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WEEKLY September 16 - 22, 2017

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The man who unlocks trapped minds

GHOST LEOPARD
The bid to revive a big cat that may never have existed

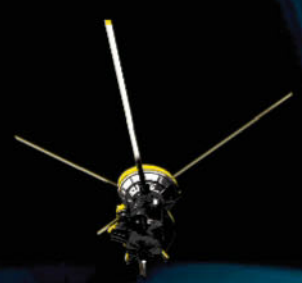
BIODIVERSITY BONANZA
20 major branches added to the tree of life

STORM WARNING Will hurricane-battered regions ever be the same again?

SPECIAL ISSUE

AFTER CASSINI

As one epic mission ends... the real journey of discovery begins



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Give us a clue

What do space travel and the future of healthcare have in common?

This is Axiom, a new film premiering at New Scientist Live, aims to answer the question.

World premiere on the Humans Stage: Thursday 28 September, 13:15–13:55

Followed by a fascinating panel debate on the biggest health issues: Friday 29 September, 10:30–11:10, The Humans Theatre

Showing on the Celgene booth (1121) throughout the event

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New Scientist Live

Date of preparation: September 2017 - UK-CELG170155d

OLI SCARFF/AFP/GETTY IMAGES

Still stronger together

UK and EU science will both be weakened by Brexit

AS THE European Union (Withdrawal) Bill wends its way through parliament, the shape of post-Brexit Britain is slowly being revealed. And not before time: as things stand, the UK will drop out of the EU in just 18 months.

The scale of the task remains momentous, and there is devil in the detail. Consider, for example, how UK science will operate once the formal ties established by EU membership have been cut. Compared with free movement and trade, science has barely been mentioned, but it matters a great deal for both parties.

Last week, the UK government revealed its hand in a position paper. What is clear is that there are many pieces missing even from this small corner of the Brexit jigsaw puzzle.

"It is the UK's ambition that collaboration… is not only maintained, but strengthened," the paper says, before calling for "a more ambitious and close partnership with the EU than any yet agreed between the EU and a non-EU country".

In principle, that seems achievable. The UK is a global science superpower. Its ties with the rest of the EU are deep and extensive: the UK is among the top five research partners for the other 27 members. All concerned have incentives to cooperate.

But in practice, there are problems. Consider Horizon 2020, an €80 billion fund that has helped UK-based researchers build strong ties with colleagues in Germany, Spain, Italy, France and the Netherlands. At present the UK is a full member, with voting rights on the future direction of the programme. After withdrawal, the best it can hope for is associate member status.

"Science is one area where the UK could plausibly push for double helpings of cake"

This would give it the same access to funds as before, but no seat at the top table. That doesn't look like a smart way to maintain, let alone strengthen, existing ties.

Similar access arrangements exist for other programmes. Non-EU countries participate in EU space research, for example, and the UK could reasonably expect to secure similar deals.

But for some programmes there is no existing third-party access. A notable example is the €500 million-a-year European Defence Research Programme, due to begin in 2022. On this, the UK government merely says it would "welcome dialogue". Nuclear R&D gets similar hand-waving treatment: "The UK hopes to find a way to continue working with the EU." Such vagueness rather undermines confidence in the lofty statements of principle.

Meanwhile, on skilled migration – a critical issue for UK science – we are told that the UK "will discuss future arrangements to facilitate the mobility of researchers engaged in cross-border collaboration" – but also that "freedom of movement will cease to apply in the UK". This smacks of having your cake and eating it, an approach criticised as wishful thinking elsewhere.

That is all the more unfortunate since science is one area where the UK could plausibly push for double helpings of cake. But with so much else to disentangle, science probably won't get the time and attention it deserves, resulting in weaker, not stronger, collaboration. That would be to the detriment of both the UK and the EU – and of global science. ■

YAMIL LAGE/AFP/GETTY IMAGES

Long road to recovery after Irma

AS HURRICANE Irma heads north, now a mere "tropical depression", it leaves behind a trail of destruction across the Caribbean and southern Florida.

Islands like St Martin, Puerto Rico, Barbuda and Cuba were hit hardest. As *New Scientist* went to press, 37 people in the Caribbean and 10 in the US are believed dead. On Barbuda, 90 per cent of buildings were destroyed.

The French and UK governments have sent aid workers, food and medical equipment to their overseas territories. Many of these islands rely on tourism and will feel the economic impact of Irma for a long time.

For many places across the region, the priorities will be safe drinking water, food and shelter. There is also an increased risk of disease, partly because stagnating water attracts mosquitoes that can carry diseases like dengue fever. In Haiti, cholera is a risk; after 2016's Hurricane Matthew, affected areas experienced a 50 per cent increase in cases thanks to a lack of clean drinking water.

Electricity must be restored to the many people who are now without. Irma knocked out power to at least two-thirds of Florida, some 6.5 million homes. Much of Puerto Rico may be without electricity for four months.

The financial cost of Irma hasn't yet been calculated. Hurricane Harvey, which hit Texas a week earlier, caused up to $180 billion of damage.

As the waters recede, people will return to their homes. In Florida, 6.3 million were evacuated. Some who find their homes and communities destroyed may move away rather than face the risk of another disaster, says Elizabeth Fussell at Brown University in Providence, Rhode Island. Twelve years after Hurricane Katrina, the population of New Orleans is still below its pre-Katrina level.

Those who return may be forced to live in flood-prone areas because they cannot afford to pay the higher rents in safer areas. There will be "growing economic inequality" in cities hit by Irma, says Fussell.

"Many Caribbean islands rely on tourism and will feel the economic impact of Irma for a long time"

In the long-term, Irma could reshape how cities like Miami, which are exposed to rising sea levels and extreme hurricanes, are developed.

"We [have] some very hard questions to ask about which places we should return to mother nature," says Eric Klinenberg at New York University. Perhaps some areas should be abandoned, he says.

But the US government is doing the opposite. President Trump has ditched Obama-era rules that made it harder to build on floodplains.

Companies looking to build in Florida will want flood insurance, says Andrew Lakoff at the University of Southern California. But outdated maps mean that insurance estimates don't include the increased flooding risk brought about by climate change.

So firms may build on vulnerable areas, knowing they will be bailed out by the government's National Flood Insurance Program if disaster strikes. Trump's government, it seems, is already creating the conditions for the next disaster.

Credit punch

EQUIFAX, a firm responsible for millions of people's credit ratings, last week announced that data belonging to nearly half the US population had been exposed in a hack.

About 143 million people whose data Equifax has collected may have had their names, addresses, dates of birth, social security numbers and, in some cases, drivers' licence numbers stolen.

"It's quite horrendous," says UK security expert Graham Cluley. "If you have people's contact details, you can begin to contact them posing as different organisations," he says, such as banks.

It's not just US citizens caught up in the hack: 44 million people in the UK may also be exposed. Many will never have heard of Equifax, much less suspect that it holds their sensitive data. The Information Commissioner's Office has advised Equifax to keep affected people updated.

Mired in fire

THE western US remains besieged by an abnormally large cluster of forest fires. As *New Scientist* went to press, there were 64 large fires raging, according to the country's National Interagency Fire Center. Montana alone had 25.

Western states remain at risk throughout this month, some into October. Oklahoma and Texas could see fires in December.

"Man-made climate change is making things incrementally hotter," says John Abatzoglou at the University of Idaho, so potential fuel dries out faster. He also says that "a legacy of fire suppression and fuel accumulation" has worsened the natural pattern of wildfires in the US, leading to more extreme fires.

Lung health charities warn that people exposed to smoke and other pollution are at higher risk of lung damage, with children and the elderly most at risk.

Mexico earthquake

THE official death toll after Mexico's massive earthquake last week has risen to 96 as more fatalities were confirmed in the hard-hit southern states of Oaxaca and Chiapas. The US Geological Survey reported the earthquake's magnitude as 8.1, making it the biggest quake in the country since 1985.

About 5000 homes were razed in Chiapas. The quake was strong enough to be felt in Mexico City, more than 700 kilometres away, and there have been hundreds of aftershocks in the days since.

It could have been much worse. An early-warning system, installed after the devastating 1985 earthquake that killed more than 5000 people, gave residents vital seconds to flee. Better building regulations after that disaster will have also helped lessen the damage. The quake was caused by the oceanic Cocos tectonic plate diving under the North American Plate and bending.

"The quake was strong enough to be felt in Mexico City, more than 700 kilometres away"

Sun belches out powerful flares

IF YOUR GPS has been acting funny, take it up with the sun. Over the past week, an active region there has been belching out sudden streams of radiation. One, on 6 September, was the largest such flare in over a decade.

Flares like this are less common at this point in the sun's roughly 11-year cycle, as it heads towards what is supposed to be its quietest period.

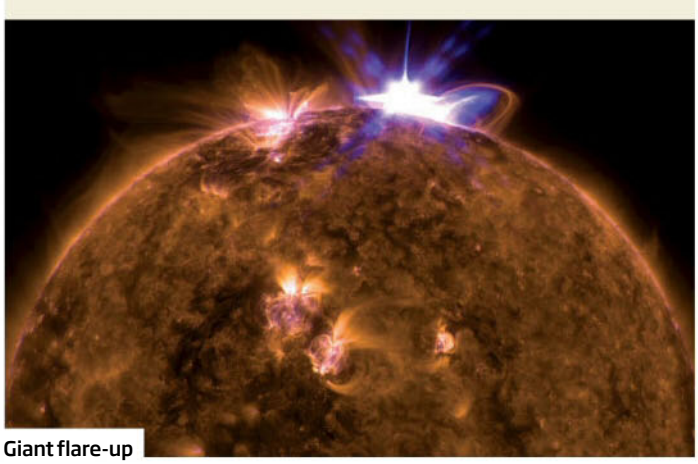
Four flares were placed in the X-class, the most powerful type of solar flare. The largest measured X9.3, the strongest since an X17 flare in 2005. Another flare, on 10 September, was classified as X8.2.

X-class solar flares are the solar system's largest explosions. They are often accompanied by twisting ropes of plasma – known as coronal mass ejections – that are 10 times the size of Earth and curl up off the sun's surface.

This time, the largest coronal mass ejection interfered with GPS communications and stopped high-frequency radios working on the side of Earth then facing the sun. The charged particles also created spectacular auroras.

NASA's Solar Dynamics Observatory captured the moment the flare erupted from the sun's active region, known as AR 2673 (below).

The most powerful solar flare ever detected occurred in 2003. It caused all of NASA's solar measurement sensors to cut out after they recorded a power of X28.



NASA/SDO/GODDARD

Giant flare-up

60 SECONDS

Pluto's name bonanza

Some of Pluto's features finally have official names. Among locations named after scientists, Pluto's pale heart has been named Tombaugh Regio after Clyde Tombaugh, who discovered the dwarf planet. One fracture is now called Sleipnir Fossa after the Norse god Odin's eight-legged horse.

Fin diesel

In a bid to address pollution in Beijing, China has floated the idea of banning the production and sale of all cars that burn diesel or other fossil fuels. The plan will kick into effect "in the near future". It would create huge incentives for electric vehicles and would shore up China's credentials as a green superpower (see page 20).

Coral on the slide

The Great Barrier Reef has been losing crucial reef-building corals for at least 100 years. Researchers only began tracking reef decline in the 1980s, but now radioisotope dating has revealed many coral deaths throughout the last century (*PNAS*, doi.org/ccz4).

Get up, stand up

Exercise isn't enough to ward off risks of sitting still for long periods. Researchers who tracked people over 45 found that those inactive for more than 12.4 minutes at a time had almost twice the risk of dying during the study period as those inactive for less than 7.7 minutes at a time. This effect held even when people did vigorous exercise (*Annals of Internal Medicine*, doi.org/ccz2).

Animals' head start

Tiny preserved burrows reveal that worm-like animals were thriving on Earth 555 million years ago, over 10 million years before other fossil evidence starts to appear. The find supports previous suspicions that animals evolved earlier than fossil bones alone would suggest (*Nature Ecology & Evolution*, doi.org/ccz5).

Life's 'dark matter' detected at last

Alice Klein

THEY were right under our noses – thousands of novel microscopic life forms, now unmasked by genetic analysis. Many belong to entirely new groups, as different from other microbes as an insect is from a chimpanzee.

Earth's microorganisms are split into bacteria and archaea. They make up the vast majority of species, but until recently we could only study a tiny fraction. This is because less than 10 per cent can be grown in the lab. The rest only survive in their native environment – be it a cow's guts or a deep-sea vent. Researchers call them microbial dark matter.

However, a technique called metagenomics is bringing them to light. It involves sequencing all the DNA in an environmental sample – its metagenome – then piecing together the genomes of each microbe present. "It's like getting a mix-up of lots of different jigsaw puzzles, and then trying to put together the pieces of each individual puzzle," says Donovan Parks at the University of Queensland in Australia.

Parks' team analysed more than 1500 metagenomes uploaded to a public database. Each contained jumbles of DNA from places like soil, the ocean, industrial effluent and baboon faeces.

Using heavy-duty computers to sift through this mess, the team reconstructed 7280 bacterial and 623 archaeal genomes. About a third were new to science (*Nature Microbiology*, doi.org/cczd).

The new microbes add 20 major branches, or phyla, to the tree of life. "To give this context, every single insect on Earth belongs to just one phylum, and every single animal with a backbone belongs to one phylum, so this is crazy new levels of stuff," says Nicholas Coleman at the University of Sydney.

"This study has put names on that dark matter," says Coleman. "Now we need to figure out what it's actually doing and how we can benefit from it."

One way will be to look for genes that resemble those of well-known organisms. "They might have a gene that looks similar to a methane metabolism gene," says Parks. But many of the genomes are highly novel, so it will take time to figure out what they do.

The microbes could yield new antibiotics, or be used in industry and waste management: to make fuel and chemicals, or break down plastic pollution, for instance. "The better we can grasp the diversity of microbes, the more we can go looking for things that are useful," says Coleman.

The expanded tree of life will also give us clues to ancient evolutionary events, such as when oxygen-producing organisms evolved, says Parks.

But the immediate question is how many more species are out there. Previous studies estimated that Earth has 1 trillion microbial species, with 98 per cent yet to be identified. "But this is probably an underestimate, as we've recently found that existing methods for estimating this actually miss a lot of organisms," says Parks.

However, the discovery of new phyla seems to be levelling off, says co-author Philip Hugenholtz at the University of Queensland. So while there are more microbes left to find, they may fill up known branches of the tree of life rather than starting new ones.

"There's still a whole lot that we don't know," says Coleman. "There are so many crazy environments out there, and even two patches of dirt side-by-side can have different organisms." ■

CARSTEN PETER/NATIONAL GEOGRAPHIC CREATIVE

Oozing biodiversity

Ultrasound turns Siri against you

DID you hear that? Alexa certainly did. Voice assistants have been hijacked using sounds above the range of human hearing. Once in, researchers were able to make phone calls, post on social media and disconnect wireless services, among other things.

That is a problem because voice assistants can also be connected to services ranging from smart thermostats to internet banking, so security breaches are pretty serious.

The hack was created by Guoming Zhang, Chen Yan and their team at Zhejiang University in China. Using ultrasound, a command inaudible to us was used to wake the assistant, giving the attacker control of the speaker, smartphone or other device, as well as access to any connected systems (*Cryptography and Security*, arxiv.org/abs/1708.09537).

The attack works by converting the usual wake-up commands – "OK Google" or "Hey Siri" – into high-pitched analogues. When a voice assistant hears these sounds, it still recognises them as legitimate commands, even though they are imperceptible to the human ear.

Yet it isn't easy to pull off. The attacker needs to be close to the target device to hack it, although it may be possible to play the commands via a hidden speaker as they walk past. Assistants falling for the ploy included Amazon's Alexa, Apple's Siri, Google Now and Microsoft's Cortana.

"Voice assistants are now connected to everything from thermostats to smart banking"

But not all devices were equally easy to fool. To take control of Siri, the owner's voice had to be surreptitiously recorded for playback before being converted to ultrasound, as Apple's system recognises only the speaker.

To secure voice assistants in the future, ultrasound could be suppressed, says Tavish Vaidya of Georgetown University in Washington DC. However, we should focus on protecting against unauthorised commands rather than limiting what assistants can do, he says.

Nicole Kobie ■

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Face ID tech can see through your disguise

DITCH the hat and scarf – face recognition software can now identify you despite such disguise.

Amarjot Singh at the University of Cambridge and his team trained a machine learning algorithm to locate the 14 key points on the face that our brains pay most attention to when we look at someone. It only needs to see a fraction of these points to guess where the others are likely to be.

The researchers then showed the system 2000 photos of people wearing hats, glasses, scarves and fake beards, hand labelling them to indicate the location of those key points, even if they couldn't be seen. Finally, the algorithm was given a subset of the images to learn how disguised faces corresponded to the same faces without any disguise.

It was able to accurately identify people wearing basic disguises like a cap and scarf 69 per cent of the time (arxiv.org/abs/1708.09317).

This isn't as good as systems that recognise undisguised faces, but the algorithm is better at seeing through disguises, says Singh. "In effect, it is able to see through your mask."

You can also probably say goodbye to CV Dazzle, the camouflage make-up mooted as a way to stay anonymous in a world of face recognition. "This will work very well for this type of camouflage," Singh says. The team will present its findings next month at the International Conference on Computer Vision in Venice, Italy.

The system could help identify criminals who are trying to hide their identities, says Singh. But he admits that authoritarian governments could also use it to identify protesters.

"There's always a trade-off between security and privacy," says Anil Jain at Michigan State University. But he says that people in public spaces are already under constant surveillance by security cameras, so they shouldn't be too worried about every improvement in the technology.

Matt Reynolds ■

JEN TZ PHOTO/ALAMY STOCK PHOTO

Mind the gap

NYC subway runs best with quantum maths

WITH its antiquated trains, rusty rails and straphangers who keep the doors from closing, the New York City subway system could hardly be described as efficient. And yet, some trains arrive with a reliable regularity, following a neat statistical model similar to that seen in quantum systems.

Aukosh Jagannath at the University of Toronto, Canada, and Tom Trogdon at the University of California, Irvine, used the subway system's real-time data feeds to analyse gaps between arrival times on two lines.

They found that the southbound 1 line that runs down the west side of Manhattan shows what are called random matrix patterns, which are "a sign of greater efficiency", says Jagannath, who is now at Harvard University. These trains run at more regular intervals (*Physical Review E*, doi.org/cczj).

In contrast, the 6 line that runs up the east side of Manhattan is inefficient. Its trains follow the Poisson distribution, a statistical model describing particles that arrive more or less randomly.

"If you were waiting at a stop for 5 minutes, waiting for the next 5 minutes does you no good," says Trogdon. In a more functional transit system, you'd expect that after waiting for a while, the probability of a train arriving soon would be quite high. The Poisson distribution does not guarantee this.

"I think the data is confirming people's intuition about the two

"The southbound 1 train on the west side of Manhattan follows more efficient random matrix patterns"

lines," says Trogdon. The 1 line is one of the three local subway lines serving the west side of Manhattan, so it's far less crowded than the 6, which at the time of the study was the only local line on the east side.

The efficiency analysis was inspired by a landmark 1990 study in Cuernavaca, Mexico. At that time, buses in Cuernavaca operated with no central controlling agency, and each bus belonged to the driver. To maximise the number of passengers they could transport – and therefore profit – the drivers set up a series of checkpoints to avoid clustering.

Upon arriving at a checkpoint, the driver would learn when the previous bus had stopped, and would slow down or speed up to optimise gaps between vehicles. Analysing the records of when buses came and went, researchers found that the buses in Cuernavaca obeyed random matrix patterns.

The parallel isn't exact for the New York City subway system, however. The random matrix patterns break down at the last 10 stations of the southbound 1 line. What's more, the northbound 1 line does not follow those patterns.

"The analysis of the New York system is less clear [than for Cuernavaca]," says Ariel Amir at Harvard University. Still, he says this kind of analysis is the first step towards optimising the subway system. For the commuters who take more than 1.7 billion rides on New York's subterranean rails a year, that's always going to be a plus. **Mark Kim** ■

Record heat from space rock impact

Aylin Woodward

IT IS the hottest temperature ever recorded on Earth's surface.

When a space rock struck the ground nearly 40 million years ago in what is now Canada, the impact briefly heated rocks to 2370 °C. That's halfway to the temperature at the sun's surface. The blistering heat has been revealed by an unexpected source: gemstones.

When space debris crashes into Earth, the impact creates hellishly hot temperatures in the collision zone. Such impacts when our planet was young changed its atmosphere and crust, and affected its habitability.

But inferring the heat generated by these ancient meteorites is tricky. Not only did they hit Earth millions of years ago but both the meteorites and the surface rocks often vaporised in the resulting shock waves.

This is a pity, since such rocks hold temperature clues. We can predict maximum temperatures – estimated to be over 2000 °C. However, a lack of physical evidence in the rock record meant it was not possible to test the most extreme predictions.

"What kinds of records can survive an event capable of vaporising rocks?" asks Benjamin Black at the University of California, Berkeley.

Now clues left behind in the Mistastin Lake crater in Labrador, Canada, which is 28 kilometres across, are revealing just how hot the impact site became.

Nicholas Timms at Curtin University in Perth, Australia, and his team found that the crater was once hot enough to transform the common mineral zircon into gem-like cubic zirconia. The zircon acts as a thermometer, because the minimum temperature necessary for this transformation is 2370 °C.

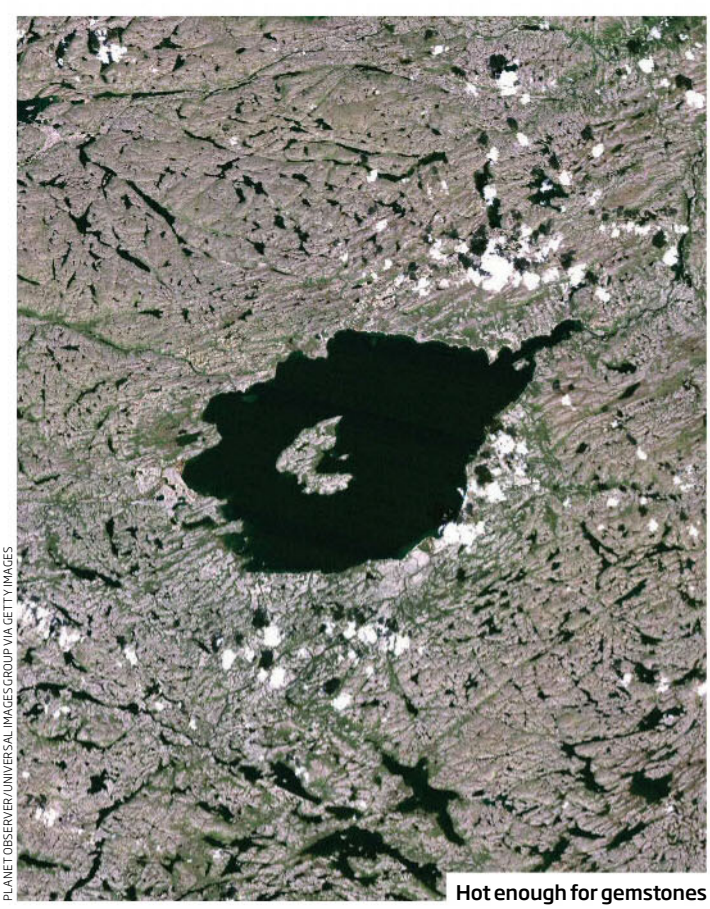
Timms's team traced the zircon's history back to the point of impact, about 38 million years ago (*Earth and Planetary Science Letters*, doi.org/cczc).

"Nobody has even considered using zirconia as a recorder of temperatures of impact melts before," says Timms. "This is the first time that we have an indication that real rocks can get that hot."

"These new results underscore just how extreme conditions can be in the seconds to minutes after asteroids strike a planet," says Black. Understanding the upper limits of temperatures during these impacts might improve our picture of the conditions on Earth's surface over 4 billion years ago, when the newly formed planet was repeatedly bombarded from space.

"These new results underscore just how extreme conditions can be after asteroids strike"

Black says superheating from more frequent and larger bombardments could have baked Earth's crust, keeping hydrogen, carbon and sulphur in the atmosphere. All these elements are considered essential for life: for instance, without hydrogen and oxygen there can be no water. But too much could have affected the planet's climate and chemistry, making it less habitable. ■



PLANET OBSERVER/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

Hot enough for gemstones

Unseen Planet Nine wasn't stolen from afar

PLANET Nine may not be from outer space after all. The mysterious giant planet that astronomers think may orbit our sun far beyond Pluto may have been born with the rest of the solar system's planets instead of stolen from another star or scooped up from interstellar space.

From the weird motion of distant objects in the Kuiper belt, researchers have estimated that if there is a planet out there, it should have a mass around 10 times that of Earth.

Since the material to build a planet that size isn't available out that far, that leaves two possible options: either the planet was formed closer to the sun and migrated out, or it was caught from elsewhere.

To find out how likely it is that Planet Nine was captured by the sun early in its lifetime, Richard Parker at the University of Sheffield in the UK and his colleagues simulated a theoretical cluster of stars (arxiv.org/abs/1709.00418).

There aren't many stars near our own now, but most stars are born in crowded star-forming regions. Parker and his team simulated such a region, but adjusted it to make it as easy as possible for stars to acquire planets - with one planet for every star and everything moving at similar speeds. Even so, they found that less than 6 per cent of the planets get captured.

In simulations of clusters tweaked further to be more like the type our sun's chemical make-up tells us it was probably born in, only three out of 10,000 stars were able to capture a planet on an orbit similar to what Planet Nine's seems to be.

Even if the sun formed in a densely populated cluster, it's still unlikely that it captured Planet Nine, Parker says. But Kat Volk at the University of Arizona says it is tough to rule out any formation mechanism, especially since we aren't even sure that Planet Nine really exists. "Three planets like Planet Nine out of 10,000 still means it's possible," she says. Leah Crane ■

BENJAMIN BECHET/PICTURETANK

Night terrors

Rats replay scary memories as they sleep

HAVE we had our first peek at the source of nightmares? When rats are given a fright while awake, the fear centre in their brains reactivates when they fall asleep.

This could explain why people who endure frightening experiences often have nightmares afterwards, says György Buzsáki of New York University.

Like us, rats store mental maps of the world they experience in their hippocampi – two curved structures in the brain. Different locations are processed by distinct groups of neurons in the hippocampi that fire together in sequence as rats run around a maze, for example.

After the animals explore an environment like this, these firing sequences are replayed as the rats sleep. It is as if they are dreaming of the routes they have taken.

This process is thought to allow memories to become consolidated for longer term storage, and has recently been detected in people for the first time.

Buzsáki's team wondered if such memory replay might include not just spatial information, but also how the animal was feeling at the time. They tested this by giving a rat an unpleasant but harmless experience – a puff of air in the face from a computer keyboard cleaner – at a particular point along a route.

As expected, the rats learned to fear the same spot. "They slow down before the location of the air puff, then run superfast away from it," says Buzsáki's colleague, Gabrielle Girardeau. "If you do it in the face of a human, they don't like it either."

As well as looking at the animals' hippocampi, the team also recorded activity in their amygdalas, a pair of nearby brain structures that become active when they are scared.

Sure enough, when the rats replayed memories of the route while sleeping, their amygdalas became more active as they mentally revisited the spot where they had been frightened (*Nature Neuroscience*, doi.org/ccz3).

This is the first replay study to bring in the emotional system, says Dan Bendor of University College London. "That's really important because our memories are not just information – we remember all the emotional context."

What isn't clear is if the rats experienced this replay of emotions as a dream, says Buzsáki. "We can't ask them." But he does think that if the same thing goes on in people, it might lead to nightmares. "It has been fairly well documented that trauma leads to bad dreams," he says. "People are scared to go to sleep."

James Bisby of University College London thinks that is too big a leap. All we know for now, he says, is that it seems to be a memory strengthening process. **Clare Wilson** ■

Revamped qubit may bring faster computing

A RETHINK of one of the most fundamental parts of a quantum computer could pave the way for ultra-powerful devices.

Andrea Morello at the University of New South Wales in Australia and his team have a design for a qubit – the smallest unit of quantum information – that could get round some of the difficulties of making quantum computers at an atomic scale (*Nature Communications*, doi.org/cczq).

Silicon quantum systems allow little room for electronics because qubits have to be so close to each other to communicate – about 10 or 20 nanometres apart. But by combining an electron and a nucleus in one qubit, Morello and his team think they have found a way to let qubits communicate over distances of up to 500 nanometres. "This would allow you to cram other things between qubits," says Morello.

Qubits in silicon systems interact through electric fields, and Morello's team shows that it is possible to extend their reach by pulling the electron further away from the nucleus of each atom.

Silicon-based qubits aren't the only candidates for quantum computers. Google is making quantum chips from superconductors, and claims it will have built the first quantum computer capable of surpassing some abilities of ordinary computers later this year.

"Combining an electron and nucleus in one qubit lets them communicate over longer distances"

However, superconducting and silicon quantum systems both work only at temperatures close to absolute zero, says Michele Reilly at Turing, a quantum start-up in California. She says diamond-based systems could be easier to scale up because they use similar types of qubits to silicon systems, but don't need to be so cold.

Simon Devitt at Macquarie University in Sydney says this new qubit could be a solution for silicon-based quantum systems. "But they're going to have to go into the lab and make this work," he says. Matt Reynolds ■

Chatbot learns apt facial expressions

Matt Reynolds

THERE'S often something not quite right about humanoid robots. They are cute up to a point, but once they become a bit too realistic, they start to creep us out – a foible called the uncanny valley.

Now Facebook wants robots to climb their way out of it. Researchers at the company's AI lab have developed an expressive bot, an animation of a face controlled by an artificially intelligent algorithm.

The algorithm was trained on hundreds of videos of Skype conversations, so that it could learn and then mimic how people adjust their expressions in response to each other. In tests, it successfully passed as human-like.

Non-verbal facial cues are a key part of human conversation, says Louis-Philippe Morency at Carnegie Mellon University in Pittsburgh. We use them to signal that we are listening to someone and engaging with them.

To mimic this organic feature of human communication, the algorithm divided individual faces into 68 key points that it monitored throughout each Skype conversation. Eventually, it learned to produce the same nods, blinks and small mouth movements that we involuntarily make during conversation.

The bot was then able to look at a video of a human speaking, and choose in real time what the most appropriate facial response would be. If the person was laughing, for example, the bot might choose to open its mouth too, or tilt its head subtly.

The Facebook team then tested the system with panels of people who watched animations that included both the bot reacting to a human, and a human reacting to a human. The volunteers judged the bot and the human to be equally natural and realistic.

JOHANNES EISELE/AFP/GETTY

Deadpanning won't cut it any more

Facebook will present the work at the International Conference on Intelligent Robots and Systems in Vancouver, Canada, later this month.

However, the animations the team used were quite basic, so it's not clear whether a humanoid robot powered by this algorithm would have natural-seeming reactions.

Additionally, learning the basic rules of facial communication might not be enough to create truly realistic conversation partners, says Goren Gordon at Tel Aviv University in Israel. "Actual facial expressions are based on what you are thinking and feeling."

In this case, the Facebook system ends up creating a kind of "average personality", say Morency. In future, more sophisticated bots might be able to pick from a range of personalities or adapt their own to match that of the person they are talking to.

Robots aren't so good at mastering these subtle elements of human interaction, says Gordon. We already know that humans prefer speaking with robots that mimic their own facial expression, he says, but now Facebook is trying to take robot conversations to the next level. "At some point we'll get out of the uncanny valley and come out at the other side," he says. ■

Our ancient ancestors leapt like acrobats

THE first primate may have been a leaper, not a clamberer. It was thought that the common ancestor of all primates scampered along thin tree branches. Now a new fossil suggests it was actually a bizarre monkey-like animal capable of impressive leaping.

Primates appear in the fossil record about 57 million years ago. They soon split into two groups: "wet-nosed" primates, which now include lemurs, and "dry-nosed" primates, which encompass monkeys and humans.

The two share traits like grasping hands and feet, hinting that these features evolved in their common ancestor, which is often imagined as a small animal that ran along branches.

But a 52-million-year-old ankle bone found in France calls this idea into question. Doug Boyer at Duke University in North Carolina and his team say it was from an early primate called *Donrussellia provincialis*.

They claim *D. provincialis* is the most primitive wet-nosed primate known. What is more, the bone suggests it flexed and extended its ankle to launch into the air (*Journal of Human Evolution*, doi.org/ccvq).

Early dry-nosed primates may have been leapers too. *Archicebus achilles* had long hindlimbs and short forelimbs, typical of such an animal.

"*Donrussellia* and *Archicebus* are definitely on opposite sides of the tree," says Boyer. "So when they both have the suggestion of leaping traits, it starts to look like acrobatic leaping behaviours were important early in primate evolution."

"It starts to look like acrobatic leaping behaviours were important early in primate evolution"

But not all primatologists agree. Philip Gingerich at the University of Michigan isn't sure that *Donrussellia* and its close relatives are truly wet-nosed primates.

The story of early primate evolution is still a puzzle, says Thierry Smith at the Royal Belgian Institute of Natural Sciences. Confusingly, some traits evolved sooner in some subfamilies than others, with no discernible pattern, he says. Colin Barras ■

Pacific islands swallowed by rising seas

EIGHT low-lying islands in the Pacific have disappeared under rising seas.

Sea levels are rising by 3 millimetres a year due to climate change. But they are creeping up even faster in the western Pacific, where a natural trade-wind cycle has caused a build-up of water over the last 50 years. In the Solomon Islands and Micronesia, sea levels have risen by up to 12 millimetres a year since the early 1990s.

In 2016, Simon Albert at the University of Queensland in Australia found that five of the Solomon Islands had been lost since the mid-20th century. Now, Patrick Nunn at the University of the Sunshine Coast has observed similar losses in Micronesia.

His team did coastal surveys, spoke to local people and reviewed satellite images for the island of Pohnpei and several low-lying islands.

Pohnpei itself shows little coastal erosion, perhaps because it is fairly high above sea level and ringed by mangrove forest. Three small islands to the west are also well preserved; they are sheltered by the main island.

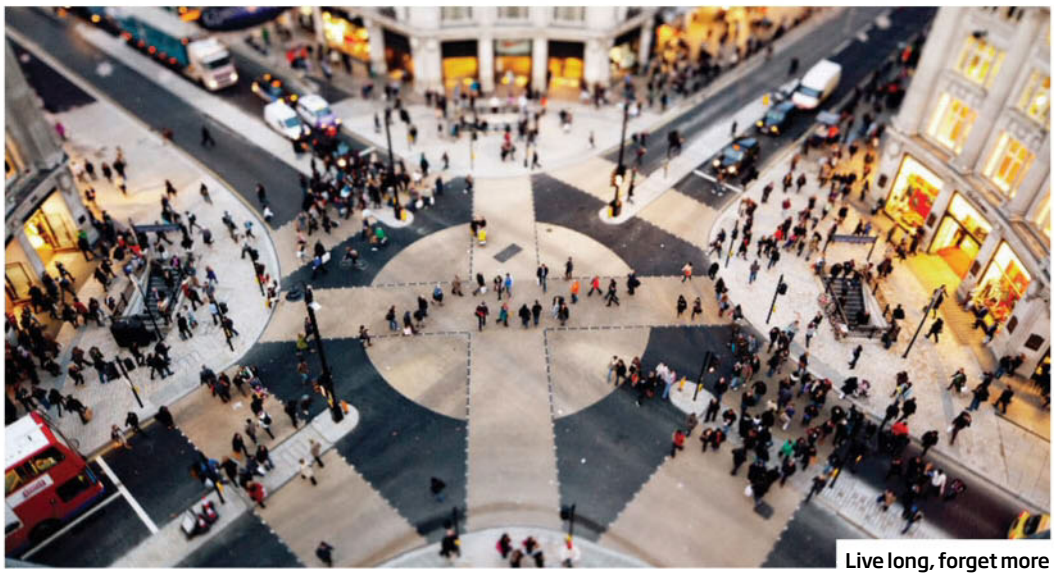
However, several low-lying reef islands – mostly to the south of the main island – have shrunk (*Journal of Coastal Conservation*, doi.org/ccxz).

Others have vanished. Local people described two islands called Kepidau en Pehleng and Nahlapenlohd – the latter famous for a great battle in 1850. Both appear to have disappeared within the last century.

Aerial images showed that another six uninhabited low-lying islands went under between 2007 and 2014.

As sea levels rise, many people will be forced to higher ground, Nunn says. This is already happening in the low-lying Carteret Islands of Papua New Guinea: the population is moving to Bougainville, a higher island.

However, one positive finding is that not all low-lying islands are being destroyed, says Albert. Islands that are sheltered, or have mangroves or lagoons for trapping sediment, appear to be resilient, he says. Alice Klein ■



WATCHLOOKSEE.COM/GETTY

Live long, forget more

Longer lifespan may be driving down average IQ

WE'RE getting stupider – and now we may know why.

For the period of about a century, average IQ scores in wealthy nations kept rising by about three points a decade. This "Flynn effect" is thought to be the result of improvements in social conditions like public health, nutrition and education, and has been seen in many countries, from the Netherlands to Japan.

But by 2004, researchers had begun to notice what seems to be a reversal of this trend, with average IQ scores going into decline. "The drop is around 7 to 10 IQ points per century," says Michael Woodley of the Free University of Brussels (VUB) in Belgium.

Some researchers believe this can be explained by the controversial fertility hypothesis: that the most educated women in Western countries have been having fewer children than the rest of the population, and this is lowering IQs .

But it's difficult to investigate hypotheses like this. Part of the problem is that IQ tests have changed over time. Now Robin Morris of King's College London and his colleagues have found a way to get around this. They have broken down old IQ tests into different categories that are easier to compare.

Morris's team looked through more than 1750 different types of IQ test from 1972 onwards for two sub-groups of tests: those that measure short-term memory, and those that assess working memory – the ability to hold in your head information for processing, reasoning and decision-making.

"The idea that population ageing may be responsible for declining IQs does make sense"

When they looked at how people performed on these kinds of tests throughout time, the team saw a clear pattern. While short-term memory scores have risen in line with the Flynn effect, working memory ability appears to have declined (*Intelligence*, doi.org/ccvg).

Morris wouldn't be drawn on why this might be the case, but his team did spot another trend in the historical IQ tests: an increase in the proportion of people sitting tests who were aged 60 or older. Working memory is known to decline with age, while short-term memory is usually preserved. In their study, Morris's team write that the over-60s may be partly responsible for the decline in working memory scores in more economically developed nations.

"The idea that population ageing may be responsible is interesting and may serve as an alternative to the oft-proposed – but empirically little-supported – selective fertility patterns," says Jakob Pietschnig of the University of Vienna in Austria. "It is a novel hypothesis that makes sense."

But both he and Stuart Ritchie at the University of Edinburgh, UK, say they would like to see stronger and more specific tests of this idea, looking at elements of intelligence whose decline with age are well established, such as processing time and reaction speed.

Until then though, Ritchie warns that the whole concept of reversing IQs should be treated with scepticism. "This is speculative stuff and it's only a handful of papers. Anyone drawing conclusions is jumping the gun." **Sally Adee** ■

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Box jellyfish may eat up the oceans

Christie Willcox

AS THE oceans become more acidic, box jellyfish may start eating a lot more. Their greedy appetites could have a huge impact on marine ecosystems.

Some of the carbon dioxide we release is dissolving in the oceans, where it becomes carbonic acid – making the oceans less alkaline and more acidic. Scientists are scrambling to identify which species will be most affected.

They are particularly concerned about those that play pivotal roles in marine food webs, because if they disappear, entire ecosystems may collapse.

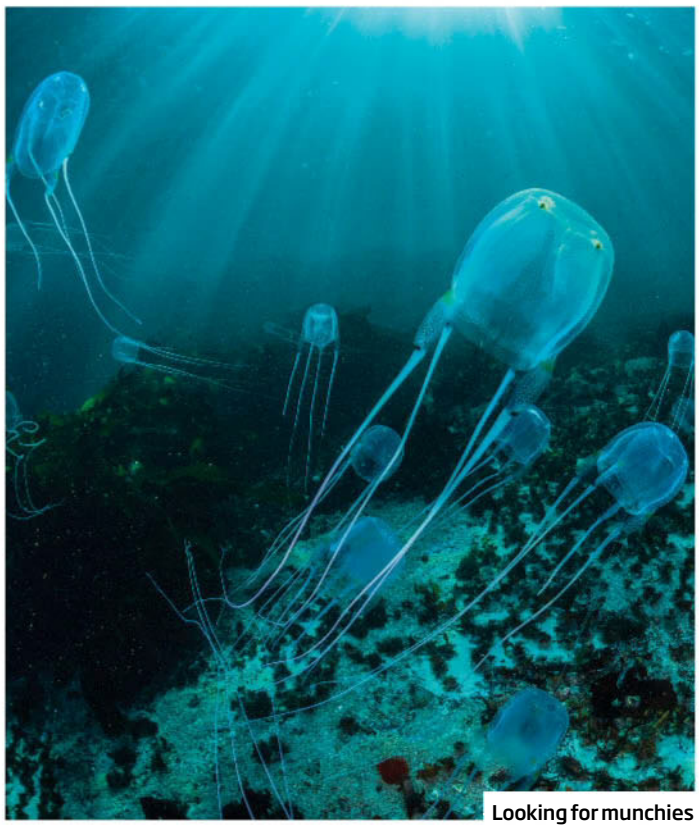
Copepods are especially critical. These tiny crustaceans are the most abundant animal on Earth by mass. They can swarm in vast numbers, creating a feast for larger animals. What happens to copepods affects all that depend on them, "which is pretty much everything", says Edd Hammill of Utah State University.

Previous studies have found they may be fairly resistant to ocean acidification. However, these have largely focused on single species, so effects driven by predators, for example, may have been missed.

To find out, Hammill and his colleagues collected copepods and one of their predators, the box jellyfish *Carybdea rastoni*, from the waters around Australia. They kept the plankton in tanks containing either ambient seawater or seawater acidified at levels predicted for 2100, then added box jellyfish to half of each set of tanks. After 10 days, they counted what survived.

Both acidification and box jellyfish reduced the number of copepods, but the two together caused 27 per cent more deaths than the sum of the two individually. The jellyfish were eating more: they ate nearly 37 per cent of copepods in the ambient seawater tanks, but almost 83 per cent in the acidified water (*Global Change Biology*, doi.org/ccvd).

Hammill thinks the copepods were weakened by the acidified water and that the jellyfish took advantage. But he can't rule out other possibilities. "It could be the jellies are being negatively affected by the acidified water and are needing more prey to get along," he says.



THOMAS P. PESCHAK

Looking for munchies

"It is a simple and clever experiment with some intriguing results," says Nyssa Silbiger of California State University. It highlights the critical need to better understand community dynamics in response to changing environmental conditions, she says. "If these results do translate to the global oceans, even just a little, it could have potentially dramatic and cascading effects on the ocean food web."

Other jellyfish are likely to respond similarly to acidified water, says Hammill.

He plans to look at the Arctic ecosystem next. "It's the most productive and one of the largest ecosystems [in] the world," he says. If the same pattern occurs, it "could be a really big deal". ■

300-page sum-up of maths proof baffles

A SUMMARY of a massive mathematical proof that has baffled mathematicians for the past five years aims to help people get to grips with the key ideas. How long is the explainer? A mere 300 pages.

The original proof is of the long-standing ABC conjecture that explores the deep nature of numbers, centred on the simple equation $a + b = c$. The conjecture has been thought for some time to be true, and in 2012, Shinichi Mochizuki at Kyoto University in Japan produced a proof to settle the matter.

Unfortunately, it was 500 pages long and developed a whole new type of mathematics called inter-universal Teichmüller theory (IUT) that nobody at the time could really understand.

Since then, two conferences have tried to get to grips with the work, and some mathematicians have made progress. But because IUT is so different from other mathematical approaches, much of the language is unfamiliar to the field. Mochizuki refuses to travel outside Japan to help explain his work, and his written explanations can seem impenetrable.

To help clear things up, Go Yamashita, a colleague of Mochizuki at Kyoto University, has written a 300-page summary paper that tries to clarify some of the language.

"The language strikes me as substantially more accessible than that of the original papers," says Minhyong Kim at the University of Oxford.

"I don't expect it will help clear up the matter. Nobody has had success understanding the details"

But others are not so sure. "I don't expect it will help clear up the matter. It's very much in the same style of Mochizuki's writing. Mochizuki and his group can't seem to communicate and nobody from outside has had any success in understanding the details," says Felipe Voloch at the University of Canterbury in New Zealand.

For the time being, the ABC conjecture is likely to remain in limbo, because no journal has been willing to publish it – the final stamp of approval for a proof. Timothy Revell ■

HANS CHRISTOPH KAPPEL/NATUREPL.COM

Bats crash into windows because of 'sonar' glitch

WINDOWS are deathtraps for bats. If they approach a smooth vertical surface like a window at an angle, none of their echolocating clicks bounce back to them, making it appear to be a gap they can fly through.

"They think it's an opening," says Stefan Greif of the Max Planck Institute for Ornithology in Seewiesen, Germany. In 2010, he found that bats perceive a smooth horizontal plate as water. When he left plates standing upright, he noticed that bats tended to collide with them.

To investigate further, Greif and his colleagues got greater mouse-eared bats to fly through a narrow tunnel. When a smooth plate was put on one side of the tunnel, 19 of the 21 bats collided with it at least once. None were hurt. When Greif put similar plates near wild bat colonies, the bats also crashed into them (*Science*, doi.org/cct4).

Greif says the beam of sound emitted by bats is like the beam of light from a torch. If you shine a torch at a mirror in the dark, you won't see a reflection unless you are directly in front of the mirror or very close to it. Smooth surfaces are the acoustic equivalent of mirrors.

"Over their evolutionary history, [bats] did not meet any smooth vertical surfaces," says Gareth Jones of the University of Bristol, UK.

No one knows how many bats are killed this way. But if buildings near bat colonies really are death traps, Greif says, the death toll could be cut with acoustic deterrents.

'Pen' could guide cancer surgery

A PEN-sized device could help surgeons tell whether they have cut out all of a person's tumour.

Distinguishing between cancerous and healthy tissue can be hard; it usually takes several days for pathologists to analyse a tissue sample. But this is too late to help surgeons ensure they cut out the entire tumour and prevent a relapse.

The new device gives feedback in seconds. When its disposable nozzle is placed on tissue, it releases a tiny drop of water. This soaks up biological material – such as fats, proteins and sugars – from the tissue surface.

These samples are then transferred to a mass spectrometer, which compares the combination of biomolecules with reference data collected from tumours and healthy tissue. Algorithms then decide whether the tissue is likely to be healthy or cancerous within 10 seconds.

Livia Eberlin at the University of Texas, whose team created the device, tested it on 253 human tissue samples (*Science Translational Medicine*, doi.org/cctx). "It gave the right answer 96 per cent of the time," says Eberlin.

The team has also used the pen to guide tumour removal surgeries in mice, and hopes to test it in hospitals next year.

Wearable sensor has got your back

MOVE over, health and safety videos. A wearable sensor could help prevent injuries caused by incorrectly lifting heavy stuff.

We are all taught that the safest way to lift items is with our knees bent and back straight. To monitor whether a person is doing it right, Eya Barkallah at the University of Quebec at Chicoutimi in Canada and her colleagues created a pair of pressure-sensing insoles to see how a person distributes their weight. They combined this with a hat-mounted accelerometer that tracks how they are moving.

The team then trained an algorithm on a volunteer lifting correctly and incorrectly. Soon, it could correctly judge the person's posture 95 per cent of the time (*Sensors*, doi.org/ccx9).

The team is on the right track, says James Brusey at Coventry University, UK, but they need to test the sensors using more people to ensure it works for everyone.

Aeroice is light like frozen candyfloss

THERE'S a new ice in town: a porous, lightweight "aeroice" that can tell us more about how water works under extreme conditions.

Masakazu Matsumoto at Okayama University in Japan and his team modelled this aeroice with a node and stick scaffold of molecules (*The Journal of Chemical Physics*, doi.org/ccvp).

In "normal ice", water cools at ambient pressure and freezes into a solid crystal form arranged in hexagons. Hexagonal ice, and the occasional bit of cubic ice in our upper atmosphere, are the only two forms that occur naturally on Earth. At below atmospheric pressure, water molecules become a less-dense, lightweight crystal that is more air than molecule – like an icy candyfloss.

Metal vampire ants from hell

A NEWLY discovered species of "hell ant" had anatomy that lived up to this name, including a lethal feeding apparatus reinforced with metal.

Hell ants lived in the dinosaur era. Instead of normal mouthparts, they had upward-facing blades unlike any modern ant. These mandibles may have shot up to impale prey.

Some hell ants had a horn-like appendage that jutted out over their tusk-like mandibles. Among these was *Linguamyrmex vladi*, which Phillip Barden at the New Jersey Institute of Technology in Newark and his colleagues found in 98-million-year-old amber.

Its blades may have flipped up and impaled creatures against the horn. "You have this sort of stopping plate, made to accommodate the mandibles closing and capturing prey," says Barden.

CT scans showed the horn was reinforced with metal (*Systematic Entomology*, doi.org/ccvb).

"Probably the metal helps to keep the horn undamaged," says Vincent Perrichot at the University of Rennes 1 in France.

L. vladi may have been a vampire. When its mandibles moved up they formed a "gutter" that might have funnelled insect blood through the mouthparts, says Barden.

His team found a beetle grub by the ant in the amber, which may have been next on the menu.

P. BARDEN & D.A. GRIMALDI

Sleep therapy eases depression and paranoia

A THERAPY designed for insomnia has been found to also help a range of mental health issues, including negative thoughts, anxiety, depression and psychosis.

Daniel Freeman at the University of Oxford and his team have been testing Sleepio, a type of online cognitive behavioural therapy. The 10-week course is intended to restore healthy sleep patterns in people with insomnia, and Freeman wanted to see if it could also relieve other problems.

His team asked nearly 1900 students who have difficulty sleeping to try using Sleepio, and nearly 1870 others to try following standard advice for insomnia.

Both groups filled in questionnaires beforehand that assessed their sleep patterns, as well as their tendency to experience paranoia and hallucinations. They repeated these questionnaires at three, 10 and 22 weeks into the experiment.

Overall, those using Sleepio slept 50 per cent better than the control group, says Freeman. The Sleepio users also had 30 per cent fewer hallucinations than the control group, a 25 per cent reduction in paranoia, and their anxiety and depression levels were 20 per cent lower (*The Lancet Psychiatry*, doi.org/cctz).

Statistical analysis revealed that improved sleep was itself accountable for up to 60 per cent of these additional benefits.

"If you have problems sleeping, we know it affects the way you think, giving you more fearful and depressive thoughts and more rumination – all consistent with a dip in mood," says Freeman.

Happy music boosts creativity

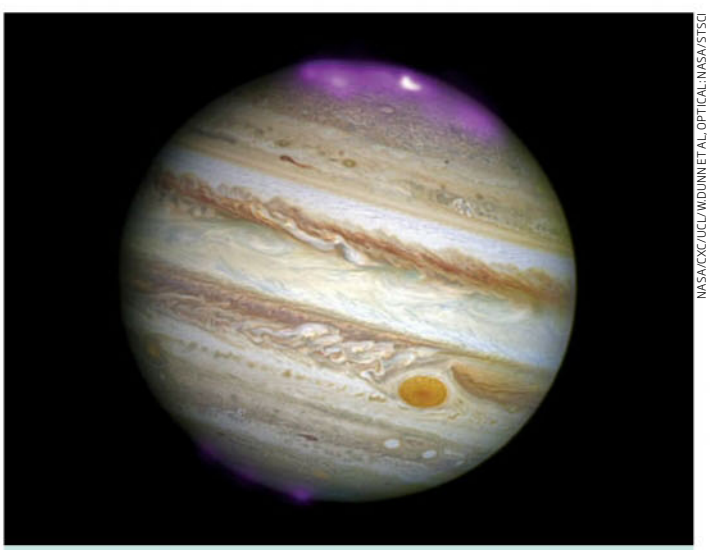
NEED inspiration? Turn on some upbeat music. Listening to positive music boosts creativity, while silence is best for problem-solving.

There are two main types of thinking: divergent thinking, which generates new ideas, and convergent thinking, which finds solutions for a problem.

To see whether music affects either type, Simone Ritter at Radboud University in Nijmegen, the Netherlands, and Sam Ferguson at the University of Technology in Sydney, Australia, put 155 volunteers into five groups. Four of these were each given different pieces of music to listen to while doing a series of tests, and the fifth group did them in silence.

People who listened to music they thought was positive came up with more unique ideas than those who worked in silence. The other types of music had no effect (*PLoS One*, doi.org/cct6). "It seems the type of music is important," says Ferguson.

However, happy music – in this instance, Antonio Vivaldi's *Spring* – only boosted divergent thinking. No type of music helped convergent thinking, suggesting that it is better to solve problems in silence.



NASA/CXC/UCL/W.DUNN ET AL, OPTICAL: NASA/STSCI

Turbulence creates Jupiter's aurora

NOT all auroras are created equal. Jupiter's light shows aren't sparked by the same process that generates Earth's flashiest polar auroras, say Barry Mauk at Johns Hopkins University in Maryland and his team, who have been studying data from NASA's Juno spacecraft.

Powerful electric fields build up along Earth's magnetic field lines, creating wells of electric potential. When electrons from the sun hit these, they accelerate towards the ground. On the way down, they collide with atoms in the upper atmosphere, release energy and emit tiny bursts of light that together create auroras.

Although Jupiter's wells of electric potential can be 30 times as strong as those on Earth, they don't align with its auroras. Instead its light shows might come from a process that causes dim auroras on Earth: ripples in the electric field that accelerate electrons less (*Nature*, doi.org/ccth).

Jupiter's size means its electric potentials could get so strong they become unstable, turning into waves and random turbulence. This accelerates electrons to produce a dazzling display.


NEW SCIENTIST

Can China save the world?

The nation leads the world in clean energy investment. Will its globalisation strategy catalyse a green revolution asks **Alice Klein**

RENEWABLE energy is having its moment in the Chinese sun. The country's investment in solar, wind and other clean energy technology has soared from $8 billion in 2005 to $103 billion in 2015. China now spends more on developing renewable energy than the US and Europe combined.

Most of this investment has been domestic, but China is now looking to sell its green tech to the rest of the world. In doing so, the nation steps into the climate leadership void left by the US under President Donald Trump. As Trump pursues an "America First" strategy and sings the praises of "beautiful, clean coal", China is looking for ways to collaborate with other countries on tackling climate change.

"Every hour, China installs at least one wind turbine and enough solar panels to cover a football pitch"

"Multilateral trade negotiations make progress only with great difficulty and the implementation of the Paris [climate] agreement has met with resistance," China's president Xi Jinping said last week at a meeting of the BRICS (Brazil, Russia, India, China and South Africa) nations. "Some countries have become more inward-looking, and their desire to participate in global development cooperation has decreased."

To strengthen relations with other nations, China has begun one of the largest-ever trade initiatives, known as the Belt and Road. This links it to 68 countries in Asia, the Middle East, Europe and Africa along the historic Silk Road trade routes.

Many climate analysts hope this will drive uptake of China's cheap renewables in the region and reduce nations' reliance on fossil fuels, but there are also fears it could expand the country's powerful coal industry.

So, as China adopts the stance of a true global power, will it help or hinder the worldwide renewables movement?

China is well placed to lead a clean energy push. Its enormous manufacturing capacity means it can churn out millions of cheap solar panels and tens of thousands of wind turbines each year. The country now owns five out of six of the world's biggest solar panel manufacturers and half of the 10 largest wind turbine manufacturers. Greenpeace estimates that every hour, China installs at least one wind turbine and enough solar panels to cover a football pitch.

This capacity has allowed Chinese companies to shift their focus to the international energy market in recent years. Between 2002 and 2012, China invested in at least 124 solar and wind projects in 33 countries, according to the World Resources Institute. Since the announcement of the Belt and Road network in 2013, this expansion has accelerated in countries taking part.

For example, Chinese firms have recently won tenders to build solar farms in the United Arab Emirates (UAE), Pakistan, Egypt, Ethiopia, Bulgaria, Jordan, Iran, Oman, Romania, Tajikistan

KEVIN FRAYER/GETTY IMAGES

and Uzbekistan. They are also building wind farms in South Africa, Kazakhstan and Ukraine, and hydropower plants in Indonesia, Myanmar, Nepal and Bosnia and Herzegovina.

China is also setting its sights on linking up green energy grids across borders. Last year, it started talks with Russia, Japan and South Korea about building a supersized clean power grid. This would allow the four nations to share their solar, wind and hydro energy and balance out each other's supplies when the sun isn't shining or winds aren't blowing – a key feature if you want to rely on renewables.

Beyond obvious financial rewards, China seeks to extend its political influence by globalising its clean energy tech, says Ma Tianjie at Chinadialogue, an independent environmental NGO in Beijing. "Over the last decade or so, the Chinese government has put a strategic emphasis on investing in renewable energy because it sees it as the next industrial revolution – one which it wants to lead," he says.

Tim Buckley at the Institute for Energy Economics and Financial Analysis in Sydney, Australia, agrees. "China wants to dominate industries of the future while the governments of the US and Australia want to dominate industries of the past."

But China's renewable energy firms are facing competition from their fossil fuel counterparts, which also want to capitalise on the Belt and Road partnerships.

Since 2001, the country has been involved in at least 240 coal power projects in 25 of the participating countries. And in its 2015 Belt and Road vision paper, the Chinese government said the initiative should increase cooperation with other countries in pursuing coal and oil resources in addition to renewable energy.

This appears to have been borne out. Since the Belt and Road initiative was proposed in 2013, Chinese involvement in coal projects in the region has tripled, according to the Global Environmental Institute (GEI), a non-government agency based in Beijing.

Shining bright

Coal competition

For example, the deal has paved the way for Chinese companies to build several coal-fired plants in Pakistan and Bangladesh, and helped kick-start the operation of a Chinese oil pipeline across Myanmar after years of delay. These kinds of investments could lock in fossil-fuel dependency in developing countries before renewable energy gets a look-in, says Lauri Myllyvirta, an energy analyst at Greenpeace in Beijing.

But Buckley believes there are several reasons why China's clean energy sector will ultimately beat its fossil fuel competitors.

First, the rapidly declining cost of Chinese renewables will make them highly attractive to other countries. Chinese firm JinkoSolar, for instance, is constructing a solar farm in the UAE that produces electricity for 2.4 US cents per kilowatt hour. In comparison, the US average is 5 cents per kilowatt hour for solar and 6 cents per kilowatt hour for unsubsidised coal.

"This is key, because at the end of the day, economics drives most decisions," says Buckley.

Speed is another advantage – a solar or wind farm can be built in six months, compared with five to 10 years for a coal-fired plant.

Many Belt and Road countries are also introducing environmental policies to limit fossil fuel use. India, which was previously the top destination in the partnership for Chinese coal investment, is now heavily backing solar energy and is aiming to get 57 per cent of its energy from renewables by 2027.

Finally, clean energy projects are more likely to win investors. The World Bank no longer finances overseas coal projects, unless under exceptional circumstances, such as in impoverished Kosovo. Now, Chinese lenders appear to be following suit. The Asian Infrastructure Investment Bank, which was set up to fund the Belt and Road Initiative, has ruled out financing coal power and promised to be "lean, green and clean". At the same time, Chinese banks have become the world leaders in issuing green bonds to finance environmental projects.

"China wants to dominate industries of the future while the US wants to dominate the past"

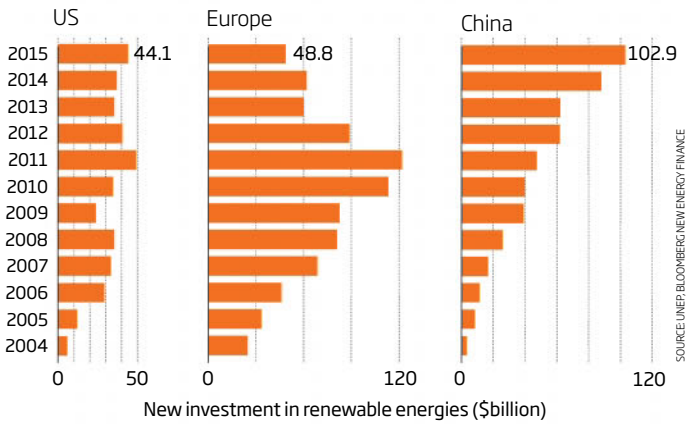
These factors will allow China to drive the "biggest acceleration of global renewables uptake we've ever seen", says Buckley. "I have almost zero doubt this will be the case."

Tianjie is also positive. "I think China is going to change the landscape of global energy very fast in the near future," he says.

If they are right, the long-held assumption that developed countries will lead the green revolution will be overturned. Instead, the fastest uptake of clean energy could come from China and the countries along the new Silk Road. Rich nations like the US may be the only ones left clinging to their "beautiful" coal. ■

Green splurge

China's upward trajectory for green investment means it now leads the world in renewable energy tech, while Europe and the US shrink back



What to wear

The strict line between clothes for boys and girls is another way we shape young minds for ill. Good riddance to it, says **Lara Williams**

WHEN the retailer John Lewis ditched gendered labels on children's clothing, a backlash soon followed.

The anger was over its decision to become the first major UK clothes seller to offer exclusively gender neutral children's clothes. Labels read "Girls & Boys" or "Boys & Girls" on all items, from newborns up to 14 years. It has also launched a unisex line for the young, with no more prescriptive pink for girls and blue for boys.

Some quickly embraced its progressive and nuanced take on gender politics. But others were instantly scandalised – calling it an example of liberal pandering or outsized political correctness (gone wrong).

It is undoubtedly a radical move – clothes have been a means of expressing gender for centuries. But it is also a legitimate move, rooted in scientific research that

increasingly shows the hardening of unwelcome and damaging stereotypes as a result of relentless gender-based marketing on the young.

We have been here before, especially with toys. "Pink gives girls permission" was the title of a study that found the explicit gendering of toys leads to "different developmental trajectories" for girls and boys.

Co-author Lisa Dinella, at the Gender Development Laboratory at Monmouth University, New Jersey, argues that this influences children's intellectual and emotional outcomes.

While play informs the development of creativity and dexterity, providing an essential formative role, clothes also act as objects of self-expression and identity. If a doll or toy soldier encourages a particular mode of being, so do the costumes we

There's a catch

Farm the oceans to feed the world? It's not so simple, says **Olive Heffernan**

WE ARE now eating twice as much seafood as we were 50 years ago. That's good for our health, but bad for ocean life. Almost 60 per cent of global fish stocks are exploited to full capacity and 30 per cent are almost tapped out. By 2050, with a predicted 10 billion people to feed and climate change hitting fish populations, things look bad.

But fear not. A solution could be in sight, say researchers who have totted up ocean areas suitable for aquaculture. They identified spots around the world where fish and shellfish could be farmed. The areas had to be up to 200 metres deep but not currently farmed or used for shipping, oil exploration or conservation.

Using less than 1 per cent of the 11 million square kilometres the team identified would match current wild-caught fisheries. Better still, if we used all of it, we could produce 100 times more seafood than we eat each year.

So could we farm our way out of the fisheries crisis and improve global food security? It sounds so simple – except it's not.

For starters, concerns about habitat damage and opposition to processing plants will mean not all areas will become fish farms. Then there's the bigger problem of unintended effects. Rather than saving wild fisheries, aquaculture can harm them further by spreading disease and pollution, not to mention the senseless practice of using small wild fish as feed. Alternative crop-based feeds are being developed, but they add to pressure on land.

"Rather than saving wild fisheries, aquaculture can harm them by spreading disease and pollution"

A lesser worry is that we will end up with a restricted menu of delicacies. Mussels and oysters are an obvious choice to farm, as they extract their own food from the sea, but this suggests a less diverse future. What's more, some species take to aquaculture better than

assume and the clothes we wear. Boys' clothes tend to veer towards more mobile and utilitarian styles, while for girls they remain restrictive, embellished and decorative.

Caroline Bettis, head of childrenswear at John Lewis, cited "not wanting to reinforce stereotypes" as the reason behind the labelling decision. Those stereotypes can take hold very young. It is thought children begin recognising gender from the age of 1, even associating certain objects with a particular gender. From here it isn't a huge leap to the gender misconceptions that harm society, such as girls believing brilliance is a male trait.

The backdrop is one of neuroscientists increasingly dismissing the idea that there are fundamental differences between male and female brains.

Gender identity doesn't always fit the binary model – it is thought that as many as 2 per cent of live births are of babies who are intersex. Gender is more complex than external anatomy. Gender doesn't necessarily match the sex you are born into. If sex and gender aren't a perfect dichotomy – why should clothing be? ■

Lara Williams is a writer based in Manchester, UK

others. Salmon cope well in packed pens whereas cod are much less resilient to problems of captivity such as sea lice.

Warm waters are also the most productive, with tropical regions dominating the areas the team identified. Herring need not apply.

Knowing that we have space to grow aquaculture beyond current needs offers some comfort, but there are many caveats. And if we keep on feasting on wild-caught fish, we may soon have to accept that our diet will change in ways we hadn't anticipated. ■

Olive Heffernan is an environment writer

INSIGHT North Korea

KYODO NEWS VIA GETTY IMAGES

Testing times

Will the US really nuke North Korea?

Debora MacKenzie

NORTH KOREA's nuclear tests continue to provoke its enemies. Some people are suggesting that a pre-emptive strike would end the uncertainty and liberate its long-suffering people.

Last week, US defence secretary James Mattis promised that "any threat to US territories (or) our allies will be met with a massive military response". That sounds pre-emptive. "We are not looking to the total annihilation of… North Korea, but we have many options to do so," he added. That sounds nuclear.

But on close inspection, it doesn't sound sensible. The country's leader, Kim Jong-un, has developed nuclear weapons for the sole purpose of deterring such an attack. If the US didn't take out all of North Korea's nukes in a first strike, its fear of nuclear attack could become self-fulfilling.

The US would be more likely to use conventional weapons, says James Acton of the Carnegie Endowment for International Peace in Washington DC, though that could also spark a nuclear response. "If Kim believed his regime were in danger, such a desperate attempt to make the US back down would not be irrational," he says.

But even if the US got lucky and took out North Korea's nukes in a first strike, Kim could still fight back. North Korea is thought to have 10,000 to 15,000 artillery guns and over 1000 short-range ballistic missiles, mostly trained on the South Korean capital Seoul, says Paul Ingram of the British American Security Information Council, a London think tank.

It is unclear how many of Seoul's 25 million people this arsenal could kill, but strategists say that return fire from South Korea and the US would take out the batteries in a day or two, leaving North Korea open for a ground invasion. So why have them? The guns, like the nukes, are deterrents: don't attack and it won't use them.

"If this results in mushroom clouds, then the barrier against nuclear weapons use will be lowered"

All this suggests a pre-emptive strike on North Korea would unleash its threat, rather than resolving it. But the real risk is the precedent a nuclear attack by either side would set.

"The primary bulwark against nuclear anarchy is the norm of non-use on battlefields," says Michael Krepon at the Stimson Center, a security think tank in Washington DC. "If the crisis with North Korea results in mushroom clouds, then the barrier against nuclear weapons use will be lowered for other states," he says.

Rather than all-out nuclear war, Krepon fears a global resumption of nuclear testing, resulting in smaller battlefield weapons that are more likely to be used than the large Cold War missiles. "We [would] be opening the gates of hell," he says.

Still, people are thinking about actually using nuclear weapons for the first time since 1945. The South Korean defence minister this week suggested reviewing the US decision to remove its small "tactical" nuclear missiles from South Korea in 1991. US analysts have calculated that a recently improved US warhead might destroy North Korea's nuclear arsenal without killing many people, by detonating at high altitude.

Such a situation, however, would almost certainly escalate, says Krepon. Other paranoid mass murderers like Stalin and Mao were kept in line by deterrence, he says, so surely, the US, with 1240 nuclear warheads ready for launch, can deter a tiny country with at most a handful of them. It may be unsettling to do nothing – but it may be the only way. ■

Clockwise from right: Esme swimming, Parkroyal on Pickering, Singapore

Chuck taking sample readings at the Geysers, the world's largest geothermal field, California

Kenzie inside a melting glacier, Juneau Icefield Research Program, Alaska

New crop varieties for extreme weather, Geneva Greenhouses, New York State Agricultural Experiment Station, New York

Madelaine in a study of stress reduction in virtual reality, Bosch Lab, Swedish University of Agricultural Sciences, Sweden

Chance and Patrick launching an ozone-sonde balloon, National Oceanic and Atmospheric Administration, Colorado

Our 'natural' world

SPOT the human. As part of a quest to explore our turbulent relationship with the natural world, photographer Lucas Foglia has captured the many different ways in which we interact with our environment.

In the main image, a woman is swimming in a pool beneath luxury flats festooned with plants in Singapore. Called Esme, she's scarcely visible, and is hidden from the passing cars by lush greenery.

The other images in his book and exhibition mainly depict scientists at work trying to understand nature. For example, at the top left are two climatologists launching an ozone-sonde balloon in Colorado to measure levels of protective stratospheric ozone.

Meanwhile, growing inside the greenhouse "on fire" (bottom left) are new crop varieties adapted to extreme weather, at the New York State Agricultural Experiment Station.

Beginning and ending his exhibition with interpretations of paradise, Foglia's images show how the human form weaves in and out of nature in a variety of settings, from cities, forests and farms to deserts, ice fields and oceans. They also reflect how humans have made an indelible impact on the entire planet. "I realised that if humans are changing the weather, then there is no place on Earth unaltered by people," says Foglia.

Foglia's images are on show at the Human Nature exhibition at the Michael Hoppen Gallery in London from 13 September to 21 October.
Andy Coghlan

Photographer

Lucas Foglia
Courtesy of Michael Hoppen Gallery

Chasing ghosts

Plans are afoot to bring back a big cat even though it might never have existed. **Sean Mowbray** investigates

"THIS is another animal from the distant wilds of the interior, whose skins the savages bring to the borders to barter with the Chinese." With these words, published in 1862, Robert Swinhoe introduced the Formosan clouded leopard to the Western world. Europe's consular representative to Taiwan, he had seen only a few flattened skins on the island, but this was enough for him to distinguish it as a species new to science. Unlike its relatives elsewhere in Asia, wrote Swinhoe, the Formosan clouded leopard had a short tail.

It was declared extinct in 2013, but this is no ordinary story about a large cat being wiped off the planet. There's a catch. Plans are afoot to bring the svelte feline's closest relative back to Taiwan – despite lingering questions over whether the clouded leopard ever existed at all.

Today, Asia is home to two species of clouded leopard. *Neofelis nebulosa* is found across the mainland from the Malay peninsula to the Himalayan foothills of Nepal. The Sunda clouded leopard, *Neofelis diardi*, is only found on the islands of Borneo and Sumatra. Both are at risk of extinction and rarely glimpsed in the wild even by those who study them.

Their broad paws and flexible ankle joints make them among the best climbers in the cat family – they have been seen hanging upside down from branches and running head first down tree trunks – and they have flowing tails that can be as long as their body, which help them balance in the trees.

There haven't been any sightings of clouded leopards in Taiwan for decades, let alone confirmed ones. In the 1980s, a hunter claimed to have caught one, but this was never verified. As a result, Alan Rabinowitz, now CEO of the feline conservation group Panthera, interviewed tribespeople and collected seven accounts of recent sightings, but these could not be verified either. Then, in 1990, large paw prints were found near Yushan National Park in 1990, which may – or may not – have been left by a clouded leopard.

So, beginning in 1997, hundreds of camera traps and hair-trigger snares were set up across the island, and conservation biologists began the long wait for the ghost-like leopards to show their face. Without so much as a flick of a tail recorded, the Formosan clouded leopard was declared extinct 16 years later.

Perhaps it was never there to be found. To this day there is a slight cloud of doubt hanging over Taiwan's big cat, says Anthony Giordano of the conservation group SPECIES. It has been so elusive, and what evidence we do have is so sparse, that some have doubted whether it ever existed, explains Po-Jen Chiang of the Formosan Wild Sound Conservation Science Center in Taiwan. An alternative explanation suggests that Taiwan was merely a staging post for traded pelts, as they travelled from South-East Asia to Japan and mainland China. ›

GK HART/VIKKI HART/GETTY

SEBASTIAN KENNERKNECHT / MINDEN PICTURES

The Sunda clouded leopard is found on Borneo and Sumatra

But most biologists, including Giordano and Chiang, believe the Formosan clouded leopard was native to Taiwan and was either a sub-population or subspecies of *N. nebulosa*. The distinction matters now more than ever, as increases in the populations of clouded leopard prey mean that efforts to reintroduce a big cat to the island are gathering pace.

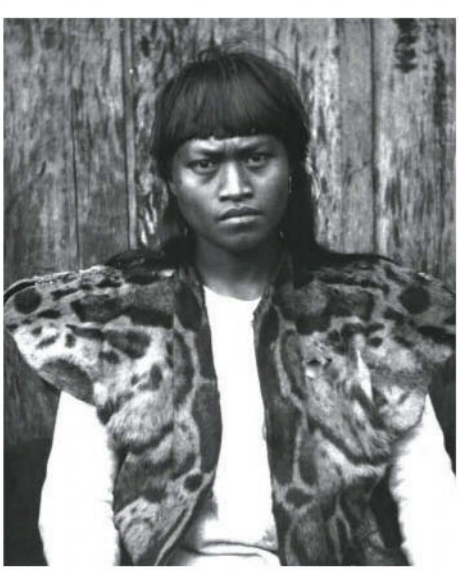
Last month a joint effort by the National Dong Hwa University and SPECIES began filling in the gaps. Researchers are gathering DNA from pelts, teeth and skulls held by the Paiwan people, and recording oral accounts from the Rukai and the Paiwan. If the DNA matches that of living Sunda clouded leopards, this will suggest the pelts arrived on the island as a result of trade, and the Formosan clouded leopard may never have existed. It would be an unexpected result, says Giordano, but cannot be ruled out.

A more likely outcome, he believes, is that the DNA will be related to the mainland species, backing the idea that the Formosan clouded leopard was related to *N. nebulosa*. Historical records will then be drawn upon to rule out trade connections to the mainland. Precisely how closely the pelt DNA matches modern mainland species would allow geneticists to determine whether the Formosan clouded leopard was a subspecies or just a sub-population of *N. nebulosa*.

Recently, Chiang found records from the 1895 to 1945 Japanese occupation of Taiwan that counter the trade hypothesis. Ammunition was controlled by the Japanese at the time, and hunters had to report how many bullets they used and what for. The records still need to be cross-checked but they suggest 24 clouded leopards were shot in 1933.

Even so, reintroduction won't be straightforward. The leading option is to release captive *N. nebulosa*, but for some scientists in Taiwan that won't do. They see different populations of the same species as exotic, says Kurtis Jai-chyi Pei of Dong Hwa University, so

DNA samples from pelts held by aboriginal communities will help trace the cat's history



TORII RYUZO/DIGITAL ARCHIVE OF UNIVERSITY OF TOKYO, C1900

nothing short of reintroducing the same Formosan clouded leopard is acceptable. "That to me is nuts," says Rabinowitz. It would rule out any reintroduction efforts unless quite by chance a zoo animal can be found that is a perfect match for the pelt DNA. Subspecies evolve mainly because of geographic separation, and in that sense are entirely artificial, says Rabinowitz. If Taiwan created a subspecies out of *N. nebulosa* once, the likelihood is that it will do so again over time.

> "For some, only a perfect genetic match would make reintroduction acceptable"

Rabinowitz believes the cat could be reintroduced – a 2015 study shows there is enough habitat to support hundreds of animals – but stops short of saying it should. "Should implies there is an ecological reason for it," he says. For that, the local ecosystem would have to be out of balance due to the gap left by a top predator. Deer and macaque populations have boomed and become a nuisance in recent years, but researchers can't say for sure that this is because there are no clouded leopards.

Suitable land and prey is one thing, willing humans are another. A litmus test of the Taiwanese people, from farmers to city dwellers, will be taken to gauge local enthusiasm. Based on previous interviews, Jai-chyi Pei believes there is support within the Rukai and Paiwan communities. But Giordano is cautious. The leopard cat, a much smaller feline, is a hardy survivalist, he says, found even on barren palm plantations. It isn't threatened across much of South-East Asia, but on Taiwan it is an endangered species. A toxic mix of pollution, habitat disturbance and persecution – particularly due to the cats' fondness for farmers' chickens – has caused its numbers to drop to the low hundreds. "How are we going to protect clouded leopards if we can't protect leopard cats?" Giordano says.

But this may be counting our leopards before they have their spots. The first step is to find out for sure whether the elusive feline really existed. If it is confirmed, then at some point in the future, Taiwan may see clouded leopards roaming its forests again and become an important stronghold for the cat's survival in Asia. ■

Sean Mowbray is a freelance journalist based in Switzerland

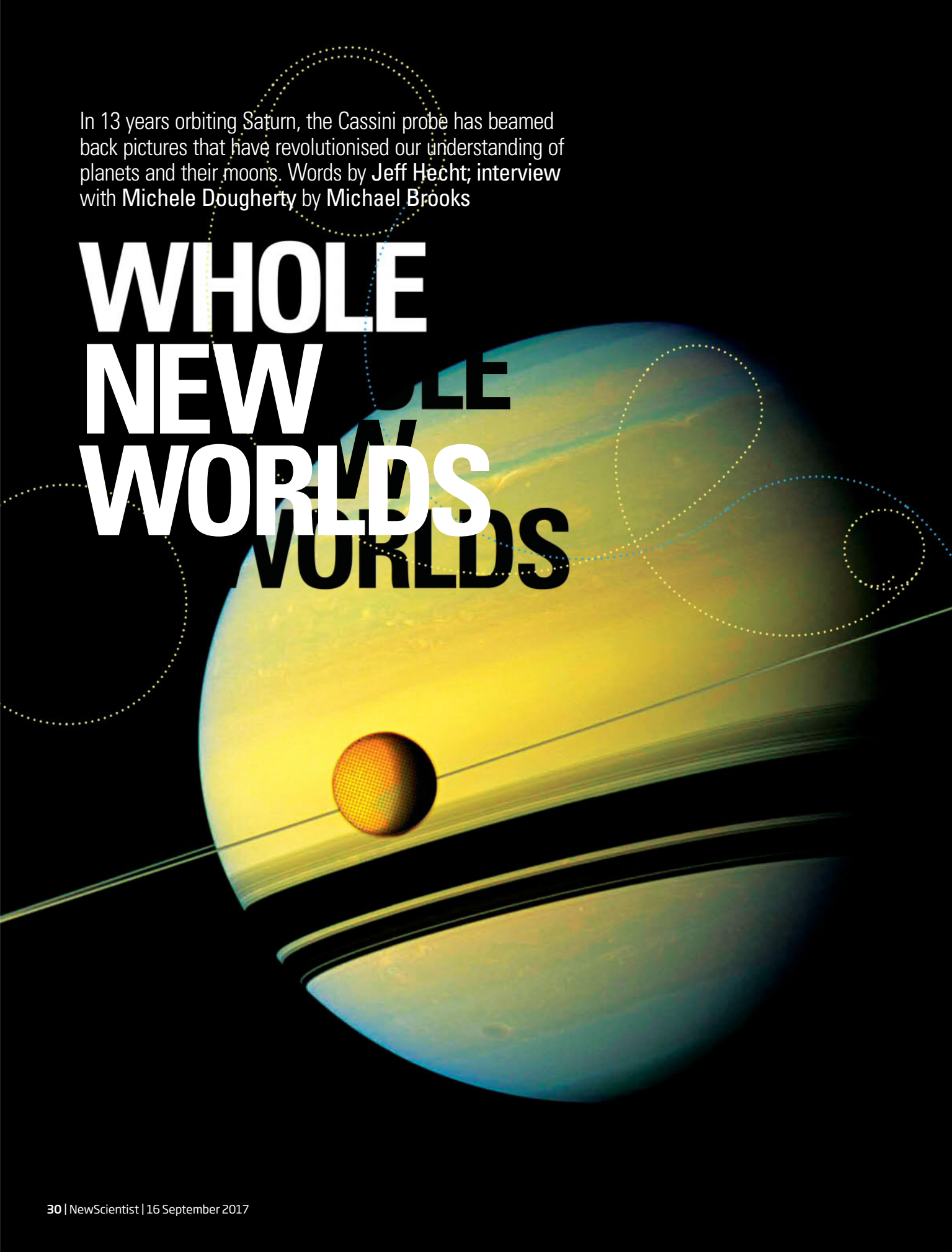
CASSINI

THE GRAND FINALE

On 15 September, the Cassini space probe will burn up in Saturn's atmosphere, ending a 20-year voyage of scientific discovery. In this commemorative special we look at the wonders Cassini has seen, where it fits in the pantheon of outer solar system missions, and why its successors will be searching for one thing – life

In 13 years orbiting Saturn, the Cassini probe has beamed back pictures that have revolutionised our understanding of planets and their moons. Words by **Jeff Hecht; interview** with **Michele Dougherty** by **Michael Brooks**

WHOLE NEW WORLDS



TITAN'S methane lakes. Icy Enceladus spouting geysers of hot water. Sponge-like Hyperion. Ravioli-shaped Pan and Atlas. Iapetus with its equatorial ridge battered by ancient craters. Close-ups of those iconic rings engirdling the gas-giant planet itself, and gigantic hurricanes around its poles.

The Cassini probe, launched in 1997, has orbited the Saturn system for 13 years. What it has revealed is astounding – and challenges our understanding of planets and their satellites everywhere, says planetary scientist Julien Salmon of the Southwest Research Institute in Boulder, Colorado. "If everything comes from the same processes, should we get so much diversity?" he asks. "It seems like every moon has a part of the story to tell."

Right up to this weekend's "Grand Finale", Cassini has been collecting more data and snapping fresh images with a series of low swoops over Saturn's moons and through its rings. But what it has already seen constitutes, arguably, the richest haul of discoveries from any mission yet mounted to another planet. "It's going to be tough to say goodbye to Cassini," says Salmon.


Michele Dougherty

Like many space probes, Cassini had only a narrow launch window in October 1997 to take advantage of gravitational assists from Venus, Earth and Jupiter on its planned trajectory to Saturn. Back then, Michele Dougherty was just about to take over as principal investigator of Cassini's magnetometer, its instrument for measuring magnetic fields. It was, she recalls, a nervous time…

"*"I thought, it's going to be so exciting. I gave the impression I knew what I was doing but I didn't. We got up three mornings in a row at some ungodly hour because the launch was going to happen at two in the morning. Two days in a row, it was postponed because of upper winds and things like that. When it finally happened and you're standing there and you're watching this thing go up, the ground shakes and you're standing there, thinking, I hope it's going to be OK, I hope it's going to be – and your heart is in your mouth. It really is."*"

THE RINGS

After a six-and-a-half-year journey, Cassini entered orbit around Saturn on 1 July 2004 – and immediately encountered the planet's signature feature, its rings. Pictures collected by the Voyager probes when they flew past Saturn in 1980 and 1981 suggested the planet was girdled by about 10,000 rings, each a cloud of particles tightly confined to a narrow orbit. "Now the number is in the millions," says Larry Esposito, principal investigator for Cassini's ultraviolet imaging spectrograph.

The rings are also complex: Cassini's images have revealed clumps, holes, gaps and other structures. Some wave-like features are due to gravitational interactions with the moons embedded in the rings, but the origin of others is unclear.

The rings probably formed initially when a large moon came too close to Saturn and was ripped apart by gravitational forces. Esposito thinks this was early in the solar system's history, and that the rings have gradually spread since then, perhaps forming moons in the process. Others think the rings go through cycles: moons collide forming new rings that coalesce into new moons which eventually collide again, with the current rings as little as 100 million years old.

Old rings are expected to be much more massive than young ones. In its past final weeks, Cassini has been repeatedly passing between the rings and the planet, accurately measuring the rings' mass to perhaps resolve the question.

Cassini's six-and-a-half year journey to Saturn was far from idle time, says Dougherty. It allowed the mission to decide what its priorities were…

"*"We spent the time planning the first four years of observations in interminable teleconferences – about four or five a week in the final weeks. We would spend hours talking about the timing of every observation. To begin with, everyone wanted to do their thing all the time. But slowly, we got to understand each other's science, and the team would say, you can have that part of the orbit if I can have another. That time was really good for us, because it got us working together as a team."*"

ENCELADUS

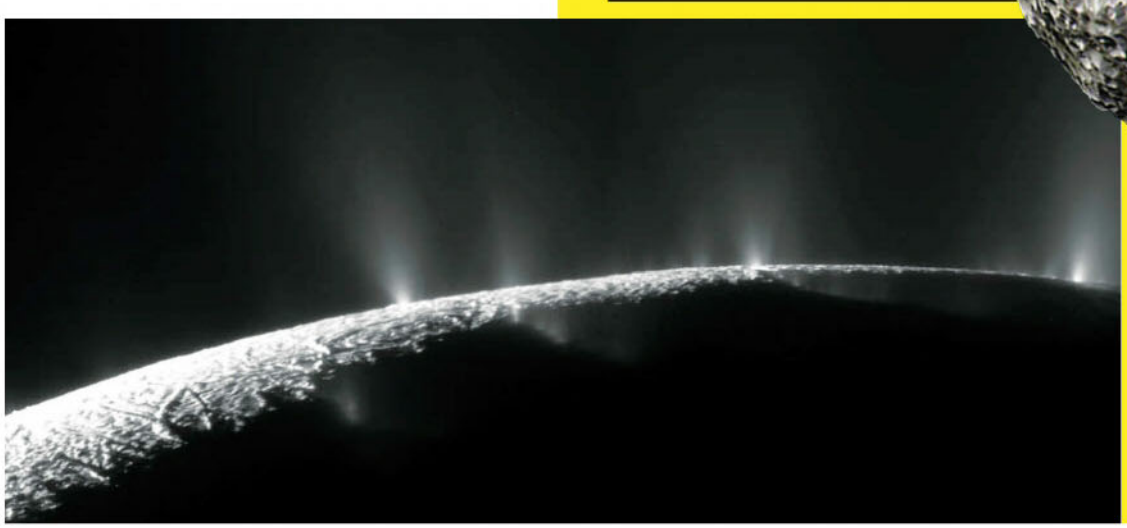
Before Cassini, researchers had expected this icy, 500-kilometre-diameter moon to be frozen solid. But on an early fly-by in February 2005, the spacecraft's magnetometer "sensed something unusual going on with its magnetic field", says Cassini project scientist Linda Spilker of the Jet Propulsion Laboratory (JPL) in Pasadena, California.

A later pass showed that the south pole was much warmer than expected, and was spouting geysers of salty water into space. Enceladus circles Saturn twice for every orbit of the larger moon Dione, inducing a gravitational interaction that melts ice inside both moons. The process squeezes Enceladus, ejecting jets of water from large fracture zones near its south pole (pictured below). Cassini measured the composition of these jets, detecting raw materials for life including salt, water, carbon dioxide, methane, other organic molecules and, most recently, hydrogen, an ideal energy source for life.

Silica found in the jets can be produced only in water close to boiling point, indicating that hydrothermal vents are also present in the subsurface ocean – making the icy moon a hot target in the search for life.

HYPERION

Trapped in a gravitational resonance with Titan, Hyperion (right) tumbles chaotically in orbit. Subject of an early fly-by in September 2005, its light, porous-looking surface resembles a battered sponge, but no one quite knows why. One possibility is that it is a fragment of a larger object shattered in a past collision. The dark zones look lower than the light-coloured ridges, perhaps because they absorbed more sunlight, causing ices below them to evaporate and the dark layer to sink down.



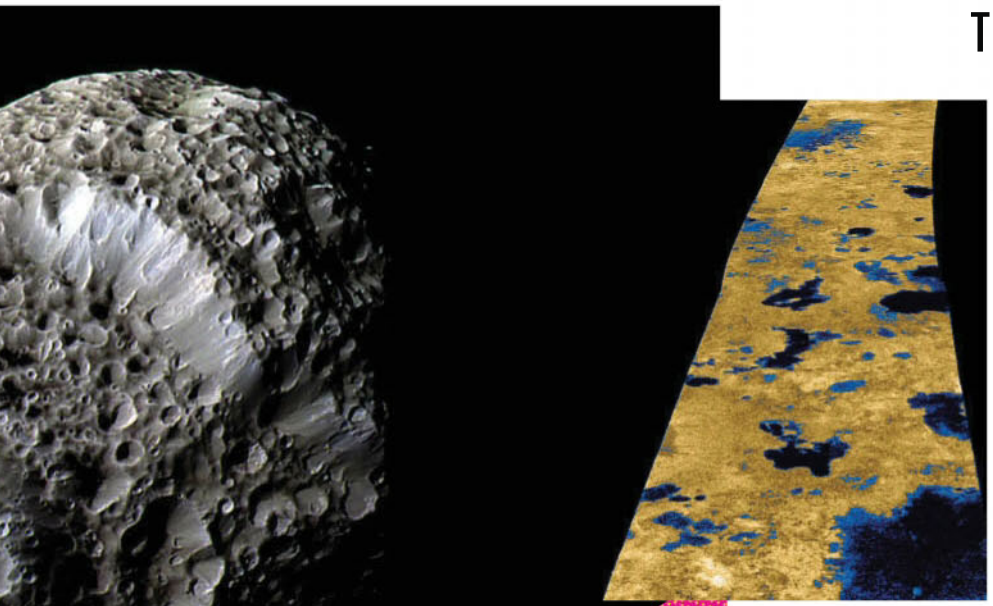
Close fly-bys revealed warm jets spouting from Enceladus (left)

The "something unusual" in Enceladus's magnetic field meant Dougherty's team had its work cut out. To investigate further meant flying closer to the moon – much closer than planned…

"The first fly-by was 1000 kilometres away above Enceladus, the second 500 kilometres below, I think. I went out to JPL to give a presentation to the icy satellites group. I was jet-lagged to hell and just before the meeting I bumped into Jerry Jones, the person responsible essentially for driving the spacecraft, in the line waiting for coffee. I said, we're seeing something in our data and we want to try and persuade the project to go really close on the third fly-by. He said: 'That would be cool, I've always wanted to go closer to a planetary body than anyone else.'

"In the meeting, some people said this is crazy, but Jerry said it'll be fine – and we eventually agreed to reduce the fly-by altitude to just 173 kilometres. That's when we saw the plume of water vapour coming off from the south pole, the hot spot and cracks at the south pole with organic material and dust coming out. Enceladus suddenly became the place to go."

TITAN



Titan's lakes (above) are filled with liquid methane

When Voyager 1 passed Titan in 1980, it couldn't see the surface of Saturn's largest moon: solar ultraviolet radiation drives reactions between nitrogen and methane molecules in its atmosphere that yield a thick, orange-brown gunk. The purpose of Cassini's Huygens lander, built by the European Space Agency, was to find out what lay beneath. Voyager had discovered that the temperature and pressure on Titan's surface would allow liquid methane. Huygens, released on 14 January 2005, was made to withstand a wet or dry landing.

Photos taken during the lander's 150-minute descent showed networks of branching streams possibly carved by liquid methane. But the touchdown was hard, on a cobblestone-strewn flood plain near Titan's equator like "something you might see in Death Valley", says Alexander Hayes of Cornell University in Ithaca, New York. But at around -180°C it was much colder, with a surface covered in plastic shavings and foam beads.

Huygens transmitted data from the surface for 72 minutes until its battery failed. In the years since, Cassini has probed Titan's atmosphere and mapped its surface on successive fly-bys, confirming the presence of liquid methane. In radar observations a few weeks apart it found evidence that methane showers had soaked the soil, then evaporated – the first proof of precipitation beyond Earth.

Titan's landscape is eerily calm, with methane seas and lakes that are "fantastically flat", says Hayes. They are more transparent than water lakes: a radar echo from one was reflected from its bottom, 160 metres down. Bright "magic islands", which appear briefly in the dark lakes before disappearing, are thought to be nitrogen bubbling out of solution.

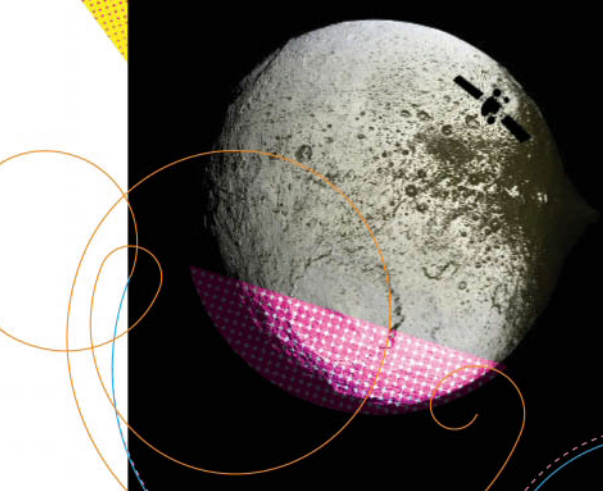
Perhaps oddest of all, Titan has two ocean levels. Beneath the hydrocarbon seas on the surface, under a shell of water ice, lies salty liquid water. This hidden ocean is, says Hayes, "the most accessible laboratory for prebiotic chemistry in the solar system" – a potential habitat for life.

Huygens's dry landing meant a long wait for confirmation that Titan was indeed a wet world, says Dougherty...

"When we first arrived at Titan, we expected to see liquid on the surface, but there wasn't any. It was maybe six years into the mission when the infrared spectrometer saw the sun glinting off something at the north pole. That was the first view that we had of any liquid. The reason we hadn't seen it before was because of the seasons. It just hadn't rained."

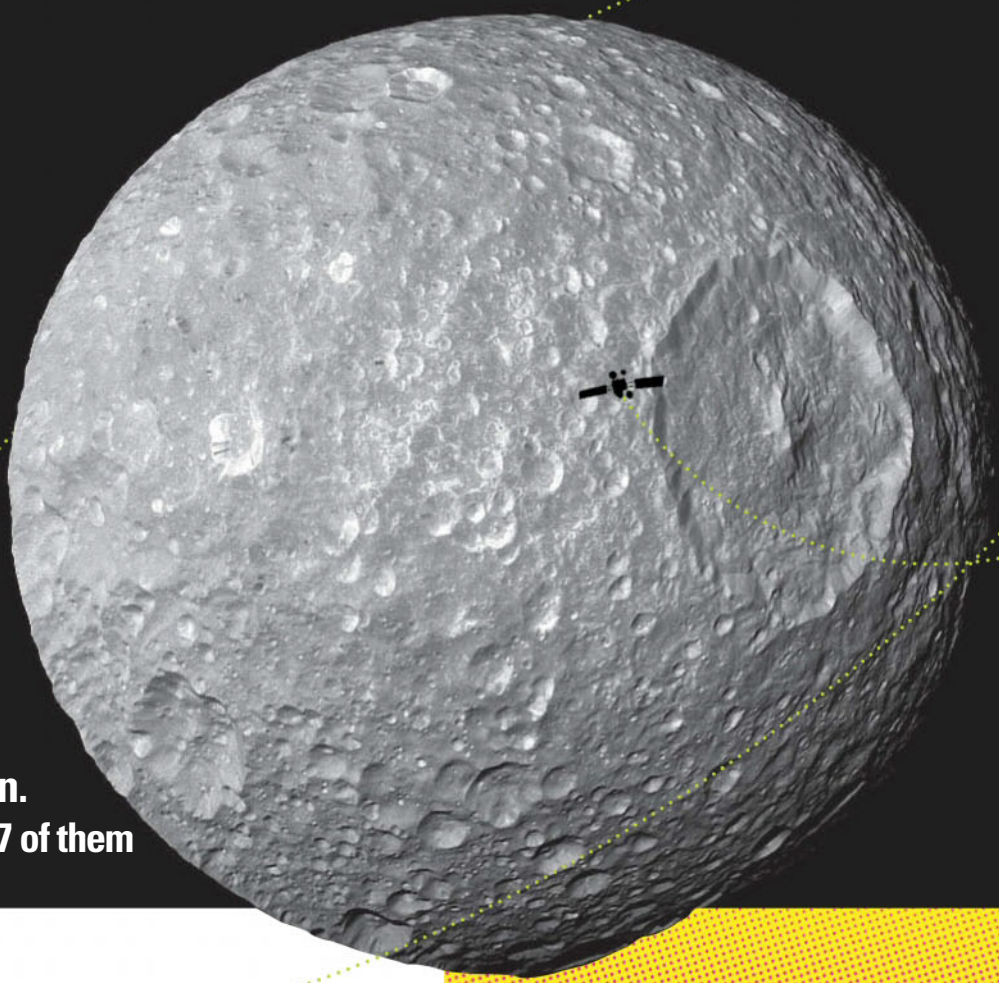
IAPETUS

At first glance, an equatorial ridge girdling Iapetus looks like a moulding mark on a factory-fresh rubber ball. A Cassini fly-by in 2007 revealed that the ridge is as heavily cratered as the rest of the 1500-kilometre-diameter moon's surface, so it must have formed long ago. Iapetus's surface is also oddly two-toned, with a darker leading edge. This is caused by gravitational forces that lock the moon into position around Saturn, causing its front face to sweep up dust.



MIMAS

At 396 kilometres in diameter, Mimas is the smallest known rounded body in the solar system. Seen closest by Cassini in February 2010, it's not completely round, however: one side is dominated by the 130-kilometre Herschel crater with walls 5 kilometres high. The giant pit makes Mimas, right, look eerily like the planet-destroying Death Star in the "Star Wars" movies. It is, however, extremely vulnerable: made principally of water ice, cracks on its opposite side show that a past impact came close to shattering it.



62

known moons of Saturn. Cassini discovered 7 of them

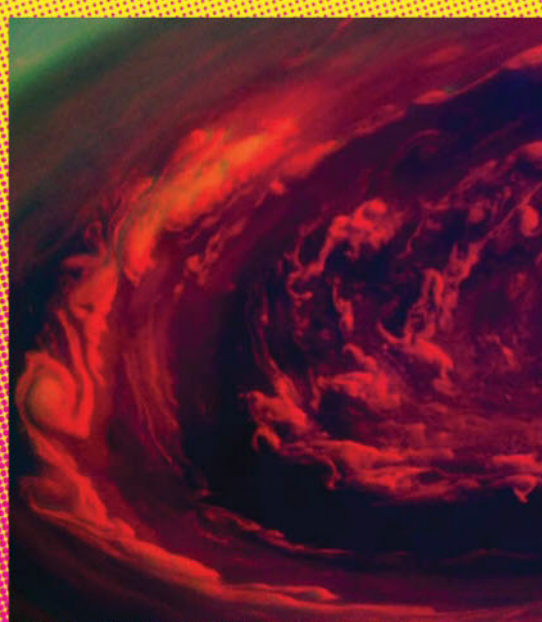
HURRICANES ON SATURN

Hurricanes on Earth tend to go towards the poles, but those on Saturn, pictured right, are fixed there. They have central eyes and eye-wall clouds like terrestrial hurricanes, and spin in the same way, but at 4000 kilometres across, three of them side by side would span Earth's diameter. Terrestrial hurricanes are powered by heat released from warm ocean surfaces. There's nothing like that on Saturn, so what powers its storms remains a mystery.

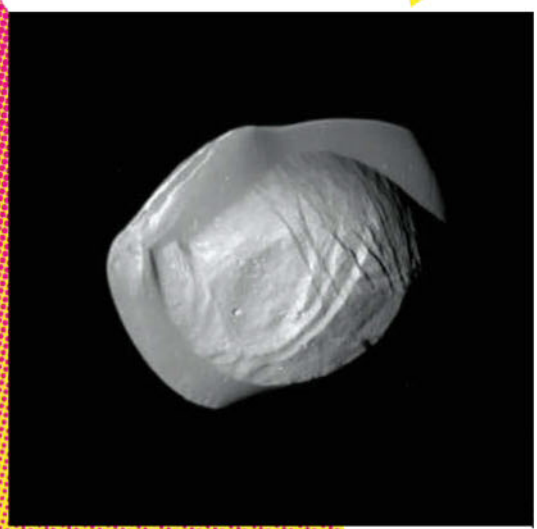
Dougherty's fascination with Saturn began long before Cassini, as a child growing up in South Africa…

"*"My dad built a 10-inch telescope when I was a kid. My sister mixed the concrete for the base. He ground the mirror. He had the telescope in the garden and I remember my first view of Saturn. You could just make out the little rings. We saw Jupiter too and the little spots of its four main moons, but I never thought I'd do what I do.*

"My dad died 12 years ago, and my mum a couple of years after that. They knew that I was taking over on Cassini, and they were chuffed about that, but they didn't get to see how well things have gone. That's one of my big regrets.""



The growth of the tiny moon Pan (below) may be curtailed by gravity



PAN

Fat, round, ravioli-shaped Pan orbits in a gap in Saturn's A-ring, the outermost of the large, bright rings. Its central core is icy, but ring particles accumulate on a strip around its circumference, fattening Pan out to a 35-kilometre diameter. Revealed in great detail in images taken in March 2017, this belt is cratered, with signs of a small landslide pulled downhill by the moon's gravity. Atlas, another moon in the A-ring, is similar, but its skirt shows no craters and looks fluffier. The moons' growth may be limited by a gravitational tug of war between them and Saturn: if ring particles pile too high on Pan's equator, the planet's gravity tugs them off again.

Cassini's discoveries are far from over as the team continues to pore over its data. But it is an emotional farewell, says Dougherty...

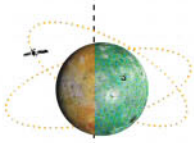
"*"Cassini has been a discovery mission. The only way you can understand a system is to orbit. The Pioneer and Voyager spacecraft gave us little nuggets, but Cassini will allow us to decide what to focus the next Saturn mission on. Is it going to be Enceladus? Is it going to be Titan? Is it going to be a polar orbiter?*

"There'll be a big get together for the end of mission itself. I'm not very emotional, at least not in public. But I gave a talk a few months ago and I showed a movie that JPL put together showing the lifetime of Cassini and how it's going to end by burning up. I was standing there, blinking, hoping the lights wouldn't go up. But I'm going to be brave. There'll be a sense of regret, and also relief, because I am exhausted after 13 years. And pride, definitely pride.""

20,000km/h

Entry speed of the Huygens probe into Titan's atmosphere

WHY THE GRAND FINALE?

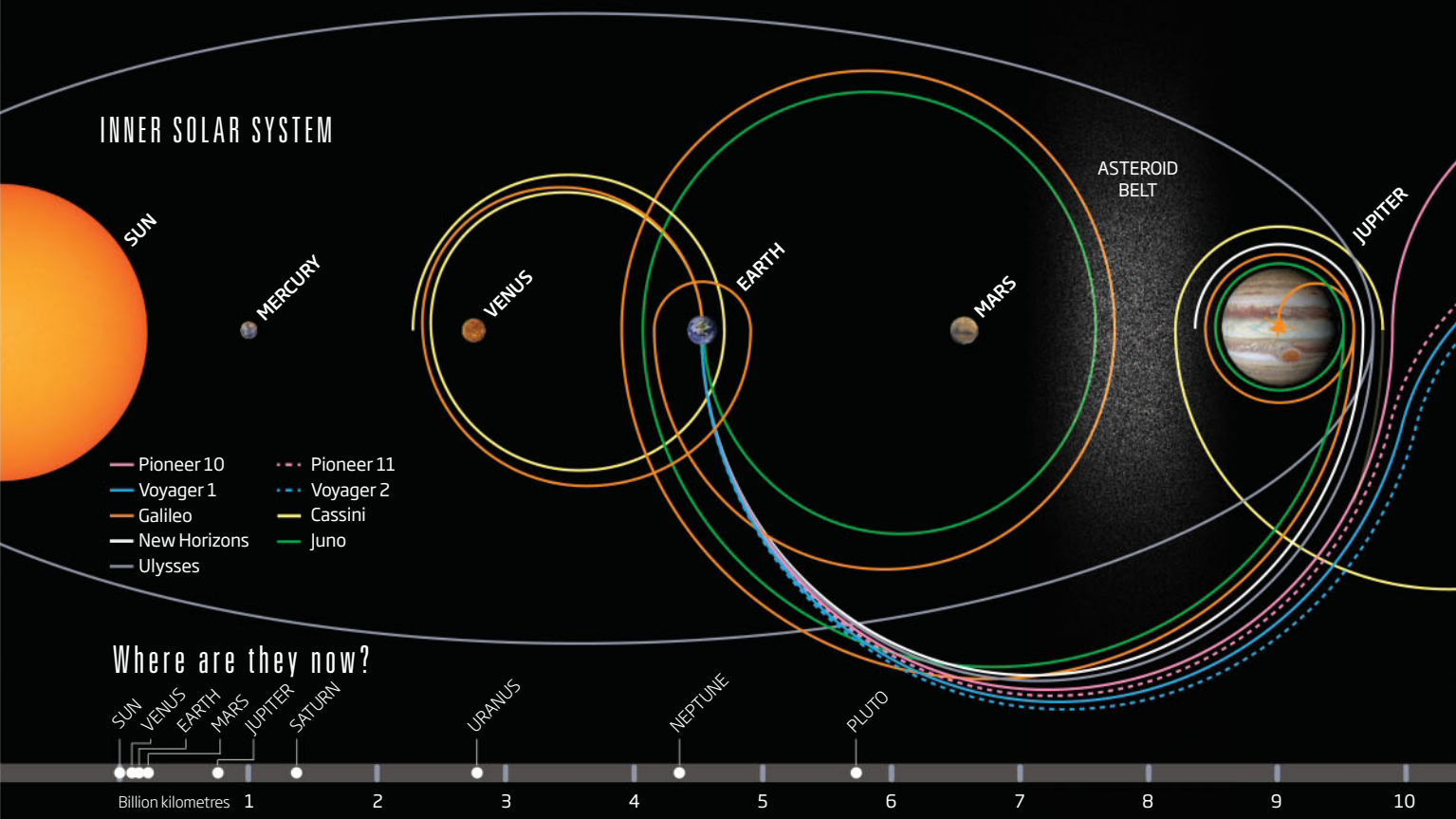


Almost 20 years after leaving Earth, Cassini's plutonium-powered generators are running out of fuel needed to adjust its course. Left to drift, it might collide with one of Saturn's moons, perhaps contaminating an environment that might contain or provide the conditions for life. To avoid that possibility, it will be steered into the atmosphere of Saturn itself, burning up like a meteor as it becomes part of the planet whose environment it has spent so long exploring. ■

Jeff Hecht and **Michael Brooks** are consultants for *New Scientist*. For the full interview with Michele Dougherty go to newscienti.st/cassini-special

MISSION POSSIBLES

In 40 or so years we have been exploring the outer solar system, nine probes have made it past the asteroid belt



PIONEER 10

LAUNCHED: 3 MARCH 1972

Pioneer 10 was the first probe to cross the asteroid belt, traversing it between July 1972 and February 1973. Arriving at Jupiter in December 1973, it passed some 132,000 kilometres from its cloud tops, and obtained fuzzy images of the four large "Galilean" moons, Ganymede, Europa, Callisto and Io. Now out of contact, this true space pioneer was last spotted coasting towards the constellation Taurus and the red star Aldebaran, which it should reach some 2 million years from now.

CURRENT STATUS:
Last contact 23 January 2003, now estimated to be 16 billion kilometres from Earth

PIONEER 11

LAUNCHED: 6 APRIL 1973

Visiting Jupiter a year after Pioneer 10, Pioneer 11 continued to Saturn, testing the dangers of navigating the planet's rings and flying within 21,000 kilometres of its surface on 1 September 1979. It almost collided with a small Saturnian moon and photographed Titan, the largest moon. An anomalous slowing of both the Pioneer probes brought long-lasting speculation that the established laws of gravity didn't work in space. The "Pioneer anomaly" is now thought to be down to heat loss from the probes' thermoelectric generators.

CURRENT STATUS:
Last contact 30 September 1995, now estimated to be 14 billion kilometres from Earth, heading towards the constellation Scutum

VOYAGER 2

LAUNCHED: 20 AUGUST 1977

In the 1960s, space scientists realised that a happy configuration of the outer solar system would allow one probe to visit four planets. Voyager 2 remains the only probe to have visited the two furthermost ice giants: Uranus in January 1986 and Neptune in August 1989. Its primary radio receiver failed in 1978, but 40 years on it is still sending back data as it crosses the edge of the solar system, called the heliosheath, and enters interstellar space.

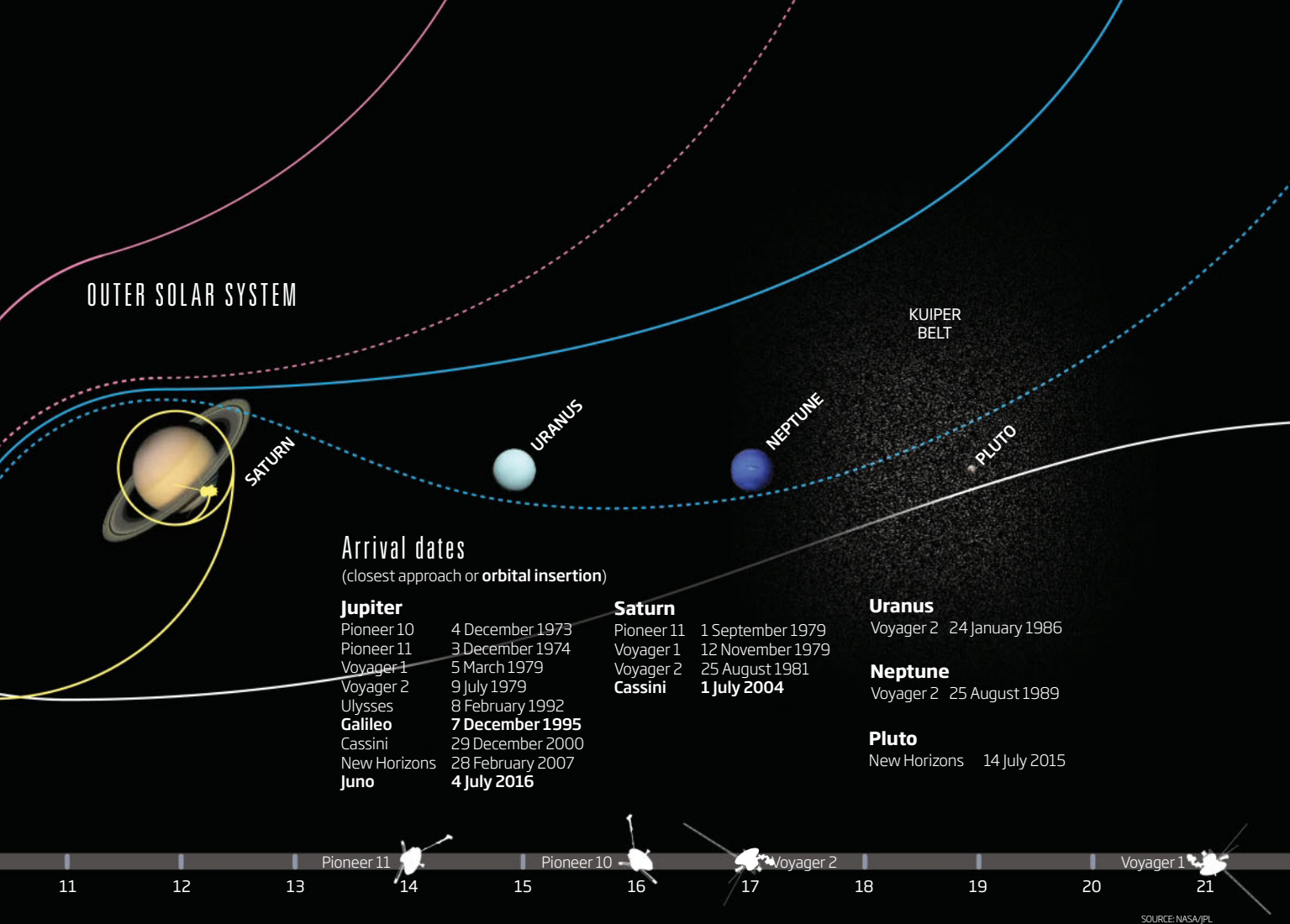
CURRENT STATUS:
17 billion kilometres from Earth, heading towards the constellation Telescopium

VOYAGER 1

LAUNCHED: 5 SEPTEMBER 1977

Voyager 1 launched after Voyager 2, but took a faster trajectory to Jupiter and Saturn, arriving at both first. Its route was optimised to bring it within 6500 kilometres of Titan, confirming Pioneer 11's observation that the moon possessed a thick atmosphere. On 14 February 1990, Voyager 1 turned its camera to take the first family portrait of Earth and other solar system planets. Still transmitting from interstellar space, Voyager 1 is now the furthest human-made object from Earth. Both Voyager probes carry "golden records" of sounds and images of Earth for any alien intercepter.

CURRENT STATUS:
21 billion kilometres from Earth, heading towards the constellation Ophiuchus



SOURCE: NASA/JPL

GALILEO

LAUNCHED: 18 OCTOBER 1989

Galileo was the first mission to spend years orbiting a planetary system, rather than simply passing through on its way elsewhere. On its six-year journey to Jupiter, it turned its instruments on Earth, picking up signs of life such as the absorption of red light by chlorophyll. Inserted into Jupiter orbit on 7 December 1995, Galileo's activities included sending a probe into the giant planet's atmosphere . It also collected data supporting the theory that Jupiter's moon Europa has a subsurface liquid ocean.

CURRENT STATUS:
Mission terminated with a plunge into Jupiter's atmosphere on 21 September 2003

ULYSSES

LAUNCHED: 6 OCTOBER 1990

The prime objective of the Ulysses probe was to survey the sun, but it took a long gravitational slingshot around Jupiter, thus entering an orbit over the top of the solar system that enabled it to monitor the sun's north and south poles.

CURRENT STATUS:
Decommissioned 30 June 2009

CASSINI-HUYGENS

LAUNCHED: 15 OCTOBER 1997

Spending 13 years cruising Saturn's moons, Cassini fulfilled the goal of sending a probe to the moon Titan (see "What Cassini saw", page 30).

CURRENT STATUS:
Mission due to terminate in Saturn's atmosphere, 15 September 2017

NEW HORIZONS

LAUNCHED: 19 JANUARY 2006

It is the fastest spacecraft ever launched, but by the time New Horizons reached Pluto on 14 July 2015, its destination had changed: Pluto had been controversially downgraded by the International Astronomical Union from "planet" to "dwarf planet" in August 2006. New Horizons took intriguing photos of this rocky world's hazy atmosphere and surprisingly varied, craggy surface, as well as its moons. It is now on its way for a rendezvous with the snappily titled space rock (486958) 2014 MU69 in the Kuiper belt, where it is expected to arrive on 1 January 2019.

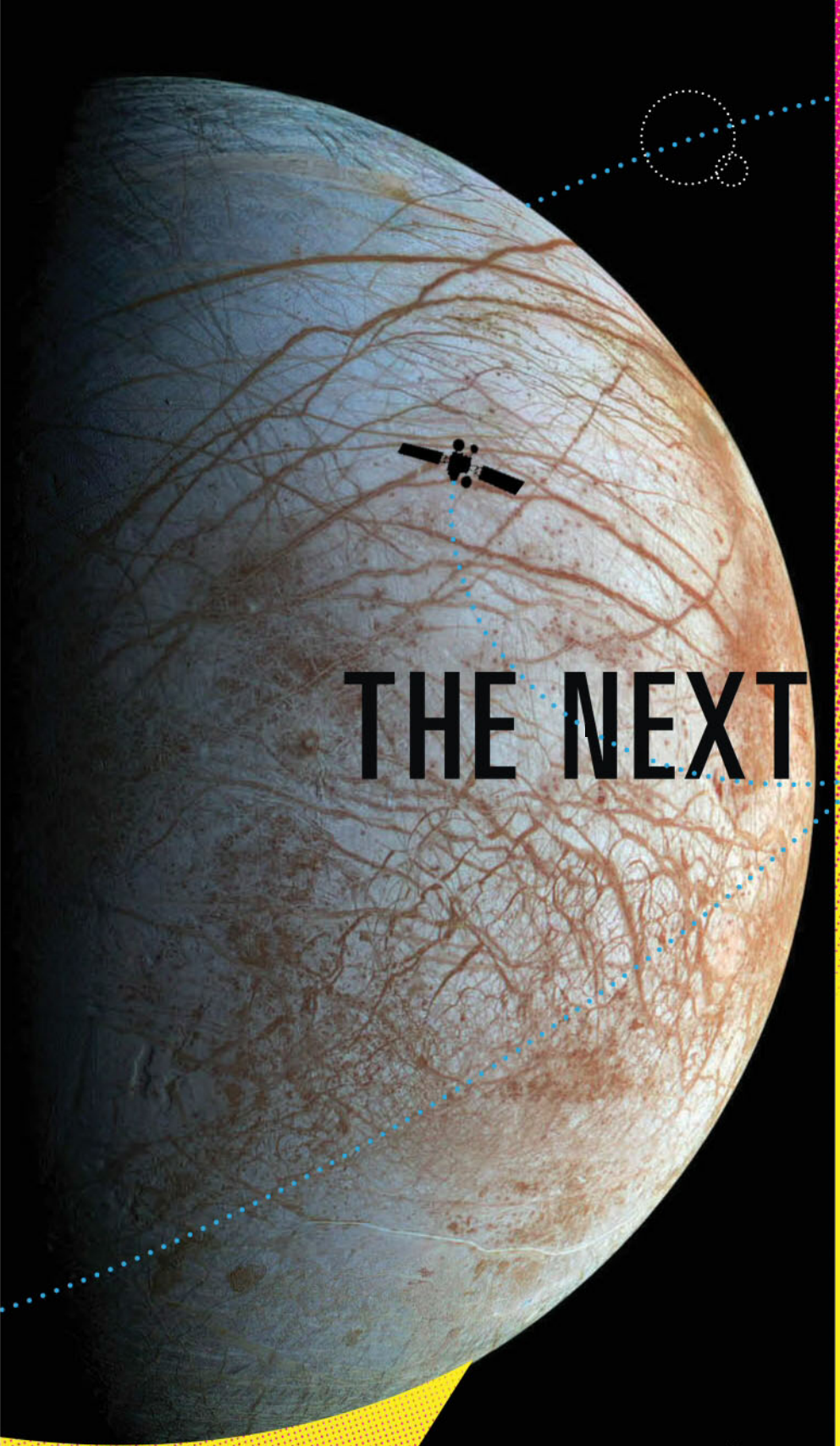
CURRENT STATUS:
In the Kuiper belt, 5.7 billion kilometres from Earth

JUNO

LAUNCHED: 5 AUGUST 2011

Unlike previous probes to the outer solar system, Juno doesn't have a nuclear reactor at its heart: it is powered entirely by solar panels. Juno entered into a polar orbit around Jupiter on 5 July 2016, with the intention of measuring the composition and gravitational and magnetic fields of the solar system's largest planet, as well as testing theories of how it formed. Its first results indicate some surprises: huge magnetic and atmospheric storms, and the revelation that Jupiter isn't as uniform as had been assumed.

CURRENT STATUS:
In orbit around Jupiter, currently 0.95 billion kilometres from Earth



THE NEXT VOYAGE

Thanks to Cassini and its predecessors, we know now what we're looking for in the outer solar system – life, says **Stuart Clark**

Under Europa's cracked surface could be the best place in the solar system to look for life

CAST your mind back to 1977. If you weren't around then, here are some pointers: Elvis died, *Star Wars* was released and flared trousers were big in all senses.

But two lower-profile and seemingly unconnected things also happened that year – a deep-sea dive off the Galapagos Islands and a pair of rocket launches from Cape Canaveral in Florida. Their consequences are converging now in the depths of the outer solar system.

Those events marked the beginning of a revolution in our understanding: a story in which the Cassini probe, now reaching the end of its life, has played a distinguished part. Just 40 years ago, we never would have suspected that the secrets of how life formed on Earth, and whether it exists elsewhere, may lie in the icy moons of the outer solar system. That revelation, for which we have Cassini and its forebears to thank, is set to shape the next decades of space exploration – and perhaps lead to one of the biggest upheavals in human knowledge we can possibly imagine.

The rockets launched in 1977 were NASA's Voyagers 1 and 2. They weren't our first probes

to the outer solar system: Pioneers 10 and 11, launched in 1972 and 1973 respectively, hold that mantle (see "Mission possibles", page 36). But the Voyagers were special because they gave us the blueprint for multi-instrument, deep-space probes able to build a comprehensive picture of distant worlds.

For the first time, we got close-up views not just of Jupiter and Saturn, but also of their moons. We discovered that Jupiter's moon Io was the most geologically active world in the solar system, with its volcanic eruptions and lava-strewn surface. Voyager 1 confirmed a suspicion that Titan, Saturn's largest moon, possessed a thick, hydrocarbon-rich atmosphere. And there were a host of other excitements including the icy visages of Jupiter's moons Europa and Ganymede, the solar system's largest moon.

Intrepid exploration paid dividends. These mini-worlds have in many ways eclipsed their parent planets for scientific interest, thanks to the discovery there of organic molecules and water – the ingredients on which all known living things depend. Researchers came to believe these moons could be essential in solving the mystery of life's origins.

Perhaps more than anyone else, in the 1980s the US astronomer Carl Sagan came to champion Titan as a time capsule that might tell us how life on Earth began. His interest in the chemical origins of life was sparked as a student at the University of Chicago in 1952, when Stanley Miller and Harold Urey performed landmark experiments. They took a sealed flask containing water, methane, ammonia and hydrogen – chemicals thought to be the composition of the atmosphere on the early Earth – and passed a spark through it to simulate lightning. Famously, they produced a tarry residue that contained amino acids, the building blocks of proteins that are themselves the building blocks of life.

Sagan endlessly tweaked and reran the experiment over a decade to find out the range of conditions under which amino acids would form. In 1979 this culminated in him and colleague Bishun Khare proposing the name tholins for the organic sludge.

A year later came the Voyager revelations about Titan's atmospheric composition. Sagan pointed out that the mix was almost identical to that in the laboratory set-up – and the idea of Titan as a replica of early Earth was born.

The Cassini mission was conceived in part to investigate this connection. The Huygens lander, built by the European Space Agency, descended to Titan's surface in 2004, and data from it and Cassini's many fly-bys has only strengthened most astronomers' belief that

"Cassini suggests that virtually all moons and planets were seeded with the ingredients of life"

Titan has significant astrobiological interest (see "What Cassini saw", page 30). "Titan has the most complicated atmospheric chemistry in the solar system," says Ravi Desai of University College London.

Cassini has made low passes through Titan's upper atmosphere several times in recent years. Passing at altitudes from 950 to 1300 kilometres, it used its plasma spectrometer instrument, known as CAPS, to "sniff" the molecules there. In July this year, Desai and his colleagues reported the presence of chemical species known as carbon chain anions, and also longer organic molecules. These molecules became more abundant deeper down – just as the anions began to thin out. "It was a definitive correlation," says Desai: the carbon-chain anions were coming together in the creation of longer chain organic molecules. These were Sagan's tholins in the process of being formed.

This suggests tholins are easy to make, explaining why we are now beginning to find these molecules in abundance across the solar system. The New Horizons mission, which flew past Pluto in 2015, showed that they give a red colour to it and its moon Charon, and they are also present on the largest asteroid, Ceres. "Our work seems to be showing that there is a universality to creating large complex organic molecules," says Desai.

But it's still a long way from organic molecules to actual life, and here this particular juggernaut comes to a shuddering halt. Huygens found no evidence of life on Titan, and suggestions of possible life signs on the frosty moon – which would have to be life not as we know it, based on liquid methane instead of water – are tenuous. Cassini suggests that virtually all moons and planets in the solar system might have been seeded with the ingredients of life, but "how chemistry turns into biology is probably the biggest open question in science," says Desai.

Better, perhaps, to take one step back. "You cannot start with the chemistry," says Michael Russell of NASA's Jet Propulsion Laboratory in California. "Right down underneath everything, you've got to know the physics. Life is not simply an agglomeration of organic molecules." Besides the building blocks, you

127 fly-bys of Titan by the Cassini mission

WHAT DOES LIFE DO?

When it comes to working out what life is, that's the one question not to ask, says Michael Russell of NASA's Jet Propulsion Laboratory. "Never ask what anything is. Ask what it does," he says. "What does life do?"

We may be tempted to answer that life passes on heritable information by the process of reproduction. But that's a limiting statement, according to Russell, because it looks at things from the point of view of our biology, rather than the underlying physical processes. "Life hydrogenates carbon dioxide," he says. It takes hydrogen from water and joins it together with carbon dioxide, which originally emanated from volcanoes in abundance. This rights what would otherwise be an unresolvable chemical disequilibrium, and produces a supply of organic molecules in the process.

Doing this requires a source of free energy to drive the chemical reaction and a small engine to make it happen. In this picture, life is made of small electrical engines, driven by the movement of free electrons in our environment. Replication – or reproduction – is just something that evolved to keep that going. As the Hungarian Nobel prizewinner Albert Szent-Györgyi put it: "Life is nothing but an electron looking for a place to rest". "Put electrons in the system and they will try to escape. That very flow of electrons is what drives these little engines to generate the organic molecules," says Russell.

need a source of free energy. That takes us back once again to 1977, this time to that deep-sea dive off the Galapagos Islands.

In February of that year, oceanographers Jack Corliss of Oregon State University, and Tjeerd van Andel of Stanford University travelled to the sea floor in Alvin, the submersible best known for exploring the wreck of the Titanic. They were looking for hydrothermal vents, which jet warm water out from beneath the seabed into the cold ocean. They not only found these "black smokers" – so-called for the colour of the minerals that precipitate out of the hot water – but also an extraordinary abundance of life around them.

Extraterrestrial tests

Corliss and others concluded that such places could have been the backdrop for the origin of life, pitting them against those advocating the idea of organic chemistry in the atmosphere. Russell, then a deep sea vent geologist working on underwater mineral deposits, soon joined the discussion. He thought the black smokers were too energetic: fragile organic molecules would be as easily destroyed as created. Instead, he proposed that life began at the calmer, warm water vents, in the mineral deposits he was studying.

The trouble was how to test the hypothesis. To simulate the sea floor would require water at pressures 10 times that at sea level. It would have to be acidic to represent the higher concentration of carbon dioxide in Earth's early atmosphere, and the whole lab would have to be more sterile than an operating theatre to ensure that no ordinary Earth bugs were inside – and nothing that sprang to life inside could get out.

The Galileo probe, which reached Jupiter late in 1995, showed the experiment might already be going on elsewhere. In particular, its images of Europa showed huge cracks in the moon's icy surface and areas where the ice blocks had moved, as if transported by currents in a subsurface ocean. Readings from Galileo's magnetometer revealed that a churning saltwater system encircled the whole moon. This ocean probably contains more water than Earth, and must be powered by a heat source at Europa's centre. That gives rise to the hope of hydrothermal vents – and a perfect place to put Russell's theory through its paces. "I'm lucky enough to be at the beginning of a big extraterrestrial test of these ideas," says Russell.

NASA and ESA are both planning return missions to Jupiter's moons. NASA's is called Europa Clipper and will launch in the 2020s. Because of the intense radiation around Europa, in the form of high-energy electrons trapped in Jupiter's powerful magnetic field, the spacecraft will not orbit the moon, but circle Jupiter and perform 45 fly-bys at altitudes varying from 2700 kilometres to just 25 kilometres. Cameras and spectrometers will determine the surface ice composition, radar will determine its thickness, and a magnetometer the depth and salinity of the underlying ocean. Together, those readings should confirm whether the conditions are suitable for life to have arisen.

But Europa is not the only object of interest. The ESA mission, called JUICE for Jupiter Icy Moons Explorer, is planned for a 2022 launch. It will dive close to Europa to take similar

The orange tinge to Titan's atmosphere, comes from organic molecules, as Voyager 1 (below left) confirmed

readings to the Europa Clipper, but also enter orbit around Ganymede. Galileo's observations suggested this satellite, too, might have a hidden ocean, not so active as Europa's and perhaps 100 kilometres down. "It might have more liquid water than Earth and Europa," says Olivier Witasse of JUICE. "It is the largest moon of the solar system, so there must be something special about it. I will not be surprised if by the end of the JUICE mission you find that Ganymede is maybe a more interesting object than Europa."

Russell is not so sure. For him, the focus remains on Europa because the radiation that makes spacecraft operation difficult is exactly what he thinks might be needed to trigger life. "Life is an electrical motor," he says (see "What does life do?", left). An electrical motor needs a battery to supply a flow of electrons. At hydrothermal vents on Earth, the battery is created by the alkaline waters of the vent gushing into the seawater, which is more acidic thanks to dissolved atmospheric carbon dioxide, as well as chemical reactions around the vent. All in all, the vents generate 500 millivolts to 1 volt.

Russell thinks that the electrons in Jupiter's radiation field can do a similar job."Europa has much of what one might expect from a battery," he says. High-energy electrons hit the moon all time, oxidising the surface. "If you can get those electrons into the ocean, you have the disequilibrium that life equires," he says.

The importance of finding life beyond Earth cannot be overstated. To find it elsewhere in our solar system would surely mean it is widespread throughout the entire galaxy. It would allow us to study the chemical composition of life: must it be based on DNA or is another molecule capable of carrying heritable information? It might also bolster the idea that not just planets, but moons in other solar systems might be profitable places to look for life.

It may be a while before we find out. Russell was part of a 21-person team who published a NASA report earlier this year on a potential mission to search for evidence of life on Europa's surface, concluding it would need to look for cells. "They can be dead, but whole cells would be what I would look for. That would be the killer evidence," says Russell. These cells might be expelled in a plume of water and caught during a fly-by, or found scattered across the icy surface using an on-board microscope to image samples. But money to develop a Europa lander was cut in NASA's 2018 budget, and the Europa Clipper and JUICE will only be able to analyse molecular compositions. In April, planetary scientists from both sides of the Atlantic called for ESA and NASA to work together to land on Europa, just as ESA developed the Huygens lander for the NASA Cassini mission.

"Beneath the ice, Europa's heated subsurface ocean probably contains more water than Earth"

Others would prefer to use any money to land on Titan and explore the organic chemistry there. Thanks to Cassini, we now know the moon has methane lakes and a hydrological cycle based on liquid methane. But with large missions taking around 20 years from conception to results, even if the money can be found, deciding which destination to gamble on first is a big deal.

But one thing is for sure. Whatever your viewpoint about the origin of life – whether as a product of atmospheric chemistry and the downward drift of organics, or underwater hydrothermal vents – the icy worlds of the outer solar system are now the place to be. "Europa has the ocean and possibly hydrothermal vents so is similar to Earth. Titan is a different environment and like the early Earth," says Desai.

As we wave goodbye to Cassini, we are far from the end of an eye-opening voyage of discovery. "It is astounding in my lifetime what has changed," says Russell. "Forty years ago we didn't know what these moons looked like up close." ■

Stuart Clark is a consultant for *New Scientist*. His latest book is *The Search for Earth's Twin* (Quercus)

IMAGES: MICHELE DOUGHERTY: DAVID STOCK; NASA/JPL-CALTECH/SPACE SCIENCE; SSI/JPL-CALTECH/NASA; NASA / JPL-CALTECH / USGS; NASA/JPL/SPACE SCIENCE INSTITUTE; NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/UNIVERSITY OF IDAHO.

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First contact – with a trapped brain

People in a vegetative state were assumed to have no awareness at all, until **Adrian Owen** asked them to imagine playing tennis

PROFILE
Adrian Owen is a neuroscientist at the Brain and Mind Institute at the University of Western Ontario, Canada. His new book is *Into the Grey Zone* (Guardian Faber Publishing)

WHEN he found out that his old flame, Maureen, was in a vegetative state as a result of a brain haemorrhage, neuroscientist Adrian Owen started wondering whether she, and other people in a similar situation, might have some awareness. He was already scanning parts of the brain to study their function, so when he got the chance a year later to scan Kate, a woman in a vegetative state, he jumped at it. Kate made occasional involuntary movements, but didn't respond to external stimuli. It was 1997, and it had always been assumed that people in this condition had no conscious awareness at all. What Owen uncovered would change everything.

What made you scan someone in a non-responsive vegetative state?
This idea was bonkers at the time. But after what happened to Maureen, it was on my radar. It seemed logical that some people might be aware, because people with locked-in syndrome – in which people can move nothing but their eyes – are cognitively fine. It seemed probable that there would also be a group of people who are conscious but couldn't even move their eyes. But there was a lot of resistance to the idea, because it makes us uncomfortable to think that a person might be completely conscious but trapped inside themselves. When my colleagues said it wasn't possible, I'd say, "How would you know? You have no way of detecting it."

And did you find any activity in Kate's brain?
A viral infection had left her in a vegetative state, but her brain was responding exactly as a healthy person's brain would. We showed her photos of family members, for example, and the same part of her brain lit up on the fMRI scan as yours would if I did the same thing to you. That was the first indication we had that any of these people had any cognitive function.

How did you feel when you realised her brain was working?
In those days, the results were a bunch of numbers – but we looked at them and went, hang on a minute, these numbers suddenly all get really big. I think she's activating! It was tremendously exciting.

Was Kate conscious?
No, we couldn't say that. We thought wow, maybe she's in there. And then somebody said, well is she? Face recognition is an automatic brain response, it's not something you necessarily have to be conscious to do.

So you had to work out how to detect consciousness?
We tried speech on the next patient, and again their brain responded normally. But then we wondered, would an unconscious brain still perceive speech? We tried it on healthy people who had been sedated and it turns out that they do. We worked out that a lot of responses don't necessarily indicate consciousness. It took us a decade to solve that problem.

And how did you solve it?
I realised I had to get a patient to somehow tell me they were conscious. If I wanted to know if you were conscious, I would say raise your arm, and you would raise it. And I realised that with fMRI we had a tool that could allow someone to do that with their brain.

So we asked someone to imagine playing tennis. It was a simple way of asking a person to do something that would make them think about moving their arms because we knew that imagining big, sweeping arm movements activates the brain's premotor cortex. That was a pivotal moment.

What happened when you asked them to imagine playing tennis?
The premotor cortex lit up on the scan. Then we said stop, and the activity went away. It was incredible because this was a woman who had been hit by two cars while crossing the road, who had been in a vegetative state for five

Photographed for New Scientist by Finn O'Hara

months and who had not produced a single response. That's the point when I knew we had something really important. It was the first time that anybody had proved a vegetative patient could actually be conscious.

So people whose brains respond are not in a vegetative state at all?
In a vegetative state, by definition, there is no awareness. The patients that we are uncovering are some other thing, for which there is no name, because nobody knew it existed before we found them.

Have you tried communicating with them?
At the start we were very conservative. If we had rushed in and said we could communicate with the woman who had been hit by cars and then failed to get it working, that would have been incredibly disappointing for her family.

I get people all the time saying, why don't you just bring patients in and let the families talk to them? And the reason is we're still not at that stage. It still takes about 5 minutes per yes-or-no question, with imagining playing tennis for "yes" or moving around their house for "no". And it involves highly skilled individuals making careful decisions about data. We have to be very careful that we don't promise too much.

We and other teams are now developing more portable brain-computer interfaces. But to my knowledge, no one has yet used one to allow communication in a patient who appears to be vegetative.

Are people treated differently after they show signs of awareness?
Yes, that's happened many times. Kate, my first patient, made a pretty good recovery in the end, and I saw her a few years later. She said something she hated was the fact that she had been treated as an object. Once people know there is more going on in someone's mind, they become much more interactive, they start to treat them as a person. I basically treat everybody as though they are completely conscious, though it's an odd thing because I'm obviously getting nothing back.

"It's uncomfortable to think that people could be trapped inside themselves"

Did you ever scan Maureen?
No, but someone else did, in 2010. There was no brain activity. For me, it was comforting that she obviously wasn't suffering. She wasn't aware. She hadn't been lying there for 20 years in pain. I was glad about that.

What proportion of people in a vegetative state ever get scanned for brain activity?
Virtually zero. People get a basic MRI scan to assess any structural brain damage, but scanning for brain function is not routine care. It is more widely used than before, but typically, people in a vegetative state live for decades at home or in a hospital and are not continually monitored. They have been quite neglected.

It is well over 10 years since we proved that demonstrating awareness has clinical utility. It can help us find which patients are going to go on to do better. That alone means it should be more widely adopted. From my experience, awareness seems reasonably common.

So there must be thousands of people out there who are conscious but nobody knows?
Yes, I'm quite certain of that. ■

Interview by **Julia Brown**
Adrian Owen will be speaking at New Scientist Live at the end of September (live.newscientist.com)

Into the moment...

Are meditation and mindfulness really good for us or do they encourage narcissism? **Michael Bond** explores

The Science of Meditation: How to change your brain, mind and body by Daniel Goleman and Richard Davidson, Penguin
Mindlessness: The corruption of mindfulness in a culture of narcissism by Thomas Joiner, Oxford University Press

IN THE West, meditation is hailed as a panacea for many ills. It is taught as a cure for emotional distress and as a recipe for happiness. It is even prescribed for pain relief and as a treatment for recurring depression when the drugs fail. In central and south Asia, where the practice originated, it represents something quite different: a spiritual exploration of the mind, a profound recasting of how we understand ourselves.

The two are not incompatible, though. The Dalai Lama, who practises in the Eastern tradition, is one of several meditation masters to encourage a de-spiritualised version, a path accessible to all.

For many years, science writer Daniel Goleman and neuroscientist Richard Davidson have collaborated with the Dalai Lama in this mission, answering his call for scientists to test the effects of meditation in the lab and apply the results wherever they might be useful. Goleman and Davidson have now written a book, *The Science of Meditation*, in which they try to cut through the tangle of claims and promises. Their aim is to make clear what works and what doesn't, and to explain why focusing our attention minute by minute on a single facet of consciousness (a mantra, our breath, stray thoughts) might have such a dramatic impact on our well-being and state of mind.

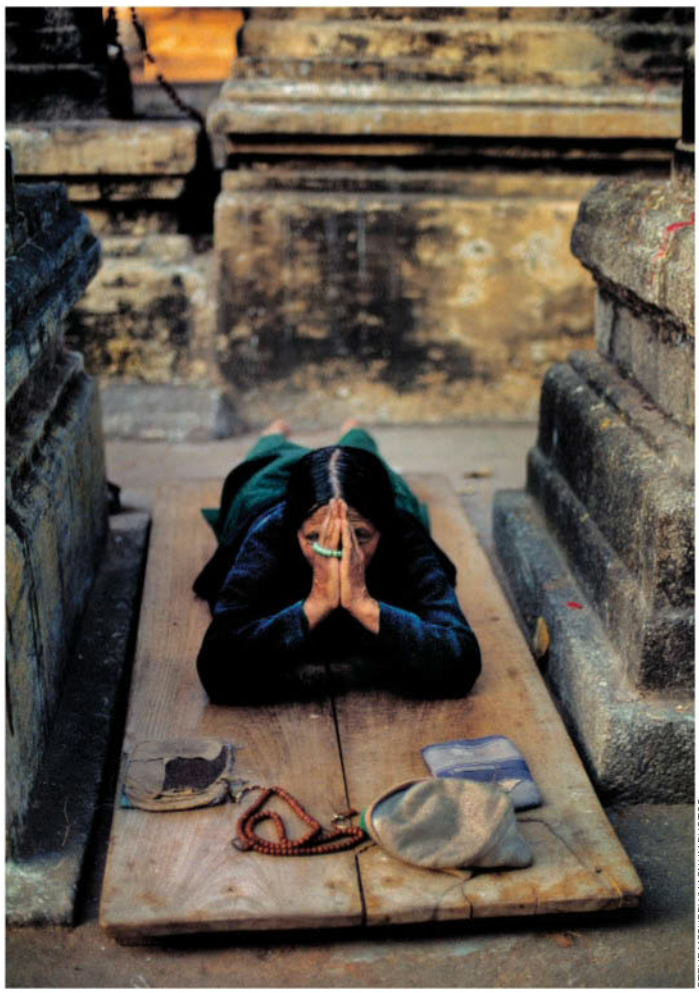
It is much needed. Of the hundreds of behavioural and neuroimaging studies carried out on meditators over two decades, many are inconclusive. Even so, Goleman and Davidson find plenty to be optimistic about. For example, there is good evidence that regular sessions of mindful attention have a calming effect on the amygdala, the brain's emotion processor, and reduce impulsive reactions to stressful or negative thoughts and experiences.

Mindfulness can help mute our emotional response to physical pain, and lessen anxiety and mind-wandering (not the kind that feeds creativity but its unfocused opposite). The benefits are apparent, even for beginners, and they increase with practice.

Compassion meditation, which aims to boost empathy, has an even more immediate effect: just 7 hours over the course of two weeks has been shown to boost altruistic behaviour. It is probably no coincidence that this makes us happier, too.

"The fundamental aim of meditation is to deconstruct the self, not shore it up"

This is the kind of affirmation that Goleman and Davidson most enjoy. They are interested less in meditation's potential for improving health or sharpening business performance and more in its capacity to cultivate enduring qualities such as selflessness, equanimity, compassion and the ability to free the mind of negative emotions – what they call "highly positive altered traits".



STEVE MCCURRY/MAGNUM PHOTOS

Lost in meditation: are devotees on a different plane of consciousness?

Much of the evidence for these traits comes from Davidson's lab at the University of Wisconsin-Madison, where he has scanned the brains of dozens of highly experienced Tibetan monks. These yogis, who have meditated for thousands – in some cases, tens of thousands – of hours, describe themselves as living in a heightened state of present-moment awareness, "as if their senses were wide open to the full, rich panorama of experience".

Davidson claims he has found a neural correlate to this mind-warp: a massive increase in the intensity of gamma waves in the brain, a signal associated with conscious perception. Are these monks living on a different plane of consciousness from the rest of us?

While Goleman and Davidson are long-time meditation enthusiasts, they are not evangelists. They are sceptical of many claims about the benefits of mindfulness, and Davidson makes a point of publishing "non-findings" from his lab. For this, he would no doubt be applauded by Thomas Joiner, a psychologist and specialist in suicidal behaviour, who argues in his own book *Mindlessness* that interest in this form of meditation has gone too far. "Authentic

mindfulness has been perverted into solipsism," he declares.

Yet he never properly draws the line between the authentic and solipsistic versions, and appears to use mindfulness as a stand-in for his real bugbear: the modern culture of self-importance and narcissism, manifest in such things as selfies, self-marriage ceremonies, self-compassion, and even trendy coffee shops.

"To ask that people gaze inward… is inviting them to let natural inclinations run amok, to the point of unseemly excess," says Joiner. Self-examination at this level ends in "the sound of a cell phone click as one takes a selfie, and… the self glorified while the culture falls around it".

Self-lightening

Really? It's easy to be cynical about popular culture, but pinning its excesses on mindfulness seems a stretch. The fundamental aim of meditation is to deconstruct the self, not shore it up, to "lighten the system that builds our feelings of I, me, and mine", as Goleman and Davidson put it.

One of their most interesting passages describes what this self-lightening looks like on a neural level, how meditation practice quietens the brain's default mode network, the constant background chatter that accompanies mind-wandering and self-absorption.

If a wandering mind is an unhappy mind, as various psychological surveys argue, then a focused mind must be worth struggling for. For Goleman and Davidson, the struggle is not so much about individual relief as global salvation, about reducing "greed, selfishness, us/them thinking and impending eco-calamities, and promoting more kindness, clarity, and calm".

Joiner may raise a sceptical eyebrow, but the Dalai Lama would probably approve. ■

Michael Bond is a consultant for *New Scientist*

Hallucinations of *Hellblade*

A new game tries to present a realistically immersive approach to the hallucinatory world of psychosis, finds **Simon Ings**

Hellblade: Senua's Sacrifice by Ninja Theory, for PS4 and PC

YOU are Senua, a Pictish outcast whose lover has been sacrificed to the gods by homicidal Norse invaders. To release his spirit, you must enter Hel, their underworld.

But is this all real?

Three years ago, Paul Fletcher, a psychiatrist at the Behavioural and Clinical Neuroscience Institute in Cambridge, UK, took a call from games company Ninja Theory. The firm wanted help creating a character who experienced severe psychosis.

"My defences were up," Fletcher admits, "but quickly I realised I was in serious company. We started by discussing the kinds of hallucinations people experience, and within two or three sessions we were into the neuroscience."

Senua's world blurs as she moves. The walls crawl as she passes. When she looks in her mirror, the wrong voice screams out of her reflected mouth. "But more interesting," says Ninja Theory's co-founder Tameem Antoniades, "was the way someone in psychosis will make sense of their world by making associations: ones that outsiders might find very strange."

Players will enjoy the way that runic images and the features of Senua's landscape conjoin in perspectival games that further or frustrate her progress. And there are incidental delights: at one point, the embers of a fire pulse to the rhythm of Senua's breathing.

Hellblade is more than a journey through a hallucinatory landscape, though. It's about a rational hero desperately trying to make sense of her world. "Most of us are pretty bad at that," says Fletcher. He's referring to a paper he co-wrote a couple of years ago, showing that people in the early stages of psychosis are actually better than the rest of us at interpreting ambiguous visual information (think of the Dalmatian illusion, in which a dog is camouflaged in a black-and-white image).

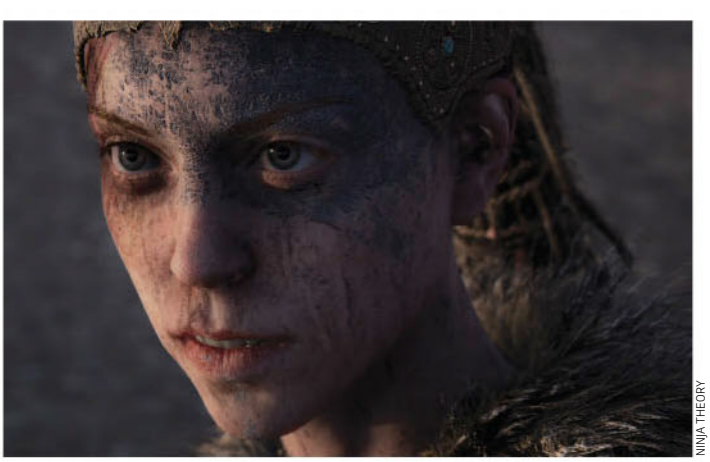
"Someone said perception is controlled hallucination. This is true. You bring what you know to bear on what you sense. That is how we recognise things."

"The game's most radical element is that while Senua is in the throes of psychosis, she is a hero"

Not all people who experience hallucinations consider them a problem. Some who hear voices, for example, have joined networks dedicated to removing the social stigma attached to the phenomenon. "A lot of people suffer not because of the content of their hallucination, but because of being ostracised," Fletcher says.

Meanwhile, games are becoming increasingly immersive. *Hellblade*'s binaural soundtrack, placing Senua's intrusive voices in distinct locales for the player, is a case in point. Fletcher hopes that psychiatrists and designers can work together to create immersive environments tailored to individual needs. "Avatar therapy", using a screen-based, computer-generated figure to represent, normalise and quell an aggressive intrusive voice, is already proving its clinical worth.

Certain players will find the game rather restrictive, and some of those limits are imposed by the psychological realism. Senua's demons are consistent, staying more or less the same. Psychosis is not a variety show. It's worth noting, though, that the game's most traditional element is also its most radical: while Senua may be in the throes of psychosis, she is also a hero. ■



NINJA THEORY

Mirror nightmare: another voice screams out of Senua's reflection

Making sense of chaos

To understand earthquakes we must endure them, finds **Alexander Densmore**

The Great Quake: How the biggest earthquake in North America changed our understanding of the planet by Henry Fountain, Crown Publishing

Quakeland: On the road to America's next devastating earthquake by Kathryn Miles, Dutton

AT THE heart of seismology lies an uncomfortable truth: each large, devastating earthquake teaches us something new about how Earth works. A visit to a stricken area triggers a sobering mix of emotions: heartbreak, at the cost of lives and livelihoods, as well as awe at getting a peek under the hood of the planet's tectonic engine. What we learn helps us better understand the hazard, but that knowledge always comes too late to help those affected.

Two new books explore our existing knowledge, albeit from very different perspectives. In *The Great Quake*, Henry Fountain dissects the 1964 Alaska earthquake (pictured, right), still the largest recorded in North America, and teases out its wider scientific impact.

Fountain focuses on George Plafker, a geologist with the US Geological Survey (USGS), showing how his careful observations were used to build up a broad picture of what happened deep within Earth along the boundary between the Pacific and North American plates. This is pure detective work, and Fountain captures the exhilaration and excitement of fieldwork and the unexpected insights that it brings.

The story is set within the wider context of plate tectonics, the unifying theory of the rigid lithospheric plates that comprise Earth's surface. The Alaska quake occurred at the culmination of the plate tectonics revolution, when seemingly disparate properties of the continents and oceans were being pieced together. Fountain shows convincingly how plate tectonics inspired Plafker to devise a new model of this and similar large earthquakes.

The Great Quake follows a large cast of characters, but focuses in particular on Chenega, the Alaskan village where a third of the population lost their lives in the ensuing tsunami. Fountain succeeds in creating a vivid portrait of both the region and the process of scientific enquiry. His descriptions of how earthquake science is carried out, written up and presented are compelling and convincing.

Kathryn Miles takes a very different approach in *Quakeland*. She focuses on critical infrastructure – bridges, levees, dams, airports – and talks to scientists and emergency managers who are trying to anticipate the timing or impacts of the next big event. Miles takes readers to a core repository to see rocks from the heart of the San Andreas fault, and to the Hoover dam to consider earthquake intensity and probability.

"Each large, devastating earthquake teaches us something new about how Earth works"

She goes deep into a lead-zinc mine to talk about stress changes in the shallow crust, and visits a wastewater injection well in Oklahoma to consider the idea that human activity can unwittingly induce damaging quakes. She also strolls around West Hollywood with an earthquake engineer to learn about structural damage, and canoes up the Copalis river in Washington state to learn how earthquakes can raise or lower the ground surface over hundreds of square kilometres.

Yet this breadth means that *Quakeland* feels stretched in places. The vulnerability of dams and mines takes up a large portion of the book, but ironically it later emerges that they are often pretty resilient. Most problematic, however, is that Miles doesn't develop the science behind the anecdotes. Too often, the reader is told that scientists "aren't sure" of something. This is no doubt true, but it misses the point; science isn't concerned with surety, but with hypothesis-testing and the balance of evidence.

As USGS volcanologist Jake Lowenstern says in *Quakeland*, "We're trying to figure things out that are 10,000 times older than our collective consciousness. We're just opening our eyes and looking around, and yet we expect to have all the answers." ■

PAUL SLADE/PARIS MATCH VIA GETTY IMAGES

Aftershock and awe: a major quake can arouse mixed emotions

Alexander Densmore is a professor of geography at Durham University, UK

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Department of Chemistry
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The Department of Chemistry, at the University of California, Berkeley, invites applications for one faculty position at the assistant professor level with an expected start date of July 1, 2018. Preference will be given to candidates in the broadly defined fields of experimental physical and/or analytical chemistry. However, we will consider creative and energetic candidates who show extraordinary promise or accomplishment in research and teaching in any area of chemistry. The basic qualification for this position is a Ph.D. or equivalent degree in chemistry or a related field at the time of application.

All applicants should submit their most recently updated curriculum vitae, a statement of research plans, and provide at least three but no more than five letters of recommendation. A cover letter, a statement of teaching, and a statement of possible contributions to enhancing diversity in higher education are optional. Applications should be submitted electronically through our web-based system at: **https://aprecruit.berkeley.edu/apply/JPF01453**.

All recommendation letters will be treated as confidential per University of California policy and California state law. Please refer potential referees, including when letters are provided via a third party (i.e., dossier service or career center), to the UC statement on confidentiality (**http://apo.berkeley.edu/evalltr.html**) prior to submitting their letters.

The deadline for receipt of application material is November 1, 2017. Please direct questions to Lauren Nakashima (**ltnakashima@berkeley.edu**).

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Concordia University Wisconsin

School of PHARMACY

Department of Pharmaceutical and Administrative Sciences
Assistant, Associate or Full Professor Faculty Position

Concordia University Wisconsin, a Lutheran higher education institution in Mequon, Wisconsin, committed to helping students grow in mind, spirit, and body, is currently seeking a qualified and motivated professional to fill a permanent full-time position as Assistant, Associate, or Full Professor in the Department of Pharmaceutical and Administrative Sciences of the School of Pharmacy.

The successful candidate will be dedicated to excellence in teaching, research, and service, and should meet the following qualifications:

- Ph.D. in Pharmaceutical Sciences, Biomolecular Chemistry, or related field;
- Excellent verbal and written communication skills;
- Exemplary teaching or research scholarship in the pharmacology of biologically based therapies;
- Experience teaching professional students (e.g., Pharm.D., M.S., M.D., Ph.D.).

Preferably, that candidate would also:

- Have experience in structural chemistry, design, and development of biologics, e.g. antibodies and cytokines;
- Teach drug design, manufacture, delivery, immunological, and/or other pharmacological issues of biologic therapies.
- Demonstrate the potential to attract external funding;
- Have teaching and research interests complimentary to those existing within the Department and University;

The faculty member's primary responsibilities will include, but is not limited to:

- Teaching Pharm.D. students in the department course series;
- Advising and mentoring Pharm.D. and M.S. students;
- Collaborating with scientists within the School and with other colleges and universities;
- Providing service to others, i.e. participation in School committees and external organizations

The Department of Pharmaceutical and Administrative Sciences is responsible for the teaching in the area of biomedical sciences, pharmacodynamics, medicinal chemistry, toxicology, pharmaceutics, pharmacy administration, and pharmacogenomics. The department is responsible for the development, delivery, and refinement of all courses offered in these areas. Contact Michael Pickart, PhD, **michael.pickart@cuw.edu** for more information.

Application screening will begin immediately and will continue until filled. Interested candidates should submit: a letter of interest with completed employment application; curriculum vitae with names and contact information of three references; statement of planned research; and teaching philosophy online at:
https://cuw.applicantpro.com/jobs/563516.html

For general questions, please contact Human Resources at human. ***resources@cuw.edu*** *or fax to 262-243-3414 and* ***refer to Job ID: 563516***
Human Resources – Pharmaceutical and Administrative Science Faculty
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Further information about the Scholarships and application forms as well as links to the individual Departments and Institutes and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

www.whoi.edu/postdoctoral

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National Postdoctoral Association

EDITOR'S PICK

Radicalisation's roots and a radical psychedelic proposal

From Kevin Stafford, Bunnythorpe, New Zealand

I thank Peter Byrne for the article on the roots of terrorism (19 August, p 30). One incident can be enough to encourage an individual to join an insurgency group or to trigger an insurgency. In 1972, shortly after Bloody Sunday, when marchers were shot by the British army in Derry in Northern Ireland, I was in Dublin in the Republic of Ireland watching university students queuing to join Sinn Féin, a party linked to the Provisional IRA. Most seemed to be middle-class, well-educated boys, who had recently left home and were open to ideas about what was valuable in life.

Maybe only a few became active Provisional volunteers, but on that morning they were open to the possibility. Whoever thinks killing innocent citizens is innocuous is not only wrong morally but foolish – unless they want to stimulate insurgency.

From Liz Berry, Lydbrook, Gloucestershire, UK

Peter Byrne points out that no classic intervention strategy to combat radicalisation seems to work and that the UK parliament's human rights committee reported that the nation's Prevent strategy may actually make matters worse. Suggested countermeasures were to encourage community engagement; to break down stereotypes, rehumanising collaborators; and encouraging empathy and compassion through brain training. Those most susceptible to the propaganda were identified as being uncertain about their lives, or having psychiatric problems.

Then I read Graham Lawton's interview with Robin Carhart-Harris (p 42). Carhart-Harris reports that subjects on psilocybin experience profound feelings of connectedness to others. Even a single dose can make the subject more politically liberal and more connected to other people.

Is it worth a try?

Elimination of diseases versus eradication

From Ditch Townsend, Chulmleigh, Devon, UK

Claire Wilson's article about rabies was fascinating (5 August, p 38). It reminded me of being raised at the Manorom mission hospital in rural Thailand. When our pet dog developed rabies in 1971, I had to undergo a series of traumatising (and still memorable) abdominal muscle inoculations aged only 5.

Around that time, the hospital adopted a policy of vaccinating, and red-inking, all stray dogs that wandered through its compound. The article suggests this was a wise approach. Unfortunately, it conflates the terms "elimination" and "eradication". This was not controversial until 20 years ago when the World Health Organization began suggesting that leprosy could be eliminated –

"It's more likely that we've always been more global than initially thought"

Kate Horrocks doubts that controversial fossil footprints show humans evolved in Europe not Africa (9 September, p 9)

which can be defined as reduction to zero of the incidence of a specified disease in a defined geographical area – without eradication, which would be permanent reduction to zero of its worldwide incidence with no further intervention required.

The confusion has now spread to other neglected diseases such as lymphatic filariasis. The small print to look out for in WHO texts is a goal of eliminating a disease only "as a public health problem".

The editor writes:

■ The WHO indeed aspires only to eliminate rabies.

The neural correlates of crowdfunding success

From Tim Duerden, Manchester, UK

Helen Thomson reports that scanning the nucleus accumbens in people's brains while they viewed Kickstarter campaigns predicts which will be successful 59 per cent of the time (26 August, p 6). Is it not more likely that successful campaigns appeal to that part of the brain?

The research may simply be identifying what triggers investment by Kickstarter funders. Perhaps it will pin down what prompts that investment, regardless of the actual viability of projects.

Research says that disinvestment works

From Andrea Needham, Hastings, East Sussex, UK

Alec Cawley asks how getting institutions such as universities and pension funds to ditch their investments in the oil, coal and gas industries puts "any pressure on the companies to be greener" (Letters, 19 August). The strategy behind such divestment is to break the hold these companies have on the political process and thus pave the way for the types of restrictive legislation necessary to bring about real change.

A 2013 study at the Stranded Assets Programme of the University of Oxford's Smith School of Enterprise and the Environment surveyed earlier campaigns and concluded that in almost every case "from adult services to Darfur, from tobacco to South Africa, divestment campaigns were successful in lobbying for restrictive legislation".

The outcome of stigmatisation that the fossil fuel divestment campaign has now triggered, the authors noted, "poses the most far-reaching threat to fossil fuel companies and the vast energy value chain. Any direct impacts pale in comparison."

Dozens of campaigns already exist in the UK targeting local pension government schemes, several of which have already committed to divest.

Search for sustainable synthetic fabrics

From Richard Marshall, Thatcham, Berkshire, UK

Joseph Poore's account of reduction in farmland was very encouraging with regard to the prospects for wildlife (12 August, p 26). One reason given is that consumer preference for synthetic fabrics rather than wool or cotton is reducing demand for land.

This disconcerts me. All fabrics break down in wear and washing. Today's synthetic fabrics break down into microplastics that persist in the environment and ›

enter the marine food chain, so we ingest them (19 August, p 7).

We could expand the range of plant-based fabrics. Flax is used to make linen and bamboo can be processed into soft, comfortable fabric, but land would be needed to grow more of these. We could see fabrics based on polymers similar to polylactic acid, which is finding use as packaging in the food industry. Such polymers break down without damaging the environment.

On religion, Finns may be quantum beings

From Ilpo Salonen, Helsinki, Finland

Bob Holmes mentions that Finns showed no anti-atheist bias and that Finland has a long secular tradition (19 August, p 22). Finland seems to me to be a curious combination of religious belief and atheism.

In a recent survey, 52 per cent of Finns said they believed in God in some way. About 72 per cent are members of the dominant Lutheran church, though church attendance is fairly low. The Christian political party is tiny. In people's everyday life and conversations I hear religion playing hardly any part at all. Knowledge and science are very much appreciated.

Maybe Lutheranism with its ideals of hard work and pragmatism has been absorbed only as a background canvas.

Perhaps Finns are quantum beings: both religious and atheist, God-believing and science-believing at the same time.

Saving energy with recycled glass

From Harm J. Schoonhoven, Utrecht, The Netherlands

As Peter Urben suggests, no energy can be recovered from recycled glass (Letters, 26 August). It has to be cleaned and sorted before it can be melted, which requires energy input.

New glass starts with crystalline ingredients that have to be melted at a high temperature. Addition of even a small amount of used glass can speed up this process and save energy.

As early as 500 years ago much glass was recycled, so glass from that period is now a rare collector's item.

Vegans concerned about animals, not health

From Naomi Elias Seaford, East Sussex, UK

As a vegan of 10 years' standing, I can assure Anthony Warner that the majority of us are animal rights advocates first and vegan as a consequence (26 August, p 24). I am certainly not vegan because of diet or health – though there are health advantages to not eating flesh. So Warner's criticism of the film *What the Health* is beside the point for me.

My diet is not a choice; it's a consequence of my vegan way of life: a way of living and of seeing the world. Some might call it more of a religion than a food choice.

More Global Positioning System spoofing, maybe

From Andrew Stone, Bristol, UK

You report ships suffering a Global Positioning System spoofing attack (19 August, p 6). This triggered a memory of sailing into Salcombe in Devon, UK, about two years ago. As I know the channel well, I was going by eye rather than instruments. Imagine my surprise when a crew member pointed to our GPS that showed us traversing the hillside on a parallel track. Another hand-held unit displayed the same track.

I have no idea what caused it, but over a few beers we decided it was "the Russians" – an explanation my mother used to suggest for most problems from bad weather and back pain to traffic jams.

Why medical psilocybin is vastly expensive

From Charles Sawyer, Byron Bay, New South Wales, Australia

Graham Lawton mentions that synthesising medical-grade psilocybin is "staggeringly expensive" (19 August, p 42). The significant cost is complying with the regulations for working with a scheduled substance. The very similar synthetic drug sumatriptan is routinely prescribed for migraine relief, and psilocybin is a simpler compound. And can't psilocybin be purified to medical grade from natural sources?

The editor writes:

■ Robin Carhart-Harris tells us that only synthetic psilocybin qualifies as medical grade.

TOM GAULD

For the record

■ **Jonathan Montgomery's term as chair of the UK's Nuffield Council on Bioethics ended in February (2 September, p 22).**

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SIGNAL BOOST

Offering your projects a helping hand

OLIVER KENNETT, LEGS4AFRICA.

Helping people walk again

The World Health Organization states that just 1 in 10 people with physical disabilities in the developing world have access to technologies that could assist them.

In contrast, in the UK there are services that provide free assistive equipment and support. There is also legislation to enable public places to be accessible to people with disabilities. In low-income countries, where life can be more difficult, little time or thought is given to disability. Thanks to a perception that people with a disability are unable to contribute to society, there is little chance of this situation changing soon.

In West Africa, detailed records are scarce and statistics regarding leg amputation and treatment are no exception. We know that the main causes of leg amputation in sub-Saharan Africa are type-2 diabetes, lack of treatment for simple infections, and accidents. Generally there is a far higher risk of leg amputation in this part of Africa than in the UK and a need for prosthetic limbs and support services. But such limbs and treatment can cost thousands of dollars so most people go without and thus have highly restricted mobility.

Legs4Africa estimates that 5000 prosthetic legs are thrown away in the UK every year. Our objective is to reclaim these so they may be used by people in low-income countries.

To date, Legs4Africa has shipped more than 3000 prosthetic legs to Gambia, Tanzania, Senegal, Zambia and Ghana. We are developing a pilot scheme, The Gambian Amputee Rehabilitation Project, which aims to create infrastructure in the country that can support those who have had a leg amputated. We want to reduce bottlenecks in prosthetic leg fitting so more people may benefit, and we want to improve rehabilitation programmes so the prostheses are used comfortably, safely and effectively. And we want to reach out to communities to make people aware that they don't have to endure the frustrations and solitude that amputation and immobility can bring. **Oliver Kennett, Legs4Africa**

If you want to help, visit **www.Legs4Africa.org/Gambia**

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PAUL MCDEVITT

EARLIER this month, we asked you how humans might be improved upon, given the mounting environmental threats to our species (2 September).

"It's clear that human brains already exceed their optimum size at birth," says Brian Horton. The obvious solution, he says, "is to take a few genes from marsupials, so that babies are born a few weeks after conception and immediately transferred to a pouch, where they will be safe for the next eight months".

Brian doesn't elucidate where these pouches will be located, but we think the idea would be popular if they were available in a range of brightly coloured fabrics from IKEA. This would allow parents to gestate their child on the shelf while they carry on life as normal in this brave new world.

The downside, of course, is that humans are already born half-baked by the standards of most of the animal kingdom. Witness the newborn gazelle, up and running in minutes, a milestone that takes us humans a year to waddle past. And given the mind-boggling 18 years or so it takes to evict a regular-born human from the nest, who knows how long it will take for these Huxleyan hatchlings to fly the coop?

MEANWHILE, Klaus Mogensen chimes in with a strategy to mitigate the effects of climate change – or rather, to mitigate our intolerance to them. "It is difficult for the body to get rid of excess heat if the outside temperature exceeds that of the body," he says, "and some equatorial regions may become too warm to be habitable."

Klaus proposes engineering humans to maintain a higher body temperature: "This would probably imply burning more calories, simultaneously reducing problems with obesity."

Feedback spies a problem: for those of us living in cooler climes, the world would feel even chillier than it does now. So aside from leading to more arguments over the office thermostat, we would habitually keep our central heating on a higher setting, burning more even energy and hastening global warming.

After a few decades of this, the world would warm enough that we had no choice but to bump up human body temperature again, and, well, you get the picture.

OF COURSE, with the latest big bang under North Korea shaking up regional geopolitics, perhaps we should stop worrying about the melting ice caps and focus on a more immediate kind of climate change.

Unfortunately, we aren't sure what sort of modifications would allow humans and a rain of nuclear fire to peacefully co-exist. Before we head to the shelters, Feedback recommends training cockroaches to keep things running in our absence. At least the gestating babies will be nicely matured once things cool off.

NINA BAKER is desperately seeking a Susan, or any woman, who has been immortalised as a scientific unit (10 June). Mike Ellis recalls that in the 1960s, long before the Ada programming language was created, he worked on the Royal Navy's early digital information system known as Action Data Automation, or ADA. "This was deliberately contrived to celebrate Ada Lovelace, who thus became both eponym and acronym – a double whammy for women."

AND finally bringing us something verging on a unit is John Davies, who tells us of the Apgar score used globally to assess the physiological condition of newborn babies.

"This provides an invaluable means of comparison, for research on procedures and treatments, as well as monitoring the progress of resuscitation," says John. "It is named after its originator, Virginia Apgar, a US obstetric anaesthetist."

CATCHING up on local news in Adelaide, Australia, Jo Hamilton discovers the lifesaving potential of eating her greens: "As little as three serves of fruit and vegetables a day should be enough to stave off heart attacks, stroke and death – and any more offers no benefit, a new study has found." We wonder what extra benefit could top immortality.

FURTHER to John Cartmell's observation that homeopathic remedies could be labelled on demand (26 August), James Fradgley recalls that the Russians got there first. "Shortly after the collapse of the USSR, I was asking about the wines a Russian supplier had, and the reply was: 'What do you want?'"

James then discovered that the supplier printed the labels after getting an order, on the assumption that the buyer wouldn't know the difference.

A STRETCH of the imagination: "I was pleased to note that the distance from shore of DONG

Energy's proposed offshore windfarm HornSea 3 is officially measured in one of the most internationally recognisable units," says Sam Millard. "i.e. 'three times the distance from Norwich to Cromer'."

For US readers, that would be about twice the distance from Roswell to Artesia. Clear?

Jo Spencely is in two minds about whether to visit a local studio offering "Quantum Yoga". Might this be where you can learn superpositions?

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Give us a clue

I do cryptic crosswords. On my first attempt, I usually finish about half the clues and get stuck. When I return to the crossword the following day, even if I haven't been consciously thinking about it, I usually get a few more clues very quickly. But after half an hour at most, I become stuck again. What's going on?

■ It is generally believed that when we have been grappling with an open-ended problem – with many routes of exploration before a solution can be found – and no insights have been forthcoming, it is best forgotten for a while. This is because our creativity becomes less active the more intent we are on finding a solution.

When returning after this so-called unconscious incubation period, new insights may appear. Sometimes they can arise unbidden in unusual places. These are called "eureka" moments.

With cryptic crossword clues, if a solution isn't immediately forthcoming and we go over it several times, our thinking rapidly becomes conditioned and we narrow down the number of potential routes of exploration. In effect, our creativity becomes temporarily restrained. When returning to the crossword, the clues are seen afresh and new insights may lead to solutions. This idea of incubation has never been experimentally verified, but two modes of thinking – analysis and insight – have been identified by neuroscientists.

Kevin Byron
Lincoln, UK

"Insights can arise unbidden in unusual places and these are referred to as 'eureka' moments"

■ This reminded me of "morphic resonance", parapsychologist Rupert Sheldrake's idea that we inherit a collective memory from others involved in the same task. This would mean that as more people work to solve a crossword, its clues become easier over time for others to solve. I believe that experiments were designed to test this, but the results did not support the theory.

In a previous job making up compounds for potential medicinal use, I found that those that had never been made before could be a devil to crystallise. However, if the prep was repeated later it proved much easier. My colleagues experienced the same thing, but others dismissed it as "folklore".

Peter Gandolfi
Chelsfield Village, Kent, UK

Read more: newscientist.com/article/mg21228441-500

Point of impact

Why can I only see round craters on the moon and on other bodies in the solar system? Surely, not all the impacts can be at right angles to the surface. What am I missing?

■ There used to be a debate about the origin of the lunar craters. If they were volcanic, it would be easy to understand why they are all circular, and for a long time this was a convincing theory. However, it is now believed that almost all craters on the moon are the result of impacts.

Even at fairly low speeds, impact craters tend to be circular because the delivery of energy to the surface forces the material outwards symmetrically, producing a crater larger than the impacting body, thus obscuring the effect of angle of impact.

For rocks falling on the moon, the speeds are not modest. The slowest possible speed for a rock hitting the moon would be 2.38 kilometres per second (the lunar escape velocity). At this speed, every kilogram of rock would have a kinetic energy about two-thirds of that released by detonating a kilogram of TNT. According to NASA, the actual speeds are much higher than that – up to 72 km per second.

"Moon craters are circular because most meteorites don't skid on impact, they explode"

The biggest impact directly observed so far was produced by a rock perhaps 1 metre in diameter with a mass of about 400 kilograms. This struck at a speed of 17 km/sec per second and released nearly 60 gigajoules (equivalent to 14 tonnes of TNT), producing a crater 40 metres across. With that disparity between the size of the rock and the crater it produces, it is hardly surprising that the angle of impact has no effect on crater shape.

Mike Brown
Knutsford, Cheshire, UK

■ The short answer is that most things don't skid, they explode.

About 5 per cent of craters in the solar system are noticeably elongated, such as the Messier crater in Mare Fecunditatis on the moon. But the rest are circular because when an impactor hits, the immense kinetic energy is nearly instantaneously converted to heat and compression. The impactor and surface fail to contain this and simply explode in a circular area between 10 and 1000 times the diameter of the actual impactor – so the impact angle is hidden.

The Wetumpka crater in Alabama is circular and 7.6 km in diameter because the meteorite was about 300 m across and hit at a 30-45 degree angle.

Non-round craters may be caused when the speed of impact is so low that the rock doesn't vaporise and slides or skips. Or the impact angle may be so shallow (less than 10 degrees or so) that the rock isn't stopped. Elongated craters can also be caused by ground faults or by multiple or split meteorites producing overlapping impact craters, such as in the Elysium Planitia on Mars.

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