BBC

STAR WARS decoded 13 pages of Q&A special

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Knowledge

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INCORPORATING BBC SCIENCE WORLD

FINDING E.T.

Are we looking for extra-terrestrial life in the right place? p30

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Are We Looking For Aliens In The Wrong Place?

Discover the exciting new frontiers in the search for extra-terrestrial organisms

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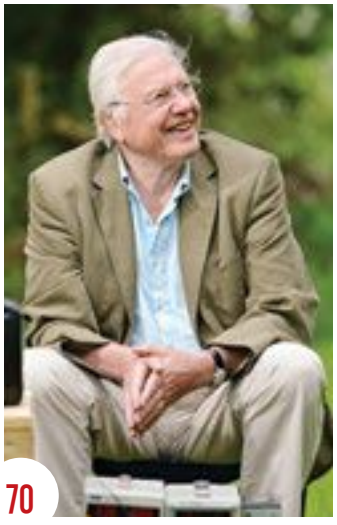
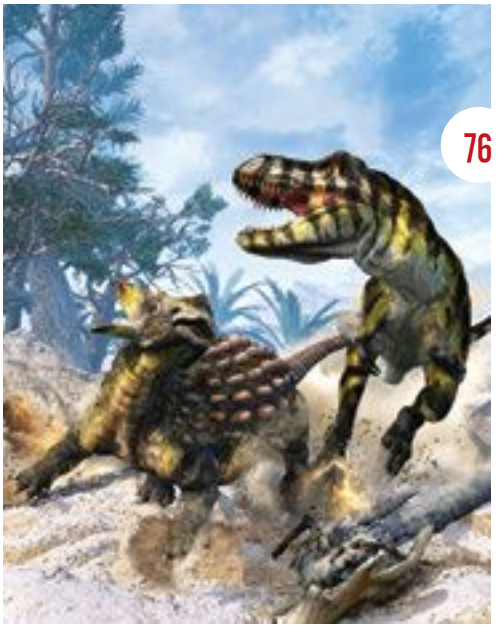
REGULARS

ERIC TOURNERET, LEON_BAASS, SUZI ESZTERHAS, MICHAEL NOLAN, HENNY BOOGERT





FROM THE EDITOR

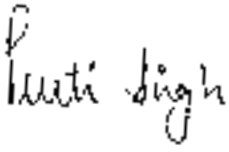
We live in such exciting times. In 1916, Albert Einstein had predicted the existence of gravitational waves – ripples generated in space-time when an event on a mammothian scale occurs, such as the collision of two black holes. It's remained a theoretical concept since the early part of the century till a few weeks ago when Ligo physicists announced that they have discovered and are able to detect these waves. The announcement has the science community electrified.

These waves are like no other they say. They are carrying data and information, in their purest form yet, about celestial bodies and events that happened billions of years ago – perhaps also about the Big Bang. The next on the list now could be dark matter.

In this issue, we seek out a bit of the magic from the cosmos. The cover story is on the age-old quest of extra-terrestrial life. Will they look like the little green men with soulless eyes or as my 10-year-old suggested, could be in a form we haven't yet learnt to recognise? Read the fascinating story about how we may be looking for E.T. in the wrong place altogether.

Another fascinating feature is one where we put together all the milestones achieved last year in science. The compilation is so awesome that we wonder – was **2015: The Best Ever Year for Science?** On page 38. Must read as well is **At Work with David Attenborough**, a day-in-the-life-kind-of piece with the world famous and enigmatic broadcaster and naturalist. And how can I forget – the magazine starts with the super special **Q&A** section, solely dedicated to Star Wars. It may a bit late in the day since the movie released but something tells me it's never late in the day to talk about Star Wars.

Happy reading.



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MRIGANK SHARMA (INDIA SUTRA)

EXPERTS THIS ISSUE

Stuart Clark is a widely read astronomy journalist. He is the author of *Is There Life on Mars? - The 20 Big Universe Questions.* In this issue, he charts out likely scenarios where we might encounter alien life. ***See page 30***

Brian Clegg is an English science writer. A proficient blogger, he is also an author and a nature lover. In this issue, he looks back at 2015 and what we accomplished in science that year. ***See page 38***

Catherine E Offord writes about the environment and nature, and contributes to publications like *BBC Focus* Magazine. In this issue, she provides an insight into the unseen world of microbial life. ***See page 48***

Jheni Osman is a well-known science presenter, author and journalist. She has written the book *The World's Great Wonders* for *Lonely Planet.* In this issue, she documents the varied sensitive ecosystems that our planet hosts. ***See page 62***

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STAR WARS® Q&A SPECIAL

EXPERT PANEL

Susan Blackmore (SB)
A visiting professor at the University of Plymouth, UK, Susan is an expert on psychology and evolution.

Alastair Gunn
Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics at the University of Manchester, UK.

Robert Matthews
Robert is a writer and researcher. He is a Visiting Reader in Science at Aston University, UK.

Gareth Mitchell
As well as lecturing at Imperial College London, Gareth is a presenter of *Click* on the BBC World Service.

Luis Villazon
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*.

ASK THE EXPERTS?

Email our panel at
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VITAL STATS

218cm

is the height of Peter Mayhew, who played Chewbacca. In comparison, Carrie Fisher (Princess Leia) is just 155cm

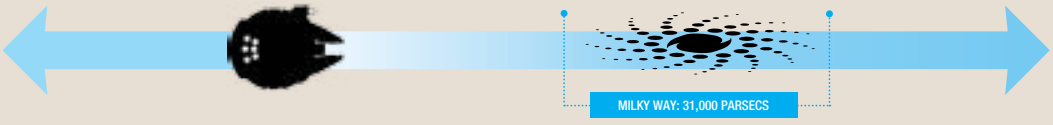
Why do some Starfighters have X-wings?

This one has kept hardcore Star Wars fans arguing for years – because the plank-like X-wings aren't aerodynamically shaped, and aerodynamics are irrelevant in the vacuum of space in any case. Apart from looking great, one possible scientific explanation for their use is to provide a Starfighter's weaponry with extra cooling surfaces. RM

What is a parsec?

Han Solo tells Luke Skywalker and Obi-Wan Kenobi that the Millennium Falcon "made the Kessel Run in less than 12 parsecs". Unfortunately, like the similarly misused 'light-year', the parsec is a unit of length, not of time.

A parsec is equal to about 3.26 light-years or roughly 31 trillion kilometres (19 trillion miles). The unit has its origins in one of the first methods of determining the distance to the stars. Using the principle of parallax, some stellar distances can be found by measuring their tiny shift in position as the Earth undergoes its yearly orbit around the Sun. This only works for relatively nearby stars. One parsec is defined as the distance at which one astronomical unit (the average distance between the Earth and Sun) subtends an angle of one arc-second. The nearest star, Proxima Centauri, is about 1.3 parsecs away, while the Milky Way is more than 31,000 parsecs across. AG



Coruscant: a nightmare for air traffic control

Will the Earth ever become a city planet?

Coruscant, which is the capital of the Star Wars Galactic Empire, supposedly has a population of around three trillion. This is about 430 times Earth's current population, but even this wouldn't be enough to create a proper city planet.

To give all of Earth's landmass the same population density as Tokyo, you would need 895 trillion people, or 300 Coruscants. Even the more pessimistic projections from the United Nations suggest that the Earth's population will peak at less than 100 billion people by the end of this century. Spread across all the land area on the planet, that would give the world an average population density lower than that of Barnsley, South Yorkshire, which is hardly a skyscraper-filled metropolis. LV

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Next

Why are Stormtroopers so useless?

It's because they're a clone army. Among soldiers, valuable qualities include courage, adaptability, persistence and average intelligence. Loyalty, discipline and willingness to follow orders are crucial. The clones might all fit this profile but a fighting unit needs variety when facing unexpected challenges. There are also specialist duties, from technical tasks and communications to maintenance and procurement. Clones designed for fighting would not be suited to these, nor to being commanding officers. These roles require high intelligence and leadership qualities that might be positively disruptive in a Stormtrooper. SB

Opting into the Dark Side didn't do Darth Vader any favours

Is being evil bad for you?

Being bad, cruel or even evil makes some people feel good in the short term. Fighting and hurting others can be exciting, give a feeling of power, or make bad people feel superior when they see someone else suffering. But the longer lasting effect is quite the opposite. Research shows that doing good makes people happy, and being happy makes people do good. So there's a virtuous cycle of kindness and generosity. Caring for others helps people to feel better about themselves and this is a lasting source of happiness. Even remembering kind deeds you have done in the past can make you smile. Happy people live longer too, although the causes are not yet clear. Health and happiness may affect each other, and a healthy lifestyle with lots of exercise and good food increases both. So don't envy the baddies their thrills. They will probably pay for it later. SB

Could a slug grow to the size of Jabba the Hutt?

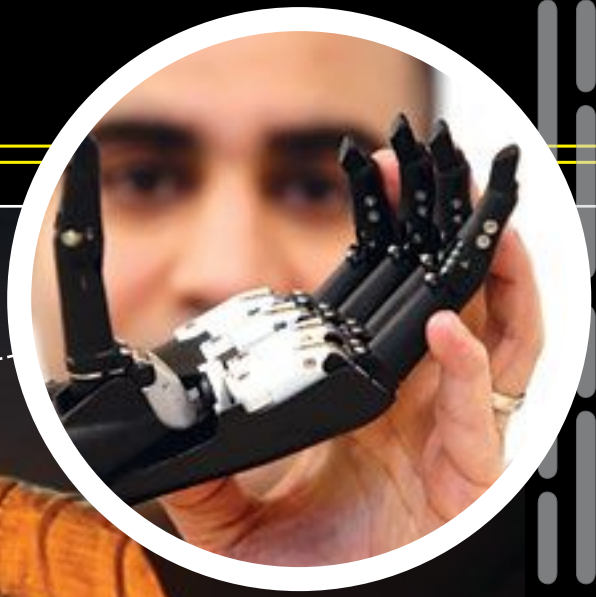
The largest land slug species is the black keel back slug, which grows to 20cm. Slugs don't get much bigger than that because they are cold-blooded, slow-moving, and can't gather enough food to power a larger metabolism. Land slugs have simple lungs and a multi-chambered heart, not dissimilar to early vertebrates that first climbed out of the sea. With the right food source, it's possible that molluscs could evolve to be as big as mammals. LV

Han Solo's mouth and throat anatomy may mean that he's physically incapable of speaking Wookiee

How could we talk fluently to aliens?

The same way that the early explorers and missionaries learnt the native languages of Southeast Asia and South America. You begin with pointing and other gestures, and slowly build from there. Children younger than five are much better at this than older kids and adults, so we could train a generation of interpreters by raising children in a mixed human and alien environment. If the aliens were particularly strange, we might not actually be able to speak their language at all. Han Solo and Chewbacca can understand each other, but Han never speaks a word of Wookiee. LV

Will we see *Star Wars* tech in the real world?



Prosthetics used by the Skywalker family are on their way

Prosthetic robotic arms

Anakin Skywalker's nifty 'mechno-arm' and Luke Skywalker's robotic hand rely on two-way communication between the brain and the prosthesis: not only must the arm obey signals to move, grip, or swing a lightsaber, but it also needs to send signals back about textures, temperatures and other sensations. The first such prosthesis became reality in autumn 2015, thanks to research at Johns Hopkins University.

Their mechanical hand was fitted to a 28-year-old who'd been paralysed for more than a decade. Wires linked the hand to the wearer's motor cortex – the part of the brain that controls movement – as well as the sensory cortex, responsible for identifying tactile sensations. This allowed the wearer to control their hand with thought, but also to 'feel' which of the hand's fingers was being touched.

Emotional robots

When it went on sale in summer 2015, Pepper was hailed as the first emotional robot. Its makers, Aldebaran, claim that Pepper can analyse your facial expressions, body language and speech, then changes its behaviour according to your mood. It doesn't, however, display the true artificial intelligence of C-3PO or R2-D2 – that's at least several decades away. Still, people can form emotional attachments to pets. Pepper is not much more expensive than a pedigree dog, and far less messy.

Pepper isn't up to R2-D2 standards

Holograms

Could you imagine video-calling your nan on one of these things?

The holograms in Star Wars are snazzier than the stuff we've seen in reality. Sadly, holographic messages like Leia's to Obi-Wan Kenobi are still science fiction. Yet holo-games may be just around the corner. Researchers at Swinburne University have developed a system that shines a pulsed laser on a flat graphene surface to create pop-up, floating 3D images. This would be perfect for board game/video game hybrids and communications – as long as you have a graphene dining table.

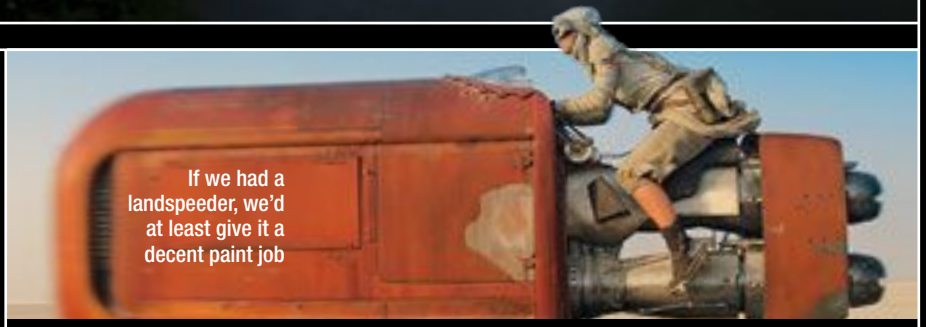
My lightsaber's better than your lightsaber

Lightsabers

With powerful lasers, it is possible to build a handheld lightsaber. It would be short-range, though not quite limited to the one-metre beam of the films. It couldn't sever an arm, nor could it cut through steel doors, but it could start fires or burn the skin. In 2013, Harvard University researchers managed to make photons of light behave like a lightsaber, by manipulating them so they acted as a solid. However 'lightsabers' made in this way would just bounce off each other. If you want to slice bits off a Sith Lord, try a regular, old-fashioned, two-handed sword (eyewitness accounts of medieval battles say they cut through the limbs and even torsos of unarmoured combatants). When the Trade Federation locks you in a steel vault, reach for your thermal lance instead, but expect it to take a few hours to burn through the door.

Faster-than-light hyperdrives

Faster-than-light (FTL) travel is the biggest gulf between reality and science fiction. As far as scientists know, the speed of light can't be surpassed. But according to Harold "Sonny" White at NASA, FTL travel is theoretically possible – he suggests using a warp drive to distort space-time around a craft, bending the laws of physics. But with colossal amounts of energy required, and no tangible results so far, humans will have to stick to slower spacecraft for now.

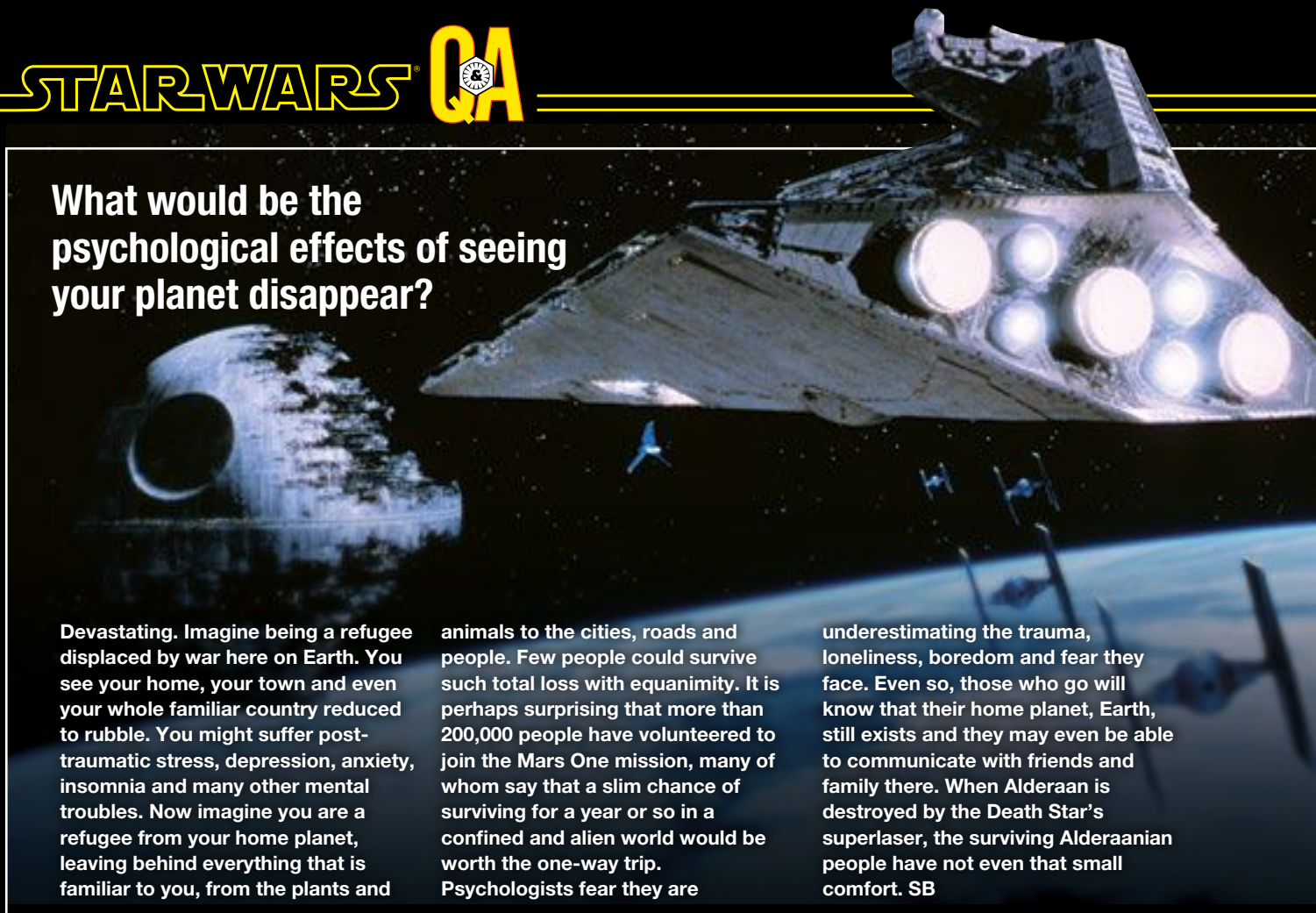


If we had a landspeeder, we'd at least give it a decent paint job

Antigravity landspeeders

The landspeeders and speeder bikes in Star Wars work using 'repulsor fields' – a kind of antigravity. Scientists working on the ALPHA experiment at CERN have investigated whether antimatter – particles with the same mass as ordinary matter but opposite charge – might 'fall upwards', exhibiting a kind of antigravity. So far, however, there have been no conclusive results, so if you want a fast, floor-hugging chariot, your best bet is a ground effect vehicle. Looking like a cross between an aircraft and a hovercraft, these use the aerodynamic interaction between the vehicle's wings and the surface to fly just a few metres above the ground. We can't promise you'll look as cool as you would in a landspeeder, though.

Ian Sturrock is a lecturer in game studies and visual effects at the University of Hertfordshire, but is not a Jedi yet.



What would be the psychological effects of seeing your planet disappear?

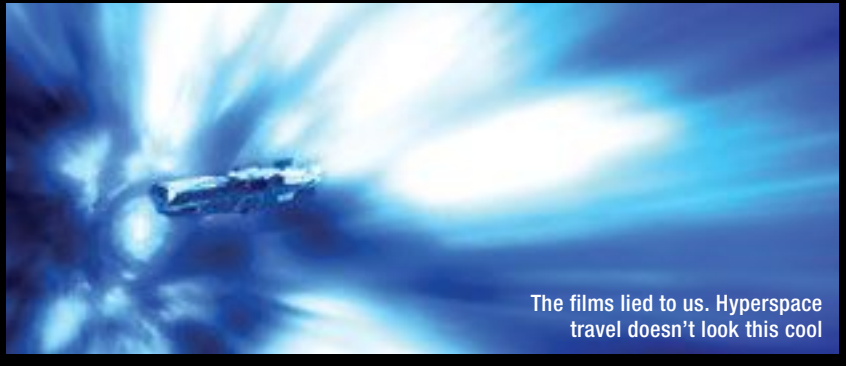
Devastating. Imagine being a refugee displaced by war here on Earth. You see your home, your town and even your whole familiar country reduced to rubble. You might suffer post-traumatic stress, depression, anxiety, insomnia and many other mental troubles. Now imagine you are a refugee from your home planet, leaving behind everything that is familiar to you, from the plants and animals to the cities, roads and people. Few people could survive such total loss with equanimity. It is perhaps surprising that more than 200,000 people have volunteered to join the Mars One mission, many of whom say that a slim chance of surviving for a year or so in a confined and alien world would be worth the one-way trip. Psychologists fear they are underestimating the trauma, loneliness, boredom and fear they face. Even so, those who go will know that their home planet, Earth, still exists and they may even be able to communicate with friends and family there. When Alderaan is destroyed by the Death Star's superlaser, the surviving Alderaanian people have not even that small comfort. SB

Can you cryofreeze a human being?

Yes, but thawing them out again is trickier. When Han Solo is frozen in carbonite in The Empire Strikes Back, he only has to wait until the next film for Leia to press the defrost button. Outside of the films, the few hundred individuals who have had their bodies frozen in liquid nitrogen will need to hang on for much longer while we figure out how to reverse the cellular damage caused by the antifreeze chemicals. There is also the problem that cryopreservation is only legal once you're actually dead, so you need to be able cure whatever the patient died of. Egyptian pharaohs thought mummification would buy them eternal life, but 4,000 years later, they are still waiting for resurrection. LV

What would faster-than-light (hyperspace) travel look like?

In the movies, stars stream out into long trails as a spaceship travels through 'hyperspace' or uses its 'warp drive'. Unfortunately, because these concepts are entirely fictional, usually involving alternative universes or extra dimensions, science can say very little about what 'real' hyperspace travel might look like. However, if we regard hyperspace travel as the ability to travel at almost the speed of light, we can categorically dismiss the idea of stars elongating as shown in Star Wars and other movies. In fact, as your speed increased, you would see the stars fade and eventually disappear as their light is redshifted into the X-ray part of the spectrum, which is invisible to the human eye. The starlight would be slowly replaced by a diffuse glow, concentrated towards your direction of travel, caused by the cosmic microwave background (the leftover radiation from the Big Bang which fills the entire sky) being redshifted into the visible part of the spectrum. AG



The films lied to us. Hyperspace travel doesn't look this cool

Are there any real-life Jedi mind tricks?

"Ten per cent off this new walking stick you will give me"

Manipulating others into believing that "these are not the droids you're looking for" is certainly possible in a limited way. The psychological manipulation techniques carried out by Jedi Master Derren Brown are an example of this. Martial arts experts can also sometimes detect an incoming strike and block it, even with their eyes closed, simply from the tiny sounds and pressure changes in the air. LV

"You will buy me a triple cheese pizza with extra pepperoni"

What could a Stormtrooper's armour be made of?

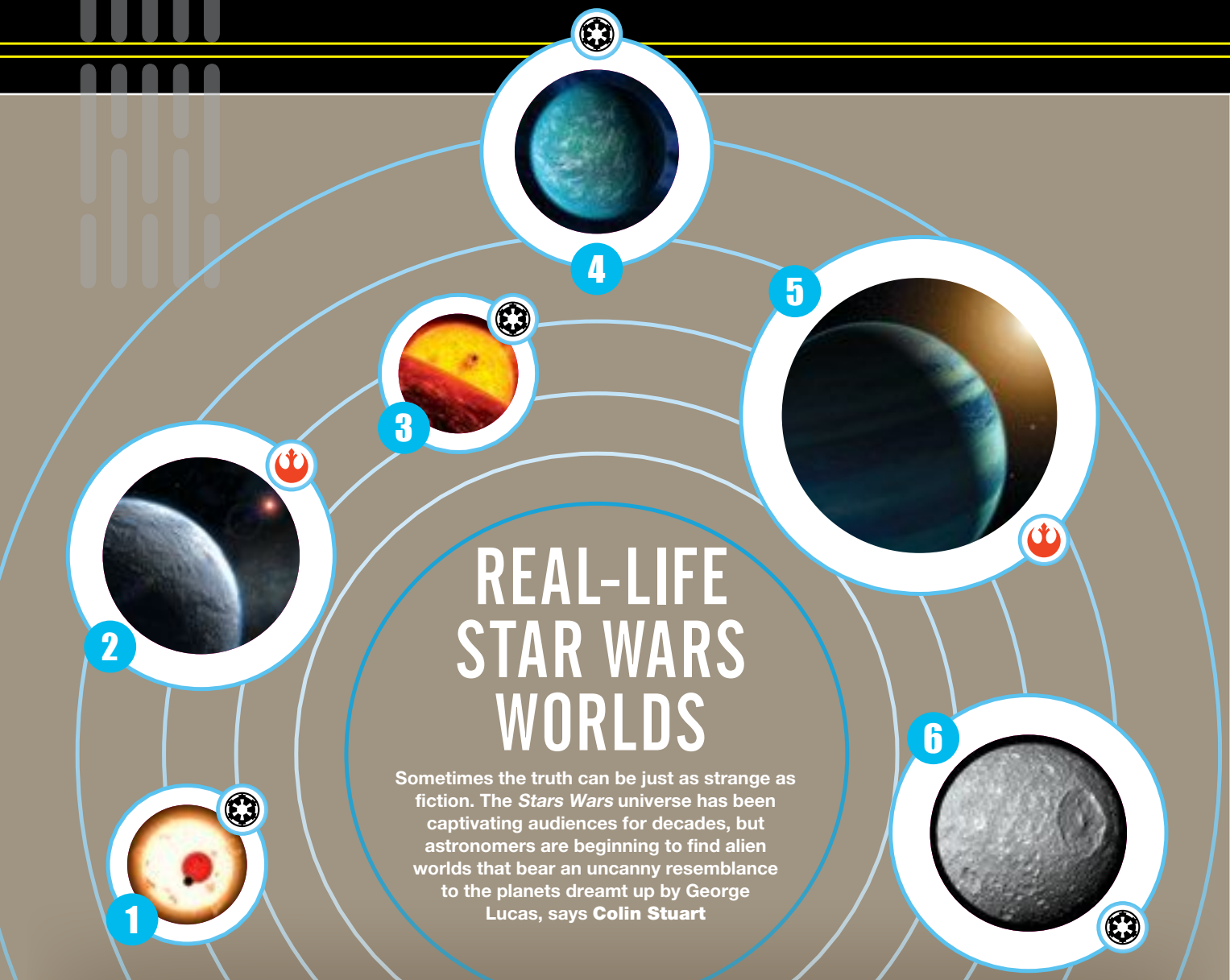
Stormtroopers: hard of armour, thick of skull

Stormtroopers' existing armour is already pretty advanced, incorporating temperature controls and blast energy sinks to absorb the impact of stray blaster bolts. But the Galactic Empire might also wish to consider so-called liquid armour made of Kevlar laced with shear-thickening fluid (STF). In STF, silica nanoparticles are suspended in a liquid polymer. As the Stormtrooper goes about its business, the material remains flexible. But should some shrapnel from, say, a Rebel Alliance thermal detonator grenade hit the suit, the fragment's kinetic energy forces the silica particles together into a rigid lattice, stopping the shrapnel in its tracks. Already elite soldiers known for their strength and endurance, the Stormtroopers might also benefit from powered exoskeletons like Lockheed Martin's HULC (Human Universal Load Carrier) or China's EEAE military exoskeleton, unveiled in 2014 at a trade show. Hydraulic actuators at the wearer's joints and along the limbs would boost a Stormtrooper's running and jumping capabilities. The only problem? Iron Man got there first in a different movie! GM

Above: The HULC allows humans to carry heavy loads across all terrains

Above: The liquid within this vest hardens on impact

LUCASFILM LTD/IMAGE.NET X2, ESO X2, NASA/JPL X4



REAL-LIFE STAR WARS WORLDS

Sometimes the truth can be just as strange as fiction. The *Stars Wars* universe has been captivating audiences for decades, but astronomers are beginning to find alien worlds that bear an uncanny resemblance to the planets dreamt up by George Lucas, says Colin Stuart

1. Tatooine/Kepler-16b
Appearing in every *Star Wars* movie except *The Empire Strikes Back*, Tatooine is a desert planet and the home of Luke and Anakin Skywalker. In *A New Hope*, an iconic scene shows Tatooine's twin suns setting over the horizon. Astronomers have found several examples of planets orbiting in these so-called 'binary systems'. The most famous is Kepler-16b – a real-life Tatooine.

2. Hoth/OGLE-2005-BLG-390Lb
In *The Empire Strikes Back*, the rebels set up their base on the snowy planet of Hoth. Most of the exoplanets found to date are reasonably warm, as planets that orbit closer to their stars are easier to spot. That said, the planet with the name of OGLE-2005-BLG-390Lb is a contender for a Hoth lookalike. With temperatures plummeting to -220°C, it is almost certain to be covered with ice.

3. Mustafar/COROT-7b
Obi-Wan Kenobi and Darth Vader duelling on the lava planet of Mustafar was a memorable moment in *Revenge Of The Sith*. The most likely real-life counterpart is probably COROT-7b. At the time of its discovery in 2009, it was the smallest rocky planet ever detected outside our Solar System. Due to its proximity to its parent star – orbiting it in just 20 hours – the temperature rises beyond 2,000°C, enough to melt the rock into lava.

4. Kamino/Kepler-22b
The water world of Kamino is home to Jango and Boba Fett. Planets known as 'super-Earths' might be entirely enveloped in water too, as their stronger gravity levels out mountains and volcanoes. The first terrestrial planet ever found in the habitable zone of a Sun-like star – Kepler-22b – has a strong chance of being a Kamino analogy.

5. Endor/exomoons
In *Return Of The Jedi* we enjoyed watching the Ewoks running around Endor, a forest moon. There's every reason to believe that similar moons exist in the Milky Way; in fact, some researchers think that habitable moons may outnumber habitable planets. Finding exomoons is hard, but astronomers are scouring Kepler data for them.

6. The Death Star/Mimas
That's no moon. Except that it is. Saturn's moon Mimas looks eerily like the Death Star in *A New Hope*. Curiously, however, there is no way George Lucas could have drawn inspiration from Mimas – we didn't know it looked like that until the Voyager 1 probe flew by in 1980. The film had been released three years earlier. Astronomers are still baffled as to why the impact that caused Mimas's distinctive crater didn't blow the moon apart.

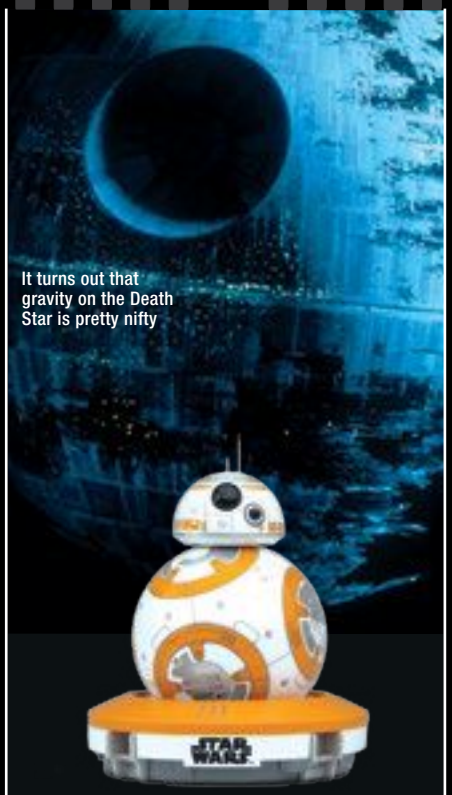
Colin Stuart is a science and astronomy writer and author.

In an infinite universe (or a quantum world), does the world of Star Wars exist in a galaxy far, far away?

Seeing double: Tattooine orbited two suns

An infinite universe doesn't guarantee every possible combination of atoms exists somewhere. The universe we can see could be a tile that's endlessly repeated across an infinite bathroom floor, without any variation. Or it could be that the density of matter tapers off forever but never quite stops, so after a while it drops to just one proton every billion cubic light-years; the only region that is dense enough for stars and galaxies to exist is the middle part we live in. If quantum physics allows parallel universes, and there are an infinite number of them, however, then it's entirely possible that one of them contains the galaxy depicted in Star Wars. But again, it's not inevitable. Imagine the roll of a die across infinite parallel universes. Every possible result will occur somewhere, including the die balancing on one of its edges. But you'll never roll a seven. Some outcomes are just impossible. LV

Yes it's fast, but its commander doesn't even know the difference between time and distance



It turns out that gravity on the Death Star is pretty nifty

Is there a constant 'up' on all the Death Star's floors, or is the core always down?

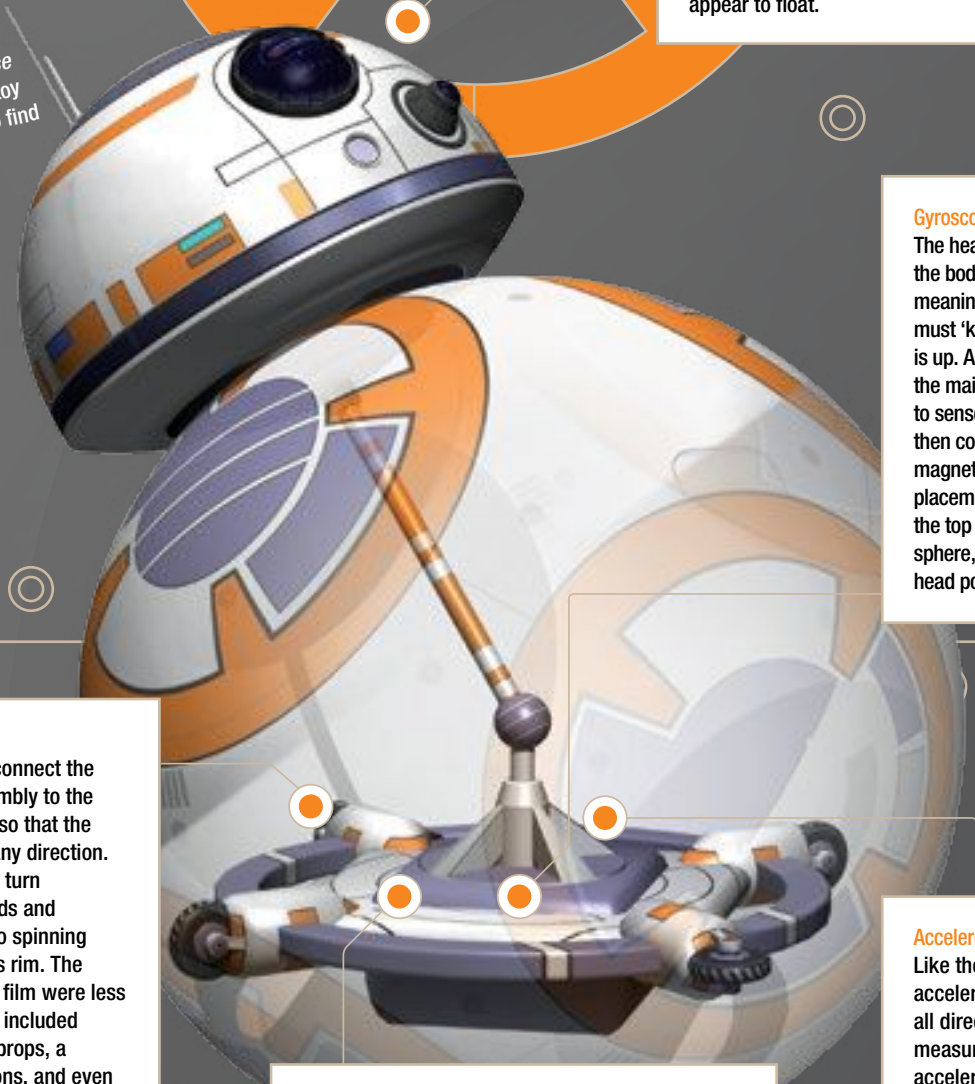
The first version of the Death Star was only 160km in diameter, which makes it more like a large asteroid than a moon, and too small to have any significant natural gravity. If the Death Star rotated once every nine minutes, this would be enough to generate 1g of centrifugal force at the surface, but this would point outwards. Instead, the Death Star has artificial gravity that points towards the core for the decks nearest the surface. In the central section, all the decks use a separate gravity that points down towards its south pole. LV

KOBAL COLLECTION X3, LOCKHEED MARTIN X2, ILLUSTRATOR: CARLOS SANCHEZ AND EMILIO GELARDO/HOWBB8WORKS.COM

HOW IT WORKS

BB-8

Looking like R2-D2's cooler, cuter cousin, BB-8 is set to be one of the stars of *The Force Awakens*. We peer inside the toy version of the rollerball droid to find out what makes it tick.



'Floating' head

BB-8's head is connected to its body by an array of magnets in the head and inside the sphere. The magnets are placed so that some attract each other, while others repel. This makes the head appear to float.

Gyroscope

The head stays on top of the body as it moves, meaning that the droid must 'know' which way is up. A tiny gyroscope in the main sphere is used to sense its alignment, then corrects the lower magnet array's placement to keep it in the top half of the sphere, maintaining the head position.

Omni wheels

Two omni wheels connect the droid's motor assembly to the inside of the shell, so that the sphere can roll in any direction. An omni wheel can turn forwards, backwards and sideways, thanks to spinning cylinders around its rim. The droids used for the film were less sophisticated: they included remote-controlled props, a puppet, trike versions, and even a throwable 'bowling ball'. They were all built as practical effects and then enhanced post-production. The working promotional version detailed here was made after filming, by the original effects team and robotics firm Sphero.

Motor assembly

The motor assembly, batteries and computer all sit at the base of the droid, between the wheels. The weight of these components helps to keep the droid stable. The motors respond instantaneously to input (the BB-8 toy is controlled via a Bluetooth app), driving the wheels as needed. Just don't ask it to climb up the stairs…

Accelerometer

Like the gyroscope, the accelerometer works in all directions, measuring speed and acceleration and feeding back to the computer. The computer then makes micro-adjustments to the motors, to keep the droid stable and moving in the right direction.

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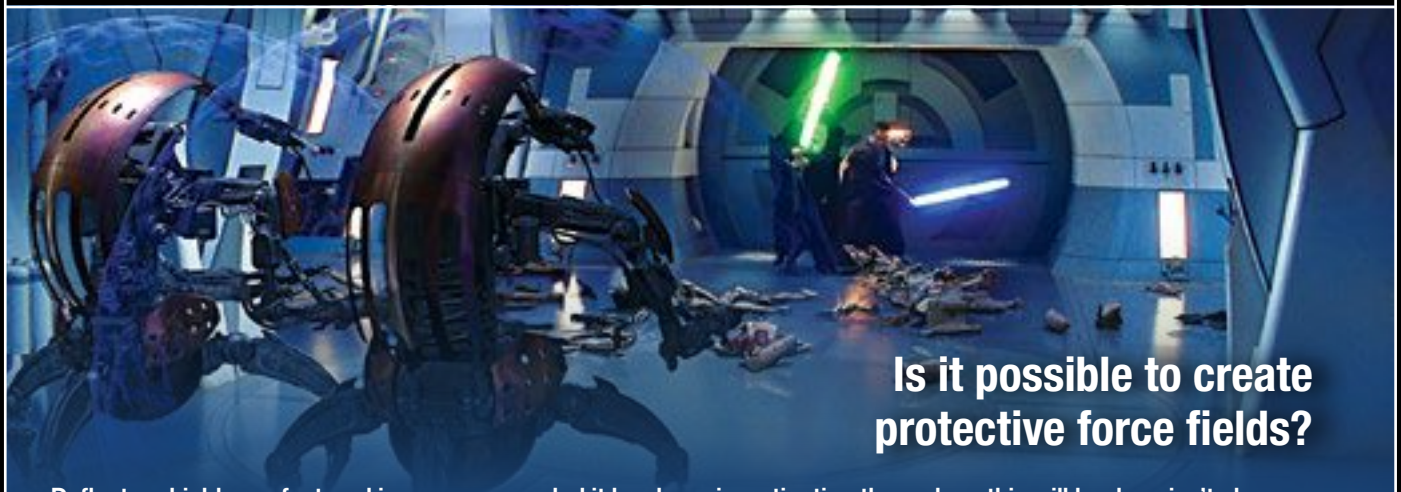
What are the odds that aliens are humanoid?

Any animal that can move about will naturally have a front end and a back end. Sensory organs such as eyes will tend to evolve at the front of the body because they are most useful there. Lifting the body up on legs reduces friction with the ground and legs are easier to coordinate if the left and right sides are symmetrical.

If the creatures from other planets are sentient, then it's reasonable to suppose that they also make and use tools to interact with their environment. That requires at least one limb to hold the object and another one to hold the tool. To keep their hands free while they move, these aliens would need at least another two limbs. Put all that together and you have a humanoid shape with two arms, two legs, a head and all the other vital internal organs in a central torso. But it's easy to imagine lots of other possibilities too. A civilisation of sentient octopuses, for example. Or a race descended from starfish, which walks on two legs and has three others available to interact with the world.

Palaeontologist and evolutionary biologist Prof Stephen Jay Gould said that even if we "re-ran the tape" of evolution here on Earth, life could end up looking different to how it looks now. On an alien planet, with higher gravity, animals might need more legs to remain stable. And aliens that float in the clouds of a gas giant might be covered with eyes that can see gamma rays, to spot danger approaching from any direction. LV



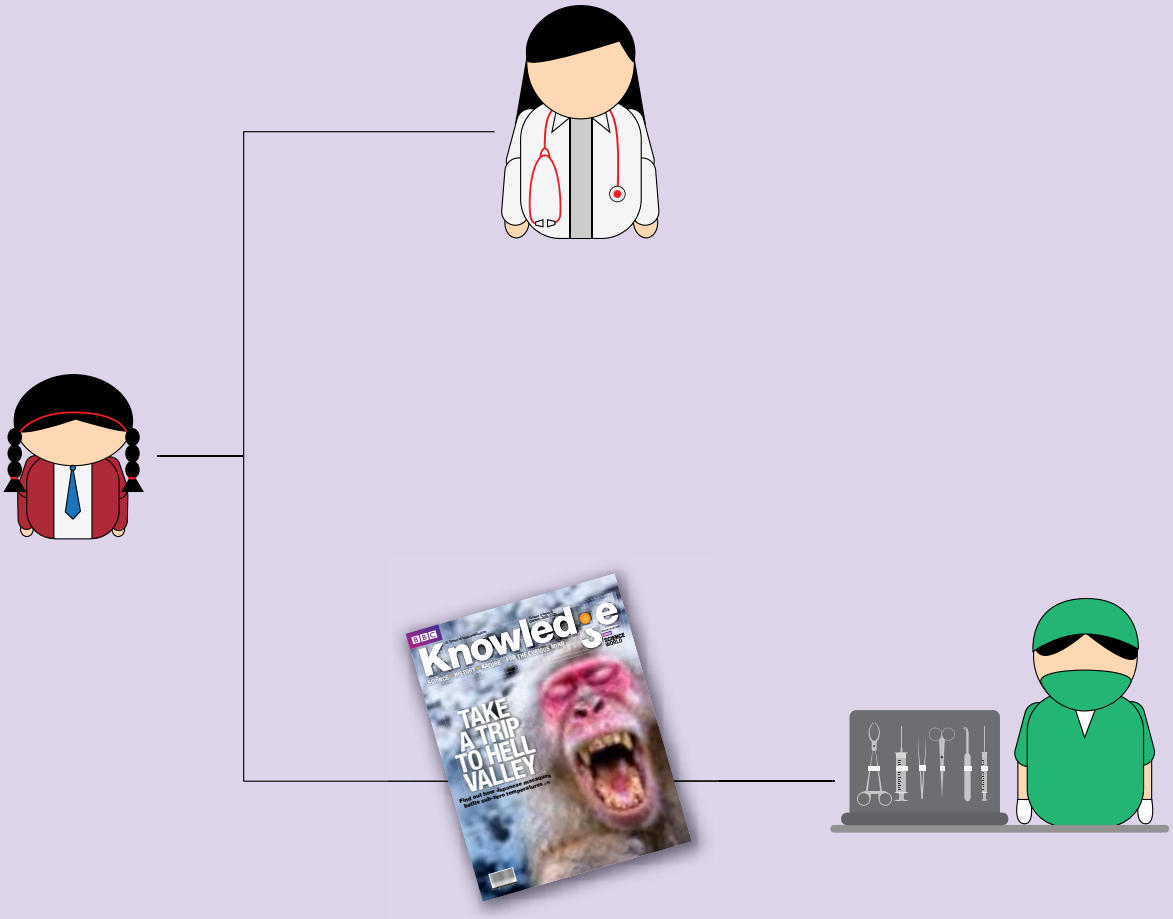
LUCASFILM LTD/KOBAL COLLECTION X2

Is it possible to create protective force fields?

Deflector shields are featured in spectacular fight scenes in the Star Wars movies, but the idea of generating force fields at will can be found in science fiction from the 1930s. Turning it into science fact has proved a major challenge, however.

Research is split into two basic areas: creating fields to protect against blast and radiation, and using them to defend against physical weaponry like shells. Earlier in 2015, the US aerospace company Boeing revealed it has been investigating the possibility of building a force field generator able to protect military vehicles against explosive shockwaves. It's not just the shrapnel from mines and improvised bombs that causes damage: the rapidly expanding gas that they produce can also wreak havoc. The Boeing system is designed to detect the incoming blast and rapidly heat the air near the vehicle, deflecting or absorbing the shockwave's energy. Exactly how this will be done isn't clear – though Boeing thinks that powerful lasers might work.

Force fields capable of stopping physical weaponry have also been studied, with the US Army Research Laboratory having looked at the use of powerful electromagnetic fields capable of robbing incoming shells of some of their energy. Again, however, such 'smart armour' has yet to see deployment. RM



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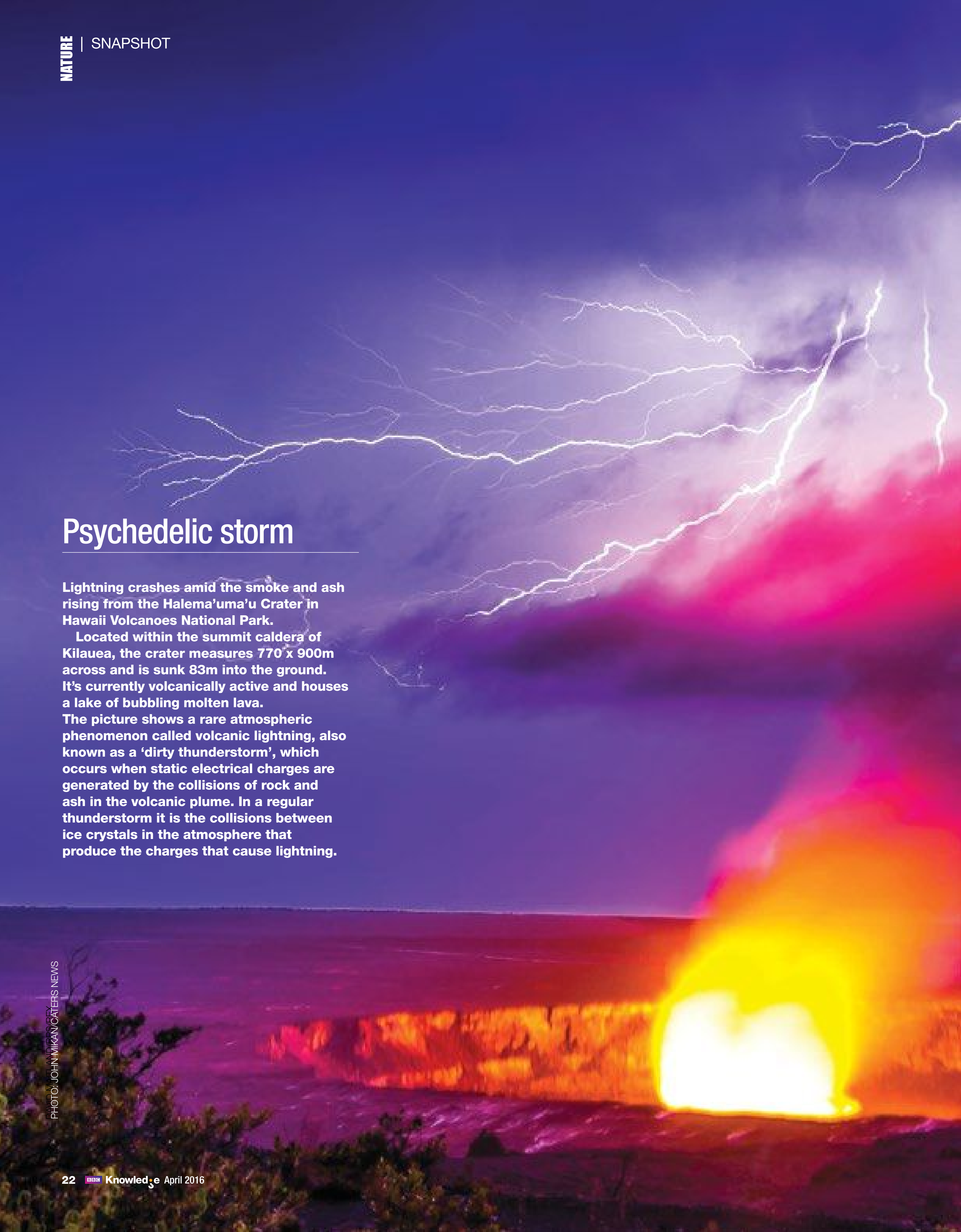


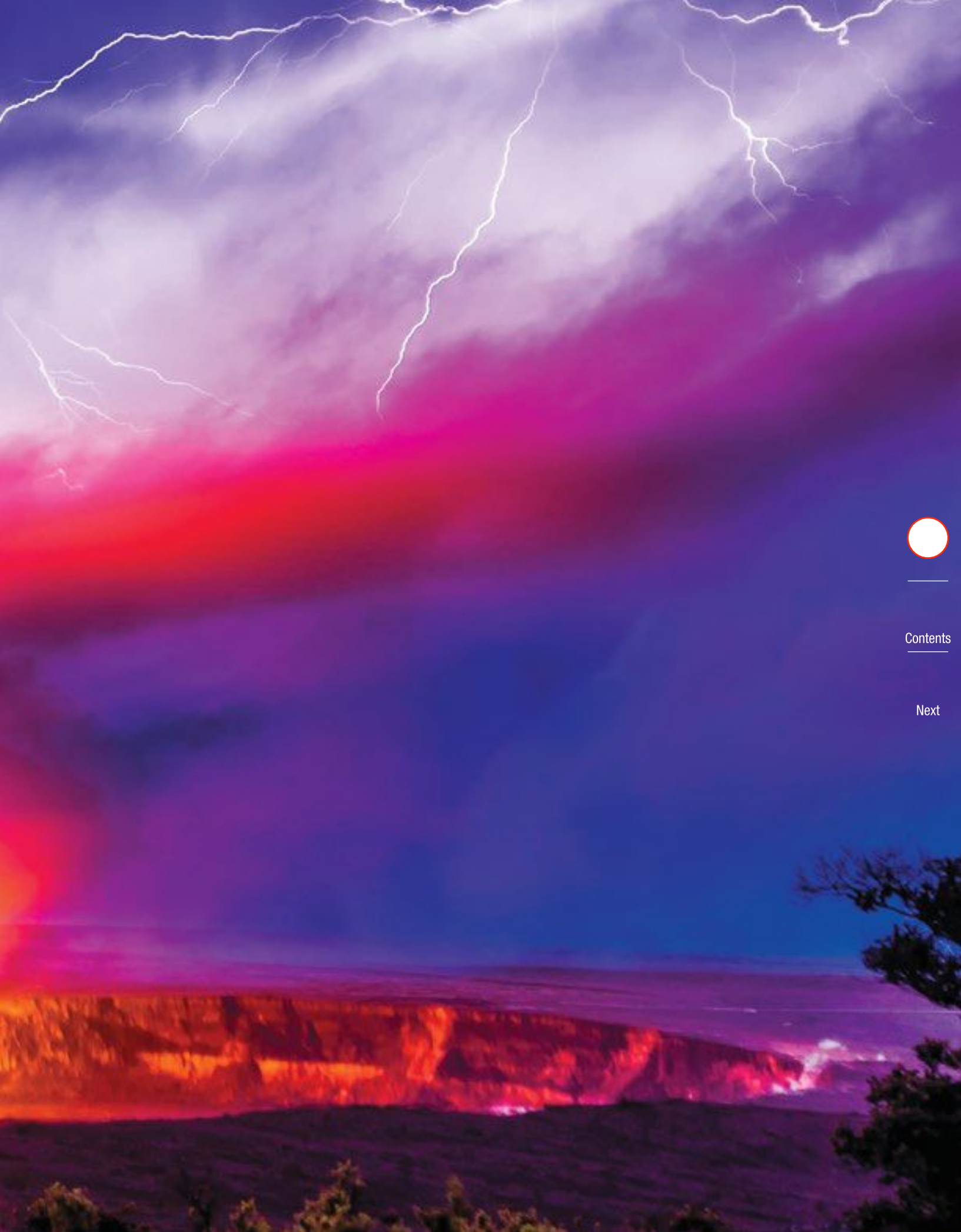
Psychedelic storm

Lightning crashes amid the smoke and ash rising from the Halema'uma'u Crater in Hawaii Volcanoes National Park.

Located within the summit caldera of Kilauea, the crater measures 770 x 900m across and is sunk 83m into the ground. It's currently volcanically active and houses a lake of bubbling molten lava.

The picture shows a rare atmospheric phenomenon called volcanic lightning, also known as a 'dirty thunderstorm', which occurs when static electrical charges are generated by the collisions of rock and ash in the volcanic plume. In a regular thunderstorm it is the collisions between ice crystals in the atmosphere that produce the charges that cause lightning.

PHOTO: JOHN MIKAN/CATERS NEWS



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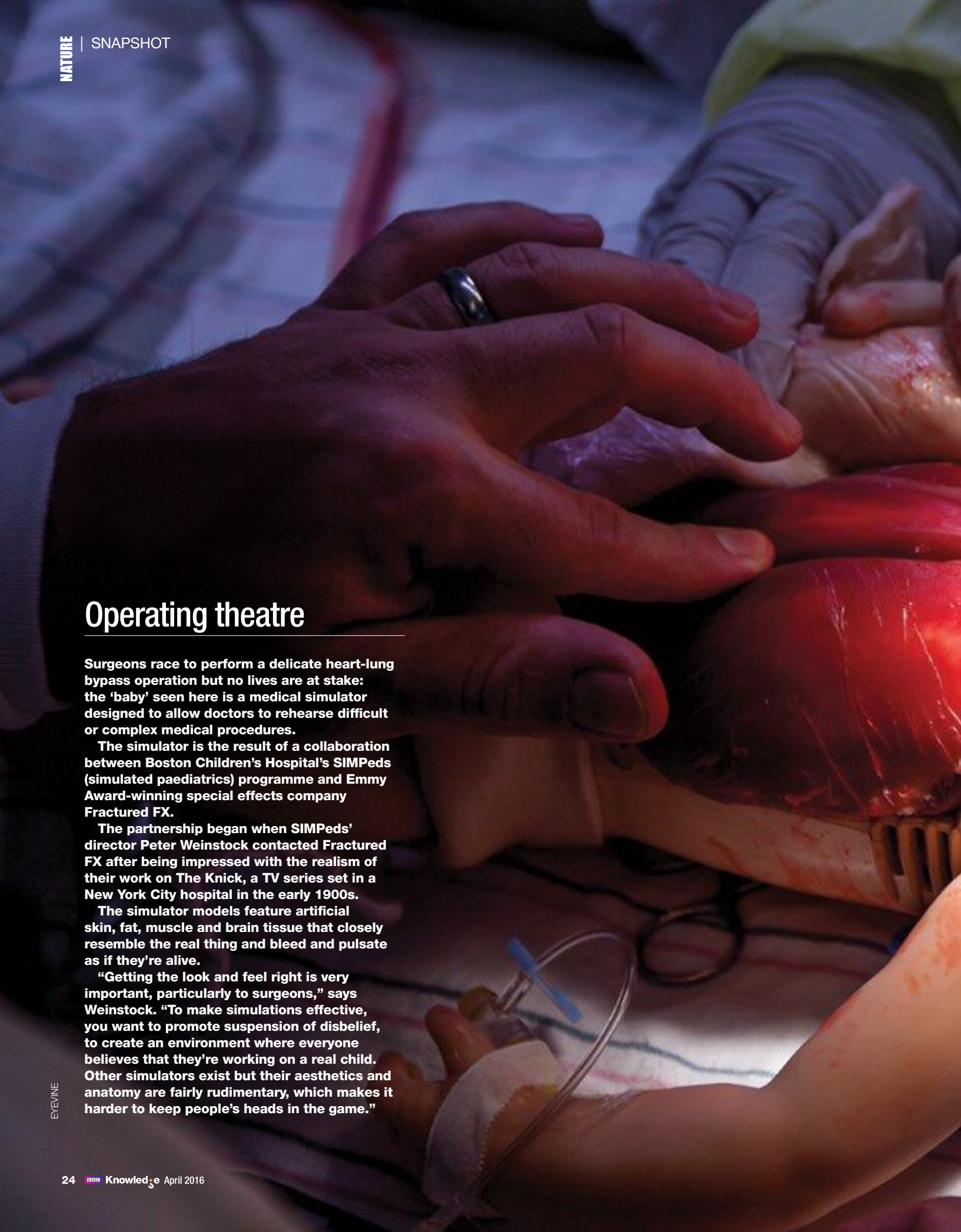


Operating theatre

Surgeons race to perform a delicate heart-lung bypass operation but no lives are at stake: the 'baby' seen here is a medical simulator designed to allow doctors to rehearse difficult or complex medical procedures.

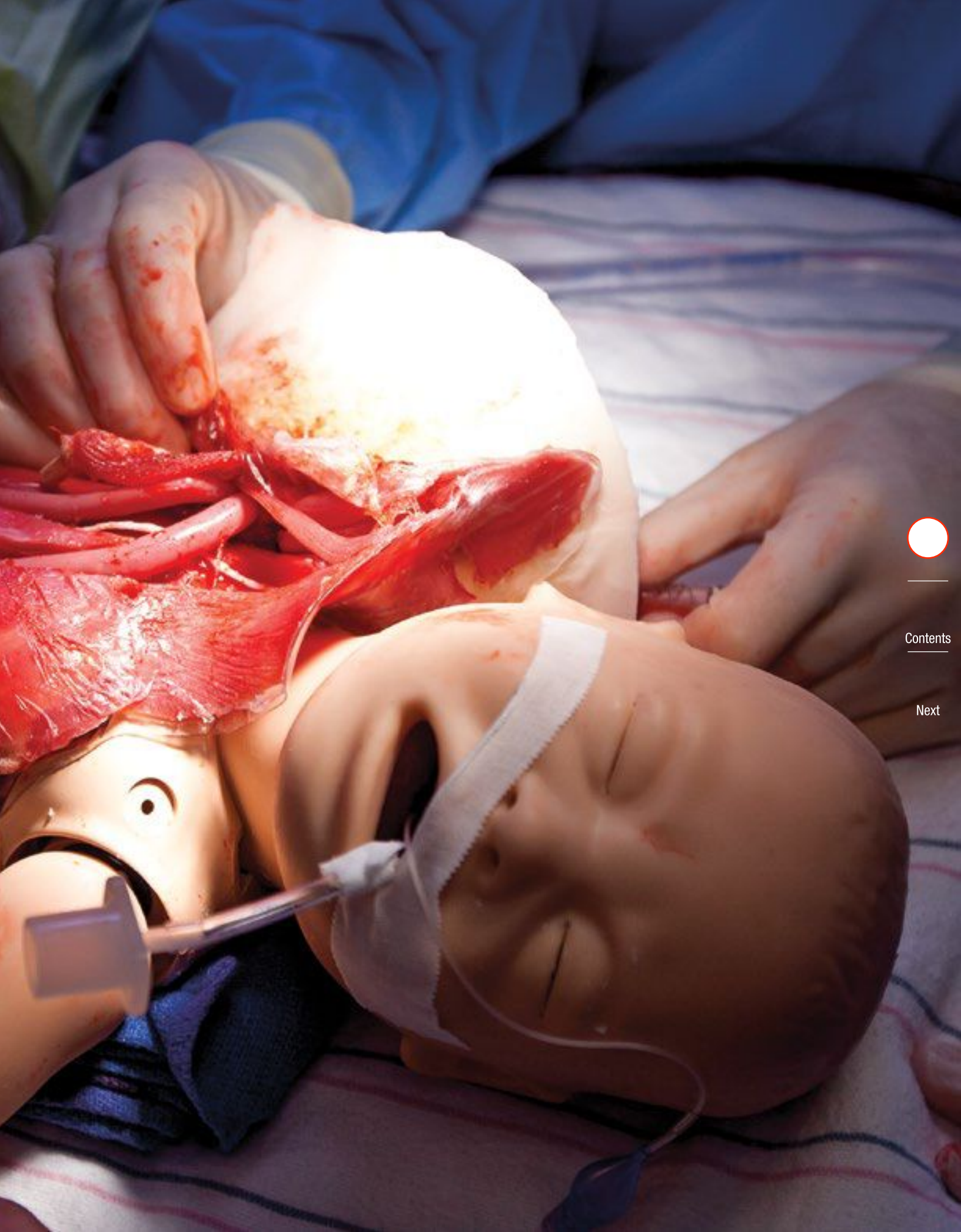
The simulator is the result of a collaboration between Boston Children's Hospital's SIMPeds (simulated paediatrics) programme and Emmy Award-winning special effects company Fractured FX.

The partnership began when SIMPeds' director Peter Weinstock contacted Fractured FX after being impressed with the realism of their work on The Knick, a TV series set in a New York City hospital in the early 1900s.

The simulator models feature artificial skin, fat, muscle and brain tissue that closely resemble the real thing and bleed and pulsate as if they're alive.

"Getting the look and feel right is very important, particularly to surgeons," says Weinstock. "To make simulations effective, you want to promote suspension of disbelief, to create an environment where everyone believes that they're working on a real child. Other simulators exist but their aesthetics and anatomy are fairly rudimentary, which makes it harder to keep people's heads in the game."

EYEVINE



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DISCOVERIES

The LISA Pathfinder experiment launched on 3 December 2015, bound for the L1 Lagrange Point

ESA, CFA/MIT, GETTY, ISTOCK

ESA KICKS OFF THE SEARCH FOR GRAVITATIONAL WAVES

The discovery of these waves hold the key in unlocking the secrets of the Universe

The European Space Agency (ESA) has successfully launched its LISA Pathfinder experiment atop a Vega rocket from a spaceport in Kourou, French Guiana.

The experiment will test a method of detecting gravitational waves, ripples in the fabric of space-time thought to be generated by massive bodies and predicted by General Relativity.

As we went to press, LISA Pathfinder was en route to L1. This is a point 1.5 million kilometres away where the Earth's and the Sun's gravity balance out, allowing the craft to remain in a stable orbit.

"We're paving the road towards a fundamentally new window on the Universe"

Alvaro Giménez Cañete, Director of Science and Robotic Exploration, European Space Agency

After reaching L1 in mid-February, it will release its payload: a pair of 46mm gold–platinum cubes separated by 38cm, which will be isolated from all forces acting on them apart from gravity. A system of lasers bouncing between the cubes will measure their position to an accuracy of 100,000th of the width of a human hair.

If the mission is a success, it will give the green light to a much larger system potentially capable of detecting the ripples caused by gravitational waves.

"Gravitational waves are the next frontier for astronomers. We've been looking at the Universe in visible light for millennia and across the whole electromagnetic spectrum in just the past century," said Alvaro Giménez Cañete, ESA's Director of Science and Robotic Exploration. "But by testing Einstein's predictions with the LISA Pathfinder, we're paving the road towards a fundamentally new window on the Universe."

Magnetic field at event horizon spotted

For the first time, astronomers have detected magnetic fields near the event horizon of Sagittarius A*, the black hole that lies at the centre of our Galaxy.

"These magnetic fields have been predicted to exist, but no one has seen them before. Our data puts decades of theoretical work on solid observational ground," said Principal Investigator Shep Doeleman, the Assistant Director of MIT's Haystack Observatory.

The presence of the fields was revealed using the Event Horizon Telescope (EHT) – a global network of radio telescopes that function as one giant scope the size of Earth.

The EHT team detected the magnetic fields by measuring the linear polarisation of the light emitted by Sagittarius A*. The polarised light is emitted by electrons spiralling around magnetic field lines and so directly traces the structure of the magnetic field.

"With this result, the EHT team is one step closer to solving a central paradox in astronomy: why are black holes so bright [if their gravitational pull is so great they can draw in light]?" said Doeleman.

This groundbreaking observation was made possible thanks to the remarkable resolution a telescope the size of the EHT offers. It's hoped, however, that more radio dishes from around the world will be added to the EHT's network enabling it to gather even more astronmical data. More data will allow the EHT's astronomers to achieve greater resolution, possibly enough to directly image a black hole's event horizon for the first time.

GOOD MONTH/ BAD MONTH

IT'S BEEN GOOD FOR:

ODONTOPHOBES

If the sound of the dentist's drill literally sets your teeth on edge, read on. A team at the University of Sydney has discovered that the need for fillings can be reduced by up to 50 per cent by using a 'fluoride varnish', monitoring your teeth regularly and brushing correctly. Look out for your teeth and you can dodge the drill!

THE QUICK-WITTED

Those who can think on their feet are perceived as more charismatic than their slower counterparts, researchers at the University of Queensland have found. The effect is seen even if the answers given by the quick thinkers are incorrect.

IT'S BEEN BAD FOR:

TALL PEOPLE

Being lanky means you always get a good view in the cinema, but it may also give you a shorter lifespan. A study at the University of Glasgow carried out on sparrows has found changes in DNA linked to ageing take place as body size increases. The effect is due to the greater number of times cells must divide to grow bigger and taller, the researchers say.

HEDGEHOGS

Numbers of British hedgehogs have fallen by one-third in the last decade, the People's Trust for Endangered Species has found. The decline is thought to be down to the popularity of paved and gravel gardens. Making sure your fence has a 13cm square gap could help hedgehogs, by letting them travel around more easily.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 DNA motors

The dream of sending microscopic robots through the body to deliver drugs or repair tissue is a step closer. A DNA motor devised by Emory University chemists moves at the speed of 1cm per week – a vast improvement on previous designs that would have taken 20 years to cover the same distance. It consists of a glass sphere with hundreds of DNA legs. The legs bind to RNA on a surface and then detach from the sphere to propel it along. The motor could be used in disease diagnosis or even biological computers.

Khalida Salaita and Kevin Yehl (below) helped create a new 'high-speed' DNA motor

9 Flat camera

A flat camera with no lens could better today's smartphone snappers in low-light conditions. To house lenses, today's cameras are cube-shaped. But Rice University scientists have developed a prototype that's around 1mm thick, enabling it to be built into wallpaper, credit cards and curved surfaces. The FlatCam has a mask instead of a lens and constructs an image using computer algorithms. Since they're made like computer chips, the breakthrough could lead to cheap, disposable digital cameras.

New lensless, flat cameras could be built into wallpaper

8 Hairy clothing

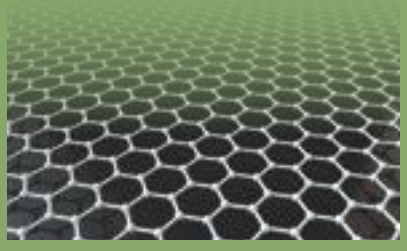
Fur is probably the last material you'd think would be water-repellent, but scientists at MIT have proved otherwise. They found that long, dense hairs help the skin below stay dry by trapping air between them. Also, the trapped air doesn't conduct heat anywhere near as well as water, so it helps semi-aquatic animals like fur seals and otters to stay warm too. The research could lead to better wetsuits and waterproof clothing.

7 Seeing round corners

It's now possible to see around corners thanks to a new camera developed at Heriot-Watt University, Edinburgh. The camera scatters a laser beam in all directions and detects any 'echoes' that hit objects and return to the camera. Applications include dashboard cameras that show drivers potential hazards around the next bend.

6 Graphene microphone

A microphone with a vibrating graphene membrane has been made at the University of Belgrade. It's 32 times more sensitive than current commercial models based on nickel. Eventually, graphene mics could capture more than just audible frequencies – a membrane with more layers could pick up ultrasonic sound.



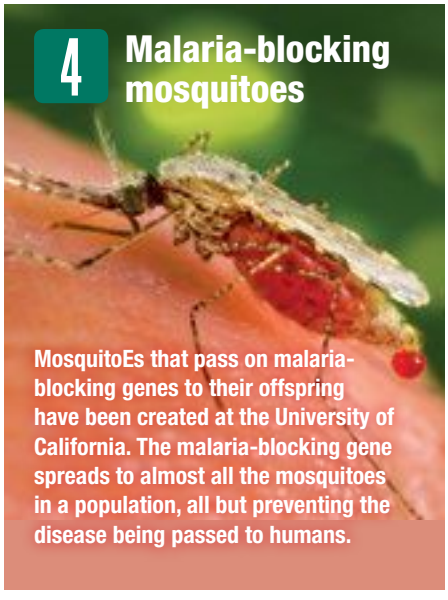
Droplets forming on a biphilic surface at -4°C

BRYAN MELTZ/EMORY PHOTO X2, LIU, RICE UNIVERSITY, ISTOCK X2, NATUREPL.COM, UNIVERSITY OF WASHINGTON

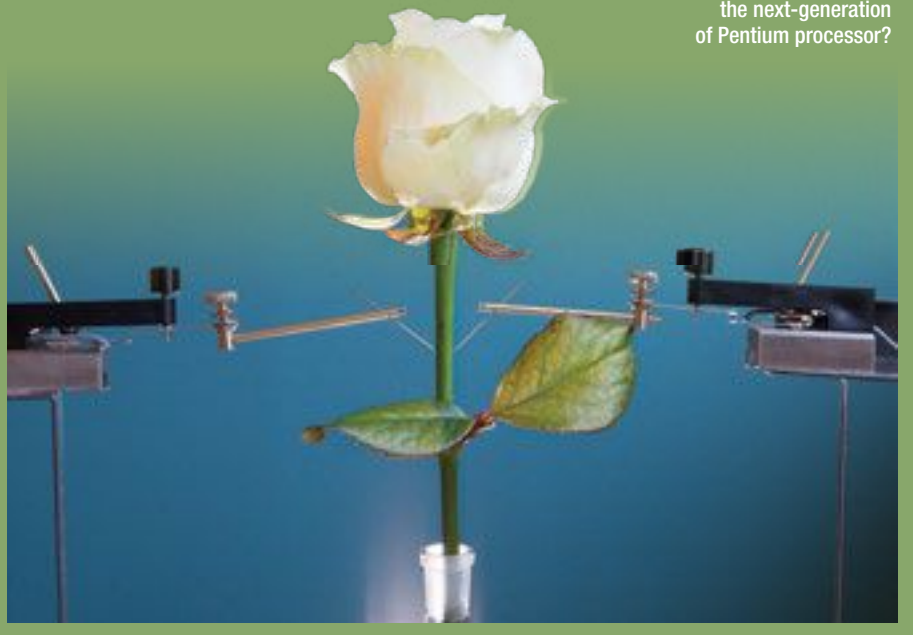
5 Gecko glue

Scientists at China's Nantong University have sequenced a gecko genome and found the genes that help it form the fine toe hairs it needs to climb walls. The study may lead to new adhesives and other breakthroughs relating to the gecko's ability to regenerate its tail.

4 Malaria-blocking mosquitoes



MosquitoEs that pass on malaria-blocking genes to their offspring have been created at the University of California. The malaria-blocking gene spreads to almost all the mosquitoes in a population, all but preventing the disease being passed to humans.

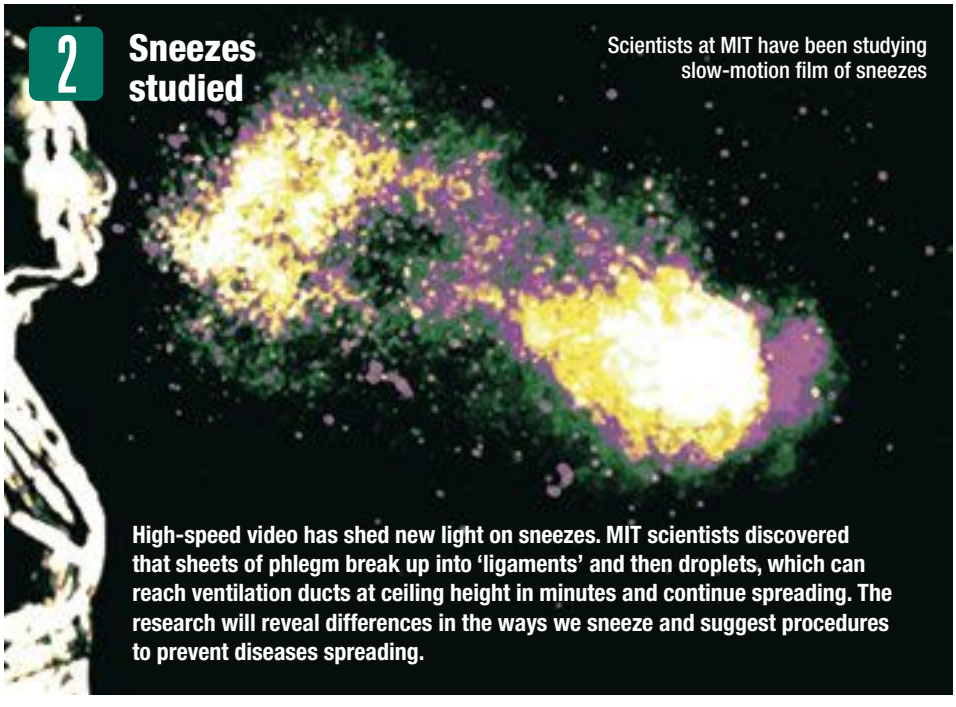


A beautiful flower or the next-generation of Pentium processor?

3 Electronic plants

Computers in your roses and Wi-Fi antennae in your trees are just two of the long-term possibilities presented by organic electronics. At Sweden's Linköping University, scientists embedded a polymer into a rose to form a working transistor. It's part of a plan to combine electronic circuits with plants' natural signalling mechanisms in the hope of tapping into energy generated by photosynthesis as well as reading and regulating a plant's growth functions.

2 Sneezes studied



Scientists at MIT have been studying slow-motion film of sneezes

High-speed video has shed new light on sneezes. MIT scientists discovered that sheets of phlegm break up into 'ligaments' and then droplets, which can reach ventilation ducts at ceiling height in minutes and continue spreading. The research will reveal differences in the ways we sneeze and suggest procedures to prevent diseases spreading.

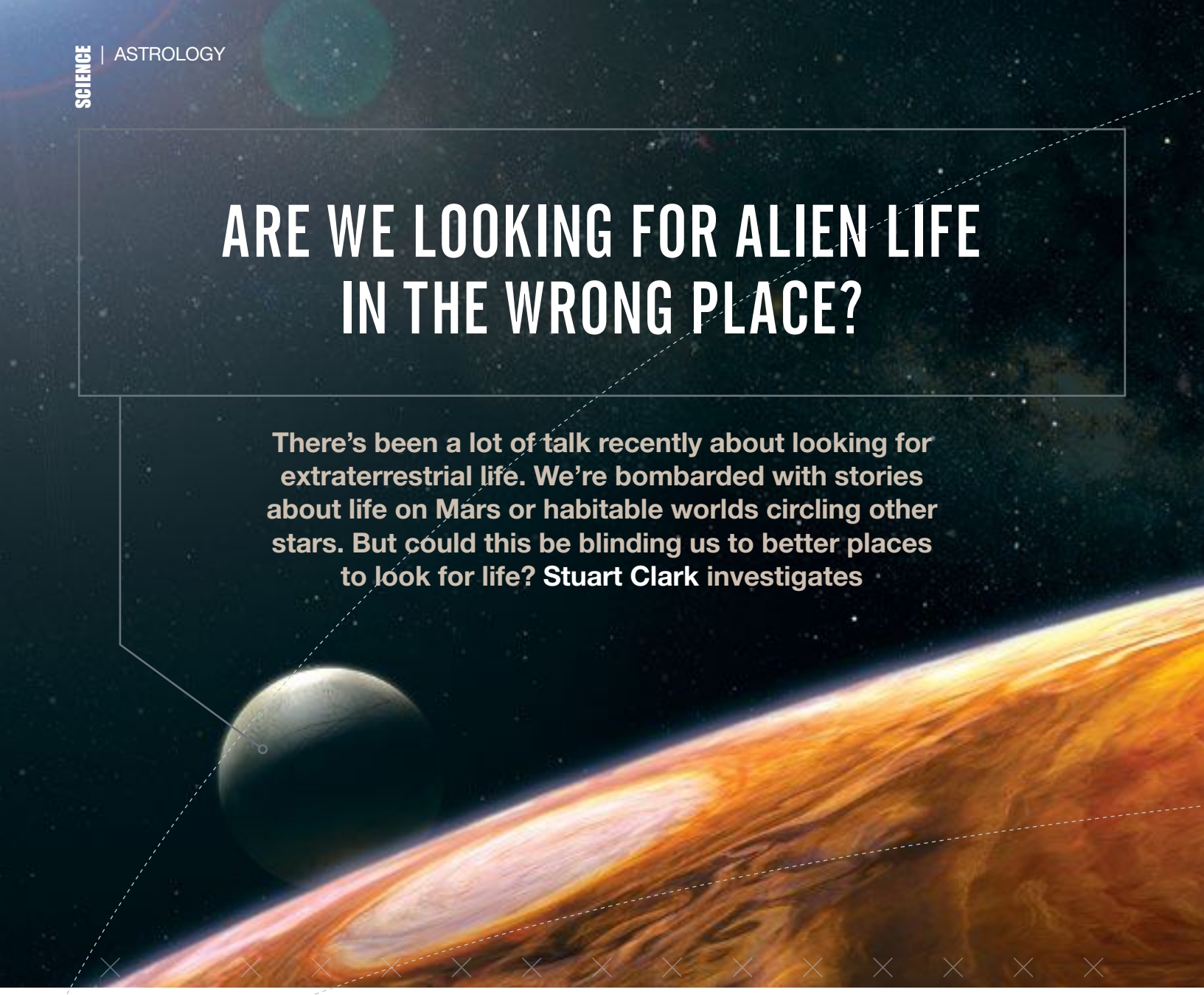
1 Robot learners

Robots that learn from their experiences, just like human infants, are on the horizon. At the University of Washington, computer scientists and psychologists built robots that learn new skills by watching how humans perform tasks. The robots then try various methods to work out how to achieve the same goal.

The new robots learn the same way babies do – by watching

ARE WE LOOKING FOR ALIEN LIFE IN THE WRONG PLACE?

There's been a lot of talk recently about looking for extraterrestrial life. We're bombarded with stories about life on Mars or habitable worlds circling other stars. But could this be blinding us to better places to look for life? Stuart Clark investigates



GETTY

The icy moons of the outer Solar System are attracting more and more attention from planetary scientists. Decades of studies have shown that there is a lot of liquid water locked away inside the outer moons. On Earth, pretty much anywhere you find water, you find life – so could be the same be true of the outer moons?

"In terms of potential habitats, I think most [astronomers] are fairly sure that there are places inside many of these moons where, if you put the right kind of organism there, they would survive. So we've got habitats, we just don't know whether they are inhabited by organisms," says David Rothery, a planetary scientist from the Open University, UK, who surveyed the moons of the Solar System for his book *Moons: A Very Short Introduction*.

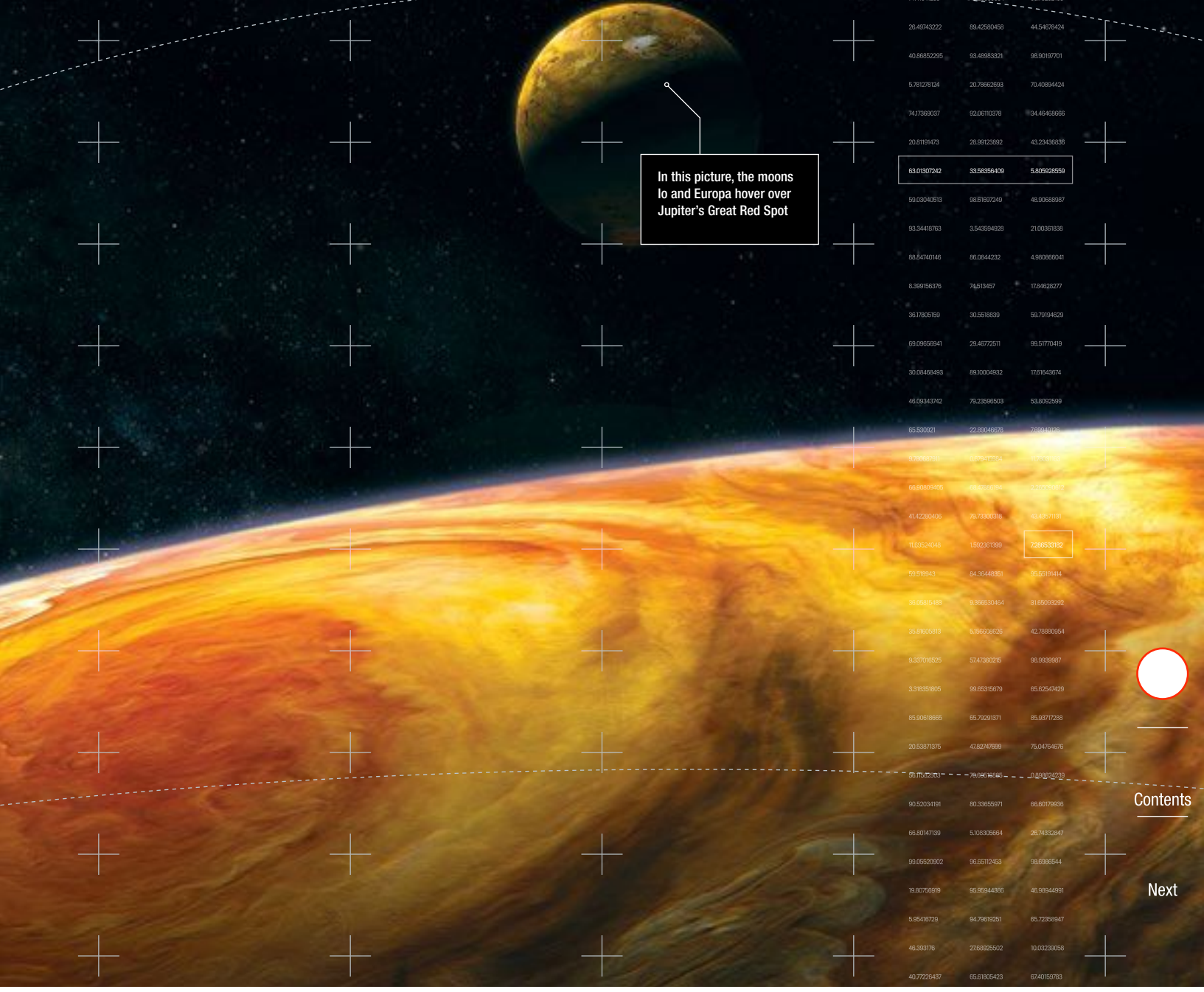
Looking for life beyond Earth is no mere exercise in intellectual curiosity, either. Should we ever find any such life, it should tell us more about how life began here on our own planet.

At present, no one knows exactly what conditions are needed to flick the switch from mere chemistry to biology. Did this process occur readily, or was it the result of a chain of unlikely events? That's something that finding life elsewhere would help us answer.

"If we can find places in the Solar System where life began independently from life on Earth, then… wow! That is pretty compelling evidence that if life can start, it will start," says Rothery.

Life needs a power source. Once, we thought that the only suitable source of such power in the Solar System was the Sun, which meant that life had to exist on a planet's surface. Hence the interest in Mars, which seems to be the most Earth-like of the other planets. However, a discovery on the floor of the Pacific Ocean in 1977 changed all that.

Researchers from the Scripps Institute of Oceanography in California were exploring around the volcanic ridge known as the East Pacific Rise. They found natural chimneys



In this picture, the moons Io and Europa hover over Jupiter's Great Red Spot

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"If we can find places where life began independently from life on Earth, then… wow! "

David Rothery, The Open University

belching black smoke into the ocean, which they nicknamed black smokers. Known more formally as hydrothermal vents, these are places where hot water percolates through the ocean bedrocks, dissolving minerals as it goes, and then shoots back up into the frigid ocean water. The sudden change in temperature causes the minerals to precipitate, creating the black 'smoke'.

Astonishingly, the Scripps team found thriving biological communities fuelled by the dissolved minerals around the vents. These were sustained not by energy from the Sun, but by the geothermal energy that heated the water.

The discovery of oceans in some of the outer moons of the Solar System, such as Jupiter's Europa and Saturn's Enceladus, instantly raised the possibility of black smokers on those far-off moons. Perhaps most intriguingly, some of the microbes found around the black smokers were shown to be genetically the most primitive organisms on the planet, which raised the prospect that these could be the very places where life began. If that were true, why not on the ocean floors in the outer Solar System as well?

Over the next six pages, we'll survey the three moons where life is most likely to be lurking right now. ▶

Europa

Parent planet: Jupiter

Orbital period: 3.551 days

Radius: 0.245 Earth radii

Mass: 0.008 Earth mass

Planetary Habitability Index: 0.49

This was the moon that opened up our eyes to the possibility of oceans in the outer Solar System. Suspicions first arose in the late 1970s, when NASA's Voyager 1 and 2 spacecraft passed the moon. The images showed a mostly smooth icy surface, almost devoid of craters. Since these impact scars accumulate as time goes by, for Europa to show hardly any meant that the surface was being renewed. But how?

Cracks on the surface provided us with an answer. In the 1990s, NASA's Galileo spacecraft explored the moon and revealed that dark materials around the cracks were salty, as if they had come from an ocean. Magnetic readings also hinted at a shifting body of water inside the moon. The final piece of the puzzle came in images of the surface, which clearly showed ice floes.

The heat to keep this ocean liquid was calculated to be coming from the gravity of Jupiter. A so-called tidal force squeezed the moon, producing friction to melt the underground ice and maybe even drive black smokers. But getting down to see them will be tough. The ice sheet that makes up the surface of Europa is estimated to be between one and 10 kilometres thick.

"It would be very difficult to go to Europa, drill through the ice and send a submersible to the black smoker on the ocean floor, but you could potentially land at one of the cracks and sample the slush that's squeezed up through it," says Rothery.

This would allow equipment to look for biologically important molecules. The kit would have to be designed to work in high radiation levels. Every day the surface of Europa is bathed in thousands of times more harmful radiation than Earth. An astronaut standing on Europa would receive a fatal dose within 24 hours. Luckily for any life on the ocean floor, the radiation will not penetrate beneath the ice sheets.

NASA is developing a mission to study the moon from orbit. Called the Europa Multiple-Flyby Mission, the space agency is currently designing the instruments that will allow it to assess the moon for habitability. Intended for launch in 2022, the spacecraft could carry a lander built by the European Space Agency (ESA).

ESA itself has a mission to Jupiter called Juice (Jupiter Icy Moons Explorer). Although not designed to concentrate on Europa, it will be making some flybys of the moon, during which it will use its ice-penetrating radar to measure the thickness of the ice crust.

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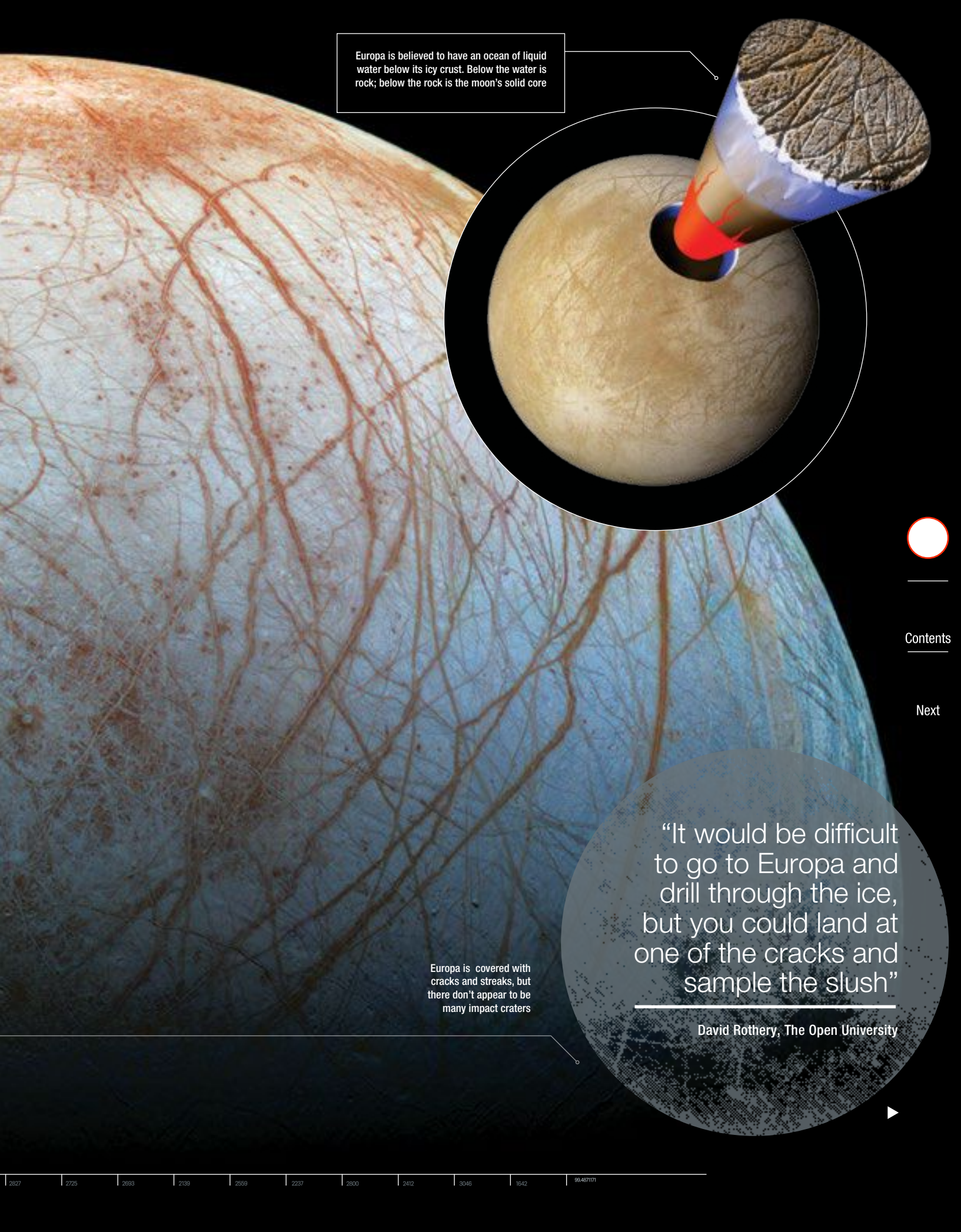


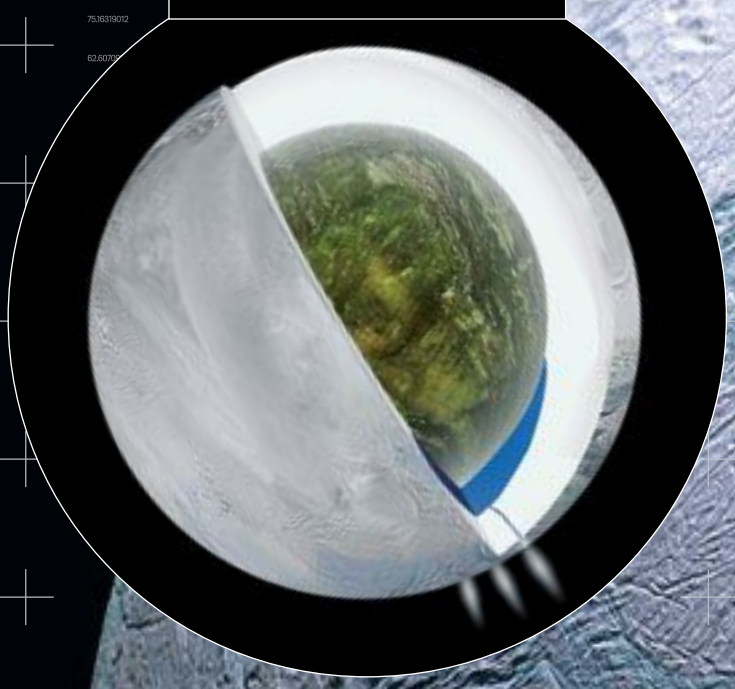
Europa is believed to have an ocean of liquid water below its icy crust. Below the water is rock; below the rock is the moon's solid core

Europa is covered with cracks and streaks, but there don't appear to be many impact craters

"It would be difficult to go to Europa and drill through the ice, but you could land at one of the cracks and sample the slush"

David Rothery, The Open University

Enceladus is believed to have a low-density rocky core and an icy outer shell, with an ocean of liquid water sandwiched in-between



Enceladus

Parent planet: Saturn

Orbital period: 0.395 days

Radius: 0.0395 Earth radii

Mass: 0.000018 Earth mass

Planetary Habitability Index: 0.35

Although Europa was in many ways the trailblazing moon for sub-surface oceans, much remains unknown because the water is mostly locked under the ice. At Enceladus, however, nature has gifted us a way of analysing the ocean just by flying past the world. This is because there are geysers jetting water from the ocean into space.

NASA's Cassini spacecraft has been targeting those plumes and flying through them, so that its onboard instruments can analyse them. Various types of dust grains and chemical have been discovered in this way, including the telltale signature of salts.

"This is pretty good evidence that we are sampling the ocean itself," says Jonathan Lunine, a planetary scientist at Cornell University. Spurred on by the discovery of

NASA X2

> "Enceladus is almost certainly habitable – we just don't know whether it's inhabited"
>
> David Rothery, The Open University

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Enceladus' water plumes, the spacecraft operators designed a sequence of flybys that would take Cassini deeper and deeper into the plumes.

"We now have an inventory of organic molecules," says Lunine. "It is not a complete list but it is enough to be able to say, yes we have carbon-bearing molecules inside Enceladus." This could be a significant discovery, because on Earth, life-giving DNA is built using carbon-bearing molecules.

On 28 October 2015, Cassini plunged to its closest flyby yet, just 48km above the icy surface and hopefully steering through the densest part of the geysers. Planetary scientists are now eagerly analysing the results. They are on the look out for molecules of hydrogen, because if this gas is present in the water jets, theory suggests that it must becoming from where hot water is reacting with rocks on the ocean floor.

Finding the molecule has implications for life. "Hydrogen can feed an organic pathway. A microbe could bond hydrogen onto carbon and get an energy kick out of it," says Rothery. This is how microbes called methanogens survive on Earth.

Of course, finding the chemical ingredients for such life does not guarantee that it is there. Nevertheless, this wealth of new information is edging Enceladus ahead of Europa in terms of where planetary scientists think that life might be found.

"I'm inclined to boost Enceladus higher than Europa now," says Rothery, "It's almost certainly habitable – we just don't know whether it's inhabited."

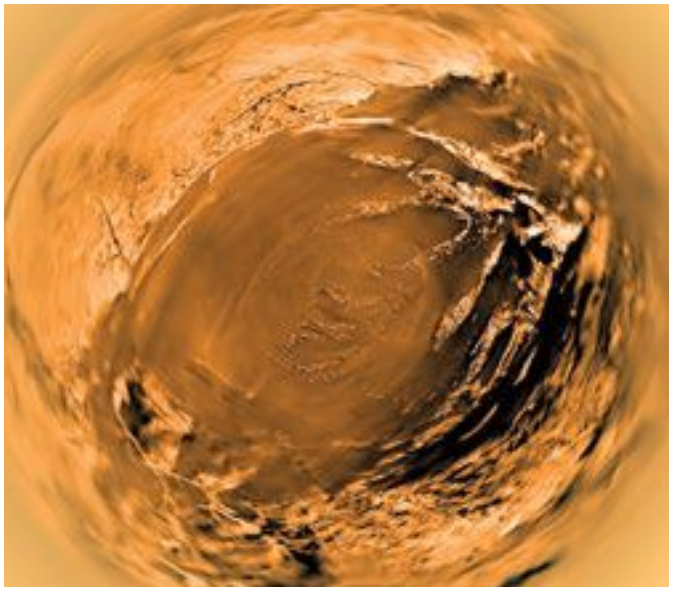
For now, there are no further plans to send anything back to the Saturn-Enceladus system. Once the Cassini mission ends, however, and planetary scientists start to really digest the new information, the chances are that a follow-on astrobiology-oriented mission will begin to gather support. ▶

The blotches on this false-colour images of Titan are thought to be lakes of liquid methane and ethane

Titan

Parent planet: Saturn
Orbital period: 15.945 days
Radius: 0.404 Earth radii
Mass: 0.0225 Earth mass
Planetary Habitability Index: 0.64

This moon of Saturn is an altogether more alien place, sitting under obscuring clouds that are rich in organic molecules. Its surface was revealed by ESA's Huygens lander that parachuted down in 2005. During the descent, the craft made some intriguing electrical measurements. Combined with measurements of the way the moon's gravitational field differs from place to place, they strongly suggest of an ocean beneath the surface.



NASA X2, ESO

An aerial view of the surface of Titan, captured by ESA's Huygens lander in 2005. Data sent back by the Cassini-Huygens mission remains our primary source of knowledge about this moon

With all the organic molecules in the atmosphere and on the surface of Titan, there's a strong chance the ocean would be full of them too, increasing the chances of life. But could we sample this ocean to test that hypothesis? "That's the question," says Lunine. "There's nothing spewing out of that ocean onto the surface of Titan."

But maybe we don't need to go deep to find life on this particular moon. There is liquid on the moon's surface, but it's not water. Liquid methane and ethane pool in lakes and seas at the moon's polar regions, the largest of which is about the size of the Caspian Sea on Earth.

Could life be based on methane rather than water? Lunine thinks so. Together with some chemical engineering colleagues, he found a theoretical biochemistry that could work for methane, but testing it is going to be extremely hard. "It's very hard to 'cook up' biochemistry in the lab," he says, "It's probably easier just to go to these places and look. It would be interesting to land on one of Titan's seas and see what's going on."

Exomoons

October 2015 marked the 20th anniversary of the discovery of 51 Pegasi b, the first planet to be discovered in orbit around a Sun-like star. It was a giant planet like Jupiter and was revealed because of the tiny 'wobble' it induced in its parent star. Since then, thousands more exoplanets have been discovered around stars in the Milky Way. Many are like Jupiter and Saturn, so it seems likely that they would also have moons.

We may be able to detect such moons by studying their 'transits'. During a transit, a planet crosses the face of its parent star and blocks out some light. This drop in brightness can be measured to give the size of the planet, which is how NASA's Kepler space telescope found more than 1,000 planets from 2009-2013. Any moons around those planets will cause additional, smaller drops in light, so it should be possible to detect them with ultra-sensitive measurements. The SuperWASP (Wide Angle Search for Planets) has detected at least one tentative transit signal that could be an exomoon, and next-generation space missions such as ESA's CHEOPS (2017), NASA's TESS (2018) and ESA's Plato (2024) also stand a chance of detecting exomoons in this way.

Many of these moons will be found around giant planets that are much closer to their parent stars than Jupiter and Saturn. That means receiving more heat, so oceans on those moons will not be underground. Starlight will melt the ice, turning the moon into a water world where life could flourish. But the habitat is unlikely to be long-lived: the weak gravity of a small moon will not be able to prevent the atmosphere being eroded by the fierce starlight. The exomoon will resemble a giant comet, with a gassy tail stretching into space, and will eventually become a tiny rocky cinder. Not ideal. But good while it lasted.

"It's very hard to 'cook up' biochemistry in the lab. It's probably easier just to go to these places and look"

Jonathan Lunine, Cornell University

Dr Stuart Clark is author of several books including *The Unknown Universe.*

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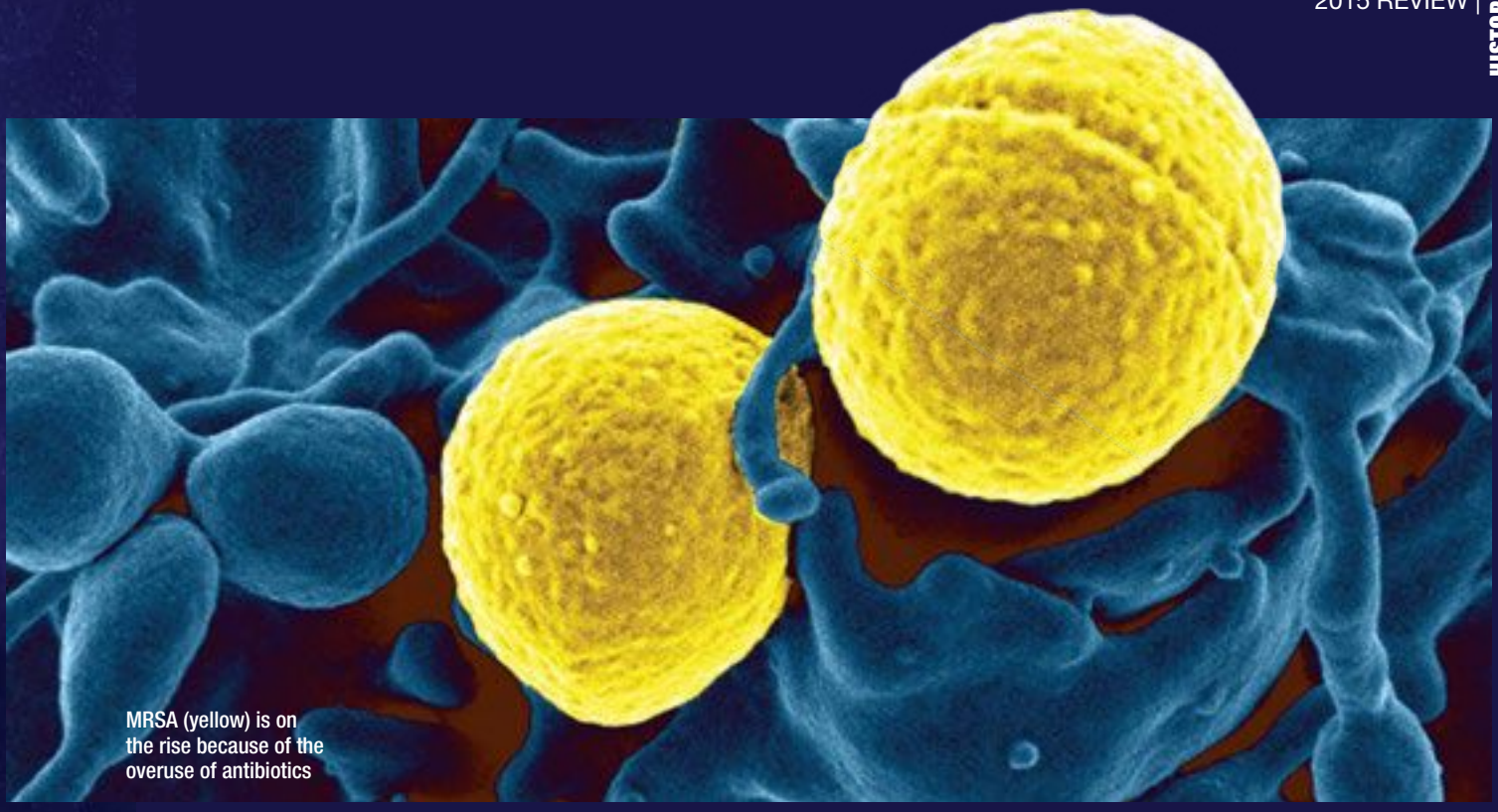
2015: THE BEST EVER YEAR FOR SCIENCE?

The past 12 months have been incredible for science. We've explored Pluto, revolutionised medicine, found evidence of water on Mars and brought animals back from the brink of extinction. So will 2015 go down in the history books as a turning point? Brian Clegg looks back over some of the year's most impressive scientific achievements

GETTY, NASA, TODD MARSHALL, ILLUSTRATOR: ANDY POTTS



MRSA (yellow) is on the rise because of the overuse of antibiotics

NEW ANTIBIOTIC IS DISCOVERED

As bacteria increasingly evolve to survive the attack of antibiotics, we could see modern medicine devastated. Overuse of antibiotics means that we are threatened by 'superbugs' like MRSA that can survive our armoury.

Until 2015, we hadn't developed a new antibiotic for decades. But two new substances are under test that could extend the fight against superbugs. One, being developed by drug company Novartis, is a variant of the existing isoniazid antibiotic that is used to target antibiotic-resistant tuberculosis. It works because it bypasses the mechanism used by a bacterium to develop resistance. But more dramatic is teixobactin, which was derived from 'wild' bacteria in soil and works in a different way to conventional antibiotics, attacking a part of the bacterial cell that is less able to mutate and produce resistance. "Uncultured bacteria make up approximately 99 per cent of all species in external environments, and are an untapped source of new antibiotics," said the researchers. If a drug is developed from teixobactin, it could be effective against bacteria like MRSA for decades to come.

WHY SHOULD I CARE? An increase in antibiotic resistance in bacteria is putting our lives at risk.

WHAT'S NEXT? Researchers are hunting for more antibiotics like teixobactin in the wild.

An iChip is used to house growing microorganisms for antibiotic research

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THE YEAR IN BRIEF...

JAN

BIG FISH

In January, a fossil that had been sitting in a Glasgow museum since 1959 was identified as a previously unknown species of ichthyosaur, Dearcmhara shawcrossi. The marine reptile lived in Scottish waters 170 million years ago, and grew up to 4m long.

A NEW EARTH?

Exoplanet Kepler 438b was confirmed in January, and is thought to be the most Earth-like exoplanet yet discovered. Sadly, further studies have shown that it's too close to its parent star to ever be capable of hosting carbon-based life, due to high radiation levels.

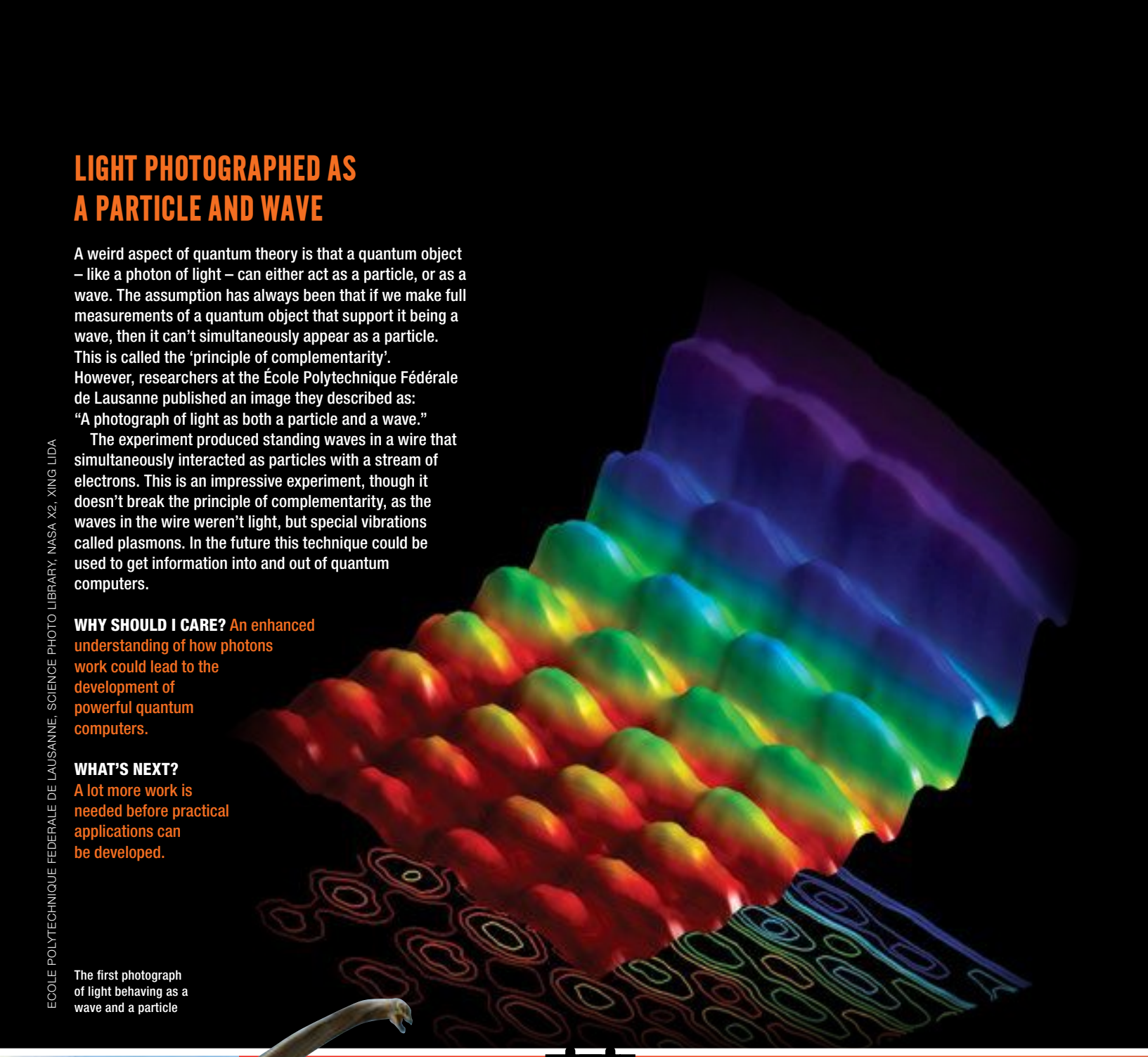
LIGHT PHOTOGRAPHED AS A PARTICLE AND WAVE

A weird aspect of quantum theory is that a quantum object – like a photon of light – can either act as a particle, or as a wave. The assumption has always been that if we make full measurements of a quantum object that support it being a wave, then it can't simultaneously appear as a particle. This is called the 'principle of complementarity'. However, researchers at the École Polytechnique Fédérale de Lausanne published an image they described as: "A photograph of light as both a particle and a wave."

The experiment produced standing waves in a wire that simultaneously interacted as particles with a stream of electrons. This is an impressive experiment, though it doesn't break the principle of complementarity, as the waves in the wire weren't light, but special vibrations called plasmons. In the future this technique could be used to get information into and out of quantum computers.

WHY SHOULD I CARE? An enhanced understanding of how photons work could lead to the development of powerful quantum computers.

WHAT'S NEXT? A lot more work is needed before practical applications can be developed.



ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, SCIENCE PHOTO LIBRARY, NASA X2, XING LIDA

The first photograph of light behaving as a wave and a particle

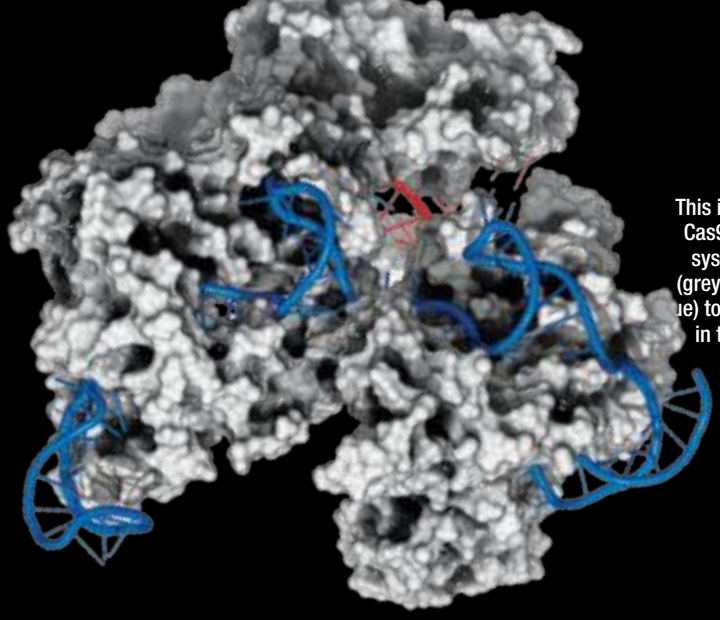
CHINESE DRAGON

At the end of January, a new species of dinosaur was discovered in China, and named *Qijianglong*, 'the dragon of Qijiang'. The 15m-long herbivorous creature lived 160 million years ago, and had a long neck that comprised nearly half its body length.

MAR

A NEW DAWN

On 6 March, NASA's Dawn spacecraft went into orbit around Ceres, becoming the first craft to visit a dwarf planet. At time of writing it is still mapping the planet's surface from low orbit, and will continue to send back data for many months to come.



This is the CRISPR-Cas9 gene-editing system. A protein (grey) uses a guide ue) to cut DNA (red) in the right spots

HUMAN DNA EDITED SUCCESSFULLY

The remarkable genetic tool CRISPR (standing for Clustered Regularly Interspaced Short Palindromic Repeat) was developed in 2012. It transformed DNA editing from an expensive, slow process to a rapid, cheap technique. The approach, which employs a mechanism found in the immune system to target specific genes, was used this year for the first time to make modifications to human embryos by scientists at China's Guangdong Province Key Laboratory of Reproductive Medicine and Sun Yat-sen University, Guanghou.

The team was attempting to modify the gene HBB that mutates to cause the blood disease beta-thalassaemia. Although the team was working on embryos with an extra set of chromosomes, meaning that the embryos cannot develop to birth, there were concerns about the ethics of the process if it were ever to be used on viable embryos, as any changes could be passed on to offspring with uncertain results. Also, the experiment did not produce a successful modification in the majority of the 86 embryos tested. Project leader Junjiu Huang said: "If you want to do it in normal embryos, you need to be close to 100 per cent. That's why we stopped."

Even where the modification worked, there were extra mutations where the CRISPR mechanism made changes to other genes – far more unwanted modification than had occurred in other experiments on mice and adult human cells. This highlights the significant obstacles that stand in the way of using gene editing to eliminate genetic disorders, yet the technique still holds out hope for cures in the future.

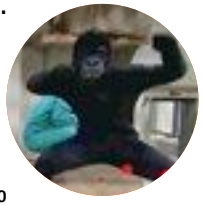
WHY SHOULD I CARE? This piece of Chinese research opens up the prospect of 'designer babies' – for good or ill.

WHAT'S NEXT? More research and hopefully some kind of international accord on the ethics involved in the editing of genes.

THEY DID WHAT?

A number of scientists took more unorthodox routes in their research in 2015…

APES WATCHED 'HORROR FILMS'



Kyoto University researchers showed two movies to apes. In the first, a person dressed as an ape leaps out from one of two doors. In the second, a person picks up a hammer and bashes the 'ape'. They used eye-tracking to see what was holding the apes' attention, then played the films again 24 hours later. When watching the first video for a second time, the apes watched the door from which they'd seen the 'ape' jump out. With the second video they stared at the hammer. This proved that apes can store and retrieve information in their long-term memories.

MUSIC COMPOSED FOR CATS

David Teie, a University of Maryland composer, wrote music specifically for cats. Cats approached and rubbed themselves on the speakers much more when they heard the feline compositions than when they were played classical music. The team says that species-specific music could be used to calm animals being kept in zoos or animal shelters.

CHEMISTS UNBOILED AN EGG

A team from the University of California figured out a way of untangling proteins in cooked egg whites and allowing them to refold, as if the egg had been 'unboiled'. First, they hard boiled the eggs. They then liquefied the cooked egg white with urea, before using a 'vortex fluid device' to apply forces to the tiny strands of protein in the white. This separated the proteins back to their clear form. Being able to reform proteins from yeast or E. coli bacteria may lead to better methods for making proteins, which could help create cheaper cancer treatments.

SOLE POWER

A team in Canada developed a new material that could make tumbles in winter a thing of the past. The material consists of rubber that's packed with tiny glass fibres. On dry surfaces it acts like normal rubber, but in icy conditions it offers greatly improved grip.

APR

NOT SO DARK

A Durham University team suggested that dark matter may n be so dark after all. They believe they found evidence of dark matte trailing behind its associated galax – suggesting the mysterious stuff is interacting with something othe than just gravity.

PHILAE WAKES UP

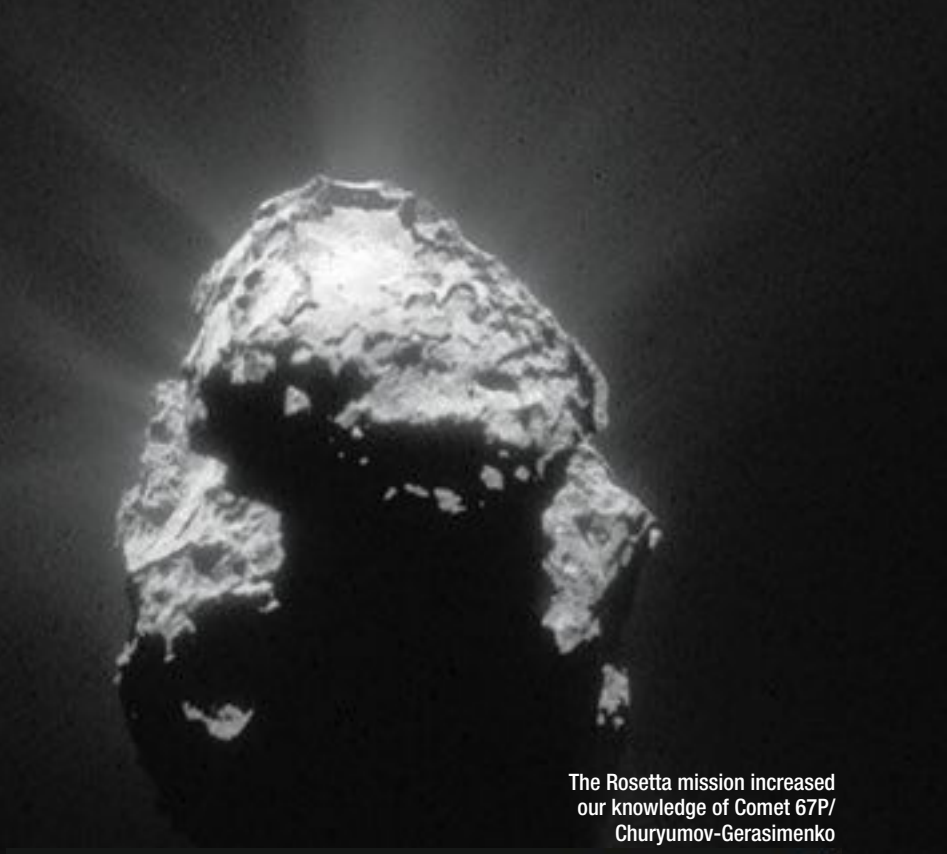
Landing the philae probe on Comet 67P/Churyumov-Gerasimenko was one of the biggest stories of 2014, with drama erupting as the probe's anchoring harpoon failed to attach, putting it in a slow motion bounce across the surface that left its solar cells shaded from the sunlight. For 60 hours, Philae was active, its 10 instruments sensing and drilling the surface of the comet, but then the probe ran out of power. As 67P continued in its orbit, chunks of the comet's surface were melted by the Sun, letting light reach the lander once more. And on 14 June, Philae's Twitter account carried the message "Hello Earth! Can you hear me?" Rosetta had detected a weak signal from its lander.

The initial link lasted for just two minutes, but was enough to establish that the systems had survived. At the time, the comet was around 215,000,000km from the Sun and 305,000,000km from the Earth, travelling at around 31km/s. Since then, another five contacts have been made with Philae, with the longest lasting around 18 minutes. The information from Philae has been sparse, but has at least enabled a study of the changes in surface temperature. Most surprising of all, analysis of the data revealed that there was oxygen present on the comet in small amounts. After July, Rosetta had moved too far from the comet to have any contact with Philae, though the orbiter has continued to provide information about 67P and may have had one more chance to receive data from the surface around the end of the year.

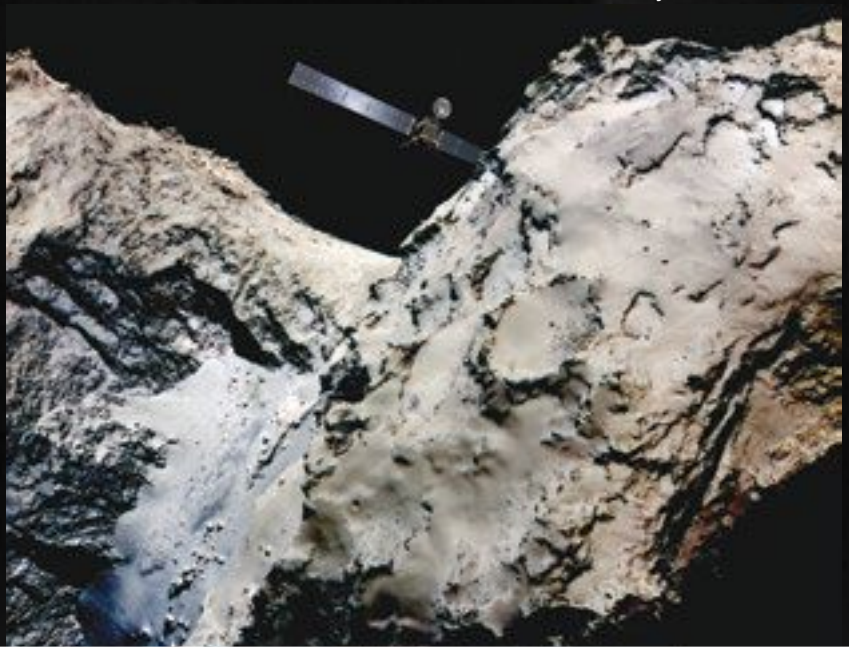
As for the lander, to quote members of the team, "If you, too, are wondering: will we hear from Philae again? Guess you will just have to wait and see."

WHY SHOULD I CARE? Because even if you have no interest in astronomy, landing on an object whizzing through space at a top speed of 135,000km/h is mightily impressive.

WHAT'S NEXT? NASA scientists will be analysing data sent back by Philae for several years yet – new



The Rosetta mission increased our knowledge of Comet 67P/ Churyumov-Gerasimenko



NASA/JPL-CALTECH X3, FWS/US FISHERIES, KRIS KRUG/FLICKR, ANDY ZHANG, CERN

JUN

BACK IN THE GAME

The Large Hadron Collider was switched back on after a two-year break. During that time, the particle accelerator underwent a major upgrade, doubling the energy of its beams so that it can now collide particles at higher energies.

PAIN-FREE JABS

Students at Rice University, USA developed a new way of giving injections. The device is placed against the skin for 60 seconds while an endothermic (heat-absorbing) reaction occurs inside it, numbing the area so a jab can be given painlessly.

PLUTO'S LANDSCAPE REVEALED

When the new Horizons probe launched in January 2006, it received little media coverage. Yet in 2015, after travelling nearly five billion kilometres, this 478kg spacecraft, around the size of a piano, captured everyone's imagination with its stunning images of Pluto. After picking up speed with a slingshot manoeuvre around Jupiter in early 2007, the probe hurtled towards the outer reaches of the Solar System at speeds that peaked at 80,000km/h, yet it took another seven years to reach its destination.

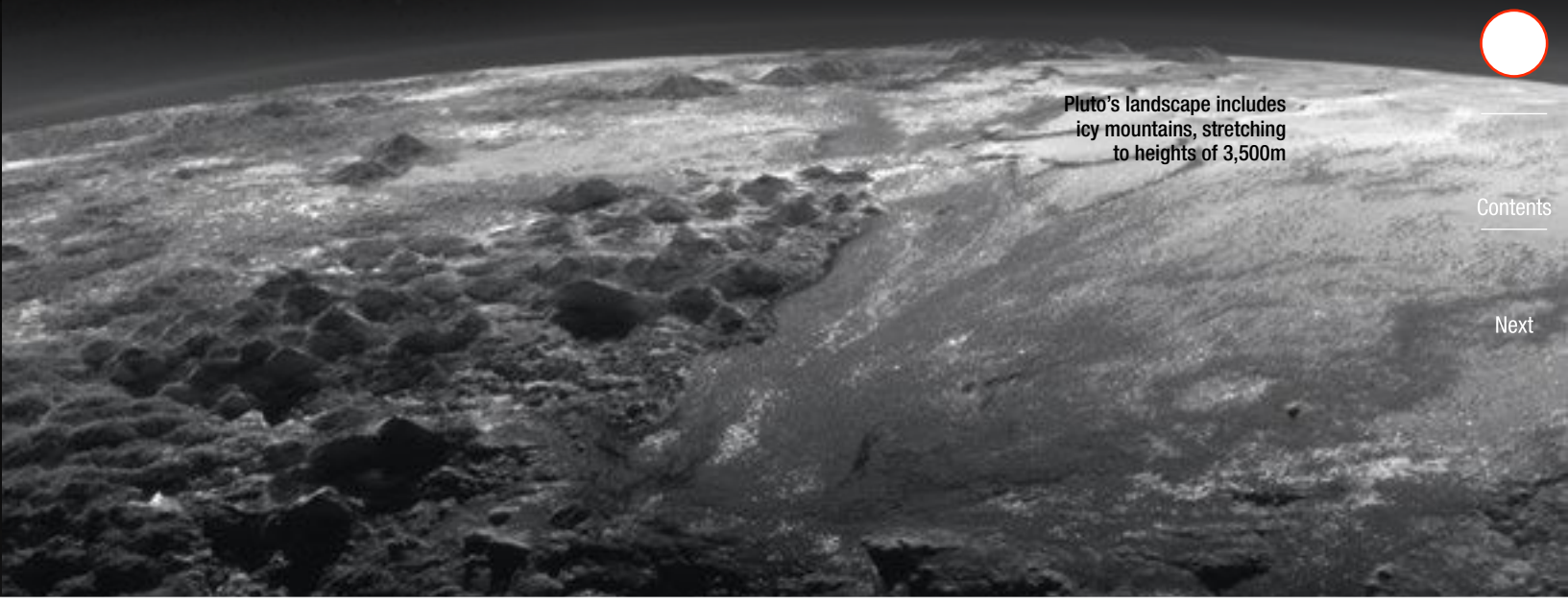
In January, New Horizons sent back the first photographs of Pluto and its main moon Charon, showing them as fuzzy dots. By May, features were beginning to appear in the images, along with Pluto's smaller moons, Nix, Hydra, Styx and Kerberos.

On 14 July the probe made its closest flyby, around 12,500km above Pluto's surface, providing remarkably detailed images of the dwarf planet's topography. Among the discoveries was a large, heart-shaped feature measuring around 1,600km across. New Horizons Principal Investigator Alan Stern commented: "My prediction was that we would find something wonderful, and we did." Despite the complexity of its journey, the probe was just one minute behind its ETA. In October, New Horizons used a 25-minute blast of its thrusters to change course, heading another 1.6 billion kilometres out towards an object called MU69, in the distant part of this region of the Solar System known as the Kuiper Belt.

WHY SHOULD I CARE? Because our knowledge of our own Solar System is still far from complete, and this is a significant new piece in the puzzle.

WHAT'S NEXT? Now that New Horizons has 'done' Pluto, it's moving on to the Kuiper Belt, and should arrive there in 2019.

Pluto looked completely different to how it had previously been visualised



Pluto's landscape includes icy mountains, stretching to heights of 3,500m

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DINO CRAZY

The arrival in cinemas of *Jurassic World* in June saw the world go briefly dinosaur-mad. The result was a short-lived publicity boom for the likes of Dr Beth Shapiro at University of California Santa Cruz and others looking the possibility of reviving long-extinct species.

BYE BYE, BIG CAT

On 16 June, the US Fish and Wildlife Service declared the eastern cougar (*Puma concolor couguar*) extinct. But don't be too upset: there hadn't been a confirmed sighting since the 1930s, and not all zoologists acknowledged the subspecies in any case.

BLACK-FOOTED FERRET SAVED FROM EXTINCTION BY FROZEN SPERM

There is much talk of reviving extinct animals such as mammoths from frozen DNA. While this is still some way from being possible, 2015 saw an endangered species put on the road to recovery using decades-old frozen sperm.

The black-footed ferret, a North American mammal, was already in severe danger of extinction when 18 of them were put in a captive breeding programme back in the 1980s. The sperm of six ferrets, including that of one called 'Scarface', was frozen. Then in August this year, Scarface became a donor father, even though he died around 20 years ago. The frozen sperm was successfully used by American zoos and the Smithsonian Institute to artificially inseminate living females, therefore improving the species' chance of survival by boosting genetic diversity in the tiny population. By adding fresh genes, the risk from inbreeding has been reduced.

The current breeding programme has helped the ferrets reach a population of around 300.

WHY SHOULD I CARE? The technique pioneered in black-footed ferrets could be used to help save other endangered species.

WHAT'S NEXT? A more concerted global effort to build biobanks of animal sperm and eggs looks increasingly like the smart move.

Frozen sperm has helped secure the future of the black-footed ferret

QUANTUM TELEPORTATION RECORD SMASHED

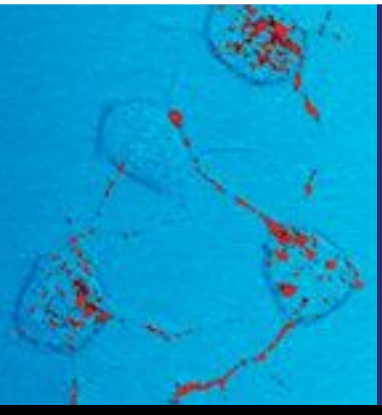
Quantum entanglement took a big step forward this year. In this small-scale version of a *Star Trek* transporter, properties of a quantum particle are transferred to another remote particle. The remote particle becomes indistinguishable from the original. This is only possible using a mix of the spooky connection of entanglement and conventional data transfer. The US researchers achieved teleportation along a 100km optical fibre link, four times the previous record. Teleportation keeps the data intact, which is crucial for quantum computers and quantum encryption.

WHY SHOULD I CARE? It could lead to unbreakable encryption – no more hacked bank accounts!

Scientists used these crystals in the process of teleporting photons of light

WHAT'S NEXT? Chinese researchers are planning a long-distance communication experiment that will teleport particles between satellites in the next couple of

SMITHSONIAN CONSERVATORY BIOLOGY INSTITUTE, GETTY, SCIENCE PHOTO LIBRARY X2, BARTEK WACLAW/MARTIN NOWAK, BRIAN LEANDER/GREG GAVELIS, PHIL/US GOVERNMENT



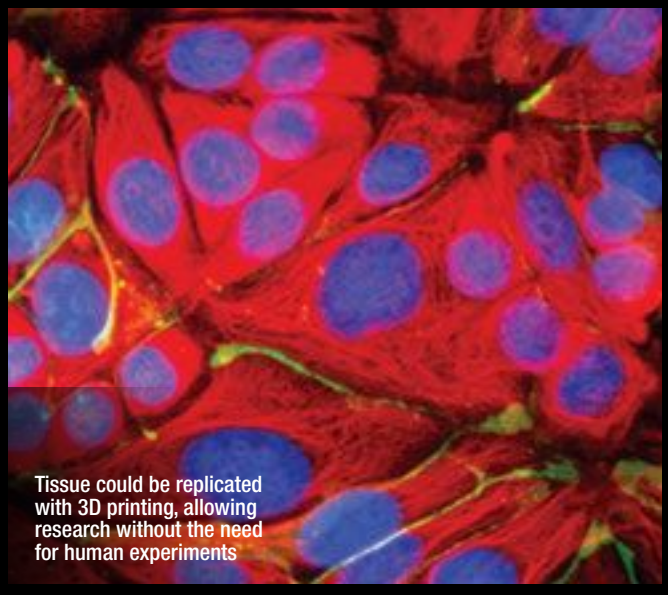
CANNIBAL CLUE

Papua New Guinea's Fore tribe, who ate human brains until the 1950s, have developed a natural resistance to kuru, a form of encephalopathy. Understanding how this new-found immunity developed could lead to treatments for CJD, Alzheimer's and Parkinson's disease.

JUL

TINY EYES

Warnowiids are tiny, single-celled marine creatures – yet in July it was discovered that their bodies contain a structure that's remarkably similar to the human eye. It demonstrates that natural selection can reach a single design through different evolutionary paths.



Tissue could be replicated with 3D printing, allowing research without the need for human experiments

SCIENTISTS CREATED 3D PRINTED HUMAN TISSUE

Experimental 3d printing of human tissue has been underway for some years, but 2015 saw real breakthroughs. A team from the University of California, San Francisco used a revolutionary technique called DNA Programmed Assembly of Cells to produce tiny models of living structures containing several hundred cells.

Within a decade it could be possible to build a living model of a cancer patient's affected organ, which could be used to test drugs for side effects.

WHY SHOULD I CARE? It opens up a world of research possibilities, without the need for human experiments.

WHAT'S NEXT? Longer term, it could be possible to grow complete organs, which would slash the length of transplant waiting lists.

The new technique called DNA Programmed Assembly of Cells used tiny 'biobricks', not unlike Lego, to build human tissue

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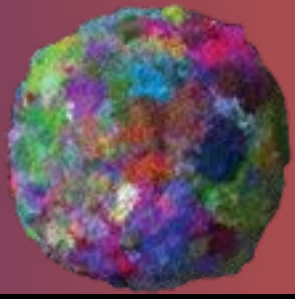
AUG



BATTLING CANCER

Scientists at Harvard, Johns Hopkins and Edinburgh produced the first 3D computer model of how tumours grow and mutate. It's hoped the model will enable more effective treatments.

ORIGINS OF LIFE

Japanese researchers modelling the effects of high-power collisions on amino acids found that such impacts could trigger the production of peptides – suggesting that a comet impact may have been the spark that ignited life.

LIQUID WATER FOUND ON MARS

It has been known for some time that there was water on Mars, notably in the polar ice caps. However, Mars has a combination of a very low atmospheric pressure – which means that any liquid water quickly evaporates – and an average surface temperature of around -63°C, making liquid water unlikely to form in the first place. It was, then, a major surprise when NASA announced evidence that there is flowing liquid water on the surface of the planet.

While no water was observed on the move, scientists found dark, narrow streaks a few hundred metres long, running down gulleys, which appeared to 'ebb and flow over time'. These are likely to have been produced by flowing water, especially as hydrated salts have been discovered on those slopes. These chemical compounds containing water are likely to have formed while liquid water was present.

The deposits were discovered by the Mars Reconnaissance Orbiter. This craft uses an imaging spectrometer, which detects the presence of different chemical structures from the light reflected by them. If the compounds were dissolved in the water they would lower the freezing point, in the same way that salt does when spread on ice, enabling the water to stay liquid despite being well below 0°C. As NASA's John Grunsfeld put it, "Our quest on Mars has been to 'follow the water' in our search for life in the Universe." This discovery will provide an important focus for future attempts to find life on Mars.

WHY SHOULD I CARE? The presence of water makes the presence of life – of some kind, at some point – a much more viable proposition.

WHAT'S NEXT? We're getting to a point where probes and landers have told us all they can about Mars – now we need to actually go there.

NASA/JPL-CALTECH X3, NATIONAL GEOGRAPHIC MAGAZINE, GETTY X7, ISTOCK X2

OCT

ALONE AFTER ALL?

New research published in October suggested that while there may be millions of Earth-like planets, Earth itself is one of the oldest – and that most habitable planets have yet to be formed. So no aliens will be arriving soon…

NOV

INSIDE JOB

French football team FC Nantes revealed that it has been tracking players' internal temperature during matches using an ingestible pill that sends data to a nearby receiver. They were researching the effects of ice therapy on recovery times.

HUMAN-LIKE SPECIES DISCOVERED

The discovery of a new human species is bound to make news, but it takes time to go from finding fossils to a clear scientific result. It was back in late 2013 that a team led by Lee Berger of Witwatersrand University, South Africa, followed up a sighting by cavers in a concealed chamber in the Rising Star cave system. The caves are around 29km from Johannesburg, in an area that has been given the nickname 'the cradle of humankind', as many fossils from early humans have been found there.

In total, a remarkable 1,500 fossil fragments were removed from the cave, and this year the world discovered what they found. The bones made up the partial remains of 15 separate individuals of an early human species. *Homo naledi*, as the hominins have been called, appears to have walked upright and reached around 1.5m in height, but had hand and shoulder structures suggestive of spending considerable time in trees.

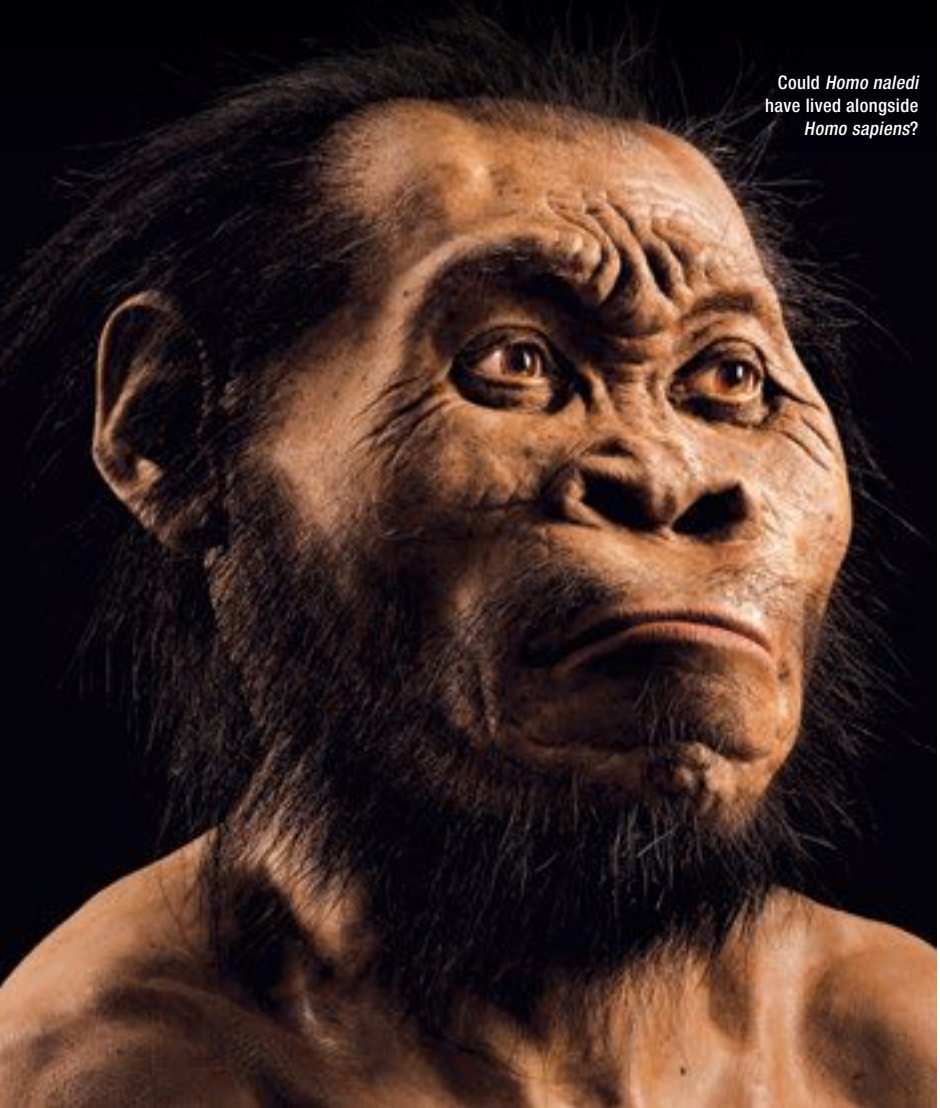
The skeletons had a mix of features, with a skull that suggested a brain around one-third the size of ours but with feet that looked surprisingly modern. The next step is to discover how old these bones are. *H. naledi* could be early humans, dating back two to three million years, or could be a relict that survived to coexist with *Homo sapiens*.

WHY SHOULD I CARE?

Because humankind's come a long way… aren't you curious to know how we got here?

WHAT'S NEXT?

The exact age of the *H. naledi* still needs to be verified, so that's the priority right now.



Could *Homo naledi* have lived alongside *Homo sapiens*?

BEST OF THE REST

2015 wasn't the only great year for science…

1543 The publication of Nicolaus Copernicus's (pictured) *De Revolutionibus Orbium Celestium* and Andreas Vesalius's *De Humani Corporis Fabrica* revolutionise the worlds of astronomy and medicine.

1846 US dentist William Morton pioneers the use of general anaesthetic, while in Germany, Johann Gottfried Galle and Heinrich Louis d'Arrest are the first to identify the planet Neptune.

1907 Leo Baekeland (pictured) invents Bakelite, the first synthetic plastic, while Ivan Pavlov conducts his experiments regarding conditioning.

1913 Our understanding of the elements leaps forward, thanks to Henry Moseley defining atomic numbers and Niels Bohr (pictured) coming up with a new model for atomic structure.

1917 Ernest Rutherford (pictured) splits the atom, spawning the discipline of nuclear physics. In France, US army surgeon Oswald Hope Robertson pioneers the use of blood banks.

1927 Werner Heisenberg lays the foundations for quantum mechanics with his uncertainty principle. That year, the first transatlantic telephone service is also introduced.

1953 James Watson and Francis Crick describe DNA. The Miller-Urey experiment shows how the first amino acids may have formed.

1961 Russia's Yuri Gagarin (pictured) becomes the first man in space. Back on Earth, the World Wildlife Fund is established by biologist Julian Huxley and ornithologist Peter Scott.

1967 At Cambridge University, Jocelyn Bell Burnell discovers the first pulsar. And speaking of things that pulse, South African surgeon Christiaan Barnard carries out the first human heart transplant.

1985 A hole is identified in the ozone layer over Antarctica by Farman, Gardiner and Shanklin. In the US, a team led by Howard Kroto discover the buckyball molecule.

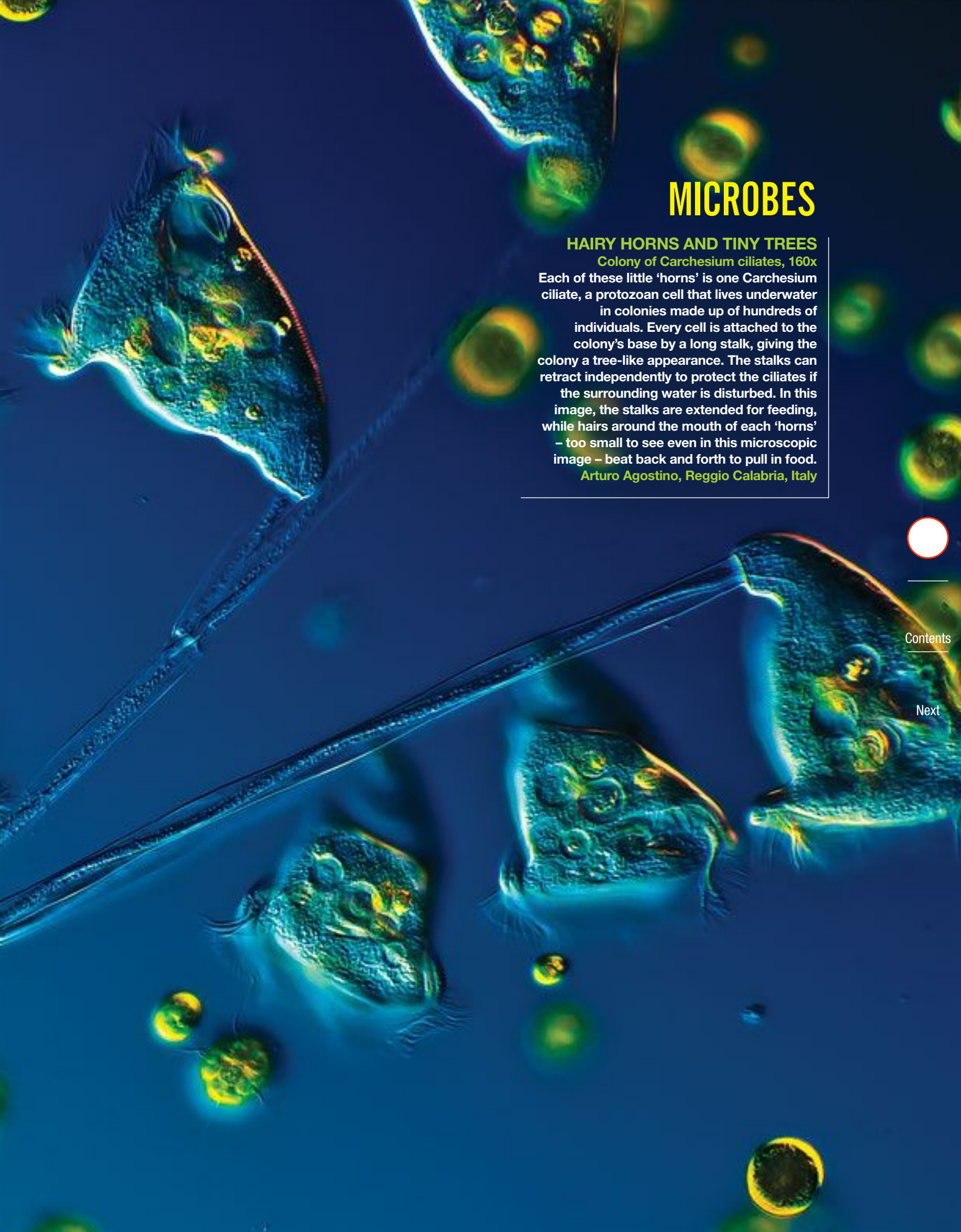
Brian Clegg is a science writer and author, whose most recent book is *Science For Life*.

PORTFOLIO

It's a SMALL *World*

Since 1975, the annual Nikon Small World competition has celebrated the art and science of photomicrography – taking pictures through a microscope. 2015's winners were announced in October, and the top 20 images chosen by the judges will now go on a tour of museums and science centres worldwide. Here, we present *BBC Knowledge's* own selection of some of this year's most striking images…

WORDS: CATHERINE E OFFORD



MICROBES

HAIRY HORNS AND TINY TREES

Colony of Carchesium ciliates, 160x

Each of these little 'horns' is one Carchesium ciliate, a protozoan cell that lives underwater in colonies made up of hundreds of individuals. Every cell is attached to the colony's base by a long stalk, giving the colony a tree-like appearance. The stalks can retract independently to protect the ciliates if the surrounding water is disturbed. In this image, the stalks are extended for feeding, while hairs around the mouth of each 'horns' – too small to see even in this microscopic image – beat back and forth to pull in food.

Arturo Agostino, Reggio Calabria, Italy

MINERALS

SHOOTING STARS

Twinned crystals of 4,4'-dibromobiphenyl, 25x

This otherworldly scene shows tiny crystals of a chemical known as dibromobiphenyl. Here, molecules of the substance have spontaneously self-organised into regular star patterns, coloured in this image using polarised light. The brominated biphenyl group of chemicals to which dibromobiphenyl belongs were once used widely in flame retardants, pesticides and plastic manufacturing. These days, however, its commercial use is limited due to uncertainty surrounding the health risks associated with it.

Dr Ryoji Tanaka, Kanagawa, Japan

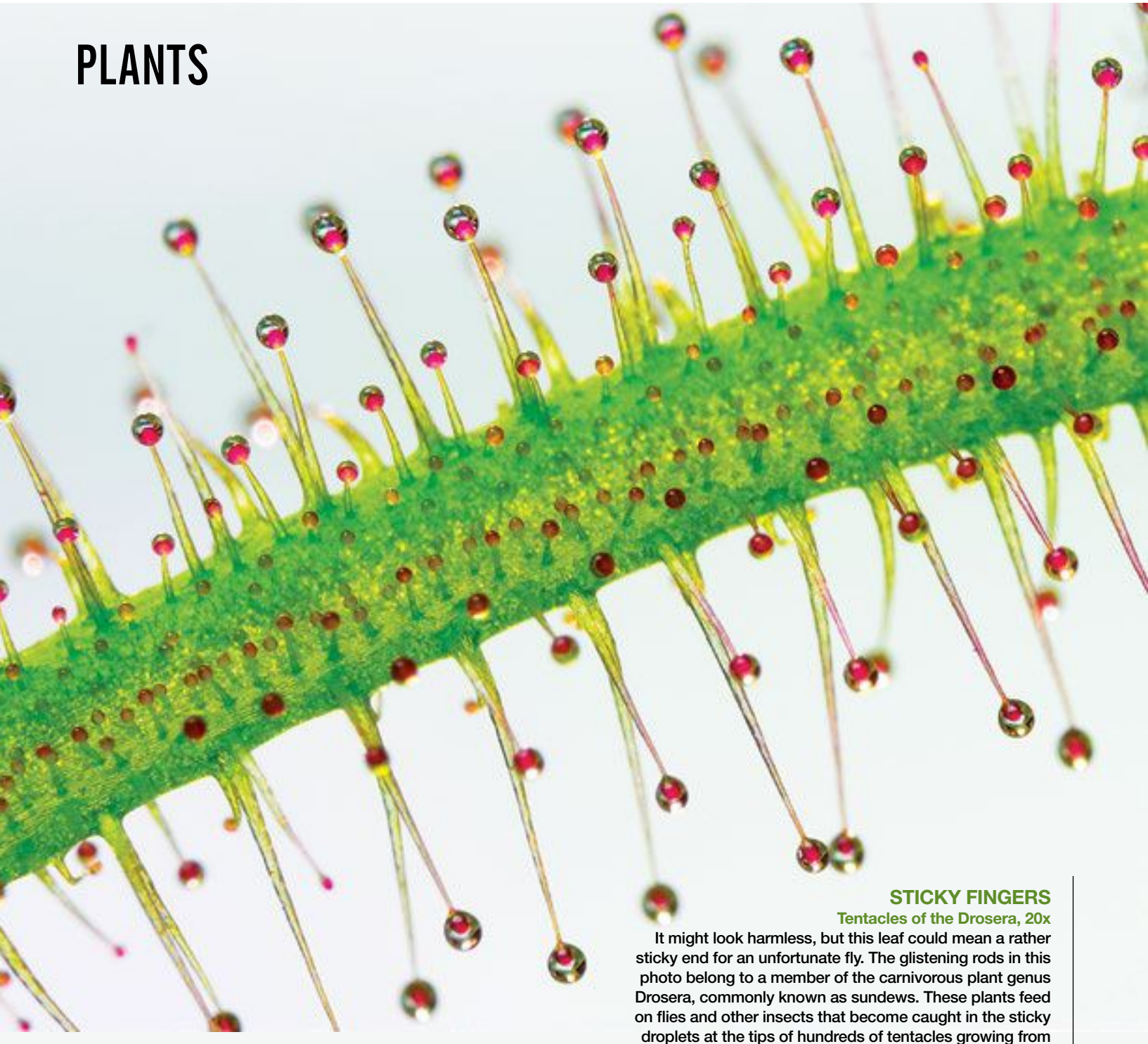
BAND OF CODE

Numerical traces on a Blu-ray disc, 100x

High magnification disguises a familiar object in this abstract artwork. The black and yellow bands in this image come from a Blu-ray disc, where they act along with an alphanumeric key (not shown) as a unique barcode, allowing distributors to identify individual copies of a disc. The 'blu' section of the Blu-ray contains the data, such as the movie stored on the disc. The striking colours in this image were achieved with angled lighting using optical fibres.

Massimo Brizzi, Empoli, Italy

PLANTS



STICKY FINGERS

Tentacles of the Drosera, 20x

It might look harmless, but this leaf could mean a rather sticky end for an unfortunate fly. The glistening rods in this photo belong to a member of the carnivorous plant genus Drosera, commonly known as sundews. These plants feed on flies and other insects that become caught in the sticky droplets at the tips of hundreds of tentacles growing from their leaves. The tentacles are extremely sensitive and can bend to bring trapped insects closer to the leaf as they're slowly digested, after which the nutrients are distributed through the rest of the plant.

José Almodóvar, Biology Department, University of Puerto Rico, USA

RELEASE THE SPORES

Spore capsule of a moss, magnification unspecified

Behold the biological storage solution of a Bryum moss. This 'capsule' sits atop a long stalk that raises it above the rest of the ground-hugging plant. When the time is right (that is, when the air isn't too wet), the tentacle-like canopy retracts to release thousands of reproductive spores stored in the capsule. The spores are dispersed through the air by the wind and those that land in damp, favourable soil will go on to make new mosses.

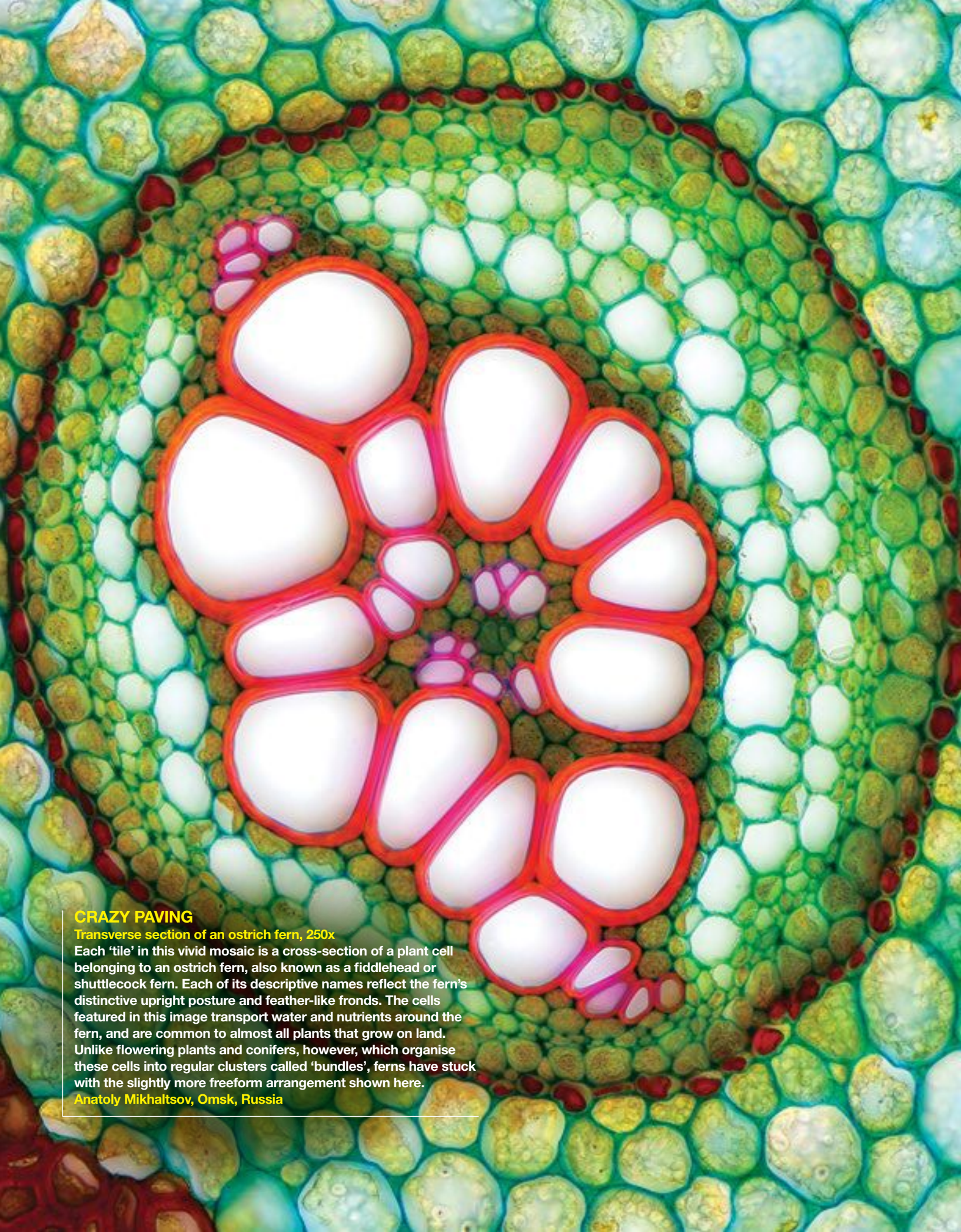
Henri Koskinen, Helsinki, Finland

GEMSTONE TERRINE

Fairburn agate from the Black Hills of South Dakota, 63x

The orange bands in this image are from Fairburn agate, a gemstone made of silica (silicon and oxygen). Named after a small town in South Dakota where it is commonly found, the stone is richly coloured by impurities in the rock. Rusty oranges like this are often caused by iron oxides. The largest intact specimens weigh over 20kg and the stone is so popular among collectors that South Dakota named Fairburn agate its 'state gemstone' in 1966.

Douglas Moore, University of Wisconsin, Wisconsin, USA

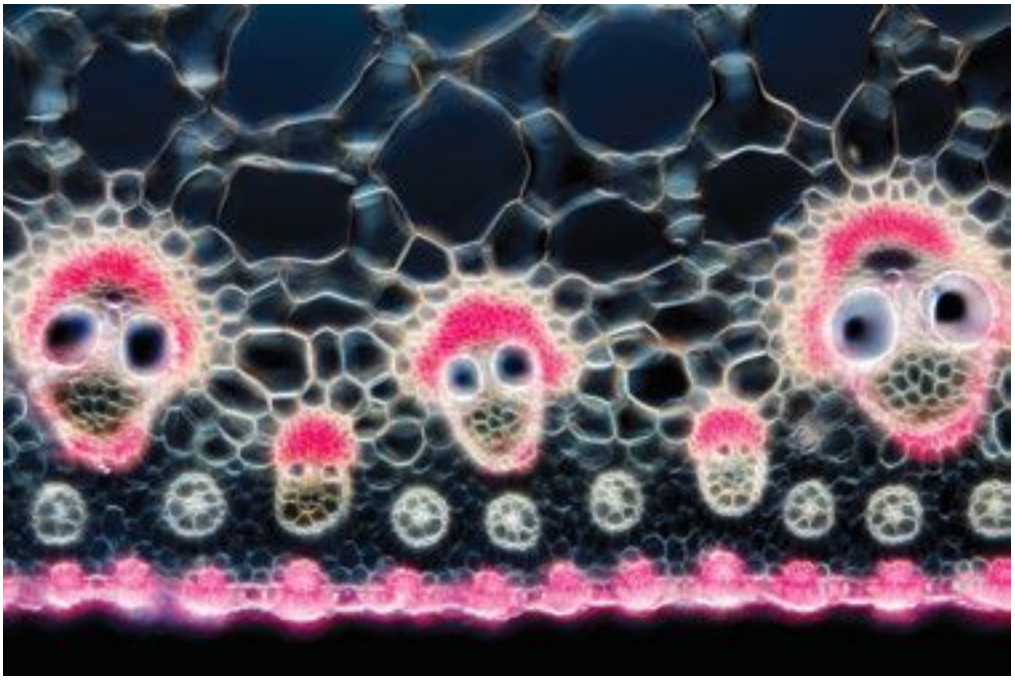


CRAZY PAVING

Transverse section of an ostrich fern, 250x

Each ‘tile’ in this vivid mosaic is a cross-section of a plant cell belonging to an ostrich fern, also known as a fiddlehead or shuttlecock fern. Each of its descriptive names reflect the fern’s distinctive upright posture and feather-like fronds. The cells featured in this image transport water and nutrients around the fern, and are common to almost all plants that grow on land. Unlike flowering plants and conifers, however, which organise these cells into regular clusters called ‘bundles’, ferns have stuck with the slightly more freeform arrangement shown here.

Anatoly Mikhaltsov, Omsk, Russia



PEERING OUT

Vascular bundles of Cyperus papyrus, 200x

These creepy little faces pop out of the cross-section of a papyrus plant, popularly known for its use as a source of paper in Ancient Egypt. Some plant cells in this image have been lit in pink using a microscopic imaging technique known as 'differential interference contrast', which uses polarised light to exaggerate small differences in lighting and colour in transparent objects. Each 'face' outlines a plumbing feature known as a vascular bundle, present in most terrestrial plants, which carries water and nutrients around the roots, stems and leaves.

Dr David Maitland, Feltwell, United Kingdom

CRYSTAL FINGERPRINT

Chiral thermotropic liquid crystal, 20x

This image shows not an aerial view of the world's most fiendish hedge maze, but the spiralling patterns formed by a liquid crystal. Crystals like this one are said to be 'thermotropic' – that is, they only exist within a certain range of temperatures. Too cold and the mixture forms a glass-like solid. Too hot and the delicate structures break down. Here, the temperature of the crystal is just right, causing it to form arms and threads that spiral around each other in mind-bending patterns.

Dr Giuliano Zanchetta, Dept of Medical Biotechnology, University of Milan, Italy

Catherine E Offord writes about the environment and nature, and contributes to publications like *BBC Focus* magazine.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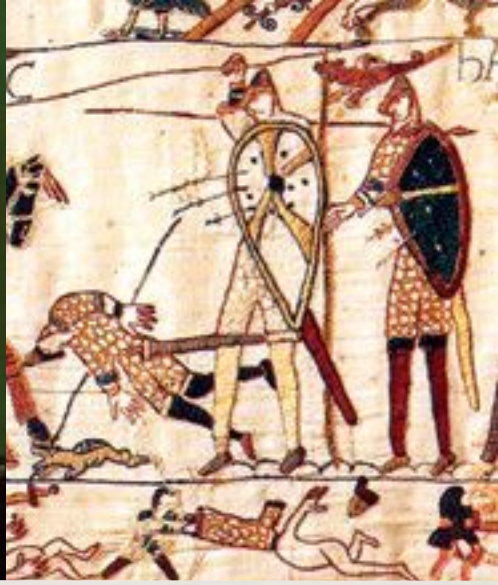
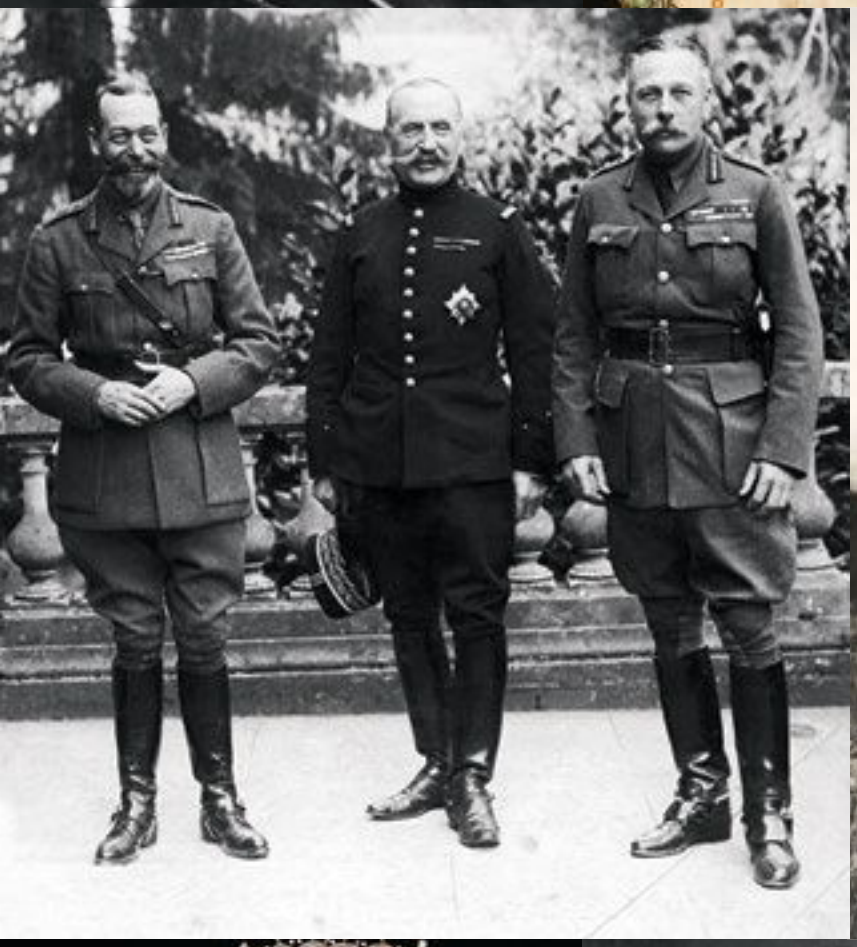




The New Year's resolutions they *should* have made…

Leading historians reveal how pivotal years in the lives of eight major figures – from Anne Boleyn to Josef Stalin – could have turned out better, if only they'd have resolved to change their ways

Compiled by Matt Elton

AKG-IMAGES/BRIDGEMAN/GETTY

1946 *Josef Stalin*
"I'll work with my allies"

In the year following the end of the Second World War, Stalin should have resolved to work more closely with his erstwhile allies. Aged 67 in 1946, he was set in his ways but, like Lenin, capable of shrewd calculation. In the 1930s he had attempted detente with the western democracies. He could have done so again.

Seven months had passed since the defeat of Germany. Much goodwill towards the Soviet Union remained in the west, where the Red Army's soldiers were seen as liberators. The security of the USSR was greater than in 1941, with a powerful Red Army. The Soviet Union, as Stalin himself put it, had passed a crucial "examination". Victory built a stronger base of popular support at home than ever before.

Instead, Stalin wasted the opportunity. The USSR tightened its grip on eastern Europe, creating a permanent friction in its relations with the west. An arms race, meanwhile, swallowed massive amounts of money, while living standards stayed low. The over-emphasis on heavy industry continued – an economic model that would lead to repeated crises and, in the end, to the collapse of Stalin's system.

Evan Mawdsley has written widely on Soviet history. A new edition of his *Thunder in the East: The Nazi-Soviet War, 1941-1945* has just been published by Bloomsbury.

A tinted photograph of Josef Stalin from c1946. Having played a decisive role in defeating Hitler, he was in a position to cement relations with the west – but didn't

General Sir Douglas Haig (right) meets King George V (left) and French marshal Ferdinand Foch in August 1916. Haig's resolution to recognise ability above status was crucial

1916 *Douglas Haig*
"I'll transform the Tommies"

In January 1916 Douglas Haig – who had been commander-in-chief of the British Expeditionary Force for less than a month – should have resolved to devote more time to sorting out the BEF's training.

As 1915 turned into 1916, there was no centralised body devoted to examining the lessons of the fighting, using them to inform doctrine, and then training the army accordingly. Unfortunately, Haig did not prioritise training, and it was not properly reformed until early 1917.

However, we know from his diary that Haig did make one resolution, and that was to promote the best talent – regardless of whether he got on with them or not. "I had no 'friends' when it came to military promotion, and I would not tolerate a 'job' being done."

In 1916, Haig largely stuck by this resolution. He had an uneasy relationship with General Sir Henry Rawlinson, whom Haig thought was devious and lacking in integrity. Yet Haig recognised 'Rawly's' skill as a soldier, and gave him the lead role on the Somme in July 1916. Rawlinson's record at the Somme was patchy, but he grew into the job and proved a highly effective commander in the victorious 1918 campaigns.

Gary Sheffield's biography of Haig is set to be revised and republished as Douglas Haig: From the Somme to Victory by Aurum Press in 2016.

1586 *Elizabeth I*
"I'll name James VI as my heir"

The question of who would succeed Elizabeth I was a thorny one – and her new year's resolution of 1586 should have been to settle the issue by naming James VI of Scotland as her heir. The two monarchs had endured a fraught relationship over the previous six years, but by then they were negotiating a treaty of alliance, and James desperately wanted a guarantee that he was next in line for the English throne to be included among its terms.

Though there was a danger that the king might engage in plots against Elizabeth to hasten his accession, it was more likely that he would wait patiently for her death, secure in the knowledge that his right was formally recognised in England. But Elizabeth resisted the pressure. As a result, Anglo-Scottish conflicts and tensions continued after the Treaty of Berwick was signed in July 1586, and political and religious uncertainty marked the final decade of Elizabeth's reign.

Elizabeth's refusal to make provision for the succession also harmed her reputation both at the time and since. For a queen who purported to care deeply for her subjects, it showed a remarkable insensitivity to their fears and concerns.

Susan Doran is a senior research fellow in history at Jesus College, Oxford, specialising in the reign of Elizabeth I.

A portrait of Queen Elizabeth I, painted by Federico Zuccari around 1586 when she was 53 – too old to produce an heir. Instead, she should have confirmed the succession of James VI of Scotland

A political badge backs Roosevelt during the presidential election year 1936. He won a record four elections as Democrat leader

1936 *Franklin D Roosevelt*
"I'll respect the political system"

As President Franklin Delano Roosevelt contemplated the start of presidential election year, he would have been well advised to resolve to respect the place of the US supreme court in political life.

In the 1936 election, FDR convincingly defeated his Republican opponent Alfred Landon. By then, the American people were willing to credit the sitting president with ameliorating mass unemployment and providing leadership in intensely troubled economic times.

However, Roosevelt's post-election plan to pack the court with his supporters – FDR requested congressional authority to appoint a new supreme court member for every justice aged over 70 and who had served for at least 10 years – was a step too far. Roosevelt was transparently seeking to shore up his liberal New Deal legislation against conservative judicial action.

The reform plan failed, and instead brought together conservative Democrats, civil-liberty advocates and Republicans in opposition to the president and to the later New Deal. Though judicial opposition to the New Deal was soon in retreat, the 'packing' plan was conceived in hubris and executed with an uncharacteristic high-handedness that caused significant damage to Roosevelt's presidential reputation.

John Dumbrell is professor of government at the University of Durham's School of Government & International Affairs.

1016 *Cnut*

"I'll roll the dice and head for London"

At the start of 1016, Cnut was a landless Viking prince with the English kingdom in his sights. By the end of 1016 he was established in London as ruler, and his rival, King Edmund Ironside, was dead – but getting there had involved a hard fight. Cnut could have saved himself a great deal of trouble if he'd made a dash for England's principal city sooner.

Edmund's father, King Æthelred ('the Unready'), had begun the year in London, where the English army was calling vainly for him to lead it. Cnut had received supplies from the royal heartland of Wessex in 1015, so was in a good position to strike. However, during the spring of 1016 his attention was taken by affairs in the north of England.

It seems that Æthelred was ill. If Cnut had known that, and headed straight for London, he might have invoked his legitimacy as the son and heir of the Anglo-Danish king Sweyn Forkbeard (who ruled 1013–14), and applied pressure on Æthelred.

As it happened, Æthelred died before Cnut arrived in London in April, but the delay allowed Æthelred's son to declare himself king. That meant that Cnut had to fight, before making peace with Edmund. It was only thanks to Edmund's sudden death at the end of 1016 that Cnut avoided the complications of a kingdom ruled by rival kings.

Ryan Lavelle is a reader in medieval history at the University of Winchester.

A silver penny from the reign of England's Viking king, Cnut

A portrait thought to be of Anne Boleyn, by an unknown artist. She might have escaped her execution if she had appeased Thomas Cromwell

1536 *Anne Boleyn*

"I'll make friends with Cromwell"

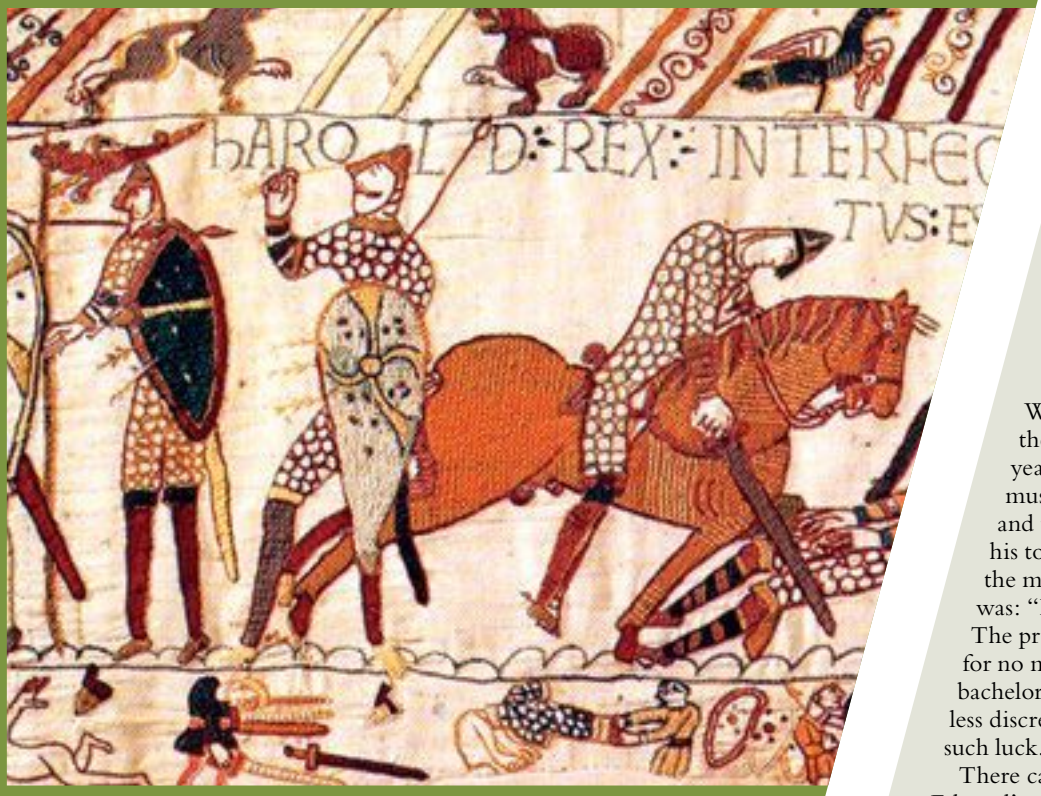
Anne Boleyn would have been glad to see the back of 1535, which had been something of an annus horribilis for Henry VIII's second queen. There is evidence to suggest that she had suffered a second miscarriage in early summer; her marriage was rapidly deteriorating; and she was increasingly at loggerheads with the king's chief minister, Thomas Cromwell.

Though Cromwell had helped Anne secure Henry's hand and shared her reformist tendencies, they had fallen out badly over the Dissolution. Anne had argued that funds from the monasteries should be diverted to charitable causes rather than to the royal coffers, as Cromwell had arranged. She had made no secret of the fact that she "would like to see his head off his shoulders".

By the end of 1535, though, Cromwell was by far the most powerful man at court and, crucially, had the king's ear. When Henry instructed his chief minister to get him out of the marriage after Anne's miscarriage early the following year, Cromwell used this as an opportunity to get rid of her for good. He concocted a case of adultery – involving not just one but five men, including her own brother – and she was condemned to death.

If Anne had made it her new year's resolution to forge an alliance with Cromwell in 1536, it might have saved her life. The ever-resourceful minister could have applied his brilliant legal mind to having her marriage to the king annulled. He might even have persuaded Henry to give Anne a second chance.

Tracy Borman is a historian whose new book, *The Private Lives of the Tudors*, will be published by Hodder & Stoughton in May.



The Bayeux Tapestry shows Harold's defeat at Hastings, which he might have avoided had he sat back and watched William struggle to feed his army

1066 *Harold Godwinson*
"I won't be so hasty"

During the first nine months of 1066, Harold did well – and his success was in large part because he'd stolen a march on his rivals. When Edward the Confessor died on 5 January, Harold immediately had himself proclaimed king, and was crowned the very next day. When his troublesome younger brother Tostig invaded in May, Harold hurried down to Sandwich to see him off, and when Tostig returned in September with the Norwegian king Harald Hardrada, Harold rushed north to surprise them at Stamford Bridge, winning a famous victory.

Naturally, therefore, when Harold heard soon afterwards that Duke William of Normandy had landed in Sussex, he thought that speed would be his friend, and sought to repeat his earlier success, hoping to catch William off-guard. But a swift engagement was precisely what his rival wanted. As invaders, the Normans had poor supply lines, and no local support of the kind that Tostig and Harald had enjoyed in the north.

Had Harold waited just a little longer, he could have assembled a larger army and watched as the Normans struggled to keep their army fed by foraging. Instead, he rushed into battle at Hastings – and looked up at precisely the wrong moment.

Marc Morris is a historian and author of numerous books including *The Norman Conquest* (Hutchinson, 2012).

1936 *Edward VIII*
"I won't marry Wallis"

With his father almost on his deathbed, the soon-to-be King Edward VIII's new year's resolution should have been: "I must marry a suitable wife, have children and thus ensure the succession." Given his total infatuation with Wallis Simpson, the most that could have been hoped for was: "I must not marry an unsuitable wife." The prime minister, Stanley Baldwin hoped for no more – he was resigned to serving a bachelor king with a mistress kept more or less discreetly in the background. He had no such luck.

There can be not the slightest doubt that Edward's resolution was, in fact: "I must marry Wallis, and marry her as soon as possible!" This was his all-consuming preoccupation – there was no room in his mind for any lesser issue.

Should Edward have resolved to remain a bachelor and kept Wallis in the background?

Philip Ziegler is a historian and author of the official biography *Edward VIII* (Harper, 2012).

ALAMY, GETTY/BRIDGEMAN

THE LANDS THAT MAN FORGOT

Rainforests were top of the agenda at this month's UN Climate Change Conference. But they're not the only ecosystems we ought to be protecting, as Jheni Osman reveals

Rainforests are the poster child for conservation. They're packed with charismatic wildlife and are essential for the health of the planet. Why wouldn't you want to try to save them? But they are not the only ecosystems playing a crucial role on Earth. For example, did you know that 450 billion tonnes of carbon is kept locked up by peat bogs? Or that the Sahara feeds the Caribbean with vital nutrients?

But because these ecosystems are less biodiverse than rainforests, they can be vulnerable to exploitation. And if we ignore their destruction, it could spell global ecological disaster. ▶

GETTY X2, ALAMY

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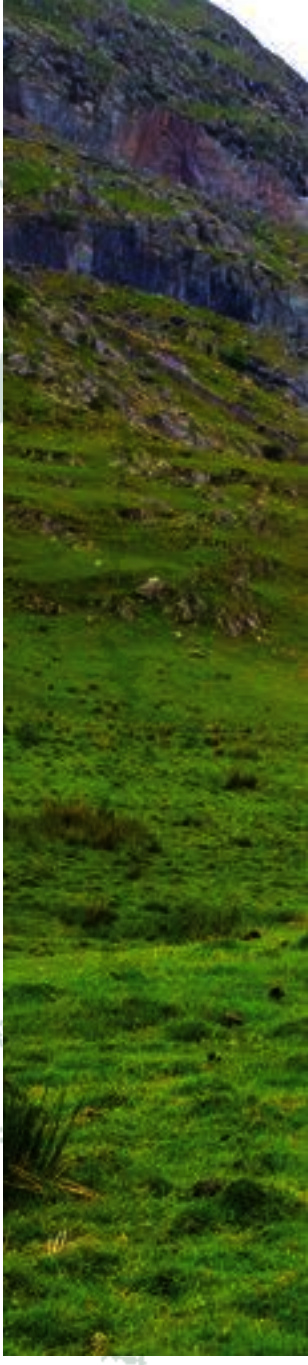
GRASSLANDS



We know that chopping down rainforests is like hacking away at Earth's lungs, so we need to protect trees and plant more of them. But experts say that poorly targeted tree planting can damage ancient grasslands and savannahs.

"As long as carbon stored in trees is valued above other ecosystem services, the conservation values of grassy biomes will remain threatened," says plant ecologist Dr Joseph W Veldman, from Iowa State University. "Threats can be direct in terms of financial incentives, such as carbon payments, and policies like fire suppression laws, which cause biodiverse grassy biomes to be replaced by low diversity forests or plantations. Then there are indirect threats – if forest is protected and/or an agricultural field is reforested, the burden shifts to unprotected, undervalued grassy biomes."

Soil stash

While boreal forests – those found at high northern latitudes – are the largest carbon store on the planet, temperate grasslands get the bronze medal. The UK Countryside Survey estimates that 660 million tonnes of carbon are stashed away in our grassland soils – about one-third of all soil carbon stocks in the country.

"It's vital we protect grasslands for carbon storage," says Susan Ward, Senior Research Associate at Lancaster Environment Centre. "Conservation value is not just for the plants we see, it's also for insect pollinators and for the soil communities beneath our feet."

Free-range meat and milk come from the likes of Daisy the cow, who lives off our grasslands. But many of our insect pollinators also live in this environment. Insects pollinate 80 per cent of all plant species in Europe, which is a service worth millions.

Before Europeans settled in the 'corn belt' state of Iowa, there were 125,000km^2 of tallgrass prairie. Today, less than 0.1 per cent of

GETTY X2

"Conservation value is not just for plants, it's also for insect pollinators and for the soil communities beneath our feet"

Susan Ward, Lancaster Environment Centre

FACT FILE: GRASSLANDS

34 per cent of terrestrial carbon is stored in grasslands all around the world.

60 per cent of newly forested areas in the EU were formerly permanent pasture or meadows.

Calcareous (chalky) grasslands are Europe's most species-rich plant communities, with up to 80 plant species per m^2.

UNESCO defines grasslands as 'land covered with herbaceous plants with less than 10 per cent tree and shrub cover'.

40.5 per cent of the Earth's surface is covered by grasslands.

There are lots of invertebrates living in this grassy field, along with the cow

Iowa's original grasslands remain. In the UK, over half the grasslands are 'agriculturally improved' to maximise yield. Species-rich grasslands, such as traditional hay meadows, have been decimated; less than 3 per cent of the original meadows are left.

After WWII ended, agriculture boomed with an injection of fertilisers, which reduced plant diversity and increased atmospheric nitrogen. The knock-on effect of higher nitrogen levels is a rise in grassland growth. This reduces species richness, which threatens biodiversity.

If losing the likes of the chirping cricket doesn't bother you, bear in mind that plants or beasts lurking in the long grass could help cure nasty bugs. Back in 2013, a new species of mushroom was discovered in the grasslands of Snowdonia. As some other mushroom species hold antibiotic properties, the discovery of *Entoloma eryriensis* put a stop to the construction of hundreds of new homes in the area.

Stopping construction locally is one thing. But how can we protect grasslands globally? "Global reforestation efforts should either constrain their 'restoration' to deforested lands or, if working in degraded grasslands and savannahs, incorporate key features of savannah-grassland restoration into their methods, such as prescribed fire," says Veldman.

Burning grasslands may sound counterintuitive, but fire is not a new phenomenon in grassy biomes and pre-dates humans by millions of years. There's even evidence of fire adaptation in some plants. The key is to tailor the fire treatment to the land. In low rainfall areas with lots of animals, fires should be spaced out over years or decades. Other areas need more frequent fires, otherwise they rapidly turn to shrublands or forests.

"Conservation agreements should recognise the important role that fire and large herbivores play in the maintenance of biodiversity and ecosystem services in many grassy biomes," says Veldman. "I hope that old-growth savannahs and grasslands can achieve the kind of public conservation and restoration support that forests have had." ▶

SWAMPS, BOGS AND MANGROVES

If the word 'wetland' conjures up memories of tramping through boggy ground, you may wonder why we should care about these places. Well, aside from being great habitats for many birds, amphibians and beneficial insects, wetlands could help us keep a lid on global warming.

Take the case of peat bogs. Formed over millions of years from moss, wood and dead plants, these swampy habitats can be vast – one the size of England was discovered in the Congo in 2014.

As decomposers can't survive in these wet, oxygen-poor conditions, organic matter doesn't get broken down. This means the carbon that was in the plants becomes trapped in the peat. Each square metre of peat can be packed with hundreds of kilograms of undecomposed organic matter. Research shows that about half of the peat in the northern hemisphere is made up of carbon, while up to 450 billion tonnes of the element is sequestered in peat bogs around the world – that's like stashing away 65 years' worth of our current carbon emissions from burning fossil fuels.

When peat bogs dry out, carbon is released into the atmosphere. Over the next few centuries, 40 per cent of carbon could be lost from shallow peat bogs and as much as 86 per cent from deep bogs.

Global warming won't just dry out peat bogs, it'll also cause frozen ones to thaw. Beneath the Arctic tundra lie more than 1,000 billion tonnes of carbon – double the human emissions since the Industrial Revolution. Man-made climate change has forced Arctic air temperatures to rise twice as fast as elsewhere around the planet, while permafrost temperatures have soared by 5.5°C since the 1980s.

While there have been fears that thawing permafrost could cause a sudden big 'belch' of methane and carbon dioxide to be released, recent research by the US Geological Survey found that it's more likely to be a gradual process. But the impact will be immense.

A so-called 'climate feedback loop' is what's really causing scientists to frown. If the permafrost warms up too much, some microbes will be able to decompose organic matter, releasing more greenhouse gases, warming the planet further and heating up the permafrost.

Water hero

Alarmed by a possible future of 'runaway global warming', some engineers are suggesting radical geoengineering solutions. But this could be too little too late. Permafrost is already thawing and what we've seen so far may just be the tip of the peat bog.

In warmer climates, mangroves are the unsung heroes of coastal habitats, storing up to four times more carbon than any other tropical forest. The secret lies in the mangrove's dense bundle of roots that anchors it in the water. Tidal water slows down as it hits the roots, reducing coastal erosion but also dumping organic material. Microbes don't decompose this material due to low-oxygen levels. Deforestation of these precious trees generates enormous amounts of carbon a year. Mangroves have a whole host of other benefits too. Not only has research shown that they protect sensitive corals from the threat of rising temperatures and ocean acidification, they've also been found to filter heavy metals and are a potential source for antibiotics.

Over the last 50 years, mangroves have been reduced by up to a half by deforestation. Sadly, protecting the habitat of the pygmy sloth or the mangrove cuckoo doesn't feature too highly on Señor's checklist when he can pull in the pesos by developing prime coastal real estate – while a wily government minister also lines their pockets.

If the little sloth doesn't tug at their heartstrings, hopefully the threat of coastal erosion and the loss of natural fish nurseries, and a pat on the back for hitting carbon emission targets, will persuade ministerial minds to give the thumbs down to new developments.

By understanding facts about ecosystems, such as drained wetlands give off the same amount of greenhouse gases as industry, some governments already see the benefits of protecting them. Over the last few decades, Sweden has built wetlands on land traditionally used for farming. Wetlands prevent surplus nutrients from leaching into lakes and oceans, protecting endangered frog and bird species. A study by Halmstad University shows that wetlands have been partly responsible for the little grebe and the little ringed plover being taken off the IUCN Red List.

The long and short of it is that wetlands are great carbon sinks, wonderful filters and a treasure trove for medicines – as well as being vital for native wildlife and local communities. ▶

FACT FILE: WETLANDS

50 per cent of wetlands have disappeared in the last century.

67 per cent of European wetlands that existed 100 years ago have been lost.

Since the 1950s, 84 per cent of peat soils have been lost in the UK due to drainage and extraction.

A quarter of the most important wetlands in Europe are threatened by groundwater overexploitation.

6 per cent of Earth's land area is wetlands.

REINHARD DIRSCHERL/FLPA, ALAMY

Lewis, in Scotland's Outer Hebrides, has a long tradition of using peat for fuel

DESERTS

Empty. Endless. Lifeless. That's what springs to mind when you hear the word 'desert'. But there's more to deserts than meets the eye. And not all of them are hot, dry and dusty – Antarctica is a desert as it experiences less than 200mm of rainfall every year.

Climate change is playing havoc with Antarctica. Rising temperatures are creating wetter conditions, altering the soil and changing the carbon dioxide levels.

"A small increase in temperature can tip the ecosystem from frozen to melting, turning patches of desert into a wetland," says Prof Ross Virginia, Director of the Dickey Center's Institute of Arctic Studies at Dartmouth College in the US. "That makes the soil a very different kind of habitat for the organisms living there, and it can change the cycling of carbon and the release of carbon dioxide."

Desert deposit

Just like grasslands and wetlands, deserts are also great carbon stores. The Kalahari Desert in Botswana is full of drought-resistant cyanobacteria that fix atmospheric carbon dioxide. And recent research suggests that vast, hidden aquifers could be stashing carbon.

For years, scientists were baffled by the so-called 'missing carbon sink'. About 40 per cent of carbon emissions remain in the atmosphere, around 30 per cent get soaked up by the oceans and almost all of the remainder is absorbed by plants. But a tiny bit is leftover – so where does it go?

Researchers from the Chinese Academy of Sciences recently discovered a huge lake beneath China's Tarim basin that holds 10 times more water than the North American Great Lakes.

"Our definition of 'desert' may have to change," explains biogeochemist Yan Li from the Chinese Academy of Sciences.

"Atmospheric carbon is being absorbed by crops, released into the soil and transported underground in groundwater. These saline aquifers under the desert are covered by a thick layer of sand and will never return to the atmosphere, probably becoming carbonate rocks or salt mines. It's basically a one-way trip. The nice side of this story is that this carbon sink is enhanced by human activities – irrigated farming speeds up carbon dioxide absorption."

While sandstorms were a pain in the backside for Lawrence of Arabia, desert dust is vital for many ecosystems. The AERONET project is a series of ground-based monitoring stations around the globe, which measure atmospheric aerosols. When dust is blown from the Sahara over the Iberian Peninsula, researchers have found that less radiation reaches Earth's surface than normal. Hence, desert dust cools the planet.

Saharan dust can be blown even further afield than Spain. In fact, it's known to travel across the Atlantic to the Caribbean. Once there, it supports plants with nutrients when levels are low in the ocean. Meanwhile, dust from deserts in Mongolia and northern China is blown as far away as the Pacific Ocean, where phytoplankton survive on the iron-rich dust.

"If there are changes in desert size or in the way people use land, there could be a greater source of dust to the Pacific," says Chris Hayes, from MIT's Department of Earth, Atmospheric and Planetary Sciences (EAPS). "It's difficult to predict, but larger deserts could produce a greater source of dust to the ocean, which could potentially increase the growth of certain phytoplankton groups."

The carbon fixed by phytoplankton is absorbed by larger organisms feeding on the algae. Working its way up the food chain, carbon gets 'packaged' into larger particles, including faecal pellets, which sink down into the deep ocean. So phytoplankton growth is important for regulating Earth's climate.

"By increasing phytoplankton growth, dust could have a positive impact on the climate by drawing down atmospheric carbon dioxide concentrations," explains Hayes.

All this goes to show it's a mirage to think that deserts are empty vast plains or freezing wastelands that are only good for a *Top Gear* special. Deserts may appear lifeless, but they are in fact vital for life.

Jheni Osman is a science writer and presenter and a former Editor of *BBC Focus*.

FACT FILE: DESERTS

11 per cent is the increase in desert foliage over the last two decades. This is due to soaring levels of carbon dioxide.

20 per cent of deserts are covered in sand.

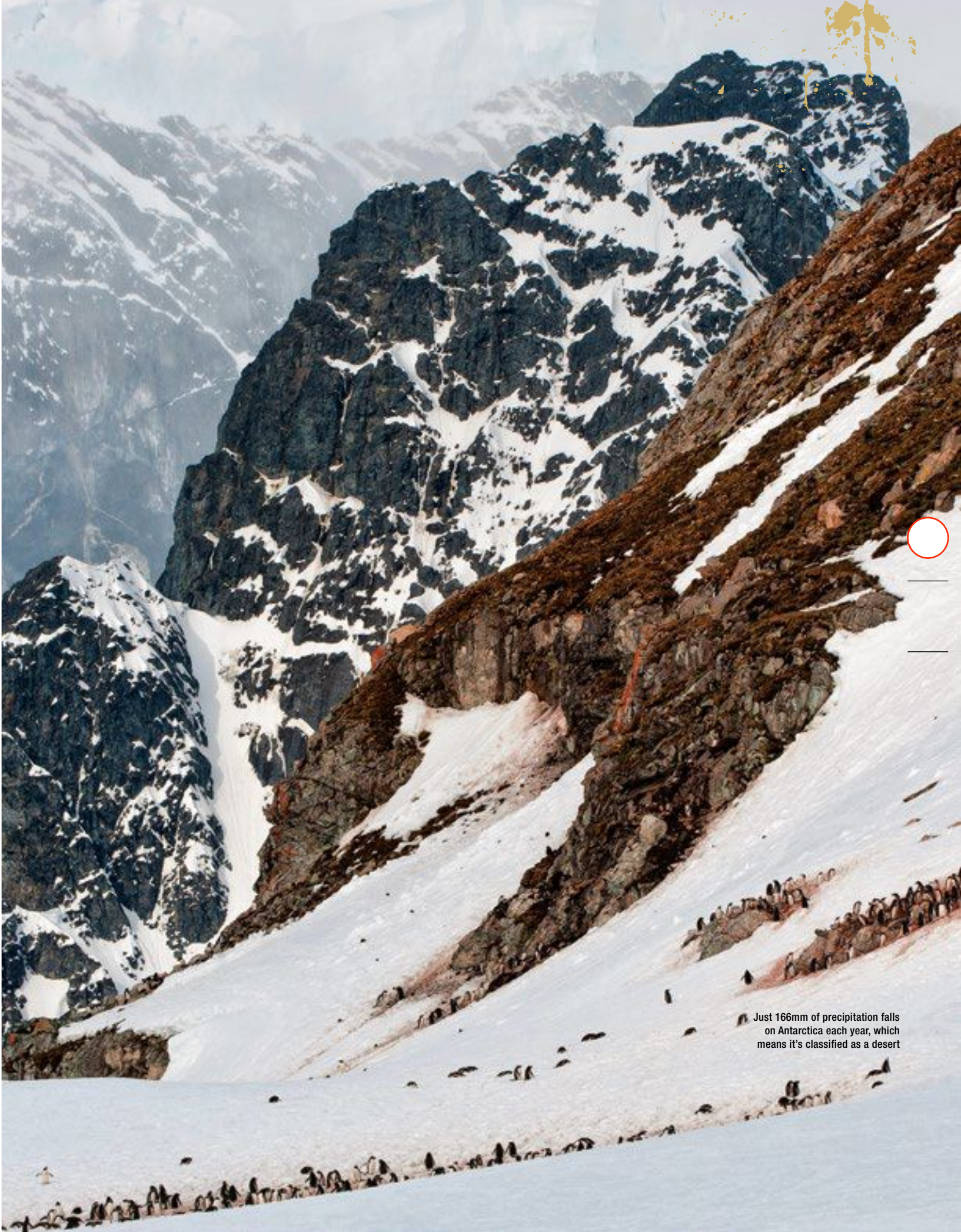
One-third of Earth's surface is desert.*

Antarctica is the world's largest desert. The only plants that grow there are mosses and algae.

China is building a 4,500km-long 'Great Green Wall' made up of 100 billion trees to try to hold back the Gobi Desert.

*Based on the definition of a desert being a region with less rainfall in a year than it gives up through evaporation.

GETTY, ALAMY

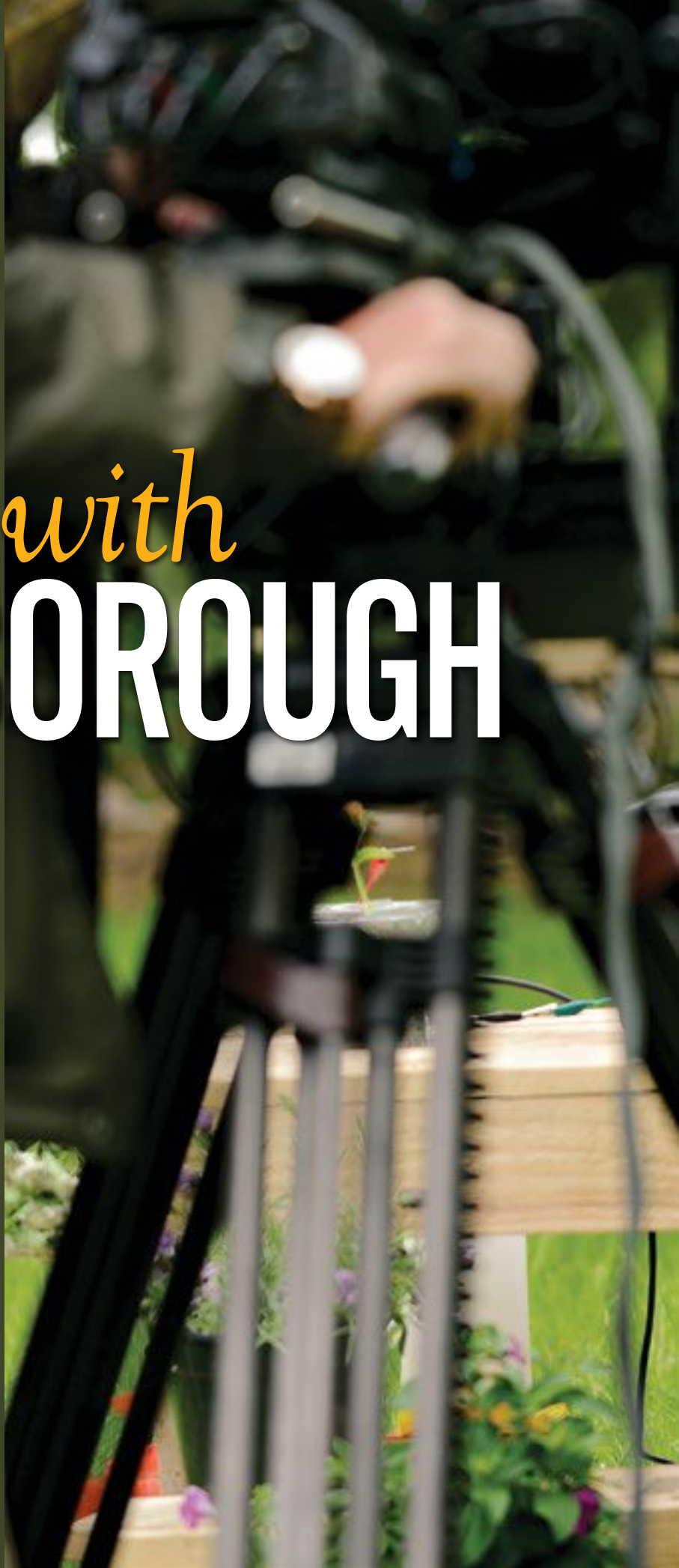


Just 166mm of precipitation falls on Antarctica each year, which means it's classified as a desert

How does Sir David Attenborough keep making such compelling TV? **Ben Hoare** spent a day on location with the famously workaholic presenter to find out

Photos ROB SCOTT

At work with ATTENBOROUGH



Do I pinch myself sometimes? Gosh, yes. I mean of course I do. I can't believe this is my day job." The famous voice pauses for effect, then adds: "Well, it's not really a proper job, is it?" Most people would say that explaining the wonders and complexity of life on Earth to millions of people counts as a job. But Sir David Attenborough has never been one to blow his own trumpet. Tongue in cheek, he told *Radio Times* that his broadcasting career amounts to just "swanning around".

This particular morning, Sir David's job is to talk about virgin birth. Otherwise known as parthenogenesis – or "life without sex", as he puts it, beautifully – the phenomenon is seen in animals as diverse as Komodo dragons and aphids. Both feature in the opening episode of the second series of *Natural Curiosities*, in which Sir David investigates often-bizarre connections between unrelated species. Other programmes find unexpected links between hedgehogs and rhinos, owls and giant squid, and flowers and electric eels.

BBC Knowledge has been invited to join one of the shoots in a Somerset cottage garden: a rare opportunity to observe this wildlife TV silverback in his natural habitat. The crew is relatively large – three producers plus a cameraman, soundman, autocue operator and lighting technician – because the day's packed filming schedule includes sequences from three different programmes in the 10-part series. Crews of just four or five are usual for Sir David's pieces to camera, especially in far-flung corners of the planet – everyone, presenter included, mucks in.

Sir David on location in Somerset in June 2013.The scientific apparatus is to demonstrate how flowers communicate with bees via electrical fields

Autocue operator

Soundman

Sir David Attenborough

Scientist's assistant

MEET THE TEAM

Here the Natural Curiosities crew film the sequence about flowers and bees.

Aphids are first on the agenda. Barely half an hour after arriving from his London home, Sir David is sitting on a deck chair in a flowerbed, going through last-minute changes to his commentary with the producer Hilary Jeffkins. In front of him, balanced on top of a briefcase, is a potted rose lovingly infested with aphids a few weeks earlier specially for the programme. Rod Clarke, the cameraman, manoeuvres his huge tripod to frame a close-up of the presenter looking at the mass of tiny insects.

Hilary calls out "David!" and for 35 seconds we're treated to a word-perfect summary of how female aphids clone themselves in our gardens. It's classic Attenborough – complex science made simple, exquisitely concise and not a word wasted. After two takes – the first is ruined by a motorbike roaring past the cottage – Hilary is satisfied.

Producer Hilary Jeffkins and Sir David discuss the aphids commentary.

Sir David rests, commentary in hand, while the next set-up is prepared. "He's incredibly efficient," says executive producer Stephen Dunleavy, whose company Humble Bee Films is making *Natural Curiosities*. "There can be lots of waiting around, but David's always doing something – reading a book, or thinking about what he has to say next. He wants to know the science better than anyone." The presenter overhears and wanders over the lawn to join us. "Oh, he's just being polite. Do you know what species of animal I'm most afraid of? TV producers!"

Next up: some tricky sequences in a small greenhouse, where Sir David is to talk about the metamorphosis and migration of painted lady butterflies. It's cramped, there are cables trailing everywhere and getting the camera angle right seems to take forever. Rod fiddles with a super-macro lens assembly resembling a drill bit – he has to film just a few centimetres away from Sir David's finger, on which, if everything goes to plan, a butterfly will perch.

Above: the crew's armoury of lenses. Below: Sir David meets a painted lady butterfly.

Instant Feedback

A razor and mirror are produced – in the early morning rush, Sir David forgot to shave and producer Sharmila Choudhury has spotted midday stubble on her monitor. "In the days of film, you didn't know if a sequence had worked," she says later. "But since the switch to video about 15 years ago, we've been able to see the images we're getting, so if need be we can change things around."

Finally, out come the painted lady guest stars, which have been gently chilled in a fridge to make them less active. (With care this macro photography technique does no harm, provided the insects are cooled for no more than 10 minutes or so.) Sharmila brushes Sir David's finger with sugar solution, opens a small box containing a sleepy butterfly and gently ushers it onto the syrupy fingernail.

It flies away. As does the next one, and the one after that. But in the end a butterfly stays and sips sugar long enough for Sir David to do his take. "The painted lady is one of our largest butterflies and a familiar summer visitor to our gardens. And yet its appearance and disappearance each year has puzzled us for centuries. It's only now that we are beginning to understand this extraordinary life-cycle…"

The sun is beating down now and the

"DO YOU KNOW WHAT SPECIES OF ANIMAL I'M MOST AFRAID OF? TV PRODUCERS!"

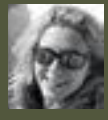
WORKING WITH ATTENBOROUGH

"I love working with David because he's so driven, so hard-working, yet humble and ever the gentleman. On safari for the BBC's Africa series, we built in break times between filming but David never sits still for long! He's hugely dynamic, involved and interested. He's also compassionate – we saw that when he met the baby black rhino face-to-face for the Africa series finale. David remains at the cutting edge of biology and is incredibly enthusiastic about new filming technology, too."

James Honeyborne
Executive producer
BBC Natural History Unit

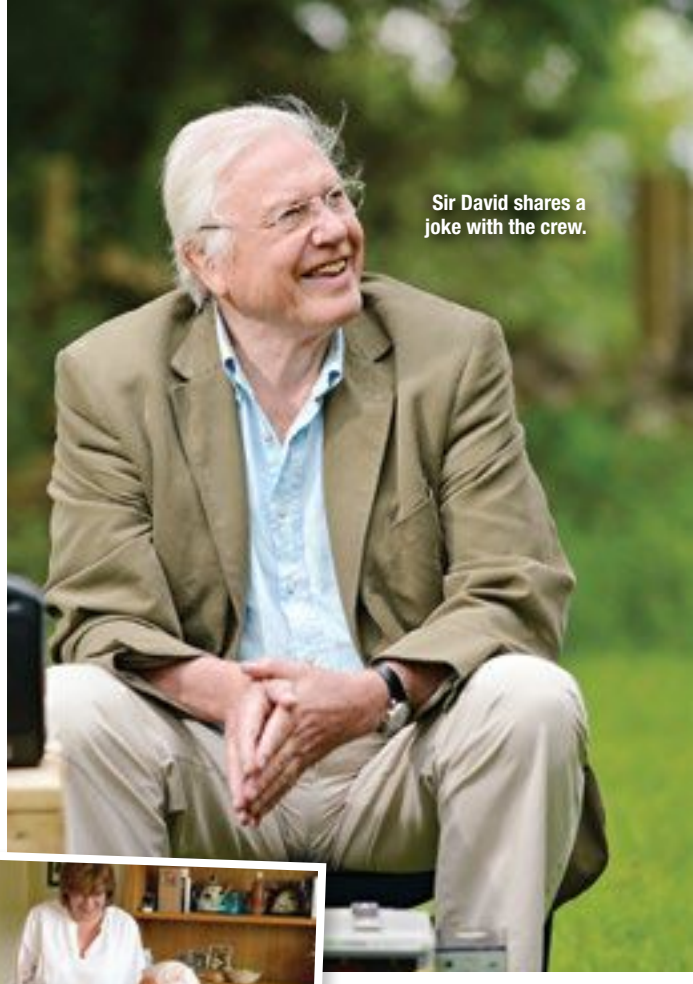
"I've worked with David for almost 30 years and have often travelled alone with him, acting as driver (David doesn't drive). Surprisingly, for such a globetrotter he's not a great traveller – I've been with him several times when he's misplaced his air tickets, passport or both. Over meals with the crew, he talks at length about music – a real passion for him. After a trip, a Jiffy bag containing a CD that David thought I might like often pops through my letterbox. How he finds the time, I really don't know."

Graham Ross
Freelance sound recordist



"I don't know if I am ever at ease around David when filming – he keeps you on your toes. I really love that – you have to be ready to defend your point of view about how, what and why you are filming. Sometimes he'll get you off guard by telling one of his brilliant anecdotes and making the entire crew crease up. The next minute, he looks you in the eye and asks a complex biological question. You'd better have a compelling answer – he sees straight through any bull****!"

Vanessa Berlowitz
Executive producer
BBC Natural History Unit


Sir David shares a joke with the crew.

greenhouse sequences have taken well over two hours to film – hot work, especially for an octogenarian presenter (Sir David turns 88 this May). He has said that work is what makes him get up in the mornings and that as long as people want to watch and listen to him he'll carry on, but still, retirement must seem attractive occasionally? Has he not even *considered* working a little less?

Sir David's brow furrows and I instantly regret asking. This must now be the question he gets posed more than any other – famously, it used to be "What's your favourite animal?", which received a different answer each time according to Sir David's mood. Then he says simply: "These are my friends," gesturing at the crew.

Afterwards, I realise what Sir David meant. If you make little distinction between friends and colleagues, work and pleasure, then retirement is an impossibility; your life is work. Or, as Sir David said a few years ago, the only stage in his life when he felt like he was actually working was the "nasty time" as a senior BBC executive. He became controller of BBC Two in 1965, then four years later was made director of programmes on both BBC One and BBC Two, but quit in 1973, hanging up his suit and tie to return to his earlier, happier existence as a peripatetic natural-history presenter.

Anecdotes and cake

When I interviewed Sir David for *BBC Wildlife* in 2012, he made a point of highlighting the teamwork in creating TV. He lavished praise on the patience and dedication of his "pals" – cameramen, sound mixers, producers, researchers. They in return respect Sir David's willingness to get his hands dirty, and the fact that, even now, he rarely needs more than one take. And they *adore* his sense of fun. He's renowned for telling stories round the restaurant table or campfire into the wee hours.

Ever the raconteur, Sir David jokes with today's crew while they set about demolishing lunch as efficiently as the hyenas they sometimes film. He reminisces about past disasters on location, including the time when all the precious rushes of one sequence were lost. "In those days, when we were away we used to post them back to the BBC!"

Sir David looks thrilled when a family from the village pop round with a giant cake they have baked, decorated with a flowery garden and blue-shirted TV presenter made of icing. He signs autographs and poses for photos with his confectionery lookalike, but isn't hungry. Later I learn that he had been feeling under the weather yet hadn't wanted to make a fuss by cancelling the filming; a few days after the shoot his doctors tell him he needs a pacemaker.


Sir David meets some young fans from the village during the crew's lunch break.

Lunch over, the three producers eye gathering clouds anxiously. There's one more sequence left to film – the aim is to describe exciting research into electroreception in bees, but will they perform in drizzle? The new study shows that when bees land on flowers, the petals are left with a slightly more positive charge, and since the insects are able to sense the electric fields produced by plants they can thus tell which flowers have already been pollinated.

Swiss scientist Daniel Robert, whose research this is, has rigged up a petunia connected to a modified ampere meter so that Sir David can demonstrate the science. The commentary is displayed on an autocue, but that doesn't mean it is fixed. At one point Sir David asks autocue operator Jim Hamling to delete a stray comma, and he's right: the seemingly insignificant tweak turns out to be a great improvement.

"David is such a perfectionist," says

ATTENBOROUGH CAREER HIGHLIGHTS

During a career spanning over six decades, Sir David has consistently broken new ground, embracing the latest technology and devising ever-more ambitious formats. We've picked six of our favourite series and documentaries – you can find classic clips at www.bbc.co.uk/nature/collections/p0048522

1979 LIFE ON EARTH

Broadcast in 100 countries, this 13-part series featured footage from 30 countries. Over 500,000 people tuned in – 11.4 per cent of the global population.

1993 LIFE IN THE FREEZER

An epic survey of the struggle for survival in Antarctica – and a massive logistical challenge to produce.

CLAUDIO CONTRERAS/NPL; BEN OSBOURNE/NPL; NEIL NIGHTINGALE/NPL

Setting up the afternoon's main honeybee sequence.

"IF I START TELLING PEOPLE TO BUY MARGARINE NOT BUTTER, THEY WON'T BELIEVE A WORD I SAY ANY MORE."

Top left and above: final preparations for the sequence in the greenhouse.

soundman Graham Ross, who like much of the *Natural Curiosities* crew has worked with the presenter many times before. "And he's really tuned into the sound of his performance, which is unusual. He's a brilliant writer who totally gets the importance of emphasis and phrasing."

Producers say that developing scripts with Sir David is invariably a collaborative process; he's not one to just turn up on the day. "He realises that it's not about him – in fact, he is the least starry TV personality I know. With David, it is all about the story," Stephen Dunleavy says.

The Attenborough brand is built on the authority of his storytelling, drawing much of its power from his refusal to do commercial voiceovers. "If I start telling people to buy margarine not butter, they won't believe a word I say any more," he says during a lull in filming. It's a line he's used before, but surely he must get some tempting offers? "Oh, not so much these days. They've all stopped asking!"

Though Sir David avoids commenting on politics, when he does choose to speak out – about England's pilot badger culls or the unfashionable topic of human overpopulation, for instance – people tend to sit up and take note.

Patron saint of wildlife TV, saviour of the BBC, national treasure, shoo-in for elected monarch, heartthrob – Sir David has been called lots of things. But really, he is the presenter all other natural-history presenters want to be. Chris Packham describes him as his main inspiration: "David tells stories so that they become irresistible to us. We want to know what happens. We care because we trust him, he is an expert and he is so very passionate."

As viewers, we should count our lucky stars. Far from retiring, Sir David has stayed at the forefront of wildlife TV. The day after leaving hospital last summer he was back on the phone to his producers. "What's next?" he asked.

1995 PRIVATE LIFE OF PLANTS
By deploying cutting-edge time-lapse techniques, the producers speeded up events in the life-cycles of plants, to stunning effect.

2005 LIFE IN THE UNDERGROWTH
A new generation of low-light macro equipment made it possible to film invertebrates' secret lives in extraordinary detail.

2006 PLANET EARTH
The most expensive wildlife TV series yet made, costing £16 million, and one of the BBC's first projects to be filmed in high definition.

2010 FLYING MONSTERS 3D
Sir David was quick to see the potential of 3D techniques and computer-generated imagery (CGI), here in a documentary about pterosaurs.

HOW DO WE KNOW?

WHAT DINOSAURS LOOKED LIKE

BY JOHN PICKRELL

Today we take the appearance of dinosaurs for granted, but it's taken centuries of careful study to learn how to accurately read the clues in the fossil record

Back in october 2015, a new dinosaur was revealed from the 66-million-year-old Hell Creek formation in South Dakota, USA. Colourful pictures of this swift, bipedal predator – covered in feathers and with a jaw full of sharp teeth – were published around the world.

Experts behind the discovery reported that *Dakotaraptor* had large, sickle-shaped claws on the second toes of its hind feet, and would have been about five metres long and slightly taller than a human. This made it one of the largest ever dromaeosaurs ('swift seizers'), the group to which *Velociraptor* also belongs. We take these kinds of reconstructions for granted these days, but just how realistic are they, and how do we know what dinosaurs really looked like?

The first attempts by humans to imagine the animals that left fossils or footprints of themselves behind were in prehistory, and there are hints that dinosaur remains made it into many ancient mythologies. Dragons appeared in Chinese texts as far back as 1100BC, and may have been influenced by dinosaur bones. Similarly, griffins – beasts that combine an eagle with a lion – are known from Ancient Greece as early as 700BC; the inspiration may have come from fossils of the beaked dinosaur *Protoceratops*, remains of which are still found in the deserts of Central Asia today.

When ancient people were faced with strange bones, they did exactly what we do today, and used the best knowledge available to reconstruct the creatures that left them behind. Sometimes this resulted in poor conclusions. The first name assigned in print to any dinosaur remains was the ignominious title of *Scrotum humanum* – a label given by British physician Richard Brookes to the broken end of a femur in 1763, believing it to be the fossilised testicles of a Biblical giant. We now know that the leg bone belonged to a *Megalosaurus* – correctly described as an extinct reptile by William Buckland in 1824. You can't entirely blame Brookes for his conclusions, as dinosaurs would not be described as a group until 1842. That was when Richard Owen, head of what is now the Natural History Museum, revealed to the world a new class of strange, extinct creatures he called dinosaurs, meaning 'fearfully great reptiles'.

He imagined *Iguanodon*, *Megalosaurus* and *Hylaeosaurus* to be reptiles with legs sprawled out to the sides, with scaly grey or green skin: something like modern lizards or ▶

The dinosaurs in Crystal Palace Park look quite different to how we visualise the animals today

GETTY, ALAMY, EMILY WILLOUGHBY

< IN A NUTSHELL

Dinosaurs roamed the planet over 65 million years ago, but by studying the shape of their bones and other details of their fossils, scientists have pieced together how they would have looked in real life

crocodiles. In 1854 artist Benjamin Waterhouse Hawkins created life-sized sculptures of these animals as directed by Owen, and you can still see these on display in Crystal Palace Park in south London. Visit them and you will see they look very different to how we depict dinosaurs today.

Over time, we have come to completely revise our understanding of the appearance of dinosaurs, and much of this began with the description of another American dromaeosaur called *Deinonychus* in the 1960s. John Ostrom at Yale University made the revolutionary suggestion that this species was a bird-like, fast, warm-blooded pack hunter, and so began the 'dinosaur renaissance' of the 1960s and 70s. Ostrom championed the idea that birds were dinosaurs, and was spectacularly vindicated when *Sinosauropteryx*, the first known feathered dinosaur, was found in China in 1996.

First steps

When faced with new fossils today, palaeontologists have a much bigger body of knowledge to draw upon when creating reconstructions. In fact, our knowledge has increased to the degree that – somewhat miraculously – we can tell the colours of the feathers of a range of dinosaur species.

All dinosaur reconstructions begin with their fossilised bones. If palaeontologists are lucky enough to have found a fairly complete skeleton, they can arrange these bones into the appropriate order – based on how the bones of birds, crocodiles and even people are arranged – and start to get a sense of the shape of the creature.

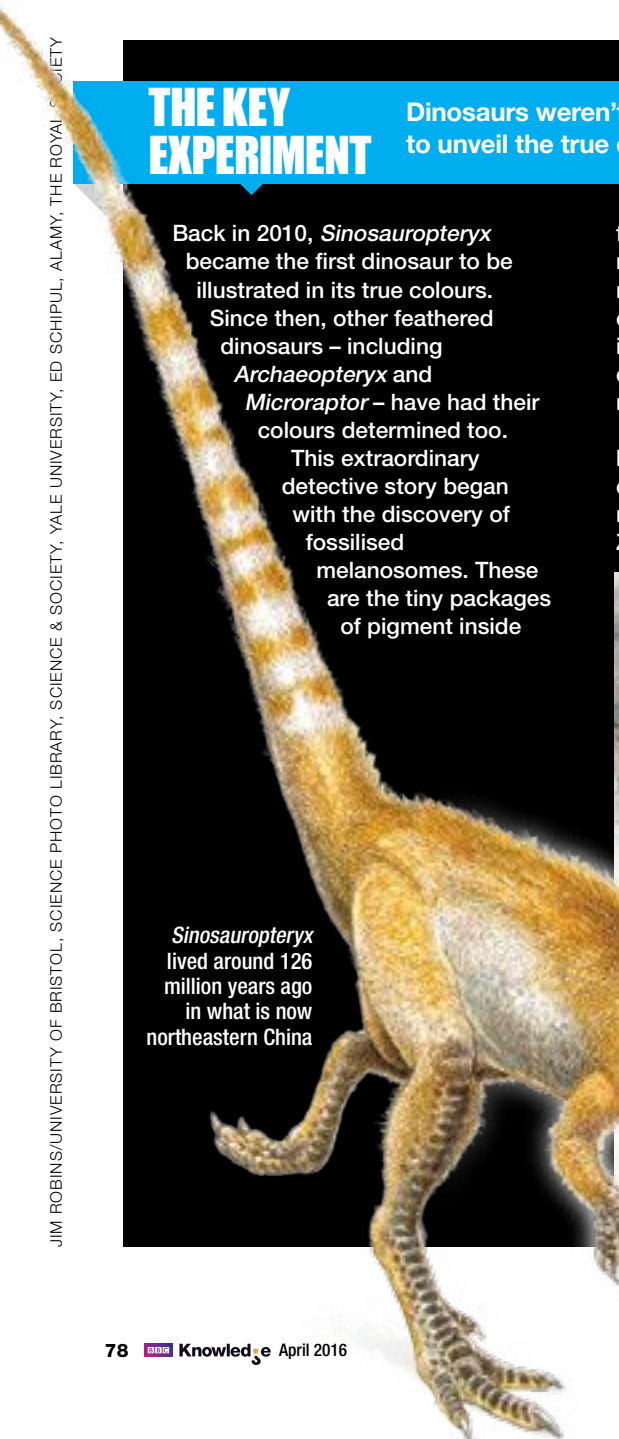
Complete dinosaur skeletons are, however, very rare. The majority of fossil specimens have bones missing, and a great number of species are only known from a fraction of the original skeleton. In these

THE KEY EXPERIMENT

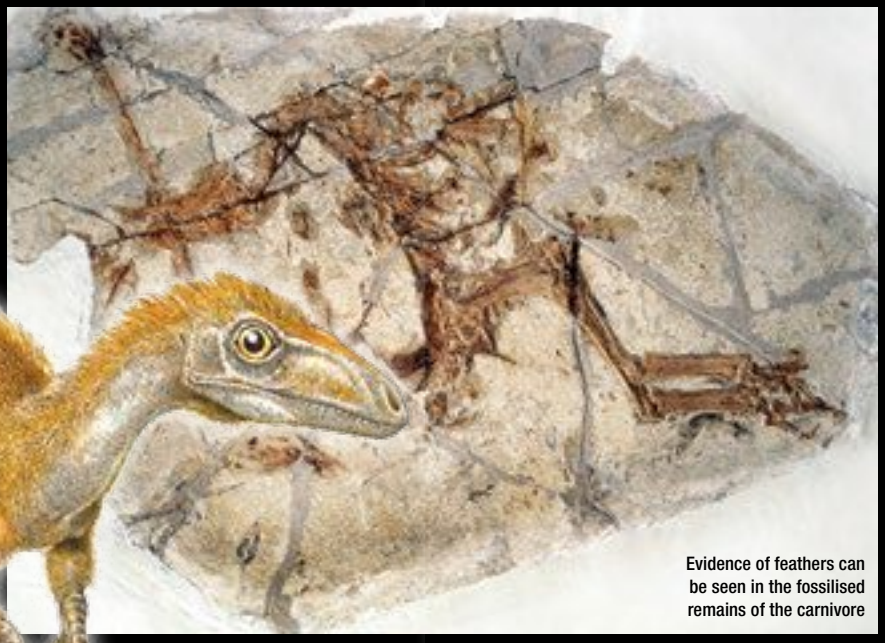
Dinosaurs weren't just green and black. Recent research allowed scientists to unveil the true colours of one of these prehistoric animals

Back in 2010, *Sinosauropteryx* became the first dinosaur to be illustrated in its true colours. Since then, other feathered dinosaurs – including *Archaeopteryx* and *Microraptor* – have had their colours determined too. This extraordinary detective story began with the discovery of fossilised melanosomes. These are the tiny packages of pigment inside feathers and hair in living birds and mammals, and are responsible for making your hair black, brown, blond or ginger. These melanosomes are incredibly tough, and under the right conditions can survive hundreds of millions of years in fossils.

When you look at the feathers of a living bird under a high-powered electron microscope, you can see melanosomes of different shapes. Zebra finches have round 'phaeomelanosomes' in the orange part of their feathers and sausage-shaped 'eumelanosomes' in the black parts. A team led by Mike Benton at the University of Bristol used this technique to look at the downy feathers along the head, neck and back of the fossilised *Sinosauropteryx*. They found that this carnivore was ginger with white stripes down its tail.



Sinosauropteryx lived around 126 million years ago in what is now northeastern China



Evidence of feathers can be seen in the fossilised remains of the carnivore

JIM ROBINS/UNIVERSITY OF BRISTOL, SCIENCE PHOTO LIBRARY, SCIENCE & SOCIETY, YALE UNIVERSITY, ED SCHIPUL, ALAMY, THE ROYAL SOCIETY

cases, the bones of different specimens can be compared to fill in the gaps, and if there are parts of the skeletons that are still unaccounted for, experts will often look to related species of dinosaur for help with the reconstruction.

Detailed knowledge of the anatomy of a range of modern species (a field known as comparative anatomy) is helpful here, and many dinosaur experts are excellent anatomists. To those in the know, small details of the shape of bones can reveal a great deal of information about the animal they came from. For example, dinosaurs and birds (which are a kind of theropod dinosaur) are unique in having a hole in their pelvis called a 'perforated acetabulum' into which the top of the thigh bone (femur) fits on each side. This is a unique trait of dinosaurs, allowing them to stand erect with their legs underneath their bodies, rather than sprawling out to the sides as in other reptiles. The dinosaur hip also allows experts to identify between the two major branches of the dinosaur family – ornithischians and saurischians.

Theropods, the carnivorous group of saurischian dinosaurs to which *T. rex*, *Allosaurus*, and now *Dakotaraptor* belong, have a series of other telltale traits in the fossils. These include hollow bones full of air pockets, three fingers on the hands, and much reduced fourth and fifth digits on the feet. Maniraptorans, the group of theropods from which birds evolved, have more distinct features, including an unusual wrist joint with a bone called a 'semilunate carpal'. This gave these carnivores more flexible wrists – useful for seizing prey with their hands – and allowed the flight stroke of birds to evolve.

When you're out on a dig with experts you realise that even small details, such as the shape of teeth or the curves of limb bones, are enough for experts to make rapid assessments about the specific types of dinosaur that they belonged to.

Beyond bones

Bones, however, are only the start of a dinosaur reconstruction. It's also important to think about muscles. For example, discs of muscle between the vertebrae of a sauropod dinosaur such as *Brachiosaurus* or *Diplodocus* would have made a great difference to the overall length of the animal. Muscles are added by referencing the exact positions and shapes of muscles ▶

CAST OF CHARACTERS

Six innovative scientists who helped us decipher what dinosaurs looked like

Richard Owen (1804-1892) was head of what is now the Natural History Museum. He was an influential anatomist and palaeontologist, who described dinosaurs as a group. He reconstructed a series of the earliest known species, including *Megalosaurus*, *Iguanodon* and *Hylaeosaurus*.

John Ostrom (1928-2005) discovered and described *Deinonychus*, now hailed as one of the most important fossil finds in history. He reconstructed it as a speedy, warm-blooded predator – at odds with the perception that dinosaurs were slow and lumbering. He brought back the idea that birds evolved from dinosaurs.

Robert T Bakker (1945-) was a student of John Ostrom. Bakker went on to lead the charge of the 'dinosaur renaissance', theorising on physiology and locomotion and stirring up controversy by suggesting that, unlike modern lizards, dinosaurs were warm-blooded. The jury is still out on that one.

Gregory S Paul (1954-) is an artist and palaeontologist whose books and anatomically accurate dinosaur illustrations have inspired a generation of artists and many of the dinosaur illustrations you see today. His work pioneered the revised look of dinosaurs in the 1970s.

Mike Benton (1956-) is a palaeontologist at the University of Bristol. He led a team of researchers in 2010 to determine the colour of dinosaurs. They showed that *Sinosauropteryx* was covered in fluffy ginger and white feathers.

Xu Xing (1956-) has discovered more dinosaurs than just about anyone else alive today. These include more than half of the feathered dinos found in China.

TIMELINE

How our knowledge of dinosaurs has improved over just a couple of centuries

1824 – *Megalosaurus* is described by William Buckland (pictured) as a giant reptile.

1842 – Richard Owen names dinosaurs as a group. Early depictions show them as giant lizards.

1905 – Giant carnivore and dinosaur-poster-boy *Tyrannosaurus rex* is named by Henry Fairfield Osborn, president of the American Museum of Natural History.

1964 – *Deinonychus* is discovered by John Ostrom, leading to the 'dinosaur renaissance' – a rebirth of interest and research into the animals.

1996 – The first known feathered dinosaur, *Sinosauropteryx*, is discovered in China by a team including Canadian dinosaur hunter Philip Currie.

2010 – *Sinosauropteryx* becomes the first dinosaur to have its colours revealed, thanks to preserved melanosomes found in its fossilised feathers.

2014 – New fossils allow scientists to piece together the detailed appearance of *Spinosaurus*, showing it was the largest ever carnivorous dinosaur. It was adapted to life in and out of water.

GETTY X3, PRESS ASSOCIATION, CHUANG ZHAO

in living animals. Fossilised bones often have 'muscle scars' that show attachment points, which aid in this process. Since we know that larger, heavier modern animals have bigger marks, we know we need to add bigger muscles to those dinosaurs.

Our understanding of the finer details of dinosaur anatomy has altered over time, and continues to improve with 3D computer models that use the physiology of living animals to make predictions about extinct species. Sauropods, like *Diplodocus*, used to be depicted with their heads held high on their necks and their tails dropping down to the ground, but we now know this wouldn't have been possible. Instead, we reconstruct them with their necks and tails in a more horizontal position, acting as counterbalances to each other. Palaeontologists are increasingly making use of digital, biomechanical models to test their ideas about how dinosaurs walked and used their jaws.

Finally, layers of fat and skin are added to our reconstructions, as well as scales, feathers, armour, crests and any other features such as cheeks, lips, claws and beaks. There are surprising pieces of evidence that come to bear on these decisions too. We have some truly incredible skin impressions for a range of dinosaurs – particularly herbivores like *Edmontosaurus* and *Saurolophus*. The prevalence of scaly skin impressions in the fossils of herbivorous dinosaurs has led experts to believe that the majority had scales instead of feathers (although a handful of herbivorous dinosaurs have been found with bristles and other feather-related features).

We also know that some herbivores, particularly the armoured ankylosaurs, were covered in defensive bony plates, spikes and knobs. These bony growths in the skin, known as osteoderms, often fossilised and give a good sense of how animals like *Scelidosaurus* – discovered in Dorset in the 1850s – would have appeared in life.

In herbivorous dinosaurs there are other features that we can infer from the bones in the skull. Duck-billed hadrosaurs have large grinding teeth at the backs of their jaws, and it's likely that these were covered with cheeks, allowing them to hold more food in their mouths for chewing before swallowing. In other dinosaurs, such as *Protoceratops*, *Triceratops* and *Oviraptor*, we can see the inner bony part of a beak that, in life, would likely have been covered with an outer keratinous layer as in birds today. Keratin is

NEED TO KNOW

A quick glossary of key terms used in dinosaur appearance

1 COMPARATIVE ANATOMY
The study of similarities and differences in the physical features of various species. This allows experts to make informed guesses about the appearance of extinct species based on living animals.

2 MELANOSOMES
These tiny granules of pigment are responsible for the colouring of hair and feathers in animals and birds. Preserved melanosomes in a *Sinosauropteryx* fossil revealed this dinosaur's true colours.

3 PALAEONTOLOGY
The study of prehistoric life, based on the fossils of animals, plants and other organisms, as well as the ages and details of the layers of rock they were found in.

4 THEROPOD
This large group of bipedal and mostly carnivorous dinosaurs includes *T. rex*, *Allosaurus* and *Sinosauropteryx*. The first birds evolved from theropods around 150 million years ago.

Zhenyuanlong **was discovered in the Liaoning region of China. It lived in the Cretaceous period, around 125 million years ago. The fossilised remains suggest that this dinosaur was covered in feathers**

the same tough protein that feathers, hair, fur and fingernails are made of. Did dinosaurs have lips? This is something we still don't know, and is an area of current debate.

Fluffy theropods

Carnivorous theropods, in contrast to the herbivores, were frequently covered in feathers. The incredible fossils of nearly 50 species – mostly from China's northeastern province of Liaoning – show a range of feathery coverings, from downy, insulating 'dino-fuzz' to flashy display and flight feathers. Some of these animals are so exquisitely preserved that we can see the shape and arrangement of feathers right across their bodies.

Though most of these feathered dinosaurs have been found in China, the spread of species across the family tree suggests that most theropods in other parts of the world were feathered too – we just have a fantastic window into the past with Liaoning because of the type of preservation found in its volcanic deposits.

Sometimes we have other evidence of feathers, such as marks on the forearm bones of *Velociraptor* which correlate to the 'quill knobs' where the ligaments of flight feathers attach on pigeons today. It's this feature in *Velociraptor* fossils from Mongolia that led experts to assume all dromaeosaurs had small 'wings' on their forearms – a feature now confirmed by the Chinese fossil of another new dromaeosaur called *Zhenyuanlong*, described in 2015 by scientists including Dr Stephen Brusatte at the University of Edinburgh. Quill knobs were also found in the *Dakotaraptor* fossil, and the scientists behind this discovery, led by Robert DePalma at the Palm Beach Museum of Natural History in Florida, estimated it to have had a wingspan of around a metre.

Artists also play an essential role in bringing dinosaurs to life, and often have expert anatomical and palaeontological knowledge to build on the scientific evidence with informed guesswork. Without these palaeoillustrators, such as Emily Willoughby who created the lovely feathery image of *Dakotaraptor*, the appearance of these animals would live only inside the minds of the scientists who discovered them.

In the last five years, the colours of dinosaur feathers have come into focus, but we may soon have a good idea of dinosaur skin colours too. We already know from the patterns of scales on some 'mummified' fossils that *Edmontosaurus* was probably adorned with stripy patterns, even if we're not sure what colour they were, and a number of studies have started to use electron microscopes to look at the structural patterns of tiny packages of pigment in the skin. Last year, an international team of scientists used this technique to show that a prehistoric marine reptile called a mosasaur had a dark back and a pale-coloured belly, while another marine reptile – a dolphin-shaped ichthyosaur – had universally dark pigmentation. It won't be long before similar methods are used to determine the colours of dinosaurs too.

Reconstructing animals from fossils is partly guesswork, but it's informed guesswork, building on the knowledge built up over the centuries by pioneering palaeontologists. Today, we have a better idea of the appearance of dinosaurs than ever before.

John Pickrell is a science journalist and author of *Flying Dinosaurs: How Fearsome Reptiles Became Birds.*

PUZZLE PIT

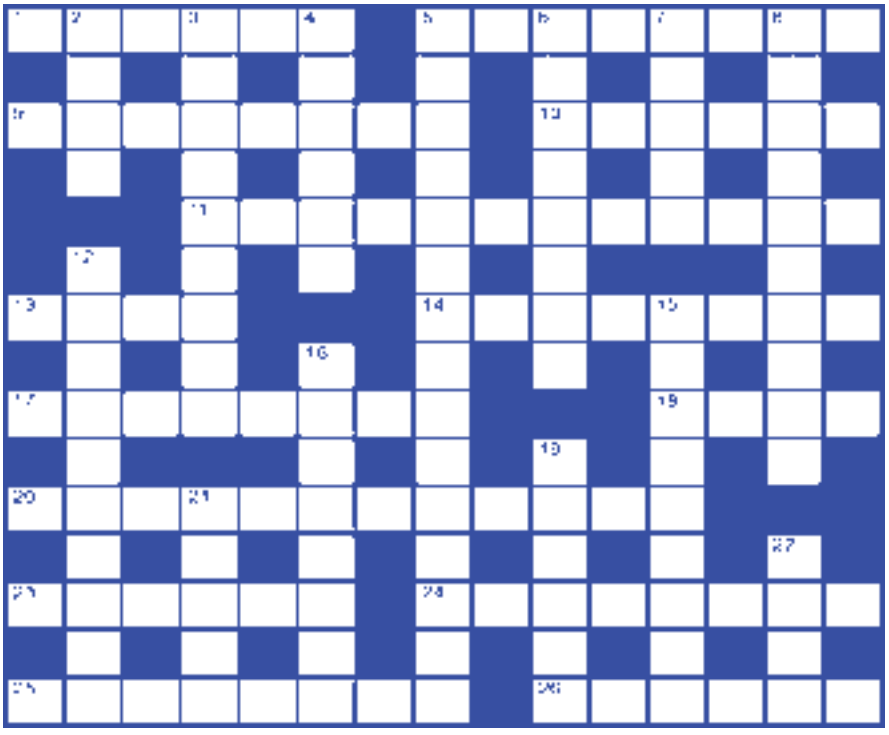
CROSSWORD NO. 31

ACROSS

1 Elude or evade (6)
5 Expert marksman? (4,4)
9 Eliminated or discarded something unwanted (3,3,2)
10 Carry off or kidnap by force (6)
11 Be obsequiously polite? (3,3,6)
13 Front of lower jaw (4)
14 Lines that are touching a circle at one point only (8)
17 Broad view (8)
18 Cut with an axe (4)
20 Halloween tradition (5,2,5)
23 Hard to get (6)
24 Of or relating to the brain or the intellect (8)
25 A coalition (8)
26 Topics or subjects under discussion (6)

DOWN

2 Caledonian (4)
3 Sri ___ set up a famous Ashram in Pondicherry (9)
4 Gives a large amount as grant or gift (6)
5 Grammarian's name for "the" (8,7)
6 Collecting or piling up (8)
7 Jewish feast - "reeds" anagram? (5)
8 Work, career (10)
12 Histrionic, connected with stage (10)
15 Mercurial, volatile (9)
16 French general and emperor (8)
19 City in Uttar Pradesh (6)
21 Welsh breed of dog (5)
22 Bluff, counterfeit or sham (4)



YOUR DETAILS

NAME:

AGE:

ADDRESS:

PINCODE:

TEL: MOBILE:

SCHOOL/INSTITUTION/OCCUPATION:

EMAIL:

How to enter for the crossword: Post your entries to BBC Knowledge Editorial, Crossword No.31 Worldwide Media, The Times of India Bldg, 4th floor, Dr Dadabhai Navroji Road, Mumbai 400001 or email bbcknowledge@wwm.co.in by **10 April 2016**. Entrants must supply their name, address and phone number.

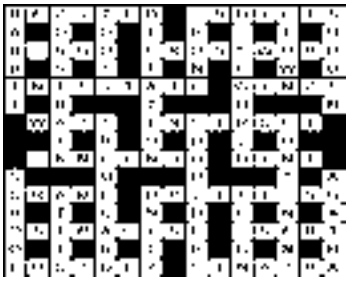
How it's done: The puzzle will be familiar to crossword enthusiasts already, although the British style may be unusual as crossword grids vary in appearance from country to country. Novices should note that the idea is to fill the white squares with letters to make words determined by the sometimes cryptic clues to the right. The numbers after each clue tell you how many letters are in the answer. All spellings are UK. **Good luck!**

Terms and conditions: Only residents of India are eligible to participate. Employees of Bennett Coleman & Co. Ltd. are not eligible to participate. The winners will be selected in a lucky draw. The decision of the judges will be final.

WINNERS FOR CROSSWORD NO. 30

Gaurang Bhatla, Panchkula
•
Anupama Hazarika, Tezpur

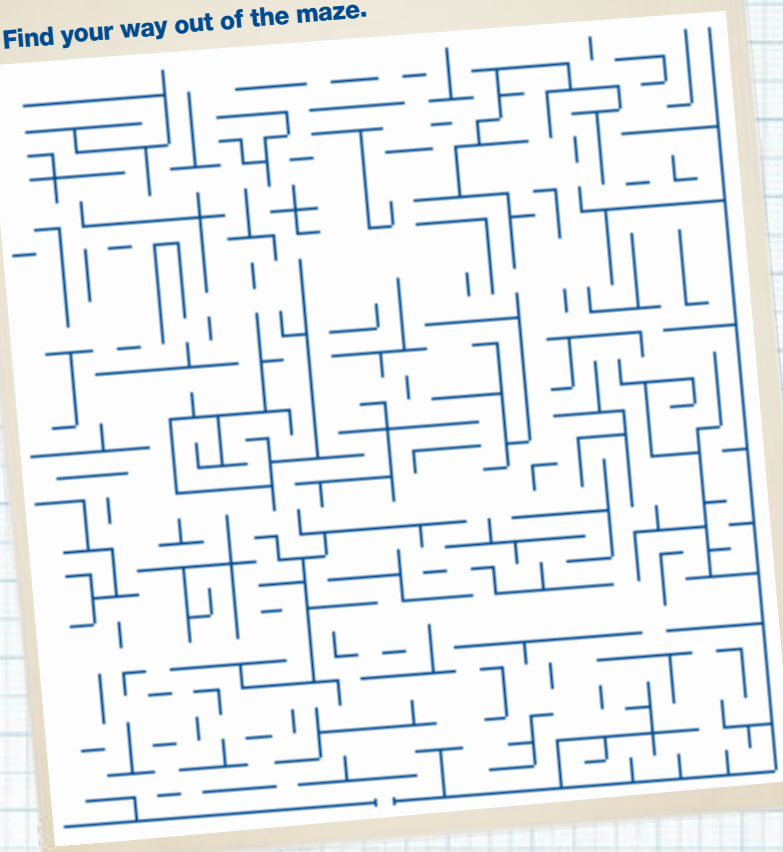
SOLUTION OF CROSSWORD NO. 30



Q1 PICTURE SEARCH

In the jumble below, the words represented by each of the 16 pictures are hidden either horizontally, vertically or diagonally forward or backwards but always in a straight line. See how many of them you can find? Look out for descriptive names.

Find your way out of the maze.



Q2 SCRAMBLE

Solve the four anagrams and move one letter to each square to form four ordinary words. Now arrange the letters marked with an asterisk (*) to form the answer to the riddle or to fill in the missing words as indicated.

TAEER

UVIRS

AEPLNT

IIPGNP

Winter is on my head, but ___ ___ is in my heart - Victor Hugo (7,6)

Q3 HEAD AND TAIL

Look at the clue to solve the answer in the form of a compound word. The second part of the next answer is the first part of the next answer.

Lawsuit — Class

Military position

Railways employee

Original tape, e.g.

Imitator

Red panda

Corroborate — out

MINDGAMES

Test your knowledge with our Big Quiz set by James Lloyd

1 **Scientists have found the oldest evidence of sexual reproduction in a flowering plant. How far back does it date?**

a) One million years
b) 10 million years
c) 100 million years

2 **Complete the recent headline: 'Researchers turn to Twitter in the search for _____'**

a) Endangered animals
b) Time travellers
c) Undiscovered tribes

3 **What's peculiar about the sex life of the *Antechinus*, a small shrew-like mammal that lives in Australia?**

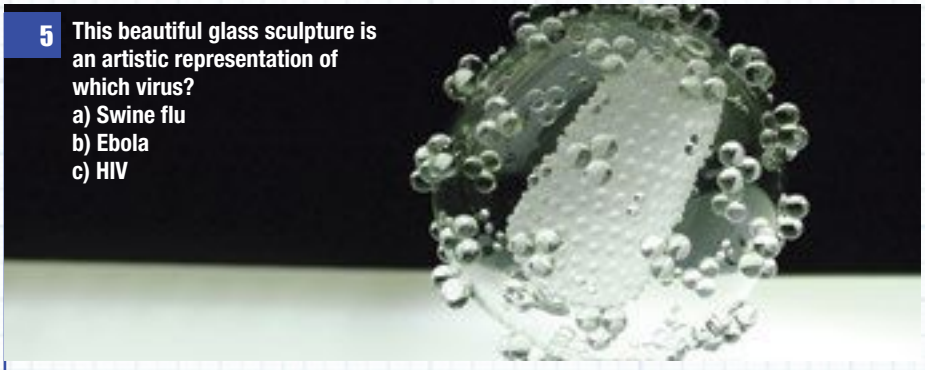
a) The males perform a strange, moonwalk-style dance to attract mates
b) The females gnaw off their partner's earlobes during sex
c) The males have so much sex that they disintegrate and die from exhaustion

4 **Which species of penguin recently captured this 'selfie' while investigating a camera in Antarctica?**

A) Magellanic Penguin
b) Gentoo Penguin
c) Chinstrap Penguin

When penguins attacked

5 **This beautiful glass sculpture is an artistic representation of which virus?**
a) Swine flu
b) Ebola
c) HIV



6 **What were delivered to astronauts aboard the International Space Station in January 2014?**

a) Christmas gifts
b) Valentine's Day cards
c) Copies of *Gravity* on DVD

7 **According to recent research, how are seahorses specially adapted for stalking their prey?**

a) Their snouts are shaped to create very few ripples in the water
b) They can sneeze out an opaque membrane that makes them temporarily invisible
c) Their skin can detect tiny pressure variations from passing prey

8 **Complete the recent headline: 'Jupiter's icy moon Europa spouts _____'**

a) Methane
b) Liquid nitrogen
c) Water

9 **In East Antarctica, researchers have recorded a new coldest temperature on Earth. What temperature did they measure?**

a) -53.2°C
b) -73.2°C
c) -93.2°C

10 **What's the name of China's lunar lander, which recently became the first rover to land on the Moon in nearly 40 years?**

a) Jade Rabbit
b) Emerald Badger
c) Green Fox

11 **Which hip hop artist has inspired a new Bitcoin-like virtual currency?**

a) 50 Cent
b) Kanye West
c) Chamillionaire

12 **Scientists recently solved which bird-related mystery?**

a) Why many birds fly in a V-formation
b) How migrating swallows get home
c) Why parrots imitate human voices

13 **Why did scientists at CSIRO in Australia create this 3D-printed titanium dragon?**

a) To publicise a new range of 3D-printed toys
b) A seven-year-old girl asked them to make her a dragon
c) To celebrate Australia's 'monster' victory over England in the Ashes

Puff the titanium dragon

LUKE JERRAM, CSIRO, REX, SCIENCE & SOCIETY, ALAMY, NASA

14 **What structure celebrated 15 years in space in November 2013?**

a) The Cassini spacecraft
b) International Space Station
c) Hubble Space Telescope

15 **Geneticist Dr Eugene McCarthy recently made the controversial claim that humans evolved after:**

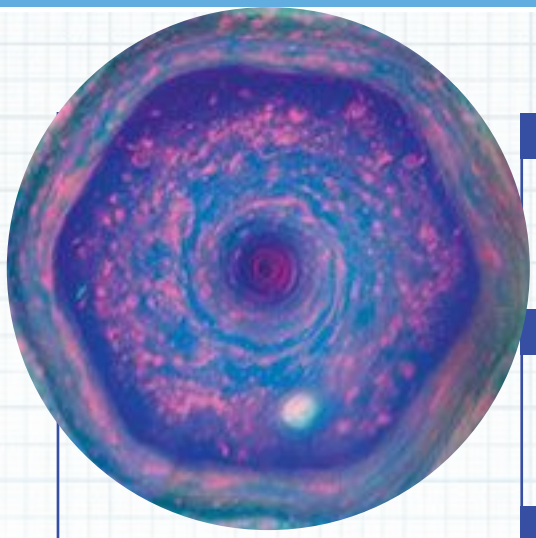
a) A pig mated with an orangutan
b) A pig mated with a chimpanzee
c) A chimpanzee mated with an orangutan

16 **According to new research from MIT, what is the world's most difficult tongue twister?**

a) Three Swedish switched witches watch three Swiss switches
b) Fifty flickering frogs claim clams corrupt
c) Pad kid poured curd pulled cod

17 **Which inventor can be seen here sitting in his Colorado Springs lab in 1899?**

a) Thomas Edison
b) Nikola Tesla
c) Alexander Graham Bell



18 **On what planet can this hexagonal superstorm be found, spanning around 30,000km (20,000 miles) across?**

a) Jupiter
b) Uranus
c) Saturn

19 **According to University of Bristol scientists, the climate of Mordor in Tolkien's Middle-earth, resembles that of which region?**

a) Eastern Japan
b) North Yorkshire
c) Western Texas

20 **According to recent research, how do koalas produce their low-pitched bellows?**

a) They use a second set of vocal cords located outside the voice box
b) They suck in air through their anus and burp it out
c) They vibrate their tongues against their palate

21 **Which company is testing unmanned drones to deliver goods to customers?**

a) Tesco
b) Amazon
c) IKEA

22 **What is the name of the HD webcam that was recently launched into space?**

a) UrtheCast
b) BigBrotherEarth
c) SayCheese!

23 **In December 2013, Prof Peter Higgs received his Nobel Prize for Physics in which European city?**

a) Oslo
b) Copenhagen
c) Stockholm

24 **Complete the recent news headline: "_____ is even more colossal than previously thought."**

a) Yellowstone supervolcano
b) Great Barrier Reef
c) The Moon

25 **Which celebrity has set up an electric car racing team to promote environmentally friendly vehicles?**

a) Leonardo DiCaprio
b) Miley Cyrus
c) Bono

26 **This scary-looking 'Merman', created from parts of different animals, can be found in which museum in London?**

a) Science Museum
b) Natural History Museum
c) Horniman Museum

SOLUTIONS:

Q1 Picture Search: Book, Bowler, Buffalo, Castle, Cave, Cuba, Divan, Eagle, Grenade, Palm Tree, Pizza, Plough, Pumpkin, Tricycle, Trombone, Wrench.

Q2 Scramble: *Words:* Eater, virus, planet/platen, piping
Answer: Winter is on my head, but **eternal spring** is in my heart - Victor Hugo

Q3 Head & Tail: Class-Action-Station-Master-Copy-Cat-Bear-Out.

4 Mindgames: 1c, 2b, 3c, 4b, 5c, 6a, 7a, 8c, 9c, 10a, 11b, 12a, 13b, 14b, 15b, 16c, 17b, 18c, 19c, 20a, 21b, 22a, 23c, 24a, 25a, 26a

GADGETS

NITIN ROSE

MAHINDRA'S REVA E2O SPORT

To give an impetus to electric cars in the country, Mahindra's latest technological innovation is the Reva e2o Sport. What is new is the 80KW electric motor and the384V battery, which when combined and running are powerful enough to allow the car to go from 0 to 60 km in 4 seconds with a top speed of 81 kmph. The car comes equipped with an electric ORVM, Driver Information System, Infotainment System, Reverse Parking Camera and Assist and a High End JBL music system with 4 Speakers & 2 tweeters with CD, DVD, MP3, Bluetooth and iPod connectivity.

Price: TBA | Website: Mahindrareva.com

THE BUDDY COLLAR

Why should humans have all the fun? The Buddy Collar is a futuristic product that not only promises to keep your pet safe but also is fun for you to use. Conceptualised by a L.A.–based pet-tech company Squeaker, the collar comes with an impressive variety of features. The LED light display can change colours, the OLED screen shows you your dog's calorie intake, temperature, activity throughout the day, etc. The device connected to an app allows you to set up geo fences on your maps and will sound an alert if your dog happens to wander off the designated area.

Price: TBA | Website: squeaker.com

ACPAD

Robin Sukroso is a percussive guitar player. The ACPAD by musician Robin Sukroso allows you to play hundreds of instruments, samples of different sounds, effects and loops – all on your acoustic guitar. It is the world's first MIDI controller that offers access to a variety of programmable feature by simply placing it on the acoustic guitar's surface. The device contains eight touch pads, 10 pre-set buttons, two looper channels and two slider faders. All these function are programmable, allowing the player to have a different tunes playing at any time. To use, simply plug in the device via a USb port to you iPad, PC or mobile device. Now go! Create music

Price: TBA | Website: robinsukroso.com

BLACKBERRY PRIV

The BlackBerry PRIV has the privilege of being the first smartphone of the BlackBerry family to run on Android software. The seamless integration features the best specs expected of a high-end android; a Snapdragon 808 processor, 3GB RAM, 32 GB memory storage amongst other things, the BB essentials; BBM, the BlackBerry HUB, and of course its famed security encryption to ensure privacy of your data. The main highlight of this device though is its slide-out portrait keyboard, which responds not only to physical typing but also scrolling, enabling predictive text and working a mouse button. Time to phase out other smartphones, don't you think?

Price: ₹ 62,990 |
Website: blackberry.com

IBERRY AUXUS STUNNER

The iBerry Auxus Stunner is truly a stunning device. This 4G-enabled smartphone comes with a virtual reality headset that gives the user a 360-degree 3D view of videos, games and other content being played on its 5-inch HD display. Its specs include a 64-bit 1.3 GHz Octa-Core MediaTek MT6753 processor with Mali-T720 GPU with 3GB DDR3 RAM and an in-built 16GB memory that can be expanded up to 128GB. Running on Android OS, the mobile also comes with a 8MP rear and 5MP front camera with LED flash lights for both.

Price: ₹ 14,499 | Website: blackberry.com

THE LIGHT PHONE

Yes, this is a phone. It is thin, light and lasts 20 days on a single charge. But don't get too excited. This is not a smartphone. In fact it is the complete opposite of a smartphone. This is the Light phone, which only lets the user make and receive calls. Takes you back to a different time, right? Still in its development stage, we are sure there will be a lot of takers for this old but new device when it hits the market

Price: TBA | Website: thelightphone.com

INFOCUS BINGO 21

Marketed as the 'perfect selfie phone', the Bingo 21 series by InFocus is the ideal phone for those looking to capture and share that winning selfie with their friends. With its 5MP front camera and 8Mp rear camera, integrated auto focus technology and LED flash, makes sure that every picture is worth sharing. Just be careful while taking those selfies, though. The device is available in the colours of white, orange and blue

Price: ₹ 5,499 | Website: infocusindia.co.in

- Moshita Prajapati

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Next

GAMES REVIEW

RISE OF THE TOMB RAIDER

Dive into another thrillride of an adventure as the intrepid Lara Croft in *Rise of the Tomb Raider*.

PC ₹999 | Xbox 360 ₹3599 | Xbox One ₹4699

The New Year kicked off with a bang for RPG enthusiasts, with the release of *Rise of the Tomb Raider (ROTR)* marking Lara Croft's triumphant return to video games. The title is a sequel to 2013's *Tomb Raider*, a game that heralded a gritty reboot of the franchise and it follows in the same vein.

Without revealing too many details, the game's plot involves Lara battling against a secret and ancient order of knights while trying to find the source of eternal life before they do. Myths and the supernatural are woven in with the action-packed storyline, and there is plenty of action!

Compared to its predecessor, *ROTR* offers even more freedom of movement for the player. Lara can now use explosives, climb trees and rooftops as well as swim. The weather and day-night cycle of the game world has also been made more dynamic, increasing its influence on gameplay. Returning features include the popular bow and arrow from the first game, as well as the weapons crafting system that encourages players to scavenge materials and create their arsenal.

While the gameplay is similar to 2013's offering, it manages to serve up enough variations on old features and fresh new ones to keep players engaged. Coming out in the last week of 2015, the game swept up most of the awards held at the end of the year, becoming a popular choice for Game of the Year. *ROTR* a great new chapter in the continued success of a massively popular, cult franchise.

SQUARE ENIX X2, WIKIMEDIA COMMONS, FLICKR X2

NEWS FEED

DESTINY SEQUEL DELAYED?

Those of you who have immersed themselves in the ambitious open-world shooter from Bungie, *Destiny*, might be in for hard times. Rumours swirling around the Bungie offices had touted the release of a sequel this year, but with a new batch of downloadable content for the original on the way, a new game is clearly far off. Let's wait and watch if the rumours for its September 2016 release hold true.

XBOX 360 GOES BACKWARDS!

Xbox 360 might be one generation too old to be a cutting edge console, but owners need not fret. The Microsoft console has been reworking its Xbox 360 titles to be backwards compatible with the latest iteration, Xbox One. A particularly exciting announcement was the inclusion of horror classic, *Alan Wake: American Nightmare*, on the list of titles due for backward compatibility. Who says you can't teach an old dog new tricks?

STRAIGHT FROM HIDEO'S MOUTH

Video game legend and creator of the *Metal Gear* franchise, Hideo Kojima, had a bittersweet 2016. He bid adieu to his labour of love with M*etal Gear Solid V: The Phantom Pain*. He also split from Konami founding Kojima Productions as an independent company. Fans of the maverick game designer who want to stay updated on the latest developments can now follow him on YouTube, where he has launched his own channel. A series of videos, titled HideoTube, will offer insights into his work and private musings.

- Dushyant Shekhawat

EDU TALK

Principal K V Arjun Rao of Oakridge International School, Bangalore, talks to Moshita Prajapati about enabling students to realise their potential through a balanced and holistic method of learning

I read that you believe in harnessing Arts as a medium for effective learning and teaching for students. Can you elaborate on this method?
An education in the Arts is the education of the soul. When schools find their budgets being affected or their academics slowing down, the first classes to be cut are the Arts. I cannot think of anything more depressing.

Unlike what a lot of people believe, access to the Arts is much more important than accomplishment in the Arts. Not everyone is going to be a master of 10,000 hours with the violin but everyone can be nudged down the path of appreciating Bach or smiling at the sunny sounds of Stephane Grappelli or watch *A Clockwork Orange* with the horrific wonder that only Stanley Kubrick can elicit.

We at Oakridge are working on ways of ensuring this access to the Arts only increases and our students look forward to lifetimes of feeding the soul.

How do you modify the learning and teaching curriculum (both teachers and students) to the adaptive changes and expectations of education today?
Schools and curricula must reflect changes in time and in society around them. At Oakridge, we have found that training and a tremendous infusion of technology has really helped teachers in this process. We have created a state-of-the-art campus that breaks every traditional idea that anyone could have about a school. In fact, most visitors find it hard to believe that this could be a school at all! Finally, with our students we have worked hard to ensure that irrespective of curriculum, they are able to develop skills that are urgently required in the 21st century.

> Our learning spaces are designed to help drive learning that is not confined to a room and its four walls

Apart from classroom learning, how does Oakridge ensure a holistic learning for its students?
For us at Oakridge, all learning is curricular. Whether it happens on a playing field, or a classroom or even the school bus through our interactive travel videos, the lessons learnt at the school will only add to the educational arsenal of each student. A very careful balance forged between what is learnt within the classroom and what is learnt outside is critical. We have ensured our learning spaces are designed to help drive learning that is not confined to a room and its four walls. We encourage students to play sport, learn music and art, and realize the crucial relationship that exists between them all.

Revisiting your student days, do you see a change in how students today perceive education and what they want to achieve from it?
Honestly, when I was a student, I'm not sure what I wanted from my education! College just "happened" and exams were frightening but not the be-all-and-end-all of life at school. I loved school because I had so much fun there. My school was a magical place where anything could happen and you went there to get away from your parents.

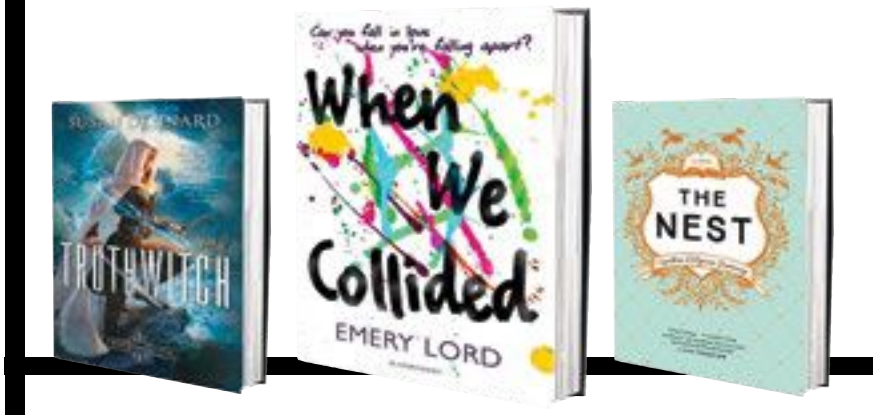
Today, I find that students are a lot more aware of what they want and what they believe they are entitled to. They expect outstanding opportunities and they all want to be superstars. They know all the stories about famous drop-outs in the world and that is exactly what they want.

Of course, schools have not helped the cause by not keeping pace with the needs and aspirations of their students.

How are students of Oakridge equipped to handle real world challenges?
Our students love coming to school. We have worked very hard to make this a place where everyone is appreciated for who they are and this gives them tremendous confidence to address anyone, converse with anyone and negotiate with anyone. Our students are not afraid of their school nor are they afraid of coming to school. This helps them build positive relationships and genuinely enable communication and collaboration.

INSIDE THE PAGES

ON THE SHELF RELEASING IN MARCH



TRUTHWITCH
BY SUSAN DENNARD

Dennard, a popular fantasy writer in the YA genre, releases the first book in her new series. Truthwitch of the Witchland series spins a tale of war spanning across two continents. Safi and Iseult are BFFs, who are forced to flee their house after getting on the wrong side of the evil Lord Guildmaster. Safi must avoid capture at all costs as she is a truwitch – she is able to discern a lie from truth and Iseult's can read people's emotions as colours. Realising that their powers can be misused if held, the girls go on an epic adventure to escape their captors with the help of magic, pirates, sword fighting and much more.

WHEN WE COLLIDED
BY EMERY LORD

What YA favourite Lord succeeds in having leap out from the pages of this book is the development of the titular characters Jonah and Vivi. Both meet under the most contrasting of situations – Jonah is struggling to get by the summer; he has to save his family restaurant from ruin, look after his younger siblings and help his mother while she grieves over the death of his father. Vivi, on the other hand, is a carefree girl who sees the rainbow in the sky even when it isn't there. So when these two collide, literally with each other, things seem to go intermittently either awry or smoothly. What happens in the end though? Through tears of joy and sadness, the end is what it is.

THE NEST
BY CYNTHIA D'APRIX SWEENEY

Every family has it problems, but none more than the Plumb family. The four siblings Melody, Beatrice, Jack and Leo Plumb meet on an wintery New York afternoon to discuss ways to safeguard their join trust fund, 'the nest', which might be in jeopardy following Leo's drunk driving accident. Grappling with the possibility of loosing out on their future plans, the siblings must learn to get along or forever stay in their state of arrested development. This debut novel by Sweeney brings alive an achingly familiar cast of characters alive to vividly capture what happens when money enters familial relations, what happens to our ambitions over time and the fragile and yet unbreakable ties we share with our family.

Author Profile

Cynthia D'Aprix Sweeney is an author whose debut novel, The Nest, was bought by Ecco, an HC imprint for a seven-sum figure. As a former marketing copywriter, she nursed the dream of being a published author, but did not nurture the illusion of making money from it. Her goal of writing her first novel was to simply as she put in an interview, "was to finish it". She occasionally contributes articles to various news periodicals like the New York Times and currently she resides in Los Angeles with her husband and children.

GOODREADS X12

Books hitting screens soon

THE JUNGLE BOOK
BY RUDYARD KIPLING

Kipling tells the story of Mowgli, a village boy who through circumstances, ends up living with a pack of wolves in a jungle. Growing up with the wolves, who raise him as his own, he comes to understand the law of the jungle and as is typical of a boy his age, he often gets into trouble, albeit unknowingly. His tutors and protectors in this are Bagheera, the strict black panther and the kind and affable Baloo the bear. Kipling creates an intense world in the jungle with classic villains, Shere Khan, the dreaded enemy, and slimy Kaa, the python. Good clean fun reading has never been more pleasurable.

LE PETIT PRINCE
BY ANTOINE DE SAINT-EXUPERY

A timeless tale, narrated by a downed pilot stranded in the Sahara Desert, of his talks with the little Prince. He tells the story of a little boy who leaves the confines of his own planet to travel the universe, learning about the erratic nature of adult behaviour through a series of unbelievable encounters, which culminates finally on Earth, in the Sahara Desert. A children's book written for grown ups, tells us how our perspective on life changes as we grow old and how as adults we bid adieu to our sense of imagination and our purpose to enjoy life.

ALLEGIANT
VERONICA ROTH

The final book of the Divergent series, has been spilt into two films. Our dystopian couple Tris and Four along with a few others have escaped from factions and are now going to beyond the fence to find a life away from the civil war. But the new reality here is even more alarming than the one they left behind. Welcomed by the Genetic Welfare Bureau into their fold, they find that they were being monitored by the Bureau since decades as part of government clean up on a genetic experiment gone wrong. From the pan into the fire, right? Tris does the unspeakable, and Tobias looses himself as he comes to terms with his 'genetic disorder'. A gripping tale, but an unnecessary plot twist spoils the fun.

THROUGH THE LOOKING GLASS
BY LEWIS CARROLL

Alice never did learn not to poke her nose in mysterious things. Whilst playing with her kitten one afternoon, Alice notices something strange and enigmatic in the looking glass and well… steps into an alternate world. Here, the smiling clock greets here, talking flowers direct her towards to the Red Queen who challenges her to a game of chess; the pieces here are animated. If she wins, she will replace the Red Queen as the new Queen. Does she succeed? And where are Tweedledum and Tweedledee and the Mad Hatter and the White Queen? There, waiting for their turn in another mad adventure tale of Alice.

FANTASTIC BEASTS AND WHERE TO FIND THEM
BY J K ROWLING

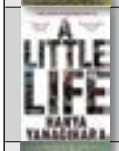
Written under the pseudonym of Newt Scamander, the author of the book, Fantastic Beasts and Where To Find Them, is a textbook a part of Harry Potter's curriculum, is an encyclopaedic collection of 86 magical species found in the world. It is written in a manner that is delightful; you have notes by Ronald and Harry in the margins, informative; helpful hints to find and avoid certain dangerous creatures and laughable; descriptions of the nature of the Loch Ness monster is rib-tickling funny. The movie adaptation differs ever so slightly; Scamander has lost some of the magical creatures he captured in a city and now with a bunch of friendly and no so friendly compatriots, he must find them before they are lost forever.

Top ten booklist: For February

The Revenant: A Novel of Revenge
by Michael Punke
Picador

The Martian
by Andy Weir Crown
Archetype

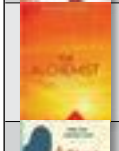
My Brilliant Friend
by Elena Ferrante
Europa



A LITTLE LIFE
by Hanya Yanagihara
Knopf Doubleday Publishing Group

Brooklyn
by Colm Toibin
Scribner

The Choice
by Nicholas Sparks
Grand Central Publishing



The Alchemist
by Paul Coelho
HarperCollins Publishers

A Man Called Ove
by Fredrik Backman
Washington Square Press

Room
by Emma Donoghue Little
Brown and Company

Ready Player One
by Ernest Cline Crown
Archetype

- List by barnesandnoble.com

DID HE SAY THAT!?

If you don't imagine, nothing ever happens at all

- John Green

- Compiled by Moshita Prajapati

IN FOCUS

WIKIMEDIACOMMONS X4

The genius that never was

William James Sidis

CLAIM TO FAME:

The polyglot and mathematical genius William James Sidis astounded the world by being admitted to Harvard at age 11. Unfortunately for science, the rest was not history.

When discussing geniuses, William James Sidis is definitely one of the smartest people you've never heard about. From being the youngest person at the time to enrol at Harvard University at age 11 in 1909 to an adult life of relative obscurity, Sidis' story is interwoven with brilliance and unrealised potential. He was a mathematical and linguistic prodigy and also tackled various other subjects but his reclusive nature isolated him from sharing his gifts with the world.

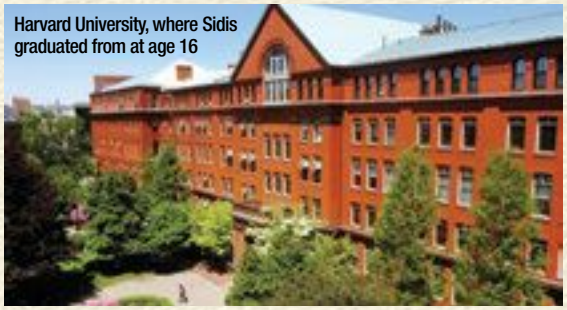
There's no refuting that Sidis displayed hints of genius from an early age. Born in 1898 to two doctors, Boris and Sarah Sidis, William picked up his parents' love for knowledge early on. Boris was a celebrated psychologist while Sarah was one of the few women to attain a medical degree in the 19th Century. Under them, William's upbringing was almost an experiment in nurturing precocity. After already being rejected at Harvard once for being too young at age nine, Sidis set a record at Harvard by becoming the youngest person to enroll at the age of 11. The national exposure he received at this young age may have turned him off from the constant public scrutiny.

Sidis' life steadily took on a more reclusive pattern after graduating cum laude from Harvard at age 16. He began teaching mathematics at William Marsh Rice University in Texas at 17 but had to withdraw as the strain of teaching students older than he grew too great. His arrest 1919 for participating in a riotous socialist May Day parade marked the end of Sidis' courtship with public fame. He withdrew from active public life, choosing to spend his days working menial jobs and studying peculiar topics that caught his interest, such as cosmology, anthropology and transportation systems. He published a number of works on his findings, but never received much acclaim as he chose to publish many of them under pseudonyms, wishing to avoid the public glare.

Sidis passed away of cerebral hemorrhage in 1944, without achieving the lofty targets that Boris and Sarah Sidis had intended for their prodigy. Instead, his story became the catalyst for a debate on how to approach educating exceptionally gifted children to avoid them burning out before reaching their full potential.

TRIVIA

- Between his rejection from Harvard at age nine and his eventual acceptance at 11, Sidis spent two years at Tufts College learning foreign languages and correcting errors in mathematical textbooks.
- By the time Sidis was nine, he had mastered eight languages and even created his own, called Vendergood.
- Sidis was able to read the New York Times by 18 months of age and by the age of five, he was being featured in the same publication for his stunning achievements.



Harvard University, where Sidis graduated from at age 16

William's father, Boris Sidis

William Marsh Rice University, where Sidis was teaching mathematics to 20 yr olds at 17

- Dushyant Shekhawat


BBC
Knowledge