most aggression, probably because they need more food,

says Brown. "There's a clear winning caterpillar and losing caterpillar," she says. "This often scales with their size."

The hungry caterpillars only attack when their target is actively feeding – an attack never occurred while a rival caterpillar was resting. The attacker seeks to disrupt feeding and claim a food source for itself (*iScience*, doi.org/fjzf).

"You can often see a single caterpillar strip down an entire plant of its leaves," says team member Alex Keene, also at Florida Atlantic University. "So, there is a big cost to these caterpillars if there are three of them on a plant with you."

Many animals become aggressive when competing for food. The team hopes to learn more about the genetic basis of this by studying the caterpillars. Karina Shah

Health

AI can tell if you have tinnitus

AN ARTIFICIAL intelligence has been devised to tell from brain imaging if you have tinnitus.

Mehrnaz Shoushtarian at the Bionics Institute in Melbourne, Australia, and her colleagues have developed an algorithm that can spot the presence of tinnitus with 78 per cent accuracy and tell between mild and severe forms with 87 per cent accuracy. Traditional diagnosis can rely heavily on subjective tests.

The team used a neuroimaging technique known as functional near-infrared spectroscopy (fNIRS) on 25 people with chronic tinnitus and 21 without the condition. This measures blood flow and oxygen levels in certain brain regions, which correspond to brain activity.

It was used while participants were given visual and auditory stimuli. Many visual-auditory neural pathways interact, both in

people with and without hearing impairments, says Shoushtarian. Earlier research shows that people with tinnitus have less activity in the cuneus, a brain region involved in visual processing.

The people with tinnitus were asked to rate how bad it was. These results were correlated with the patterns of brain activity based on their fNIRS signals.

The team found that people with more severe tinnitus had higher levels of background connectivity between certain brain regions. In those with louder tinnitus, brain responses to both visual and auditory stimuli were reduced, possibly because the background neural activity with tinnitus affects the brain's ability to respond (*PLoS One*, doi.org/fjzq).

The researchers then trained an algorithm on the fNIRS and tinnitus severity results. The AI's ability to objectively distinguish between mild and severe tinnitus may help to improve treatment, says Shoushtarian. **Donna Lu**

Medicine

Solar power used to sterilise surgical kit

FOR medics performing surgery in remote regions, sterilised equipment isn't always readily available. Now, a portable, solar-powered device can generate the conditions to sterilise medical instruments in such spots.

Lin Zhao at the Massachusetts Institute of Technology and his team have developed a device that can power an autoclave, a machine used to sterilise equipment with

the use of high-pressure steam.

The new tool works even in hazy or cloudy conditions. It consists of a solar component that heats water to generate steam, which is connected to a pressure chamber.

A key component of the solar heater is an aerogel – a solid, foam-like material – made from silica. The gel is transparent, so it doesn't impede the absorption of sunlight, but it does act as an insulator to prevent heat loss.

To be effective at sterilising equipment, autoclaves must maintain a temperature of at least 121°C for 30 minutes, with a pressure of at least 205 kilopascals.

In a field test in Mumbai, India, the researchers set up a prototype and showed that it could generate steam at 128°C and 250kPa. They estimate that it generates 260 watts of power. When exposed to sunlight, the solar heater took about 10 minutes to heat water to the temperature and pressure needed for the autoclave (*Joule*, doi.org/fjzp). **DL**





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Really brief



BRITTANY MUMMA/NATIONAL GEOGRAPHIC

Microplastics are found on Everest

Tiny bits of plastic less than 5 millimetres across have been found on Mount Everest. A sample taken near Everest base camp in Nepal had 79 microplastic particles per litre of snow while one at 8440 metres above sea level was found to contain 12 pieces per litre (*One Earth*, DOI: 10.1016/j.oneear.2020.10.020).

Island toads are shrinking rapidly

Toads introduced to two Indian Ocean islands from South Africa 100 years ago have shrunk quite quickly. Female toads on Mauritius are now up to 33.9 per cent smaller than their South African counterparts. Those on Réunion are up to 25.9 per cent smaller. Males shrank on Mauritius, but not on Réunion (*Biology Letters*, doi.org/fjq8).

Vegan diet linked to more broken bones

People who don't consume animal products are more at risk of breaking bones, especially hips, according to the largest study of this issue. The overall risk was quite small – about an extra 20 bones broken per 1000 people over 10 years (*BMC Medicine*, doi.org/fjx6).

Drug discovery

Potent antifungal found in sea creature

A NEW antifungal compound that works even on treatment-resistant fungi has been discovered in the microbiome of a marine animal.

Fungal infections affect hundreds of millions of people every year. "They're particularly a problem for people whose immune system is suppressed," says David Andes at the University of Wisconsin-Madison. The new compound may help because it is effective against many fungal

pathogens that infect humans, such as *Candida auris*.

Andes and his colleagues found the compound – which they named turbinmicin – inside *Micromonospora* bacteria that live within sea squirts. They made the discovery by screening bacteria isolated from a variety of marine animals. The team searched for bacteria with promising chemical fingerprints and found that turbinmicin targeted a fungal protein called Sec14p, which no other antifungal drugs target (*Science*, doi.org/ghktcp).

Turbinmicin's efficacy against

C. auris is promising, given that this contagious fungus appears to have developed resistance to almost all currently available antifungal drugs.

One problem with antifungal drugs is potential toxicity, because of similarities between fungal and human cells. Fungi and humans are both eukaryotes – organisms with complex cells containing a nucleus and organelles that are bound by membranes. "It's hard to kill them without hurting us," says Andes. So far, the compound shows no sign of toxicity in animals, he says. DL

Robotics



Warehouse bot upgrade could cope with e-shopping surge

PICK-AND-PLACE robotic arms for packing boxes in warehouses can now work more than 350 times faster because of a neural network that predicts how quickly they can safely transport items.

The pandemic has led to a surge in online shopping. To address the need for faster robots, Ken Goldberg and Jeffrey Ichnowski, both at the University of California, Berkeley, have improved the speed of a robot arm once it has grasped an object, a bottleneck in automated packing.

Robots can move quickly, but not always safely. The level of "jerk", or rapid change in acceleration, can mean the difference between a

successfully delivered package and one flung on the floor. Jerk can also lead to wear and tear on the robotic arm, reducing its working life.

Ichnowski and Goldberg and their colleagues added a so-called neural network to their robotic software. They then let the network assess the way the robotic arm performed as it moved thousands of objects over the course of several weeks.

Eventually, the network learned to identify the best movement path to take in any given scenario within 80 milliseconds. The pre-existing software took 29 seconds to run the calculation (*Science Robotics*, doi.org/fjqq). Chris Stokel-Walker

Materials science

Spray can make pills steerable

A GLUE-LIKE magnetic spray can turn objects such as pills into mini robots that can be controlled and navigated through the body.

Magnetic fields can be used to make sprayed objects roll, flip and crawl. Yajing Shen at City University of Hong Kong and his team even used the spray to animate an origami crane's wings.

"Our spray can convert various tiny objects to mini robots," says Shen. Objects can be flat or 3D and only a thin coating of spray is required, he says. Dubbed M-spray, the substance contains polyvinyl alcohol, gluten and iron particles.

The coating can be removed using an oscillating magnetic field to break it down into powder, leaving the object intact, says Shen. This could prove useful for delivering pills to a particular location. The powder can be absorbed or excreted by the body.

The team tested this by manoeuvring an M-spray-coated drug to a target area in an unconscious rabbit's stomach and disintegrating its coating (*Science Robotics*, doi.org/ghkr7w).

The spray's properties make it a good candidate for biomedical uses, says co-author Xinyu Wu at Shenzhen Institute of Advanced Technology, China. Ibrahim Sawal



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The columnist

Attitudes to food are cultural not scientific, says James Wong **p24**

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The Californian desert that is an unreal sea of oil pumping jacks **p28**

Culture

Documentary *Crazy, Not Insane* explores why people kill **p30**

Culture columnist

Emily Wilson finds *His Dark Materials* a delicious treat **p32**

Comment

The cost of fossil auctions

The sale of the amazing Duelling Dinosaurs fossil to a museum may do palaeontology more harm than good, says **Riley Black**

THE Duelling Dinosaurs are just the sort of remains that fossil fans dream about. Encased in huge lumps of tan sandstone are the dark bones of two dinosaurs that were buried together more than 66 million years ago.

One of the fossils is a familiar three-horned *Triceratops*. The other is a probable young cousin of *Tyrannosaurus rex*, a rare representative of what the “tyrant king” was like during its gangly, awkward years. There is no evidence the two dinosaurs died in combat but they have still been the subject of palaeontological gossip for a decade.

Enough cash has now finally been stumped up to give the bones a home. Rather than being bought by a private bidder, a museum has paid – probably millions – for the fossilised duo. Although palaeontologists should be able to examine the fossils, bone buying is a dangerous game and it isn’t clear that museums should ever shell out for specimens like this.

Commercial fossil hunter Clayton Phipps and his colleagues found the skeletons in 2006 on a private ranch in Montana and undertook the excavations themselves with an eye towards a future sale. Years before, a near-complete *T. rex* nicknamed Sue had been purchased for more than \$8 million at auction, starting off a commercial fossil boom that started ratcheting up the market value for dinosaurs.



Buzz around the Duelling Dinosaurs started to kick off in 2011. Word among experts was that the owners of the fossils were looking to sell to a national museum for a price exceeding \$9 million. Yet no one bit. So the Duelling Dinosaurs went to auction at Bonhams auction house in 2013 but failed to meet the reserve price. It seemed as if the bones were in limbo – invisible to science for not being in a museum, but far too pricey for any institution to afford.

The North Carolina Museum of Natural Sciences has now announced that it has bought the

fossils, although it hasn’t said how much it spent. We don’t yet know what the Duelling Dinosaurs fossil will be able to tell us about life in the Cretaceous, but I worry that combined with the record-breaking auction of Stan, a *T. rex* sold for \$31.8 million earlier this year, we may be seeing a price boom that harms science.

The US doesn’t treat fossils found on private land as part of its natural history heritage, as many other places do. A landowner is free to turn away academic palaeontologists in favour of commercial fossil hunters who promise big payouts.

Palaeontology often operates on a shoestring budget. The millions spent on single specimens could fund research departments, graduate students and field expeditions for decades. A single department could find many more fossils and generate much more research with the same fundraising effort, but, as things stand, star specimens are more likely to draw dollars as well as attention.

The issue doesn’t just affect the US. The burgeoning commercial market for prize fossils inadvertently fuels black market sales, whether that is tyrannosaurs illegally exported from Mongolia or “blood amber” sold in Chinese markets that fuels genocidal conflict in Myanmar.

Change may be slow in coming. Sweeping legislation similar to the Historical Resources Act of Alberta in Canada, which requires finds to be documented and assessed by experts after discovery, could help.

At the moment, experts face a devil’s bargain of either buying ethically questionable fossils or watching them disappear into inaccessible private collections. On the open fossil market, scientific desirability often trumps ethics. The gleam of a tyrannosaur’s teeth is beautiful, but the petrified smile should say “buyer beware”. ■



Riley Black is the author of *Skeleton Keys: The secret life of bone*. She lives in Salt Lake City, Utah

#FactsMatter

A cultural view of food Many people hold strong opinions about genetically modified food, but it is important to remember these concerns are cultural rather than scientific, writes **James Wong**



James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

Huge stacks of voiceover scripts for a new BBC documentary called Follow the Food, which looks at how humanity might feed itself by 2050.

What I'm watching

Being painfully true to British stereotype, I am binge-watching The Crown on Netflix.

What I'm working on

I am starting to film an online course on houseplants next week.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

IHAVE always been fascinated by people's cultural relationship with plants. You might assume understanding this is all about voyaging up the Amazon river to learn how indigenous peoples use traditional medicines, but, to me, the most interesting cultural beliefs lie much closer to home. Nowhere is this more the case than when it comes to the contentious issue of genetically modified crops. Yet it might surprise you to know that my concern is exclusively cultural, not scientific.

One of the most intriguing things about culture is that it is such an intrinsic part of how we see the world. It can seem like culture is something only other people have, as within any given culture, its unique biases and preconceptions are largely invisible to those who share them. So it is unsurprising that many people with a cultural aversion to genetic modification are unaware that this is what it is. Many may be convinced that these are valid scientific concerns, reflecting the evidence. To illustrate that this is an illusion, all you have to do is look at a few examples.

With so many everyday crops now developed using GM techniques, many argue that choosing organic is the only way to avoid the practice in some countries. On this point, they would be right, but here is where the argument gets tricky. I bought some lovely Star Ruby grapefruit at an organic store the other day. Some may consider these to be perfectly natural, unless, of course, you know about their actual history.

Star Ruby grapefruits are based on a genetic mutation generated by exposing plant material to atomic radiation. Known as radiation mutagenesis, this

is a common breeding technique first developed in the 20th century that aimed to create all sorts of novel crop traits, using everything from cobalt-60 released in bursts from underground concrete bunkers in fields to simply strapping seeds to the insides of hospital X-ray machines. The potentially hundreds of mutations created were entirely random and unpredictable, and we have been able to identify only some of them. Everything from a cultivar of mint used to make menthol to a barley variety used to make beer were created through this technique and it is still in active use today.

"The transfer of genes happens all the time in nature. So if you are against GM crops, you are against sweet potatoes"

By comparison, modern GM techniques that identify single genes, potentially just turning one on or off, are far more precise and are run through a battery of tests. So if your concern about genetically modified organisms is based on unknown consequences of tinkering with the genome, then the range of organic crops created via radiation mutagenesis, with their mysterious catalogue of random, untested mutations, would logically be far, far more worrying. Perhaps surprisingly, there seems to be no such fear.

Yet as in all cultures, the concern about GM crops isn't monolithic. You may be perfectly comfortable with the idea of inducing genetic mutations – after all, these occur all the time in nature. It might just be the extent to which we can transfer genes from one species to another that troubles you. The seemingly unprecedented ability

to make changes on this scale can understandably make transgenic crops feel culturally challenging.

However, let's consider the case of the sweet potato. All cultivars of this crop contain bacterial genes that were transferred into them thousands of years ago. In fact, the insertion of genes between species actually happens all the time in nature through a process known as horizontal gene transfer. So if you are against GM crops, you are against sweet potatoes. Depending on how far you want to take the argument, you might even be concerned about your own body, which contains 100,000 pieces of viral DNA inserted in our distant past, making up to 8 per cent of the human genome.

You might say that these changes to genes took place so long ago that millennia of testing has had the chance to identify any long-term side effects. Then again, you might find it surprising to learn that millennia of use is by no means evidence of safety – take comfrey, for example, an ancient crop that has only recently been shown to be unsafe to consume in large quantities. The problem with the precautionary principle – the idea that caution should always win out – isn't just that following it to its logical conclusion means no innovation can ever truly be justified, but that it seems to be applied in a highly selective way to concepts to which we already have identified a cultural aversion.

Now, as someone interested in cultural beliefs about food, I don't think I can dismiss the ideological aversion to genetically modified organisms anymore than I would the cultural taboos some people have about eating pork, beef, meat in general or even root vegetables. Yet it is important to clarify that this is what they are: cultural, not scientific. ■

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Editor's pick

How to tackle worries over coronavirus vaccines

14 November, p 8

From Keith Macpherson,
Clevedon, Somerset, UK

There are worries that anti-vaccine sentiment may hamper the use of inoculation to combat the coronavirus and get life back to near normal. However, no one has really mentioned the vaccination certificates that will undoubtedly be required for international travel to fully resume. Individuals will surely have to present this proof at foreign ports prior to being allowed to enter a country. This alone might improve the vaccine uptake.

From Jack Podmore, London, UK

Do the UK's vaccination plans – or those of any other country – take into consideration the millions of UK residents (or similar in other nations) who have already been infected by the virus and probably have some level of immunity?

The UK has bought enough of the Pfizer and BioNTech vaccine for 20 million people. If we were tested for antibodies first, assuming they do last for a fair time, it may be possible to better use the limited supply by not vaccinating those who have already had covid-19.

The existence of 5 billion Earths would be scary

14 November, p 14

From Tim Stevenson, Great Missenden, Buckinghamshire, UK
You report research by NASA showing that there may be up to 5 billion Earth-like habitable planets in the galaxy.

On one level, this is terrifying. I say that because of how it relates to the Drake equation, which is used to calculate the possible number (N) of other advanced civilisations out there. Given we have never heard from any, N seems to be low.

NASA's finding pins down a number of factors in that equation. This throws light on one in

particular: the length of time for which such civilisations release detectable signals into space (L).

If the number of planets suitable for life is found to be high, but N appears to be small, then L is probably short. Looking around me, that seems horribly plausible.

From Frank Kolmann,
Sydney, Australia

Even if there are 5 billion Earth-like planets in our galaxy, it doesn't mean life is there. Our moon may well have been necessary for life to arise on Earth – it would take an entire article to fully explain why, from spin dynamics to atmosphere stripping to tidal effects. We need to find an Earth-like planet that has a moon like ours to have a chance of finding life.

We could breed hunting instinct out of pet cats

31 October, p 42

From Robert East, London, UK
Your article on the impact of predation by pet cats reminded me of a study of 70 cats conducted in a UK village in 1987.

It showed a gamma distribution of prey numbers – that is to say, a large number killed few animals and a small number killed many. One cat was responsible for 10 per cent of animals killed in total. At the other end of the distribution, several cats brought back no prey in a year. This suggests it might be possible to breed pet cats with a lower tendency to kill wildlife.

How to untangle the morality mismatch

31 October, p 23

From John Cantellow, Derby, UK
Sylvia Terbeck's article about how moral actions can differ from moral decisions reminded me of the work of Daniel Kahneman

and others, who found some behaviour was largely determined by non-conscious processing that was fast and intuitive. Conscious processing was slower and gave a different, fabricated explanation for the actions taken.

Perhaps the difference between moral decisions and moral actions can be explained by the difference between conscious and non-conscious processing.

From Peter Slessenger,
Reading, Hampshire, UK

When it comes to the thought experiments about either diverting a runaway trolley so it kills one person or letting it continue so it kills five, I know exactly what I would do in those circumstances – panic.

From Robin Buxton,
Harwell, Oxfordshire, UK

The trolley problem, a test of our moral decisions, has another choice. If throwing a stranger in front of the trolley would stop it, so, too, would throwing yourself.

Machines may hollow out the middle tier

10 October, p 44

From Hillary Shaw,
Newport, Shropshire, UK
You wonder whether we should fear automation coming for our jobs. I think it may actually make the job market more unequal rather than shrink it outright.

There are some roles that we could automate, but in which it is cheaper to employ a human. Automation may remove middle-tier jobs in which a machine is cheaper, leaving a swathe of lower-paid roles plus some highly paid posts. For example, workers using IT-based navigation systems have already replaced many taxi drivers who have mental navigation skills.

While computers can create art and carvings, humans will still clean the tools.

A dream's purpose may be very individual

7 November, p 34

From Annie Macdonald,
London, UK

As a psychotherapist with 25 years' experience, I was intrigued by the idea that dreams could have a single purpose. I have seen that dreams are more than just noise. Context is all. The purpose and the meaning of one individual's dream will be different to a similar dream from another person.

In space, nothing can feel the turn of your rudder

31 October, p 46

From Matthew Allan,
Eastleigh, Hampshire, UK

You portray an attractive vision of space travel powered by sails to capture solar winds. The seductive parallels with sailing ships on Earth distract from the issue of steering such space vessels. A sailing ship can only work at the intersection of two fluids – in our case, air and water. In space, there is an equivalent to Earth's wind, but no counterpart to water, which creates the ability to steer. Or am I missing something obvious?

When the machines start casting votes...

24 October, p 30

From Rachel Feilden,
Tallisford, Somerset, UK

Vijaysree Venkatraman closes her review of books on the use of data in elections by saying "after all, it is still humans who cast the votes, not machines". That isn't always the case: the documentary *How Ohio Pulled It Off* (2008) showed the result of a software engineer's analysis of voting machines used in the state in 2004. Some people who had voted Democrat noticed that, at the moment they pushed the "submit" button, the machine flipped their vote to Republican. ■



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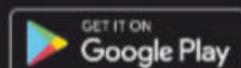
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Surreal oilscape



Photographer David Gardner

THIS landscape looks more like a bizarre film set than a real place. What was once a desert occupying more than 40 square kilometres across the foothills in Kern County, California, has been rendered unreal by an immense sea of oil rigs and pump jacks that leave little trace of its natural state.

The Kern River Oil Field has been mined extensively for crude oil since the spot was first discovered in 1899. Its reserves were estimated at more than 475 million barrels in 2006, with oil currently being removed at a rate of 70,000 barrels a day. Extraction has been made easier by fracking, a drilling process that allows oil producers to tap into more reserves than ever.

This image is part of a collection of photographs entitled "Into the Anthropocene" taken by photographer David Gardner. The collection won him the Judges Choice prize in the Professional Climate Change category in this year's BarTur Photo Award.

Gardner's work highlights the environmental destruction taking place throughout the western US in order to support an ever-growing human population.

"In each location, I was simultaneously dazzled and disturbed by the scope of these transformations – many occurring in my lifetime," writes Gardner on the BarTur Photo Award website. "What was revealed I found compelling – strangely alien but completely human."

For more on the 2020 winners and details of a related exhibition, visit barturphotoaward.org.

Gege Li



Why do people kill?

True-crime shows focusing on the act of murder are booming. A new documentary instead looks at what might spawn a killer, says **Elle Hunt**



Film

Crazy, Not Insane

Alex Gibney

On Sky in the UK from 1 December and streaming on HBO in the US

THERE is a scene in *Crazy, Not Insane*, a documentary about the work of forensic psychiatrist Dorothy Otnow Lewis, where she recalls the day Martin Scorsese rang. The director was shooting *Cape Fear*, and had heard of Lewis's study of violent murderers. Robert De Niro, playing a psychopath, wanted to meet one. Could she possibly make an introduction?

"It was so funny," says Lewis in the film, clearly still tickled by the memory. "I felt like a casting director!" They compromised on an attempted murderer. Her brush with Hollywood doubles as both welcome light relief in a film otherwise trained on the darkest corners of the human psyche – and a shrewd comment on audiences' fixation with them.

Even as a child, growing up in New York City during the second world war, Lewis was fascinated by what spurred some people to kill. While others at her elementary school celebrated Adolf Hitler's death by suicide, she remembers feeling regret that his mind would never be studied.

By the time Scorsese called in 1991, Lewis had made her name as an expert in the psychology of murderers and as a witness in high-profile trials, often called on by the defence to give a scientific explanation for why the defendant killed someone. This made her an unlikely celebrity, just like her subjects, people such as serial killer Ted Bundy and Mark David Chapman, who shot John Lennon.

As with *Going Clear*, director Alex Gibney's Emmy-winning 2015



documentary about Scientology, *Crazy, Not Insane* is based on a book – Lewis's memoir, *Guilty by Reason of Insanity* – with excerpts read by actor Laura Dern. The documentary has been tipped for an Oscar nomination next year on the basis of Gibney's credentials and the contemporary "true

"On hearing of Hitler's suicide as a child, Dorothy Otnow Lewis felt regret that his mind wouldn't be studied"

crime" boom, which its scientific rigour somewhat punctures.

Since 2014, when the hugely popular *Serial* podcast gave the genre a veneer of respectability, audiences have had no shortage of stories of real-life murder cases, such as *The Jinx*, *The Staircase* and two seasons of *Making a Murderer*. But in telling the story of Lewis's pioneering (and still controversial) work, *Crazy, Not Insane* focuses

not on the act of murder, but on the motivation for killing.

Working alongside neurologist Jonathan Pincus in the late 1970s, Lewis studied dozens of young people with murder convictions and found three consistent factors: brain injury, childhood abuse and a loss of contact with reality, particularly paranoia. This challenged conventional thinking at the time that murder could be attributed to socio-economic deprivation, lax parenting and even innate evil.

Lewis drew controversy for her support of dissociative identity disorder (DID), once known as multiple personality disorder. She has long argued that murderers often develop a homicidal persona, or "alter", in response to trauma, and disassociate in the act of killing. A DID diagnosis complicates the question of mental competence at the time of the crime, a pillar of the US justice system.

Lewis first came to public

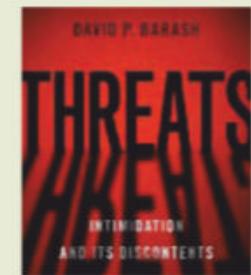
Dorothy Otnow Lewis on the stand during the Arthur Shawcross trial

attention in 1990 as a witness for the defence of New York serial killer Arthur Shawcross. She presented evidence of brain damage affecting his impulse control and footage of him apparently being interviewed as his "alter" (his mother, Bessie, who he said abused him in childhood). Lewis supported Shawcross's plea of not guilty by reason of insanity, arguing that he was psychologically predisposed to violence and, as such, should be institutionalised, not imprisoned.

But the jury was unreceptive, and Lewis was widely ridiculed in the media. Thirty years later, Park Dietz, the forensic psychiatrist who testified for Shawcross's prosecution, tells Gibney that he still believes DID to be a "hoax". There remains much conflict about it within the profession.

The chief point of contention is whether DID is a discrete

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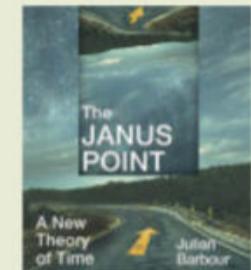
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Hundreds of Earths

Multiverse stories can be tricky to follow, but a new sci-fi novel gets it right, finds **Will Heath**



Book

The Space Between Worlds

Micaiah Johnson
Hodder & Stoughton

THE multiverse isn't easy to wrap your head around – so many versions of reality, in which events in one place may or may not be linked to what happens in another. As such, learning the rules of a sci-fi multiverse can be a difficult affair. But Micaiah Johnson's debut novel, *The Space Between Worlds*, tackles the idea with ease. It is a witty, deep and savvy tale about travelling through multiple universes.

Cara is a young woman who works across a multiverse of 380 Earths in her job as a "traverser". Each time she arrives at a new version of the planet, she has to collect vital information about what makes that Earth unique before bringing it back home to her bosses.

A traverser can only visit an alternate Earth if they are already dead in that universe. Luckily for Cara's job prospects,

there aren't very many versions of her still alive. She grew up in a brutal and fascistic wasteland, and so only eight versions of her are still going. This means she is free to travel to almost every Earth in the multiverse, making her a valuable employee.

The Space Between Worlds is set primarily in two places, each of which is visited across multiple realities. The first is the rich and clean Wiley City, where Cara now lives, and the other is the wild, *Mad Max*-style wastes of Ashtown that she hails from. Both places are on Earth, though it isn't clear when in time the novel is set.

The book explores a lot of exciting possibilities about alternative realities, but it soon becomes clear that exploration and world-building on a multiversal scale isn't its goal. Instead, it is a surprisingly intimate novel about facing down your demons. It muses on questions of identity, nature vs nurture and the consequences of our actions.

Although there are a few awkward steps in its world-building process, the novel never falls under the weight of too much complexity. The characters are sharply written and the way that the plot twists and turns is gripping. There are intense and weighty revelations right from the beginning. At times, the book is reminiscent of Terry Pratchett and Stephen Baxter's *The Long Earth*, and at others, it is closer to Luiza Sauma's *Everything You Ever Wanted*.

The Space Between Worlds is a fresh and interesting take on the multiverse. On this version of Earth, anyway. ■



trauma-based disorder with its own diagnostic criteria or a label applied to a group of distinct mental health conditions. Some criticised DID's inclusion in the 1994 update of the *Diagnostic and Statistical Manual of Mental Disorders*, a US handbook of accepted psychological conditions, for lending it credibility.

In 2009, *Current Psychiatry* published a viewpoint calling for DID's removal from a forthcoming edition of the manual, with author Numan Gharaibeh arguing that the listed diagnostic criteria were "almost meaningless". It remains in the most recent edition, but *Crazy, Not Insane* is sure to spark the debate anew.

To the layperson, at least, the footage of Lewis cross-examining "alters" is convincing, and Gibney clearly stands with his subject. The film treads a careful line, presenting childhood abuse not to excuse people's crimes, but to ask what might be a just response from society. Lewis supports life imprisonment, describing herself as "haunted" by the prospect of someone who may be predisposed to violence being executed.

At a time when it can seem as if no serial-killer story has gone untold, the nuance of the discussion is striking. As Lewis says in the film: "We are all far more curious about what the murderer did, the gory details of the crime, than about why they did it." The fact she is quoting Bundy, from one of their interviews before his execution for murder in 1989, adds to the irony.

Crazy, Not Insane lands like an intervention – and maybe a rebuke to our thirst for grisly true-crime stories. Lewis says her motivation is to understand the psychology of homicide so it might be prevented: "Murderers are made, not born." If we fail to extend to them humanity, and are content merely to consume their crimes, are we part of the problem? ■

Elle Hunt is a freelance writer based in London

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The TV column

From Dust to dark matter An exceptional cast continues to make *His Dark Materials* a spine-chillingly brilliant show. The introduction of a character who studies the secrets of the cosmos is the cherry on top, says **Emily Wilson**



Emily Wilson is the editor of *New Scientist*. You can follow her on Twitter @emilyhwilson or email her at editor@newscientist.com



TV

His Dark Materials

Jack Thorne
BBC One and HBO

Emily also recommends...

TV

Fringe

J. J. Abrams, Alex Kurtzman and Roberto Orci

For five seasons, *Fringe* told the story of a glossy FBI special agent, Olivia Dunham, and her investigations into fringe science/strange goings-on with a “mad scientist”, Walter Bishop, and his son Peter. As the show goes on and its backstory builds, a parallel universe – featuring the same characters, but altered – becomes central. Great stuff!



SEASON two of *His Dark Materials* begins exactly where we left off in series one, with Lyra and her daemon Pan washed up in a strange new world. Here, in what appears to be an abandoned city, she will soon meet another young hero, Will. Until now, he has been following his own storyline in a different version of reality to Lyra’s. From now on, it seems, they will fight the good fight against the forces of darkness together.

Everything about the BBC’s rendering of Philip Pullman’s series of novels is gorgeously done and elegant. The title sequence – the music, the art – is spine-chillingly excellent and the visuals and effects throughout the show are movie quality.

Not only is the writing tight, the cast is also exceptional. The young leads Lyra (Dafne Keen) and Will (Amir Wilson) do a fantastic job

of holding the centre of the story. Lord Asriel (James McAvoy), Lyra’s father, is out for this season, but instead we get Will’s father, played by Andrew Scott, aka the priest from *Fleabag*. Phoebe Waller-Bridge voices his daemon, in a neat little Easter egg for *Fleabag* fans.

“Through the new character Mary Malone, we get a glimpse of the ‘science’ behind the strange goings-on”

I watched the first series of *His Dark Materials* with children, and when I came to watch season 2, alone, I wondered whether I would enjoy it as much without it falling under the welcome umbrella of delightful viewing for the whole family, of which, for us, there is never enough.

Lyra (Dafne Keen) and Will (Amir Wilson) explore a strange new world

In any event, there was no reason to worry. The leads are children, but there is enough going on for any adult – plus, of course, there is Mrs Coulter (Ruth Wilson). For the first five episodes of this season, at least, Mrs Coulter dominates. Dressed as some sort of 1940s femme fatale, she is terrifying, and yet heartbreakingly human.

Every time she enters a room, one beautifully shod foot at a time, it is Drama. For reasons that cannot now be fathomed, I have never read the books on which the show is based, so I am fascinated to find out more about Mrs Coulter, especially her relationship with her monkey daemon. It fights and frightens on her behalf, and yet can be separated from her, which goes against daemon lore. Is that by her dreadful will alone, or are they not really a human and daemon pairing at all?

A further joy of this latest season comes with a new character, Mary Malone, played by Simone Kirby. Malone lives in Oxford in Will’s world, which is basically our version of it, and she studies dark matter – or, as Lyra knows it, Dust.

She seems to have spent her career ploughing a fairly lonely furrow in the pursuit of the secrets of our cosmos. Now, suddenly, she is someone at the heart of an adventure story that spans worlds. Through her, we get a glimpse of the “science” behind the strange goings-on in this multiverse-set epic.

In these dog days of a long year, thank you to Mr Pullman – and, of course, the gods of the golden age of television – for this delicious, rather festive-feeling treat. ■



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A quantum twist in space-time

The universe is expanding faster than our models can explain. It might be time for a radical rethink of how the cosmos works, says **Stuart Clark**

AT FIRST, it was a whisper. Now it has become a shout: there is something seriously wrong with our understanding of the cosmos. When we measure the rate at which the universe is expanding, we get different results depending on whether we extrapolate from the early universe or look at exploding stars in nearby galaxies. The discrepancy means that everything is speeding apart more quickly than we expect.

The problem originally surfaced a few years ago, and the hope was that it would fade away with more precise observations. In fact, the latest measurements have made it impossible to ignore. “It is starting to get

really serious,” says Edvard Mörtzell, a cosmologist at Stockholm University in Sweden. “People must have really screwed up for this not to be real in some sense.”

Cosmologists have been scrabbling for answers. They have played around with the properties of dark energy and dark matter, those two well-known, yet still mysterious, components of our standard model of cosmology. They have imagined all manner of new exotic ingredients – all to no avail.

The conclusion could hardly be starker. Our best model of the cosmos, a seemingly serenely sailing ship, might be holed beneath the water line. That has led some researchers

to suggest taking the ultimate step: abandoning that ship and building a new standard model from the ground up, based on a revised understanding of gravity. It is hardly the first such attempt. Now, however, it comes with a twist – almost literally. By putting a quantum spin on Einstein’s theories of space and time, we might finally make sense of the over-accelerating expansion of everything.

Our understanding of the universe has continually evolved in response to new observations. In 1915, when Albert Einstein’s general theory of relativity described gravity as a result of mass warping space-time, he presumed that the universe sculpted by this large-scale force is static. He even added



a term to the equations called the “cosmological constant” to stop the universe expanding wildly or collapsing in on itself.

A few years later, however, astronomer Edwin Hubble showed that distant galaxies were speeding away from our own, and thus that the universe was expanding. This meant it must have begun in a hot, dense state that came to be known as the big bang.

Then, in the 1990s, two groups of astronomers used light from exploding stars to demonstrate that this expansion is accelerating, an effect we now tend to attribute to a mysterious repulsive force – “dark energy” – which, as it turns out, looks a lot like the cosmological constant. ➤

By this time, astronomers who observed the rotations of galaxies and clusters of galaxies had also noted that they are whirling around far faster than they should be for the amount of visible matter they contain. The astronomers' solution was to update the model yet again, incorporating a new, invisible dark matter that far outweighs the normal stuff we see.

These are the foundations of the standard model of cosmology, known as lambda-CDM, the lambda being the dark energy and CDM standing for "cold dark matter". It has been extraordinarily successful, accounting for pretty much everything we observe in the universe at its grandest scales. Lambda-CDM even fits with our most precise map of the cosmic microwave background (CMB), the first light in the universe, released just 380,000 years after the big bang. "It is a perfect model, to be honest," says Carsten van der Bruck at the University of Sheffield, UK.

Cosmic tension

But that close fit with the CMB suggested a definitive test of consistency. Cosmologists could take precise measurements of the universe's expansion rate when the CMB was released and use the model to wind forward and predict the current rate of expansion, known as the Hubble constant. "It's the ultimate end-to-end test of the universe," says Adam Riess, an astrophysicist at Johns Hopkins University in Maryland. "To go from the beginning to the end and have the two ends of the bridge that you are building meet up."

The trouble is that they don't meet. When we extrapolate forwards from the big bang using lambda-CDM, we get a lower rate of expansion than we do through astrophysical measurements of the distance to exploding stars in relatively nearby galaxies. The expansion of the universe is measured as the speed at which every million parsecs (Mpc) of space expands, a parsec being 3.26 light years. Working forward using lambda-CDM, cosmologists predict a Hubble constant of 68 kilometres per second for every million

parsecs (km/s/Mpc). But looking at the rate of expansion today by measuring distances in space, astrophysicists get 73 to 74 km/s/Mpc.

This discrepancy is referred to as the Hubble tension. If lambda-CDM correctly describes the universe, it shouldn't be there. Most cosmologists, unwilling to give up on such an otherwise successful model, had assumed the tension isn't real – that the observations were wrong. But last year, a measurement made using a third method matched the higher, astrophysics-based value. This summer, the positions became even more entrenched when a new look at the CMB using the Atacama Cosmology Telescope in Chile bolstered the lambda-CDM prediction.

The message is clear: the measurements are irreconcilable, and the Hubble tension is real. There is something fundamental we don't understand about the universe.

Over the past year or so, theorists have been casting around for a fix with fresh urgency. "It seems like there is a new solution posed every day," says Mörtsell. In the grand tradition of dark energy and dark matter, many of them involve adding more unseen ingredients to lambda-CDM in the hope that

this will increase the predicted expansion rate. But when Mörtsell tried to be agnostic about the nature of an extra ingredient and just looked at how much energy you would need to add to the early universe to fix the tension, the results were sobering. "It is not easy," he says. "You can ease the tension a bit. You can maybe get halfway, but not much more than that."

As well as fitting the Hubble constant, any model must correctly describe other observations, such as the rate at which galaxies form, the amount of galaxy clustering on various cosmological scales and the appearance of subtle ripples in the clustering of galaxies, known as baryon acoustic oscillations. As it stands, lambda-CDM agrees well with those observations, and any changes that increase the Hubble constant quickly put these other predictions out of whack.

Another option is to tweak the behaviour of an existing component, for example by making the repulsive force supplied by dark energy stronger in the early universe. "You can ease the tension a bit, but you can't go all the way," says Mörtsell. The same goes



Are we missing something about how galaxies and galaxy clusters shape the universe?

for tweaking the properties of dark matter.

There is a third obvious place to look for the source of the tension: the idea that matter and energy can be thought of as being more or less evenly distributed across the universe. This is a key computational assumption of the lambda-CDM model, and was certainly the case around the time the CMB formed. But in the intervening 13 billion years, as gravity has pulled celestial objects together, the universe has become increasingly lumpy. Astronomical surveys show that 30 to 40 per cent of the cosmos now contains clusters of galaxies. These have drained matter out of the rest of space, leaving 60 to 70 per cent being largely vast regions known as voids.

Out of the void

Galaxy clusters have become so dense that they have decoupled from the expansion of the universe. They exist as gravitationally stable objects, meaning there is enough pull to stop the space within them expanding. The surrounding voids, meanwhile, being largely empty of mass, can expand at a faster rate. This is called “back-reaction”, and it is completely ignored by lambda-CDM. Most researchers assumed that on sufficiently large scales, the clusters and voids would average out, making any effects negligible. But what if they don’t?

In 2018, Krzysztof Bolejko, a cosmologist at the University of Tasmania in Australia, realised that if the back-reaction could alter the overall expansion rate of the universe by just 1 per cent, it could solve the Hubble tension. He quickly put together a “toy” model of the universe and ran the numbers. It looked good. “I was quite enthusiastic about it,” says Bolejko.

But when Hayley J. Macpherson at the University of Cambridge and her colleagues simulated the large-scale universe with a full lambda-CDM model sensitive to back-reaction, they found that the average expansion was virtually unchanged. As far as easing the Hubble tension is concerned, back-reaction too is a bust. “Right now, it

“Space-time could be affected by the quantum-mechanical spin of matter”

looks like back-reaction will not be able to solve this problem,” says Bolejko.

So where to go from here? Adding new ingredients doesn’t work, tweaking existing ones has failed and rethinking our assumptions delivers no answers. For Bolejko and Mörtsell, that leaves only one option, even if many of their colleagues have yet to accept it. “In a few years’ time, cosmologists will need to get rid of the lambda-CDM model and they will need to replace it with a better model,” says Bolejko.

That involves going back to basics and reconsidering the theory that governs the relationship between the universe and its components. It is a nuclear option, because general relativity has yet to flunk a single direct observational test. But here we are.

To be fair, most “replacements” for general relativity are in fact additions to the existing equations. A group of theories under the banner of bimetric gravity, for instance, postulate that a whole different set of equations take over from Einstein’s original terms when certain conditions are met, such as gravity exceeding or dropping below a certain strength. These grabbed Mörtsell because a change in gravity’s behaviour over the course of cosmic history could drive a change in the expansion rate of the universe.

A massive twist?

After tweaking the theory to explain the Hubble tension, though, the essential check he needs to make is whether the theory still correctly predicts the appearance of today’s galaxy clusters. And that is where things become overwhelmingly complicated. “The equations are too hard to solve,” says Mörtsell. This is perhaps a good moment to note that unravelling the full complexities of general relativity’s equations has occupied cosmologists for decades.

Bolejko has taken a different approach. He has revived the work of Élie Cartan, a French mathematician, who in the first half of the 20th century proposed an extension to general relativity called torsion. In Einstein’s formulation, mass is the only property of ➤



ESA-STÉPHANE CORVIA

matter that warps space-time. Effectively, Cartan proposed that space-time could also be affected by the quantum mechanical property of spin in the matter that makes up celestial objects.

Torsion is appealing because it is one of the simplest ways to extend general relativity, says Christos Tsagas at Aristotle University of Thessaloniki in Greece. Rather than adding something ad hoc, you are incorporating a physical property known to exist in matter. In the process, you are adding a new field to the universe, the properties of which are governed by several parameters that are still to be constrained.

That gives room for manoeuvre. "You can fine tune this new field," says Tsagas. If you get it right, you can potentially solve the Hubble tension. "You change the nature of the geometry of the space-time," he says, and anything that affects the geometry of space-time will affect the expansion of the universe.

Bolejko thinks he might have already done the trick. "The results that we have are very

encouraging," he says. "We can actually explain away the Hubble tension. We are getting 73.9 [km/s/Mpc]. That's good enough for me." He notes that his work is preliminary. If his calculations hold up to further scrutiny, however, it would be the first time in this argument that a cosmological model has reproduced the astrophysicists' value.

One thing in favour of torsion is that there is an obvious way to test the idea. It involves comparing two different ways to measure distance on cosmological scales. One observes the size of similar celestial objects and equates any difference to the "angular distance" between them. The other gets the distance by comparing the brightness, or luminosity, of similar objects.

In standard general relativity, those two distances are related by a specific relationship known as Etherington's distance-duality equation. But earlier this year, Bolejko and colleagues calculated that with the addition of torsion, space-time becomes more complicated and this will change the

The European Space Agency's Euclid satellite will measure billions of galaxies with peerless precision

distance-duality equation. "This is like a smoking gun that will be used in future to test torsion," says Bolejko.

As of now, telescopes aren't sufficiently sensitive to execute such a test. In the next few years, however, cosmologists are expecting a flood of new data. Several upcoming projects will make huge surveys of the large-scale structure of the universe, not least the European Space Agency's Euclid satellite. Launching in 2022, Euclid is designed to measure the shapes and distances of 2 billion galaxies, with a view to probing the expansion history of the universe and the formation of cosmic structures to unprecedented levels of precision. NASA is planning a similar mission, the Nancy Grace Roman Space Telescope, set for launch in the mid-2020s.

That could be make-or-break time for any challenge to Einstein. "When you start modifying gravity, you start modifying how structures like galaxies and galaxy clusters grow in the universe," says Mörtsell. "Satellites like Euclid will be very good at measuring this with a much higher precision than now. They will be very useful for investigating the scenarios where you actually have another gravitational law than the one suggested by Einstein."

Could this really be the end of lambda- CDM ? It might seem impossible that such a successful model could be felled by a small discrepancy. Again, history has a different lesson: it was tiny inconsistencies in things such as the orbit of the planet Mercury that set Einstein on the road to replacing Isaac Newton's earlier theory of gravity.

Perhaps we are on the cusp of yet another revolution in cosmology brought about by fresh observations, even if we don't know what that revolution might look like yet. "To me it's very exciting," says Riess, "because we now have the potential to discover new things about the universe." ■



Stuart Clark is a New Scientist consultant. His latest book is *Beneath the Night* (Faber)



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Free Sk'aliCh'elh-tenaut

Efforts to gain freedom for an orca held in captivity for half a century have taken an extraordinary twist, finds **Elle Hunt**

ABOARD a small boat in Biscayne Bay, Florida, Raynell Morris (Squil-le-he-le) beats a steady rhythm on a handheld drum. When she shouts towards the shore, her voice cracks with emotion. "Your people are here," she says. "We'll bring you home."

Morris's call is directed at the Miami Seaquarium where an animal she considers her kin is kept in captivity. Sk'aliCh'elh-tenaut – also known as Tokitae or Lolita – is a Southern Resident orca. It is the last week in September, and Morris has travelled 5500 kilometres from her home in Washington state to mark the 50th anniversary of the whale's capture. Sk'aliCh'elh-tenaut's incarceration remains an open wound for Morris and the rest of the Lummi Nation, the Native American people in whose territory the whale was taken. Various groups have been fighting for her release for decades. Now, the Lummi are leading a new approach.

The latest bid to free Sk'aliCh'elh-tenaut centres on her cultural significance, striking at the heart of questions about how to recognise Indigenous rights and make amends for historical harms. Morris and another Lummi tribal elder, Ellie Kinley (Tah-Mahs), intend to sue the Miami Seaquarium to release Sk'aliCh'elh-tenaut under the Native American Graves Protection and Repatriation Act (NAGPRA), the federal US law governing the return of objects of cultural importance to Native Americans. If they do, it would be the first time the law has been applied to a living being. Those involved believe it is the best hope yet of getting Sk'aliCh'elh-tenaut released.

Southern Resident orcas are a single clan of whales, consisting of three interrelated matriarchal pods found in the Salish Sea, off the coast of the Pacific Northwest. To the Lummi, who have lived on the shore alongside them for thousands of years, they are sacred: they call them qwe'lhol'mechen, "our relations under the water". To scientists, who have studied them intensely for a decade, they are a trove of information about orca social life and communication. But the population is highly precarious due to habitat degradation, noise pollution and declining numbers of Chinook salmon, which make up 85 per cent of their diet. Last year, there were just 73 individuals – with Sk'aliCh'elh-tenaut making 74.

In 1970, she was one of seven calves taken from their pod at Penn Cove in the Salish Sea and transported across the US for display in marine parks. Today, Sk'aliCh'elh-tenaut is the sole survivor. Her mother is believed to be Ocean Sun, the 92-year-old matriarch of one of the pods. For most of Sk'aliCh'elh-tenaut's life, home has been a small tank that is as deep as she is long – 6 metres – which she

"In 1970, she was one of seven calves taken from their pod in the Salish Sea"



MARICE COHN/BAND/TRAIBUNE NEWS SERVICE VIA GETTY IMAGES



The captive orca performs twice daily under the name Lolita

shares with two Pacific white-sided dolphins. When the Miami Seaquarium wasn't closed to the public by the coronavirus pandemic, she performed to visitors twice daily.

"You can hardly call it a life," says Ingrid Visser at the Orca Research Trust in New Zealand, who has spent 25 years studying orca behaviour in the wild and campaigning for an end to their captivity. In 2016, she was an expert witness in PETA's unsuccessful lawsuit against the Miami Seaquarium under the US Animal Welfare Act. In her report, Visser described Sk'aliCh'elh-tenaut's tank as "grossly inadequate" and noted that the orca displayed signs of a compromised immune system, extreme stress and deprivation.

For the Lummi, who draw no distinction between what they call their "blackfish" and human kin, Sk'aliCh'elh-tenaut's captivity is nothing short of imprisonment. "We are one and the same," says Morris. "We call ourselves a pod." Nevertheless, she also recognises that these ancestral spiritual ties aren't enough to secure Sk'aliCh'elh-tenaut's freedom. "You have to walk in the white world," says Morris. Before returning to the Lummi Reservation in 2007, she worked for more than 22 years in corporate banking, and then as a White House staffer under Bill Clinton. It is this experience, she believes, that led her ancestors to task her with the "sacred obligation" of bringing Sk'aliCh'elh-tenaut home.

To that end, Morris and Kinley have enlisted help from the Earth Law Center, a Colorado-based non-profit organisation that aims to transform laws worldwide so that they protect, restore and stabilise ➤



**Southern Resident orcas
are few in number, but have
been intensely studied**

ecosystems. In July, they informed the Miami Seaquarium and its parent companies in writing of their intent to sue under NAGPRA. The Miami Seaquarium, having received federal funds, meets the definition of a museum, so is subject to this legislation, they argue. Their aim is for Sk'aliCh'elh-tenaut to be repatriated as "cultural patrimony", defined by NAGPRA as "an object having ongoing historical, traditional or cultural importance central" to a Native American group or culture.

"I think it is unique," says Jan Bernstein of Bernstein & Associates NAGPRA Consultants in Denver, Colorado, who isn't involved in the case. She believes the argument is convincing and, if successful, would set a precedent in terms of applying the law to a living animal. However, she adds, filing a lawsuit would be the last step of many to reaching an agreement.

Indeed, it may not come to that. Grant Wilson, executive director of the Earth Law

Center, is hopeful that the Miami Seaquarium can be persuaded to partner with the Lummi on Sk'aliCh'elh-tenaut's release. There is mounting opposition to keeping cetaceans in captivity, he says. Other marine parks have already taken the initiative. For instance, the National Aquarium in Baltimore, Maryland, has been working towards relocating its eight bottlenose dolphins to a managed "ocean sanctuary" since 2016. Similar

"The Lummi draw no distinction between their 'blackfish' and human kin"

enclosures are springing up around the world, including in Iceland, Bali and Australia. Wilson suggests this trend, along with the financial strain of the pandemic, should be an incentive to bring about a "positive end to this decades-long story".

Plans for Sk'aliCh'elh-tenaut are already in the works. With funds raised over the years for her release, the Lummi have contracted the Whale Sanctuary Project – a non-profit organisation working to create a permanent refuge for captive cetaceans off Nova Scotia in Canada – to draft a proposal for how she might be returned to the Salish Sea. Executive director Charles Vinick, who helped reintroduce *Free Willy* star Keiko to the wild in Iceland two decades ago, says Sk'aliCh'elh-tenaut's resilience would need to be evaluated in stages, starting with a health assessment. She also needs to be taught survival basics, such as how to catch live fish and how to swim at speed, before there is any possibility of reintegration with her pod. "The key to this is doing it responsibly – for her, for her family and for the other Southern Resident orcas in the area," says Vinick.

Nevertheless, he believes that of all the attempts to free Sk'aliCh'elh-tenaut over the decades, this one has the greatest chance of success because it is a "spiritual endeavour" led by the Lummi. For Morris, the cooperation across worlds is creating unstoppable momentum for Sk'aliCh'elh-tenaut's release. "We have the culture, they have the science, and now we have the law," she says. "We are going to complete our sacred obligation."

One party, however, has yet to come to the table. A Miami Seaquarium spokesperson declined an interview with *New Scientist*, saying the organisation didn't comment on pending or threatened litigation. However, in September, curator Chris Plante released a statement reiterating the Seaquarium's previous position, that the "perilous move... could endanger the life of Lolita".

Vinick, Visser and others accept that Sk'aliCh'elh-tenaut's advanced age and half-century in captivity mean she isn't

a strong candidate for release. A supported “retirement”, such as the open sea pen where Keiko settled in Norway after failing to embrace the wild, may be the most likely outcome. That, they say, would be a marked improvement on her current situation.

Indigenous knowledge

As for Plante’s suggestion that energy would be better spent protecting the Southern Resident orcas, Vinick says: “It’s not a question of ‘either/or’, it is a question of ‘both/and’. You have to do it all.” The Lummi Nation already supports the Southern Resident orcas in a range of ways, from providing ceremonial offerings of live Chinook salmon to opposing infrastructure developments that would further degrade their habitat. They see bringing Sk’aliCh’eltenaut home as equally important to their work protecting and restoring the Salish Sea – a view that reflects a deeply felt connection to that ecosystem, not readily accounted for by Western frameworks of science or law.

“Indigenous people have different knowledge – of animals, the water, sky and land – that have to be honoured,” says Morris. “We’re starting to be heard, but we feel like there’s a lot more work to do to build that awareness.” The Earth Law Center recognises that such knowledge is essential to navigating the rapidly looming ecological collapse, says Wilson. However, recently published research by Helen Wheeler at Anglia Ruskin University in the UK reveals that Indigenous knowledge is regularly underutilised or misunderstood when it comes to environmental decision-making. There is a common misconception among non-Indigenous scientists that it is limited in scope or needs “verifying” to be useful, precluding productive and equitable partnerships, she says.

Wheeler believes that developing methods to work with both systems while respecting the needs of Indigenous peoples could be a win-win for advancing common environmental goals. Wilson shares this view.



Protesters outside the Miami Seaquarium in 2015 (above). A Lummi family in 1915 (below)

He hopes that Sk’aliCh’eltenaut’s case will prove “one of many where we can listen to Indigenous voices and world views, and apply them in a way that is beneficial for all of us”.

The Earth Law Center isn’t letting up the pressure. In September, at a virtual event to mark the 50th anniversary of Sk’aliCh’eltenaut’s capture, it alleged that by holding her, the Miami Seaquarium is in breach of the United Nations Declaration on the

Rights of Indigenous Peoples. Indigenous leaders from New Zealand, North America and Central and East Asia expressed solidarity, with many invoking the destruction of their own sacred animals. The Seaquarium hasn’t responded publicly.

Morris also sees parallels between Sk’aliCh’eltenaut’s separation from her family and the experience of the Lummi under colonialism. From the late-19th century, hundreds of thousands of Native American children were taken from their parents to be raised in boarding schools. “We know how Ocean Sun feels with her daughter still being enslaved,” she says. “We feel that the healing can begin when she’s brought home, and she’s free.” ■



Elle Hunt is a freelance writer based in London. She is a former reporter and features editor for *The Guardian*

Features



The hunt is on

What if we could track down the virus that will cause the next pandemic before it leaps from other animals to humans, asks **David Adam**

LURKING in the air, water, soil and inside every other living creature, viruses have us surrounded and hopelessly outnumbered. For every star in the known universe, there are at least 10 million viruses on Earth. They are so small that more than 100 million can fit on a pinhead.

As 2020 has shown, just one of these is enough to bring society to its knees. The covid-19 pandemic offers a grim demonstration of how hard it can be to stop a new infection once it takes hold in the human population.

But what if we could hunt down the next pandemic-causing virus before it starts spreading? If surveillance of viruses evolving in animals could identify the likely candidates, then we might be able to pinpoint the all-important leap they could make into humans. And by identifying the animal species carrying the most problematic viruses, measures could be put in place to prevent their spread.

This kind of viral detective hunt is a Herculean endeavour, even before you add the difficulty of predicting which candidate out of millions will go on to infect us. Critics argue that it is impossible to stop the occasional rogue virus from jumping into humans and that we should instead focus on stamping out those infections when they occur. The debate has split scientists, but it needs to be resolved soon. Even as we continue to battle covid-19, the clock is ticking down towards the next outbreak of a novel pathogen.

The health of humans, wildlife and ecosystems is intimately connected. As our population grows, more people live in contact with wild and domestic animals and so the odds rise that “zoonotic” pathogens will spill over species barriers to infect us.

Yet even if new viral pandemics that spread from animals are inevitable, they are also staggeringly unlikely events. Fate and biology must combine in a precise way to put the wrong virus in the wrong place at the wrong time. First, a virus circulating in an animal must pose a threat to humans. Most don’t. They lack one or more of the bits of molecular machinery needed to bind onto human cells, replicate once inside and then spread further to other cells and other people – all without being mopped up by the immune system. Next, the animal harbouring a potentially dangerous virus has to come into contact with a susceptible person and shed enough infectious material near them to pose a threat. Lastly, the person needs to be infected by the virus somehow and be in sufficient contact with others to spread it.

Breaking barriers

Thankfully, this series of hurdles is so difficult for a virus to clear that, of the millions of different types of viruses believed to be out there, fewer than 300 are known to infect humans. Unfortunately, however, some of the natural barriers that protect us from the viral threat are eroding and others have been smashed to bits. International ➤



“Fate and biology combine to put the virus in the wrong place at the wrong time”

air travel means that few outbreaks can be contained as local problems. A virus can now travel across the world in less than a day, giving medics and scientists little time to react – hence the call for better surveillance to act as an early-warning system.

“We absolutely need to understand what viruses are circulating in animals,” says Tracey Goldstein, a specialist in viral surveillance at the University of California, Davis. “We need to understand more about the hosts and their behaviour and when they might be shedding the viruses.”

At its most ambitious, such a surveillance scheme would sample and sequence the genomes of the viruses that live within all wild and domestic animals that humans could encounter. That’s a lot of animals, but an even larger number of viruses. Nobody knows for sure how many viruses such an effort would need to find and analyse, but it is probably more than 500,000. That is likely to cost a few billion dollars and entail a decade of trudging around caves, jungles and forests looking for species and taking samples of their urine, saliva and droppings.

Such a scheme was proposed in 2016. The Global Virome Project is marketed as “the beginning of the end of the pandemic era”. Although it can boast some high-profile supporters – former UK prime minister David Cameron backed the idea in June – it is yet to raise the necessary funds.

This project isn’t the only attempt at global surveillance, and it isn’t the only initiative to illustrate the scale of the undertaking. A US government-funded programme called PREDICT was launched in 2009 to provide an early warning of pandemics, prompted by the 2005 bird flu outbreak. PREDICT was cancelled by the Trump administration earlier this year (although it has since been given a six-month reprieve to assist with the covid-19 pandemic). Spending \$207 million in 60 countries and taking 164,000 samples from wildlife, livestock and humans, it discovered 949 novel viruses. In other words, PREDICT only scratched the surface of an estimated 10,000 potentially zoonotic viruses in wild mammals. It found just one

1.6 million

Estimated number of undiscovered viruses in birds and mammals

Researchers in Thailand don protective equipment to catch bats in a hunt for coronaviruses

that was possibly linked to deaths in humans – the Bas-Congo virus – and it didn’t spot the coronavirus that causes covid-19.

“We targeted the animals that we thought had the highest potential to carry the most viruses that could spill over,” says Goldstein, one of the leaders of PREDICT. “That’s not completely comprehensive, but you have to start somewhere. And we targeted primarily RNA viruses. Those are the ones that are less stable and those are the ones that have caused most of the pandemics in the past.”

Finding a virus in an animal is just the start. The next step is to assess the potential pandemic risk by seeing if it can infect



SAKCHAI LALIT/AP/SHUTTERSTOCK

human cells in lab tests. Most viruses from animals can't do this because they lack the proteins needed to bind to our cell receptors. For example, the PREDICT team found a coronavirus in a bat in Uganda in 2017 that looked genetically similar to the MERS virus, which is found in camels and can infect people. But there were differences in the spike protein, which viruses use to penetrate would-be host cells. Lab tests confirmed that this made it harmless to humans.

In 2013, the team identified a coronavirus similar to the one that causes SARS. It could infect human cells, but there was no evidence it had actually infected people. And in 2018, the project identified another novel virus in a bat, this time in Sierra Leone. Called Bombali virus, it is from the same family as Ebola. Lab experiments confirmed that it could infect human cells, yet, again, there is no evidence that anyone has actually caught it or that it could be spread from person to person. It isn't even clear whether the Bas-Congo virus is a human pathogen. It was found in blood samples taken from a nurse who treated two children who died of a haemorrhagic fever in the Democratic Republic of the Congo in 2009. But the virus hasn't been found in anybody else since, and something else could have killed the children.

Another programme to detect emerging viral threats took place in Vietnam, and focused on people who live and work closely with animals at high risk for zoonotic pathogen transfer. From 2013 to 2016, the VIZIONS project followed almost 600 farmers, animal-health workers and people involved with animal slaughter or who sell rats for meat. Whenever one of them reported a cough, sore throat or fever, local doctors would visit within 48 hours to take samples and record details about their exposure to animals.

About two-thirds of the workers developed a respiratory infection over the three-year period. Analysis of the samples found mostly common pathogens such as the influenza A virus, but also some novel viruses. It isn't clear where these came from or if they might pose a clinical risk, but the VIZIONS



LAUREN DECUCA/GETTY IMAGES

researchers say their discovery proves that this type of screening is an effective way to catch emerging zoonotic infections.

Even when viruses do get inside host cells, they still face the challenge of replicating without alerting the immune system. And we don't fully understand what changes allow a virus to flourish in one species and struggle in another.

A successful zoonotic virus – including SARS-CoV-2, the cause of covid-19 – tends to be a generalist, says Mike Farzan, an immunologist at Scripps Research in Florida. This means that “most of its proteins work in most cells from other species”. Zoonotic pathogens with many different host species have a higher chance of survival, and of

A bat's toenails are painted to help identify it after sampling its bodily fluids

eventually finding their way into the human population. As well as bats, SARS-CoV-2 has been found to infect a wide range of animals including pet cats and dogs, lions and tigers at a New York zoo, farmed mink and wild ferrets, hamsters and macaques – although the risk of a person catching covid-19 from these animals is believed to be low. So viruses that can spread from animal to animal are a priority for scientists looking for potential human threats.

Take Hendra virus, which is usually found in bats but can be passed to horses, and from them into people, causing fever, coughs and sometimes meningitis and coma. Dozens of outbreaks and four deaths have been reported in north-eastern Australia since 1994. Hendra outbreaks are linked to periods of heavy rainfall, says Raina Plowright, an infectious disease ecologist at Montana State University. In wet conditions, trees such as the eucalyptus produce fewer flowers for infected bats to eat. As a result, they are more likely to search for food on farms, where they may come into contact with horses. Hungry bats are also stressed and so tend to shed higher quantities of the virus.

500,000

Estimated number of animal viruses capable of jumping to humans

\$1.2 billion

Cost of the Global Virome Project surveillance programme

949

Novel viruses discovered by the PREDICT surveillance programme



SERGEI REBOREDO/VWPICS/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

Understanding this transmission cycle could allow scientists to better predict outbreaks, from studying weather cycles perhaps, or checking on viral levels in the bats. It also suggests a possible way to stop spillover events from happening. "A postdoc in my lab a few years ago suggested we set up mango juice stands for the bats and I remember laughing," says Plowright. "But we've come to realise that's the killer experiment. We're starting to build up a nice evidence base that replanting winter-flowering trees could stop spillover."

A similar approach is being used to stop the Nipah virus being passed from bats to humans in South-East Asia. The virus causes flu-like symptoms and brain inflammation and is often fatal, but its spread can be curtailed by using nets to prevent bats accessing collection pots for date palm sap, a popular drink in the region.

Pandemic prediction

The ecosystem approach could combat viral threats identified elsewhere too, but it requires serious investment to understand complex ecological scenarios, viral dynamics and the interplay of wild and domestic species. "There needs to be a push to galvanise activities in a coordinated, globally funded way," says Barbara Han at the Cary Institute of Ecosystem Studies in New York. "In order to do pandemic prediction or prevention with any level of accuracy, you have to have a way of assessing the who, what, where, when

and why of spillover. And ecology is really critical for getting at all of those areas."

The research needed to fill the gaps in knowledge sounds old-fashioned in an age of genome sequencing. It comprises basic questions related to things like social structures and the interactions of animal groups, their metabolism, lifespan and how many times a year they have offspring. "These things might seem a bit removed from our goal of being able to predict pandemics, but if you don't know what the animals are doing, then you're not going to have a chance of being able to make predictions that are useful," says Han.

Not everyone agrees. Colin Carlson, a biologist at Georgetown University in Washington DC, says the idea that basic ecological studies can prevent pandemics is an example of the unhelpful "covidisation" of research. The risk, he says, is that attention and funds get diverted away from proven methods of fighting infections and protecting public health. Hype over the importance of viral surveillance means "you have a bunch of wildlife biologists essentially at the forefront of global efforts to prevent the next pandemic".

A similarly damning argument was made in an article in *Nature* in 2018 by three leading biologists, who argued that efforts such as PREDICT and the Global Virome Project were of little practical value and that "making promises about disease prevention and control that cannot be kept will only further undermine trust". Money should be spent instead on boosting

Vietnamese farmers working with animals like ducks have been tested for new viruses

health capacity in developing countries, to spot the early signs of infection in people, they argued.

But Jonathan Epstein, a disease ecologist with the EcoHealth Alliance, a conservation and public health organisation that was part of the PREDICT programme, insists that viral surveillance offers a way to slash the risk of spillover events – even if it can't always stop them. Changing human behaviour to keep people away from the sources of zoonotic viruses in the first place is key, he says, using methods such as tighter controls on live animal markets.

"You can certainly understand what the major activities are that promote spillover and work to reduce the risk there," he says. "We have to try to reduce risks but at the same time be ready to respond when an outbreak does happen."

Most of the world got that response wrong this time around – too slow, too little and too late. We didn't heed earlier warnings. This is a planet of viruses, and we need to take the fight to them. ■



David Adam is a science writer based in Hertford, UK. His most recent book is *The Genius Within*



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The back pages

Puzzles

Have a go at our latest crossword, quick quiz and brain teaser **p52**

Almost the last word

Why do some people struggle to tell left from right? **p54**

Tom Gauld for

New Scientist

A cartoonist's take on the world **p55**

Feedback

Putting the "oo" into humour – the week in weird **p56**

Twisteddoodles for **New Scientist**

Picturing the lighter side of life **p56**

Citizen science

Zooming into outer space

You can help astronomers explore distant galaxies from the comfort of your living room. **Layal Liverpool** explains how



Layal Liverpool is a digital journalist at *New Scientist*. She believes everyone can be a scientist, including you. @layallivs

What you need

Internet access

A web browser opened to galaxyzoo.org/

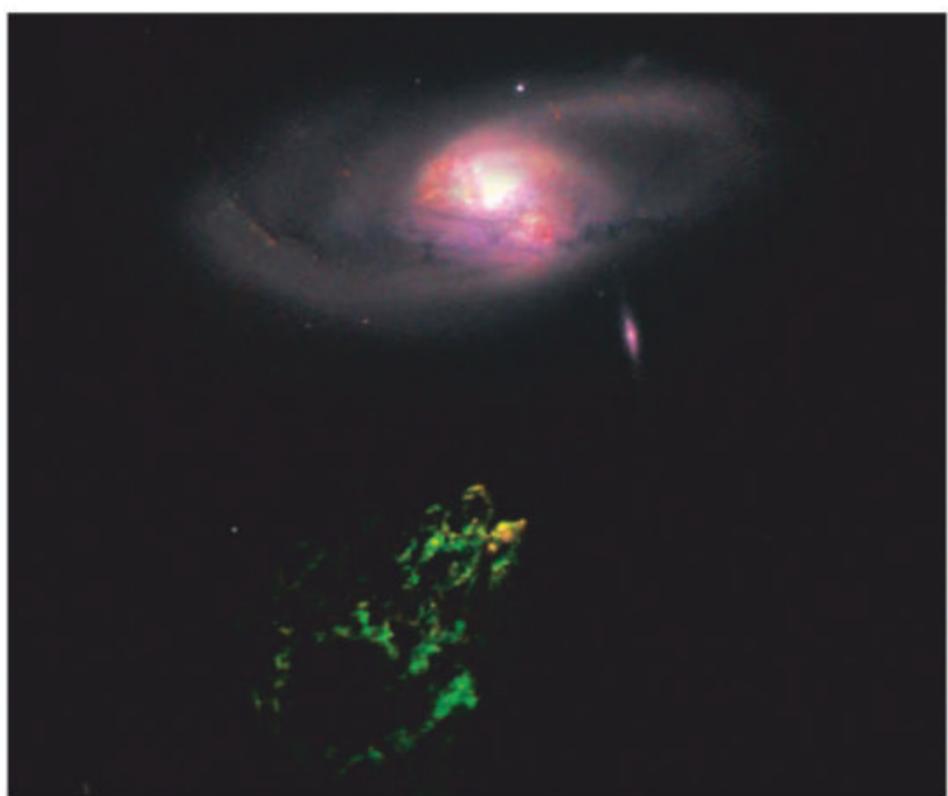
I AM peering deep into the cosmos. I can see a cluster of bright lights shining in the distance – a faraway galaxy. I click “smooth” when asked about its shape. I am an armchair astronomer, flicking through telescope images to help researchers who are studying remote galaxies.

There are more images from telescopes than researchers could ever analyse on their own. Since the Galaxy Zoo citizen science project was launched more than 10 years ago, hundreds of thousands of people have helped identify more than a million galaxies of a wide variety of shapes and sizes as well as identifying previously undiscovered interstellar phenomena.

This is exactly what happened to Dutch schoolteacher Hanny van Arkel in 2007, when working through images on Galaxy Zoo gathered by the Sloan Digital Sky Survey. “She noticed... that there was this sort of blue sludge,” says Karen Masters at Haverford College in Pennsylvania, who is part of Galaxy Zoo’s science team.

That blue sludge turned out to be a big deal. Named Hanny’s Voorwerp (Hanny’s object in Dutch) after its discoverer, it was in fact an extremely hot cloud of gas which was being lit up by light from a quasar – a bright, energetic object powered by a supermassive black hole at the centre of a galaxy called IC 2497. The cloud can be seen in the image above, below the galaxy and rendered in green.

Researchers have since discovered and analysed more



NASA IMAGE COLLECTION/ALAMY

of these objects. Patterns in the light from them help us identify past changes in the galaxies that illuminate them.

More than 60 scientific papers have been published by astronomers using Galaxy Zoo’s crowdsourced data so far. When the project first started, machine learning techniques weren’t good enough for analysing galaxies. Nowadays, Galaxy Zoo relies on a mixture of machines and human interpretation – with some easy classifications now possible using artificial intelligence.

Galaxy Zoo’s latest set of images comes from the Dark Energy Camera Legacy Survey, which is 10 times more sensitive to light than the Sloan Digital Sky Survey, allowing the galaxies to be seen in unprecedented detail.

While you will see snapshots of these vast objects, there is much more to them.

“When we look at a picture of a galaxy, it looks static, it looks frozen in time, but these are actually very dynamic objects, everything is moving, there are giant collections of stars, gas and dust orbiting around the common centre of mass,” says Masters.

Looking through the starry images was strangely soothing to me. If you are looking for a new hobby, I can highly recommend exploring the vastness of space from the comfort of your sofa. To join the effort, just head to galaxyzoo.org/. ■

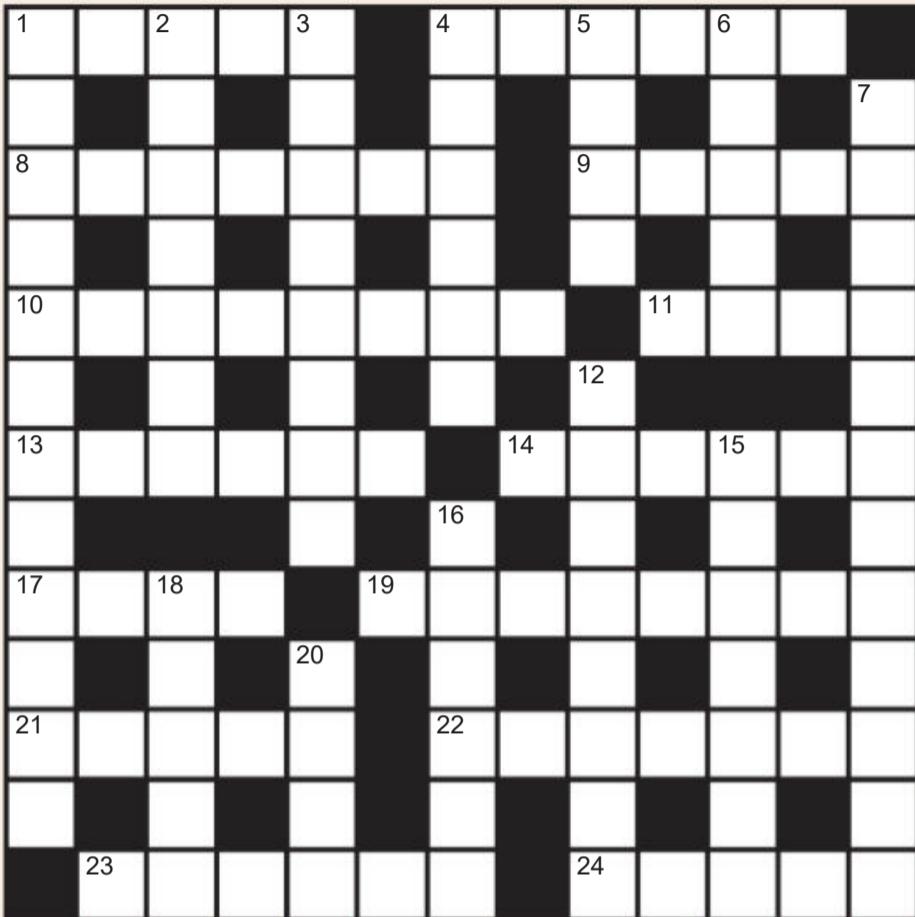
Citizen science will appear every four weeks

Next week

Science of cooking

These articles are posted each week at newscientist.com/maker

Cryptic crossword #45 Set by Rasa



ACROSS

- 1** Leaders in science agree to investigate new material (5)
- 4** Dog consumed select items (6)
- 8** Gauge portion engaged in arm-twisting (7)
- 9** Contrarily dismisses section of letter (5)
- 10** Inopportune communication buried in tilled ground (3-5)
- 11** Programmer's output is third-rate poem (4)
- 13** Mathematician's on the road with nothing to lose (6)
- 14** Winner of the 13 Across Award playing viol around Saskatchewan (6)
- 17** Intimidate with large Batman accessory (4)
- 19** Book covers small unit of mass appearing in Hindu markings (8)
- 21** Squash a callus (5)
- 22** Partnership accepting letter of resignation, that is plain (7)
- 23** A father met with your indifference (6)
- 24** Centre and west end of Derby wreathed in fog (5)

DOWN

- 1** Florence Nightingale, for example, using and reusing antics (12)
- 2** Thunder's initial rumble shattered glass (7)
- 3** Superfan essentially describing Tolkien tree sustenance (8)
- 4** Race attendant requiring extra energy (6)
- 5** Reckless breakout (4)
- 6** Roughly dangling from end of elephant trunk (5)
- 7** Unusual nerve effects characterised by ebullience (12)
- 12** Find plastic in heat-generating field? (4,4)
- 15** Thoughtful Communist family (7)
- 16** Thick layer like a golf ball's surface (6)
- 18** Hoot owl, dropping wings, perches on climbing bear (5)
- 20** Insect that bites King Cole in the ear (4)

Scribble zone

Answers and the next quick crossword next week

Quick quiz #79

- 1** In which country would you find the world's largest single-aperture optical telescope?
- 2** What name is given to the equation that describes how particles like electrons behave when they travel close to the speed of light?
- 3** What was Earth's largest mass extinction event to date?
- 4** Fermenting soya beans with *Rhizopus oligosporus* creates which foodstuff?
- 5** Which Swedish chemist is credited with discovering cerium and selenium?

Answers on page 55

Puzzle

set by Zoe Mensch

#87 Poll position

A biased and manipulative pollster is doing a survey of your cul de sac, where half the residents vote Red and the other half Blue. He wants to use the poll to "prove" that Reds are in the majority. His plan is to pick a house to start and visit all the homes in a loop going clockwise, but to stop the poll at the first instance that Red takes the lead.

As it happens, you know how everyone on the street votes. Is there a house where you can get the pollster to start from where you can be certain his plan will be foiled. If so, what is an easy way to find it?

Answer next week



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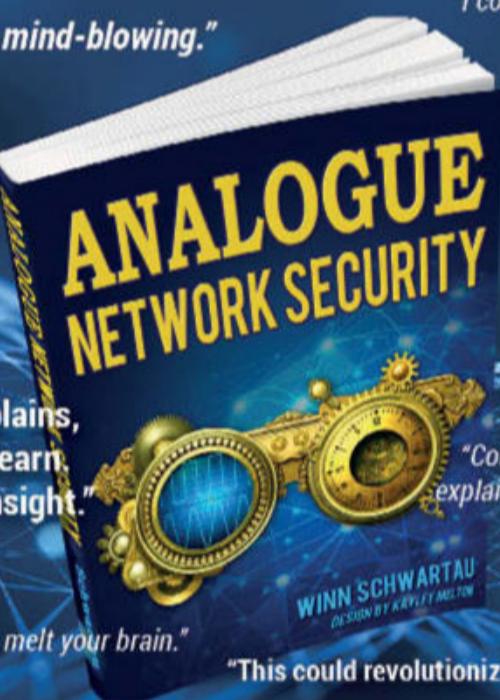
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Right, wrong

Why do some people struggle to tell left from right?

Valerie Moyses

Bloxham, Oxfordshire, UK

I used to confuse left and right so badly that my driving teacher had to instruct me to "turn my-side" or "turn your-side". I am still working on it.

It seems to be a matter of semantics: the terms "left" and "right" don't carry the same sort of natural meaning as other words for location, such as "above" or "behind". The ancient Romans were probably less likely to get the two confused since their word for left, "*sinister*", came to be associated with misfortune and their word for right, "*dexter*", with things being beneficial and correct.

Guy Cox

St Albans, New South Wales, Australia

As a young boy, I had real trouble telling left from right. However,

"In many languages, the word for right has positive connotations. 'Left' comes from the Old English word *lyft*, meaning weak"

I was a thumb-sucker, and my Eureka moment came when I worked out that the skin on my right thumb looked different from that on my left, due to the sucking. So when I had to choose between left and right, I just looked at my thumbs. After a few years, the pattern was fixed in my mind.

Chris Daniel

Glan Conwy, Conwy, UK

Mixing up left and right is surprisingly common. One study found that up to a third of people have problems with it sometimes. It can be associated with dyslexia and dyspraxia, as well as difficulty telling the time. In languages such as French,



ALEX MIT/GETTY IMAGES

This week's new questions

In a spin Earth spins round the sun, the sun round the galaxy and galaxies spin on their axes. Where does all this spin come from? The big bang? *Peter O'Connor, via email*

Reading matter Is it better for the environment to read a book or newspaper online or in a paper format? *Jackie Jones, Brighton, East Sussex, UK*

Spanish and English, the word for right has positive connotations of being correct, straight and direct. In Latin and Italian, it is associated with dexterity.

"Left", by contrast, comes from the Old English word *lyft*, meaning weak. The French word for left means clumsy, while the Italian word means sinister.

Many of the animal and plant kingdoms have bilateral symmetry. While top and bottom and front and back are very distinct from one another and have physical realities, left and right have little visible difference except for being mirror images of one another. The concept of left and right is complicated by being linked to the observer, so spatial awareness is needed to learn that your right may be someone else's left.

Gerry Gormley

Queens University Belfast, UK

The neurological processes that underpin left-right discrimination are complex. The task requires many higher cognitive functions, including the integration of visual information, language and memory, as well as being able to rotate objects in your mind.

A significant portion of the population struggles to learn which side is which. In healthcare, aviation and shipping, this can be catastrophic. Some of the most infamous errors in medicine were due to performing surgery on the wrong side of the body, such as removing the wrong kidney or limb.

What can be done to help? There are techniques to distinguish left from right – for example,

From planets to galaxies, the universe is full of spin. Where does it come from?

extending the left thumb at a right angle to the index finger forms the letter "L" to identify the left hand and side. However, research I have carried out indicates that this method isn't foolproof.

Incorporating safety systems when making critical left-right decisions can help reduce wrong-sided errors – for instance, a surgical team taking a time out before an operation to run through a checklist to ensure surgery is carried out on the correct side of the patient.

Some people who have difficulty distinguishing left from right feel stigmatised and may want to conceal their struggles. Being comfortable saying that you have difficulty with this, and gaining support from those who work with you, could make all the difference.

Sniffy dilemma

Is it better to sniff or blow one's nose to clear non-infectious secretions?

David Livermore

Cambridge, UK

My father used to induce sneezing during the cold season by tickling his nasal passages. Presumably, he hoped that this would help displace viral particles from his nose into his handkerchief. I wonder whether this was a recommendation at the time of the 1918 flu pandemic, during which he was a small child.

Katherine Conroy

Manchester, UK

A healthy person ingests around 1.5 litres of nasal secretions a day, so sniffing and swallowing isn't harmful. Any pathogens within the phlegm will be easily neutralised by gastric secretions.

On the other hand, repeated and forceful nose-blowing can generate pressures that are high enough to force mucus into the

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sinuses, which could be a factor in chronic sinusitis. If you are going to blow your nose, stick to one nostril at a time and do it gently.

Whether you sniff or blow is usually dictated by local etiquette: Some cultures find public nose-blowing to be abominably rude, while others view sniffing as an intolerable faux pas. Social setting may influence your choice more strongly than physiology.

Harsha Kariyawasam
Royal National ENT Hospital,
London, UK

It helps to understand why our nasal system produces secretions. The watery mucus dripping from both nostrils is the release of glandular secretions from the nasal lining at the front of the nose.

A degree of wetness in this area of the nose is healthy. However, when the surface of the nose senses a real or perceived threat, such as the cold virus, cold air or irritants, this can trigger a rapid release of nasal secretions to "trap" the threat and flush it out of the

"Some cultures find public nose-blowing to be abominably rude, while others view sniffing as an intolerable faux pas"

nose. In such circumstances, it is best to blow the nose rather than sniff to avoid anything harmful getting deeper into the airway.

Deeper inside the nasal cavity, glandular cells are constantly active and can make more than a litre of mucus in 24 hours. With the help of cilia, tiny hairs on cells that line the airway, this mucus drains towards the back of the nose where it is usually swallowed.

When sinuses become infected or inflamed, this can trigger excess or more viscous mucus production. When this happens, mucus doesn't easily move to the back of the nose and there is no choice but to try to blow it out. This is easier said than done when the inside of the nose is congested.

So it is fine to either sniff or to blow non-infectious secretions

depending on which part of the nose (front or back) is producing the mucus.

Seeing the light

Why does light reflect in a mirror but go straight through glass?
(continued)

Reiner Zorn

Juelich Centre for Neutron Science, Germany

The previous answer was wrong to claim materials are transparent or reflective depending on whether they have a crystalline structure. Mercury is liquid, not crystalline, and is reflective. Diamond is crystalline and transparent. Delocalised electrons cause reflectivity, and this has nothing to do with crystalline structure.

Eric Kvaalen

Les Essarts-le-Roi, France
Amorphous materials aren't necessarily transparent – take obsidian, for example. Crystalline materials are often transparent. Consider rock salt, or quartz. ■

Answers

Quick quiz #79

Answers

1 Spain. The 10.4-metre Gran Telescopio Canarias is found on the Canary Islands.

2 The Dirac equation.

3 The Permian-Triassic extinction event, in which some 90 per cent of species were wiped out.

4 Tempeh.

5 Jöns Jacob Berzelius.

Quick Crossword #71

Answers

ACROSS **1** Vaccine, **5** Pabulum, **9** Thawing, **10** Occiput, **11** Mass ratio, **12** Umami, **13** Necrology, **16** Reeks, **17** Trace, **19** Steel wool, **22** Tears, **23** Reflector, **26** Nursing, **27** Treacle, **28** Simpson, **29** Scarlet

DOWN **1** Vitamin, **2** Classic, **3** Icier, **4** Eight, **5** Prototype, **6** Becquerel, **7** Laplace, **8** Metrics, **14** Open-skies, **15** Oestrogen, **17** Tetanus, **18** Anagram, **20** Optical, **21** Largest, **24** Fetus, **25** Enema

#86 Yam tomorrow

Solution

Abel got 10 yams, Babel seven, Cabel five and the monkey three. Suppose in the morning the sailors find three yams and each gets one. This means Cabel took $(1.5 \times 3) + 1 = 5.5$ yams – but it must be a whole number. Raising the number to two each (six yams) means Cabel found 10 (and took three), Babel found 16 (and took five) and Abel found 25 (and took eight). The next solution with whole numbers would be 106 yams, but that exceeds the capacity of the crate.

Glimping a moist flange

Reflecting recently on the overzealous censorship of the proceedings of a scientific conference by a prudish AI, we called for professional help to establish what it is about the sound of words like "flange" that makes them ripe for double entendre (7 November).

Cometh the hour, cometh the man: psycholinguist Chris Westbury at the University of Alberta in Canada, co-author of such papers as "Telling the world's least funny jokes: On the quantification of humor as entropy" and "Wriggly, squiffy, lummox, and boobs: What makes some words funny?".

His central thesis, tested first on made-up words, is that a word's intrinsic amusement factor is related to the improbability of its character combination, which can be measured in terms of the word's contribution to the overall disorder, or entropy, of the English language. Broadly, words containing less common sounds are rated as funnier. Proffic, quingle, probble – clearly funny. Chertin, screnta, clester – not so much.

Feedback finds this explanation entirely quixulubble, but what of the rudeness factors of real words? Here, Westbury's work has enabled many valuable insights. Words containing an "oo" sound, for example, are disproportionately likely to be rated as funny and also to have or to acquire – cause and effect being not so readily disentangled here – questionable connotations. Well, screw our fruity bloomers.

To circle back, perhaps unwisely, to our starting point, "flange" is only mildly funny measured by its phonetic qualities, barely scraping into the top quarter of all English words, by Westbury's calculations. Some additional thesis is required to account for its phnarf factor – perhaps the other words whose company it regularly keeps, we speculate?

Westbury thinks not. "I have been asked the same thing several times about the word 'moist', which

Twisteddoodles for New Scientist



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apparently many people find rude," he says. "Although its sexual connotations are obvious, by far the most common neighbours had to do with cake."

To humo(u)r us, though, Westbury ran "flange" through his semantic relations widget, coming up with the following list: flanges, crossmember, flanged, ferrule, mounting flange, splined, rubber grommet, piston rod, mounting flanges, tensioner. Goodness gracious, and all that in a family magazine.

The AI is a bottom

The basic problem of computer prudery is, Feedback recalls, known in the trade as the Scunthorpe problem. It is named after the town in Lincolnshire, UK, residents of which have, from time to time, found themselves cut off

from online services for fear of upsetting the morals of the wider world.

Many thanks for sending in your own examples, although we suspect many of these primarily serve your own titillation at writing rude-sounding words.

For pure silliness, we commend Geoff Vaughan and his email subject line "Nuclear security", auto-corrected to "Nuclebottomcurity", as well as Rod Ward for his story of a police choir's conductor stymied in sending material for a Christmas carol concert. The problem? *Ding Dong Merrily on High*.

The mask slips

We draw breath with a headline spotted by Jane Fisher on Australia's ABC News website on 2 November: "Face wearing

in Victoria will be part of life for the foreseeable future."

Good cop, good cop

A frisson of delight ripples through our inbox as many of you, your attention no doubt drawn by the recent focus on Philadelphia's extended presidential ballot-counting process, point to the city's police commissioner, Danielle Outlaw, who has occasionally frequented this page.

We have a warm, fuzzy glow, meanwhile, thanks to the unexpected news that the outgoing Trump administration's appointee as director of the next National Climate Assessment is not only an experienced climate scientist, but also believes in the reality of anthropogenic global warming. Indeed, Betsy Weatherhead seems admirably qualified in every way.

Don't be negative...

Staying in the City of Sisterly Love, as it has been re-nicknamed in honour of the 100th anniversary of the 19th Amendment to the US constitution, Trump campaign lawyer Jerome Marcus was pressed on his claim that campaign representatives weren't being allowed into the city's election count. Asked by judge Paul Diamond whether any observers were already there from the campaign, Marcus replied: "There's a non-zero number of people in the room."

It is an answer that Feedback can just about justify if some of those present were lawyers whose tiresome arguments were sucking life out of the room, effectively creating a non-zero, negative number of people.

Simultaneously – and, we can only assume, coincidentally – our attention is drawn to an advert for Always Platinum sanitary towels, claiming "up to zero leaks, up to zero odours and up to zero bunching". Quite what their suboptimal performance amounts to, we would rather not speculate. ■

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