

BBC



HOW WILD IS YOUR CAT?

Your feline friend is more lion than you think



Telepathy

Brain-to-brain
messaging is here!

**Robot
swarms**

They're just like ants

**Are screens
bad for you?**

How smartphones
affect your health

FOCUS

SCIENCE AND TECHNOLOGY

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ISSUE 274 / NOVEMBER 2014 / £4.25

HOW TO TRAVEL **FASTER THAN LIGHT**

Wormholes, warp drives and other ways to beat the cosmic speed limit

BRIAN COX SPEAKS
He's back with *Human Universe*



DINOSAURS REINVENTED
Feathers weren't just for flying



SMART WATCHES
Motorola 360 takes on Apple



MAN OF TODAY

GERARD BUTLER FOR BOSS BOTTLED



BOSS
HUGO BOSS

#MANOFTODAY



VICTORINOX

COMPANION FOR LIFE

KOBE (JAPAN), 1995

THE CAN OPENER

We had just arrived in the emergency shelter seeking protection from the earthquake when the next obstacle presented itself: there wasn't enough food for everyone in the shelter. Some of the people who still had enough strength, set off to search for food in the rubble. Covered in dust and completely exhausted, they brought back a large number of canned food items. We were very happy, until we realized there was no can opener to be found anywhere in the tent. Hungry and desperate, we stared at the inaccessible food. Then, I remembered my Victorinox pocket knife which I had intuitively taken with me during the evacuation. With it, I opened one can after the other and could see the relief and gratitude in the faces of the others. Most of us spent a sleepless first night in the emergency shelter – but at least we were well-fed.

Atsuo Murata, 2012

Victorinox products are a companion for life. What experiences have you had with Victorinox products? Share your story at victorinox.com



WELCOME



EVERYONE KNOWS THAT nothing can travel faster than light. Yet this month's big movie *Interstellar* depicts a way of doing just that. If you could fly a spacecraft into a wormhole, suggests the film, you could take a shortcut through space and time. On p36, Stuart Clark examines wormholes and other ways we could exceed the cosmic speed limit.

I'd love to visit the past to see living dinosaurs. I've seen fossils in the Natural History Museum, but what did they look like in the flesh? Strange as it may seem, the answer may be 'feathered'. Author John Pickrell investigates on p61.

Millions of years after dinosaurs, humans learned to use tools. And around 17,000 years ago, some of our ancestors used these tools to paint on the walls of Lascaux caves in France. Now, modern technology is preserving the past by creating a precise replica. Find out how it was done on p79.

Back in the Stone Age, animals had yet to be tamed – and if you own a cat, you'll know it still has a wild side. Dr John Bradshaw, presenter of a new BBC TV series, finds out just how wild your feline can be on p51.

Elsewhere we look at robot swarms (p54), ask whether screens are bad for you (p45) and journey to the heart of a human cell (p94). Enjoy the issue!

Graham

Graham Southorn, Editor

PS Don't miss our December issue, on sale 13 November 2014



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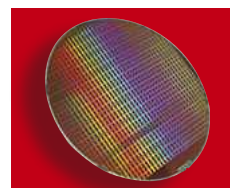
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THIS MONTH WE...



...interviewed technology leaders at the RE.WORK Summit in London. Which exciting new technologies will shape our world? Visit our YouTube channel to find out more.

...found out how computer circuits will recreate the human brain. Our interview with Karlheinz Meier, who is leading a project to build 'neuromorphic' chips, will feature on the podcast.



...spoke to Caleb Scharf, author of *The Copernicus Complex*, about exoplanets and the likelihood of life existing elsewhere in the Universe. Listen to Caleb on this month's podcast.

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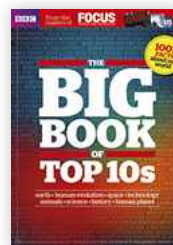
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APPEARING IN THIS ISSUE...



John Bradshaw

Dr Bradshaw of the University of Bristol studies how humans and animals interact. He's written our felines feature (p51) to tie in with his new BBC series.



Holly Cave

Holly is the author of *Really, Really Big Questions About Science*. In this issue, she asks if staring at phone and computer screens adversely affects our health (p45).



Stuart Clark

Stuart is the author of several space-related books, including *Is There Life On Mars?* In this issue he examines the prospects of travelling faster than light (p36).



Katherine Nightingale

Katherine is a cellular biologist and a science writer at the Medical Research Council. In this issue she reveals how scientists learned what makes up a human cell (p94).



WANT TO SUBSCRIBE?

Turn to p32 to **save 30%** on the shop price of *BBC Focus*



SUBSCRIBER BONUS

On p32, cosmologist **Andrew Pontzen** delves deeply into that most mysterious of substances: dark matter

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Awe-inspiring images from the world of science

MegaPixel

The hills are alive

LOCATED IN THE John Day river basin in eastern Oregon, USA, the colourful layers of the Painted Hills formed back in the days when the area was a floodplain – some 20 million years ago.

“The Painted Hills aren’t actually painted, except by the brush of deep geological time,” says Dr Matt Genge, a senior lecturer in Earth and Planetary Science at Imperial College London.

Instead, the colours of the different layers give clues to their origins. The black layers were formed from the decayed remains

of vegetation that grew along the side of the floodplain. The grey rocks are mud and silt drawn from the water when the plains flooded, and the red layers are laterite, a soil formed when warm water saturates the ground over long periods of time.

“Within the colourful layers are some surprising fossil remains. Bones of early horses, dogs, cats and saber-toothed cats are present together with camels and rhinoceroses,” explains Dr Genge.

PHOTO: MARK BRODKIN/SOLENT NEWS







MegaPixel

Fake snake

WHEN IT COMES to crowning the greatest role-player in nature, the snake-mimicking hawkmoth caterpillar has to be in with a shout. That's right - this is actually a caterpillar.

Hemeroplanes triptolemus lives deep in the rainforests of Central America, where its nifty powers of imitation come in handy in the cut and thrust of jungle life. When threatened, the bug draws in its legs and head and expands parts of its rear end to imitate a snake's head. To maintain the illusion, it will even strike out at any attackers - despite being unable to actually bite.

"Snakes are a very strong deterrent for many animals. Some species of monkey are inherently frightened of snakes - even monkeys never exposed to them will respond with alarm to hose pipes," says BBC presenter and entomologist Adam Hart. "But if the snake disguise doesn't work then it doesn't have much to fall back on, although many hawkmoth caterpillars can regurgitate their gut contents, which provides some protection."

PHOTO: DANIEL JANZEN/CATERS



MegaPixel

Plastic fantastic

You're looking at one of the most widely used materials on the planet, although you may not recognise it. This almost alien-like landscape is a 1,750x magnified view of a polyurethane, a polymer used in everything from mattresses and trainers to airport seats.

Like any polymer, polyurethanes are made up of repetitive individual units. If you change these building blocks you can vary the properties of the final product: from liquid, through flexible foam, to solid plastic.

"Pictured here is an open cell foam that is only 3 per cent polymer," says Dr Anthony Ryan of Sheffield University. "The key trick in polyurethane foam is to ensure that the bubbles meet and burst just as the polymer solidifies. If they burst before it solidifies, it collapses and shrinks."

Invented by German chemist Dr Otto Bayer back in the 1930s, polyurethanes were first widely used during World War II, commonly as a replacement for rubber, or as coatings on aircraft.

PHOTO: MARTIN OEGGERLI/MICRONAUT



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Brain activity prior to conscious thought does NOT rule out free will, argues Henry Parr



MESSAGE OF THE MONTH

Do we have free will?

The idea that we don't have free will (September, p72) is preposterous. The fact that Benjamin Libet detected brain activity half a second before the subject 'decided to act' proves nothing unless you know exactly what that brain activity was. And he relied on the subject's own notification that they had 'decided to act', which is hardly scientific. It seems to me that every action is a complex co-operative venture involving various parts of the brain, some conscious, some less so. The conscious mind is in charge but is in constant contact with the subconscious as it consults and negotiates. Of course there

will be brain activity before an action – it's called deciding! The idea that this means we have no free will seems to me to be sensationalist nonsense.

Henry Parr

In his 1985 experiment, Libet told subjects to move their arm. He discovered activity in their brains before they were aware of their decision to move it. But the interpretation of this, that there is no free will, is indeed controversial. Other areas of the brain than those studied might be in control, and most tasks are more complex than the one studied. The jury's still out... – Ed

+

Write in and win!

The writer of next issue's Message of the Month wins a Kisai Radioactive LED Watch worth £95. Made by Tokyoflash Japan, the watch has a brushed stainless steel case and tells the time through coloured lights resembling a nuclear reactor console. www.tokyoflash.com



Moon colony

Your article on lunar tunnels (September, p30) was fascinating. These tunnels could offer a perfect radiation shield and a benign environment that made me think about the possibilities of space colonisation. This would certainly involve a number of huge challenges, both technological and economical, to overcome. We should also consider that the survival of human civilisation, as argued by Stephen Hawking, may well depend on our ability to successfully colonise new worlds.

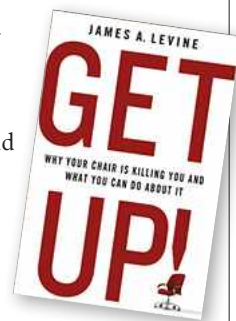
David Williams, Lytham St Annes

Standing: it's bad for you

Further to Michael Mosley's review of *Get Up! Why Your Chair Is Killing You* by James A Levine (September, p106), although I would agree that being too sedentary can lead to many disorders, spending too much time standing also has many drawbacks.

Having spent most of my working life (about 30 years) on my feet, I find I now have aching ankles, knees and hip joints, sciatica, and a very poor posture. It's due to leaning over a workbench, leading to muscular backache. Many of my colleagues have similar or identical issues. The fact is that too much of anything is not healthy. When someone finally writes a sensible book entitled *Do Everything In Moderation*, I may take note and read it!

Charles Frost



Alien hunt questioned

In the search for alien life, scientists have been targeting planets with the appropriate living conditions for a human (H₂O, O₂ etc) in the belief that they may also apply to alien life forms. But after millions of years of evolution, adaptation and survival, isn't it entirely possible that aliens may not require those living conditions? Therefore, are we looking in the wrong place?

Ben Kitching, Southampton

Bye-bye flies

Regarding the article on the best way to swat flies (September, p74), one technique not discussed was that you can put your open hand behind them, and go down as they go up. Flies take off by literally jumping backwards, so all you have to do is indent your palm a little and you can trap or stun them.

Geoff Willmetts, Bridgwater

No 13 for NASA?

Have the scientists at NASA-JPL succumbed to superstition by not using '13' in numbering the components of the Low-Density Supersonic Decelerator (August, p12)? How quaint... and also a little disturbing.

Steven Bottomley, Graveley

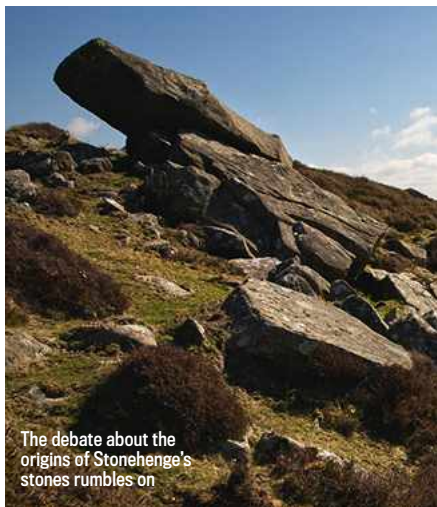
NASA's rescue of the Apollo 13 astronauts was its finest hour, so I'd be surprised if superstition was a factor in the apparently missing numbers. – Ed

Stonehenge secrets

It was good to see your article on Stonehenge and the bluestones (July, p48). However, Mike Pitts has got a few things wrong.

He says the glacial transport of the bluestones is "dismissed by mainstream science", but the majority of experts have written in support of it. Pitts rightly reports that new geology shows that many of the bluestones came from the northern slopes of Preseli, but he is wrong in claiming that ice over-riding Preseli would have preferentially picked up erratics [boulders] from the southern slopes. Glaciologists are happy about erratics being swept away from those areas now identified as the provenances for Stonehenge monoliths, and the new geology does nothing to support the "human transport" hypothesis, which remains as fanciful as ever.

Brian John



The debate about the origins of Stonehenge's stones rumbles on



Team *Focus* would never get a job at B&Q, clearly...

Going nuts

Having read the superb 'Don't try this at home' article (September, p49) featuring the work of Dani Jiménez, the commentary on viscosities highlighted language that leads to costly mistakes when misunderstood. Was it a 'bolt' or 'screw' that was dropped in the liquids or, as the picture seemed to show, a 'nut'?

Having sold them all, I'm still a bit nutty about them!

Brian Williamson, Alnwick

YOUR COMMENTS ON OUR FORUM

On the unmasking of 19th Century serial killer Jack the Ripper...

MikeG *The identity of the infamous criminal has finally been ascertained. DNA amplification techniques were used to examine the shawl of one of the victims. The DNA found was compared to the DNA of the suspect's descendants and his identity confirmed.*

Shadowwolf *I'd be inclined not to believe this latest claim. Barring the discovery of additional evidence or a time machine, the true identity of the killer may simply not be discoverable.*

M Paul Lloyd *I have to agree. Seems to me the evidence is somewhat circumstantial and the possibility of it standing up in court slim at best.*

MikeG *I am curious to see if any follow-up studies are done, to determine conclusively one way or the other. For the time being, I'll assume this was just pretty good marketing to sell a book.*

Join the discussion at
<http://sciencefocus.com/forum/>

FOCUS

SCIENCE AND TECHNOLOGY

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24.2
MEGAPIXELS



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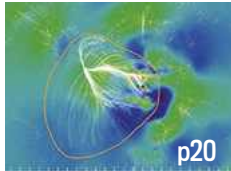
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DISCOVERIES

News and views from the world of science

EDITED BY
JASON GOODYER



OUR NEW ADDRESS

The Milky Way is part of a galaxy supercluster known as Laniakea

p20



STONEHENGE SECRETS

Archaeologists have discovered exciting monuments at the prehistoric landmark



NEW LIFE DISCOVERED

A strange new life form is baffling scientists

THE BIG STORY

BRAIN-TO-BRAIN COMMUNICATION

Scientists have managed to allow people to 'talk' to each other telepathically

CAN YOU IMAGINE being able to beam your thoughts directly into the minds of other people? Soon, this fantasy may become a reality. An international team of neuroscientists and robotics engineers has managed to allow brain-to-brain communication between two



True telepathy is a little way off, but researchers have completed the first step

PHOTO: SCIENCE PHOTO LIBRARY

One person thinks of a word, which is picked up by the headset (left) and sent over the internet to a receiver (right)



GOOD MONTH/ BAD MONTH

It's been good for: PIZZA LOVERS



EVERYONE HAS A fave pizza topping. But when it comes to the cheese most people are in agreement: it needs to be golden and melted, with the right elasticity. After testing various cheeses, the University of Auckland's Bryony James found Gruyère, Provolone and Emmental came out top. Yet combining one of these with mozzarella gave the perfect balance of elasticity and browning.

INSOMNIACS

HARVARD RESEARCHERS HAVE located a neurone in the parafacial zone of the brain stem that is responsible for sending the body into deep sleep. The findings could lead to new medications for sleep disorders and development of safer anaesthetics.

It's been bad for: WINNERS



DO YOU FIND that you win everything so easily that you get bored? A team at Istanbul's Şehir University has found it's the uncertainty of a close game that creates enjoyment, regardless of the outcome. They had 72 undergraduates play video games against one another. Almost 70 per cent of winners said they would rather play opponents of similar ability than ones they could beat.

PEOPLE WITH BLOOD TYPE AB

AB IS THE rarest blood type, found in just 4 per cent of the population, but a study has found that those with AB blood may be more likely to develop memory loss. A total of 30,000 individuals were followed for 3.4 years on average. People with type AB were 82 per cent more likely than others to develop the thinking and memory issues that can lead to dementia.

→ humans. Researchers from Spain's Starlab Barcelona and Axiom Robotics in Strasbourg, France have successfully transmitted the simple greetings 'hola' and 'ciao' between the minds of participants located 8,000km (approx 5,000 miles) apart.

"We wanted to find out if one could communicate directly between two people by reading out the brain activity from one person and injecting brain activity into the second person, and to do so across great physical distances using existing communication methods," explains study co-author Alvaro Pascual-Leone. "One such method is, of course, the internet, so our question became, 'Could we develop an experiment that would bypass the talking or typing part of the internet and establish direct brain-to-brain communication between subjects located far away from each other in India and France?'"

It turns out the answer was 'yes'. To do it, the team attached a series of electrodes to the transmitter's scalp to record specific

patterns of activity that were triggered when saying a simple greeting. They translated this into binary code and then emailed the results from their base in India to a laboratory in France. A computer-brain interface transmitted the message to the receiver's brain through non-invasive brain stimulation. The 'receivers' experienced this as a sequence of light flashes in their peripheral vision that they were able to successfully decode.

"This in itself is a remarkable step in human communication, but being able to do so across a distance of thousands of miles is a critically important proof-of-principle for the development of brain-to-brain communications," says Pascual-Leone.

The system is currently slow, transmitting only 2 bits of information per minute. However, if it speeds up, future applications could include communicating with stroke victims and sending messages to soldiers in combat.

TIMELINE

A history of brain-to-brain communication

1912

Russian physiologist Vladimir Pravdich-Neminsky carries out the first animal EEG to measure the response of a dog's brain to electrical stimulation.

1924

German physiologist and psychiatrist Hans Berger invents the device known as the electroencephalogram (EEG) and uses it to conduct the very first human EEG. He published his findings five years later.



1976

US researcher Jacques Vidal creates a Brain Computer Interface that lets users guide a virtual object through a computer-generated maze.

2013

A Duke University team achieves brain-to-brain communication between two rats, allowing them to transmit information to one another.



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PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world



Disney's drone spectacular

IF YOU VISIT A Disney theme park in the near future, you might be forgiven for thinking that the Mad Hatter has slipped something into your tea. A recent patent application reveals that Disney is planning to populate its parks with blimp-sized marionettes that swoop and sway beneath the command of a fleet of drones.

The unmanned vehicles will be attached to the marionettes by tether lines, which will pull on the characters' arms and legs like hands manipulating humongous string puppets. A control system on the ground will choreograph the drones' movements so that the characters appear to walk, dance and fly through the air.

Two more Disney patent applications detail how the flying vehicles could also carry projection screens in aerial displays, or even be used as 'floating pixels' that flash and glow to simulate fireworks. It promises to be even trippier than a tumble down the rabbit hole.

Patent application number: US20140231590

Digital sandwich boards

SANDWICH BOARDS COULD soon be getting a 21st Century reboot. Nomadix Media is patenting a modern version that supports an LCD screen above the wearer's head. A mounted camera captures images of the audience and sends them to a remote server, where they're analysed. The system then selects a suitable advert for the onlookers, making sure that no old ladies are bombarded with adverts for the latest Slipknot album.

Patent application number: GB2511129

Burglar-proof bike

BICYCLE THIEVES MAY have met their match. Three engineering students in Chile have come up with what might be the world's first unstealable bike. The clever idea behind their Yerka Project is to make the lock an integral part of the bike's frame. To securely lock up the bike, the down tube is divided into two and rotated by 90°; then the seat post is taken out and threaded through. A would-be thief would need to break the bike in order to steal it, effectively rendering it useless.

Patent pending
nadiemelaroba.cl

SPACE

Milky Way's new address

The Milky Way is actually part of a much larger group of galaxies

THE MORE PERNICKETY among us might want to update our address books: astronomers have determined that the Milky Way is part of a huge, newly identified supercluster of galaxies dubbed Laniakea.

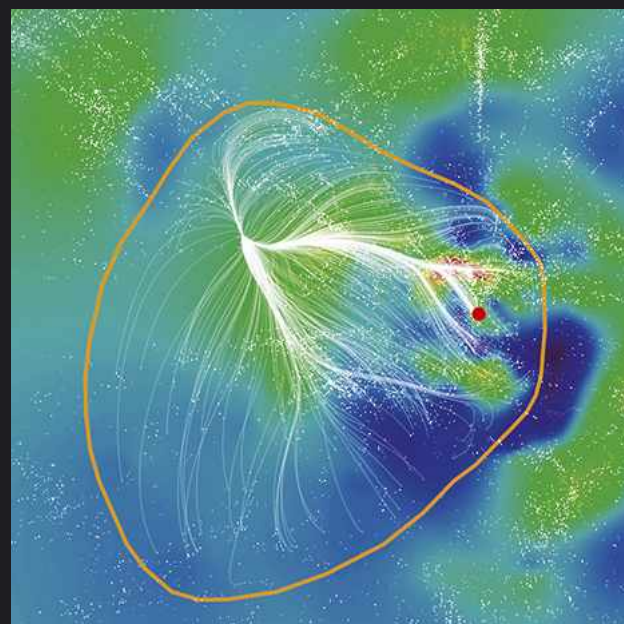
Researchers made the discovery by piecing together data from several radio telescopes, including West Virginia's Green Bank Telescope, to form a detailed 3D map.

Superclusters contain dozens of galaxies, making them among the largest structures in the known Universe. They are so big that the gravitational forces they generate affect the motion of nearby galaxies. By measuring the velocities

of galaxies throughout our local Universe, the researchers were able to determine their positions.

The Laniakea supercluster is 500 million light-years across, contains in excess of 100,000 galaxies and has a total mass of 100 million billion Suns. Its name means 'immense heaven' in Hawaiian.

"We have finally established the contours that define the supercluster of galaxies we can call home," said lead researcher R Brent Tully. "This is not unlike finding out for the first time that your hometown is actually part of much larger country that borders other nations."



Laniakea is contained in the orange circle; the Milky Way is the red dot

“Of course, if you enjoy mopping, scrubbing and vacuuming, iRobot® might not be your thing...”

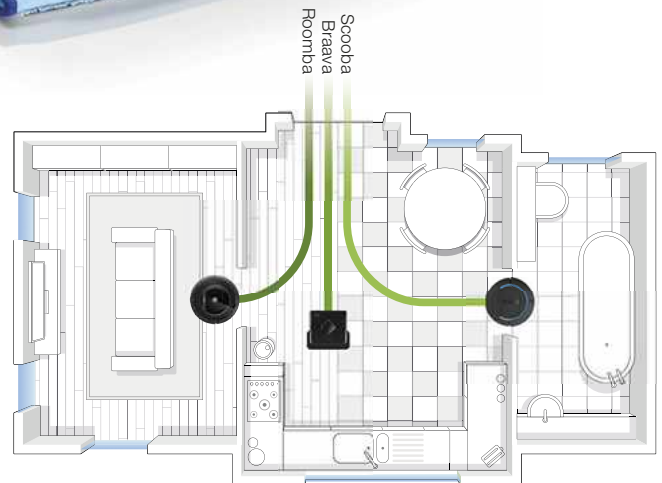


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1 MINUTE EXPERT

Majorana particles



What are they?

As yet undiscovered particles that act as their own antiparticles. They are named after Ettore Majorana, the Italian physicist who proposed them in 1937.



Tell me more!

When most particles confront their antiparticles – particles with the same mass but opposite charge – they annihilate each other and emit energy. It is theorised that Majorana particles do not do this.



Are we any closer to finding them?

University of Surrey researchers have created a method of potentially detecting them, by using photons and superconducting circuits to find Majorana particles' signatures.



So what can they be used for?

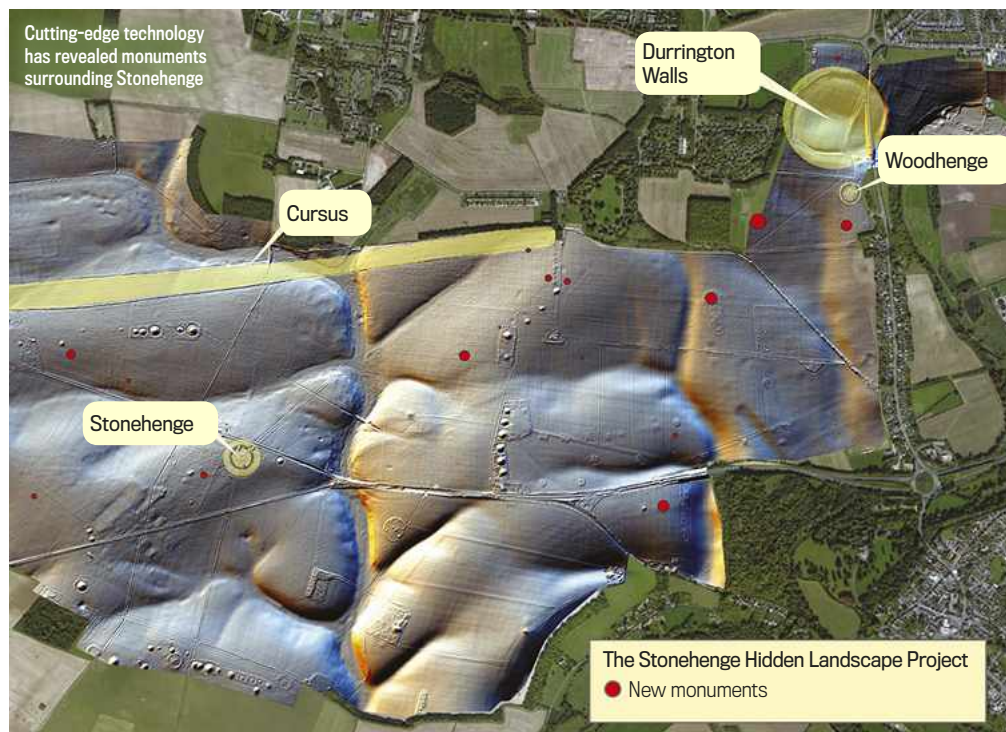
Researchers believe the particles could be of use in the production of functioning q-bits, the building blocks of quantum computers.



Ettore Majorana proposed the particles

ARCHAEOLOGY

Stonehenge site mapped



IT'S ONE OF the UK's most enigmatic monuments and has puzzled researchers for decades. Now, thanks to a digital scanning project, archaeologists have discovered more about Stonehenge than ever before.

Using cutting-edge remote sensing and geophysical imaging techniques, researchers from Birmingham University have discovered 17 previously unknown monuments surrounding the famous landmark, including burial mounds, circular ditches and an enormous timber building thought to have been used in funeral rituals.

"Despite Stonehenge being the most iconic of all prehistoric monuments and occupying one of the richest archaeological landscapes in the world, much of this landscape in effect

remains terra incognita," explains project leader Vincent Gaffney.

The work has revealed prehistoric pits that seem to line up with constellations, as well as Bronze Age, Iron Age and Roman settlements.

The researchers have found that Durrington Walls, the 1.5km-circumference 'super henge' situated close to Stonehenge, was once surrounded by 60 three-metre-tall posts, some of which may still remain beneath the surface.

"This project has revealed that the area around Stonehenge is teeming with previously unseen archaeology and that the application of new technology can transform how archaeologists and the wider public understand one of the best-studied landscapes on Earth. Stonehenge may never be the same again," added Gaffney.

WHO'S IN THE NEWS?

Jack the Ripper

Has London's infamous serial killer finally been caught?

What's he been up to now?

The last murder attributed to him was in 1888. His identity has eluded researchers for over 100 years, but new DNA analysis carried out by scientist Jari Louhelainen has named the killer as Aaron Kosminski, a Polish barber.

DNA found where, exactly?

In 2007, businessman Russell

Edwards bought a shawl that was allegedly found at the murder scene of Catherine Eddowes, one of the Ripper's victims. He contacted living descendants of Eddowes and Kosminski, and their DNA matched that on the shawl.

How long can DNA survive?

A 2012 study found that DNA has a half-life of around

500 years, depending on conditions. Theoretically, the Ripper's DNA could have survived. The biggest issue is contamination during storage.

So that settles it, then.

Not quite. Despite Edwards's claims, the work has yet to be submitted for peer review. The shawl's provenance has also been questioned by some.

What lies beneath the Arctic sea ice?

DAVID SHUKMAN

The science that matters



A FEW YEARS ago I flew on a US Coast Guard plane that was patrolling Alaska's Arctic coast. Over the din of the engines, an admiral shouted into my ear: "My job is to guard the waters around the United States and there's a lot of water where there used to be ice."

The sea ice covering the Arctic Ocean expands and melts with the seasons, but the past 35 years have seen a decline of nearly 14 per cent each decade. As this region becomes more accessible, science is getting dragged into the spotlight.

Research into when the Arctic might be clear enough

for new shipping lanes is closely watched, as is work on potential movements of fish stocks. But nothing attracts more attention than studies of the ocean floor.

This year, Canada dispatched two vessels to survey part of the seabed. This kind of activity has huge political and economic significance because the Arctic may hold enormous reserves of oil and gas, and ownership will be decided by mapping.

The stakes were raised in the summer of 2007 when a flamboyant Russian politician used a mini-submarine to plant his country's flag at the North Pole. Moscow's case is that an

undersea feature, known as the Lomonosov Ridge, extends from the Russian continental shelf right up to the roof of the world. So, it is argued, any oil and gas up there must be Russian.

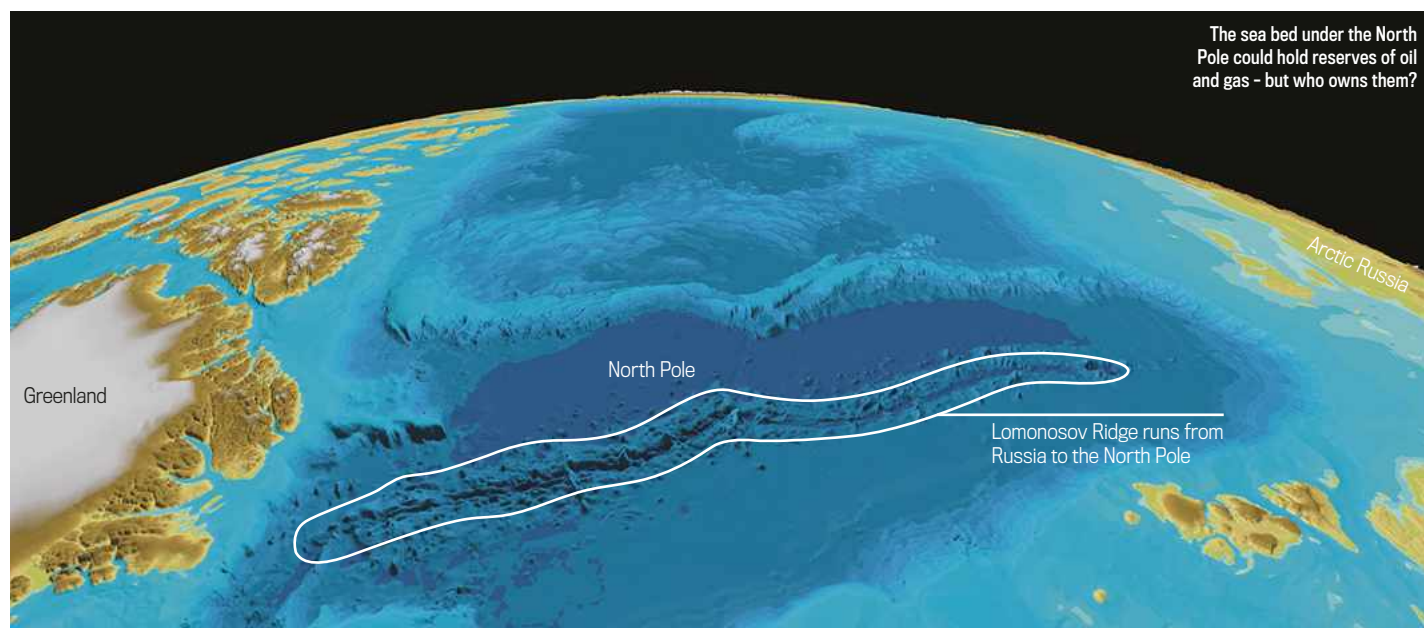
Not so fast, say other countries bordering the Arctic. Denmark, which owns Greenland, also claims a geological connection to the ridge, as does Canada.

So far, this contest is being fought with a combination of rhetoric and research. Each nation's ships are deploying sonar systems and robotic submersibles to build up a picture of the seabed's shape.

The results may show that the Lomonosov Ridge is connected to one country or another, but more likely the results will be a matter of judgement. At some point, the various claims will come before the United Nations. And the geologists involved, more used to polite exchanges at an academic seminar, will find their work under scrutiny.

In this new version of a gold rush, science may come up with answers, but not everyone will appreciate them.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc



THEY DID WHAT?!

Birds taught carpentry... by another bird

What did they do?

After living at a research centre for two years, a Goffin's cockatoo named Figaro began

breaking wooden material into sticks to retrieve food or toys that lay inside a cage. The researchers then had other cockatoos watch his behaviour to see if they could learn it.

Why did they do that?

Many bird species use tools in the wild, but Goffin's cockatoos do not. The researchers wanted to see if Figaro was a one-off



or if other cockatoos could also learn how to use tools.

What did they find?

Three of the six cockatoos picked up the skills themselves. They used different techniques to Figaro, suggesting they were not copying his movements but acting creatively. Two of these birds went on to reproduce Figaro's tool-making behaviour.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10



Salamanders: not just a pretty face

Wound-healing ointment

EVER CUT YOURSELF and wished you could spontaneously heal, Wolverine-style? Studies of a protein taken from the skin of salamanders may result in more effective wound-healing

ointments being developed. Tylotoxin, a peptide containing 12 amino acids, was found to promote healing when tested on skin wounds in rats. The next step is to test the process on humans.



Another day in the office for Harvard University's robot

Tough robots

THIS IS HARVARD's latest soft robot. But don't be fooled by the word 'soft'. This bot is one tough cookie. Made from silicone rubber backed with Kevlar, it has survived crawling through snow and ice, walking through flames and being run over by a car. Moreover, it is the world's first untethered creation of its kind, meaning it can operate independently under its own power source. Future iterations of the bot could be used in search and rescue missions following natural disasters.

7

Graphene paint

RESEARCHERS HAVE FOUND yet another use for wonder material graphene: using it as paint. A team of scientists at Manchester University created a paint made from graphene oxide that forms an incredibly strong, transparent and non-corrosive coating that can be applied to almost any surface.

It could be used on everything from packaging and glassware to medical devices and ships.



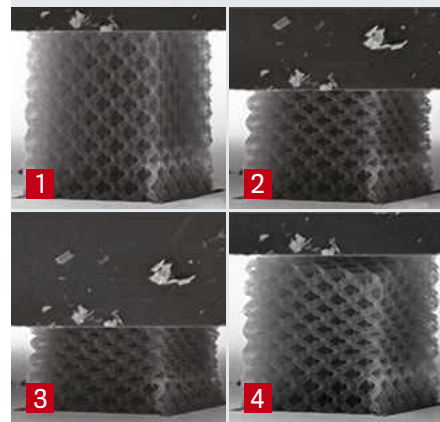
Dr Rahul Nair with a graphene membrane

9

Shatterproof material

BIT OF A butterfingers? Fear not, because materials scientists have developed a shatterproof ceramic material that can spring back into its original shape after being dropped.

It could be used to create everything from synthetic bone to balloons, researchers say. The material was created by constructing a 3D nanometre-scale lattice. This was done by 'sculpting' solid polymer with a laser. The structure can then be coated with almost any type of material.



Sequence demonstrating how the flexible ceramic can recover after being squished by 50 per cent

6

Fishing nets for greenhouse gas

IT SOUNDS LIKE something plucked from the pages of a surreal joke book: researchers in Japan have created a polymer 'net' capable of removing greenhouse gases from the atmosphere. Named PIM-1, the material is peppered with cavities less than 2 nanometres in diameter that capture CO₂ and other harmful gases while allowing other components of air to pass through. The material could potentially cut the cost of capturing CO₂ by 1,000 times, the team says.

Could a net capture the gas from human activities?



5 Tiny radio chips

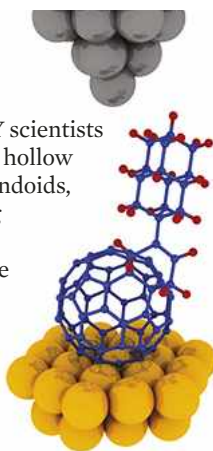
ENGINEERS AT **Stanford University** have built an ant-sized radio chip that could make the internet of things a reality. The team has squeezed a functioning radio into single battery-less silicon chip that can harvest energy from incoming radio signals.



This radio could allow appliances to talk to each other

3 Shrunk computers

STANFORD UNIVERSITY scientists have combined buckyballs, hollow carbon spheres, and diamondoids, tiny carbon cages weighing less than a billionth of a billionth of a carat, to create a diode. Diodes are key components of electronic circuits. **The resulting 'buckydiamondoids' could be vital in miniaturising computer chips.**



4



Honey has been renowned for its wound-healing properties for centuries

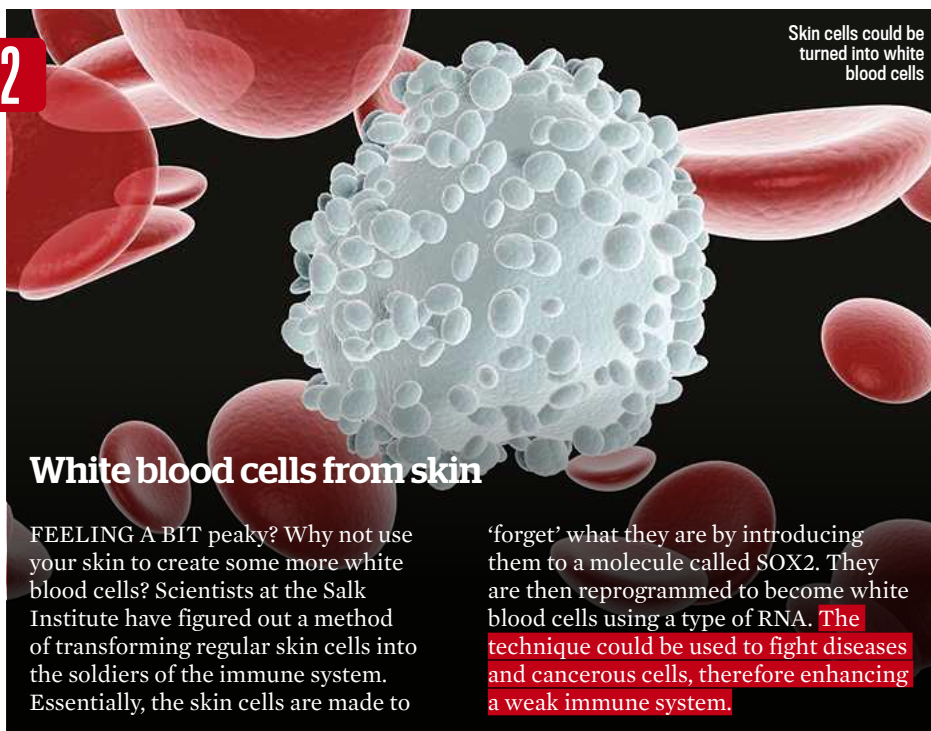
Sweet new antibiotics

A TEAM AT Sweden's Lund University has found an unlikely ally in the battle against antibiotic resistance: bees.

A group of 13 unique lactic acid bacteria found in fresh honey can effectively counteract a range of infectious

pathogens, including antibiotic resistant MRSA. It has so far only been tested for the treatment of wounded horses but if it proves equally successful in human trials, the bacteria could soon find its way into hospitals and pharmacies.

2



Skin cells could be turned into white blood cells

White blood cells from skin

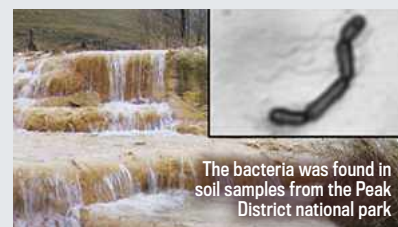
FEELING A BIT peaky? Why not use your skin to create some more white blood cells? Scientists at the Salk Institute have figured out a method of transforming regular skin cells into the soldiers of the immune system. Essentially, the skin cells are made to

'forget' what they are by introducing them to a molecule called SOX2. They are then reprogrammed to become white blood cells using a type of RNA. **The technique could be used to fight diseases and cancerous cells, therefore enhancing a weak immune system.**

1

Waste-eating bacteria

IT MAY BE famous for its lush countryside and stately homes, but the Peak District is also home to **bacteria that could potentially help in the disposal of nuclear waste.** Scientists at the University of Manchester have discovered 'extremophile' bacteria capable of 'eating' chemicals that could otherwise bind with disposed radioactive waste and allow the substances to enter the water supply.



The bacteria was found in soil samples from the Peak District national park



CLICK HERE

New websites, blogs and podcasts



94 ELEMENTS

94elements.com

This project aims to tell stories relating to all 94 naturally occurring elements that make up Earth and most of the things on it. Currently, you can hear the touching tale of a patient who remains

optimistic despite needing supplementary oxygen for a severe respiratory condition, but more stories are still to come.



NEW HORIZONS COUNTDOWN TO PLUTO

seeplutonow.com

Pluto may no longer be a planet, but that doesn't make it less interesting. The New Horizons spacecraft was launched in 2006 – just a few months before Pluto lost

its planetary status – and is due to reach the ice dwarf and its moon Charon in July 2015. Keep up with the mission here.



FEYNMAN LECTURES

feynmanlectures.caltech.edu

Whether you're a physics undergraduate or an interested amateur, Feynman's lectures are well worth bookmarking. You'll find all three volumes here, all free and optimised for mobile

devices. Feynman gave the lectures to undergraduate students at Caltech in the early 1960s, but they're timeless to this day.



97 HOURS

skepticalscience.com/nsh

Ever heard someone say there's no consensus on climate change? Show them this. Created by Skeptical Science, 97 Hours brings together 97 quotes about climate change from 97 scientists who work in the field. The number was from a study that found 97 per cent of climate scientists agree that humans are the main cause of global warming.



KELLY OAKES is a science journalist who tweets from @kahoakes

METEOROLOGY

Grab an umbrella: weather is set to get more unsettled

IT'S OFTEN SAID that British weather is so unpredictable that it's possible to experience all four seasons in a single day. Well, if researchers from the University of Sheffield are correct, we may soon be experiencing such unsettled weather more and more.

The Sheffield team has found that British winters are becoming more unstable thanks to extreme pressure variations over the North Atlantic – known as the North Atlantic Oscillation (NAO) – ranging from very mild, wet and stormy to extremely cold and snowy. After studying weather data from British winters over the last 115 years, the researchers found that three out of five all-time record high NAO values, and

two out of five record lows for December, occurred during the last decade.

“Our study highlights the changing nature of North Atlantic atmospheric circulation patterns that has given the UK more variable winter conditions in recent years,” says researcher Prof Edward Hanna. “We cannot use these results directly to predict this winter's weather. But according to the long-term NAO trend we can say that the probability of getting extreme winter weather – either mild/stormy or cold/snowy – has significantly increased in the last few decades. Further research is needed to show whether or not this increased volatility is linked to global warming.”



According to researchers, British winters could become far more extreme



INSIDE SCIENCE

ROBERT MATTHEWS

From homeopathy to climate change, some issues can't help but cause the 'red mist'

ANYONE CAN START a fight in a pub; just shove your way to the bar, spill a few pints on the way, then ignore the complaints. Getting people to kick off at a genteel tea-party is a bit harder – but it can be done. Just pour the tea for everyone, ask if they want milk in before or after – then put the tea in first anyway, and tell them not to be so daft. Cue complaints – or worse – when victims insist milk always be put in first. “It stops the tea tasting too bitter,” they’ll say, or “It conforms to BS 6008, the British Standard for making tea.” Yes, really.

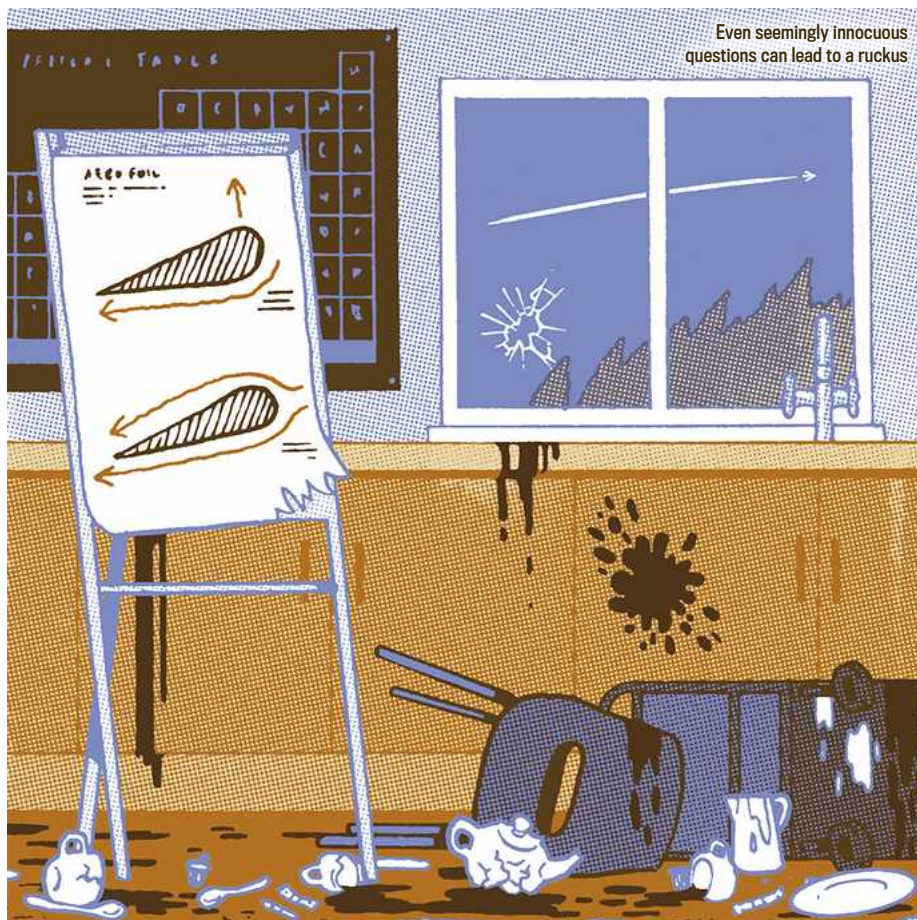
Then cue the other lot, explaining how it makes no sense to add milk until you’ve seen how strong the tea is. That was George Orwell’s conclusion in his polemic on the subject, published in 1946. He knew he was asking for trouble. When I did a piece on the science of tea-making for a newspaper, the heaps of mail I got showed nothing had changed 50 years later.

Ever since, I have been perplexed by why some issues cause the ‘red mist’ to descend, while others leave people unmoved. There’s no telling what it might be. Having facts to argue over seems irrelevant. It’s been proven beyond all reasonable doubt that there’s no link between the MMR vaccine and autism, yet it’s a brave person who’ll sound off on the subject at the local antenatal group.

Having a scientific training doesn’t prevent the red mist effect either. One newspaper recently ran a piece about the notoriously provocative subject of animal experimentation. The resulting comment section featured the usual nutters from both sides of the debate – along with professional scientists hurling abuse at one another.

It doesn’t even have to be about anything important. Take the case of what dries the clothes in a spin-dryer. It’s centrifugal force, right? Whoah – you might think so, but as any science writer knows, using the C-word to explain what’s happening will unleash a torrent of outrage from retired physics teachers; indeed, I’ll probably get rebuked just for saying it’s not a very important issue.

The effectiveness of homeopathy, the reality of climate change, whether hot water freezes faster than cold... there’s a whole host of seemingly random issues capable of causing even the most rational of



“There’s a whole host of issues capable of causing even the most rational of people to descend into fury”

people to descend into fury. But why these? There’s no outrage, for example, over the 1,000-plus deaths caused each year by the radioactive gas radon seeping into UK homes. No-one’s much bothered about whether, say, teapots benefit from being warmed first.

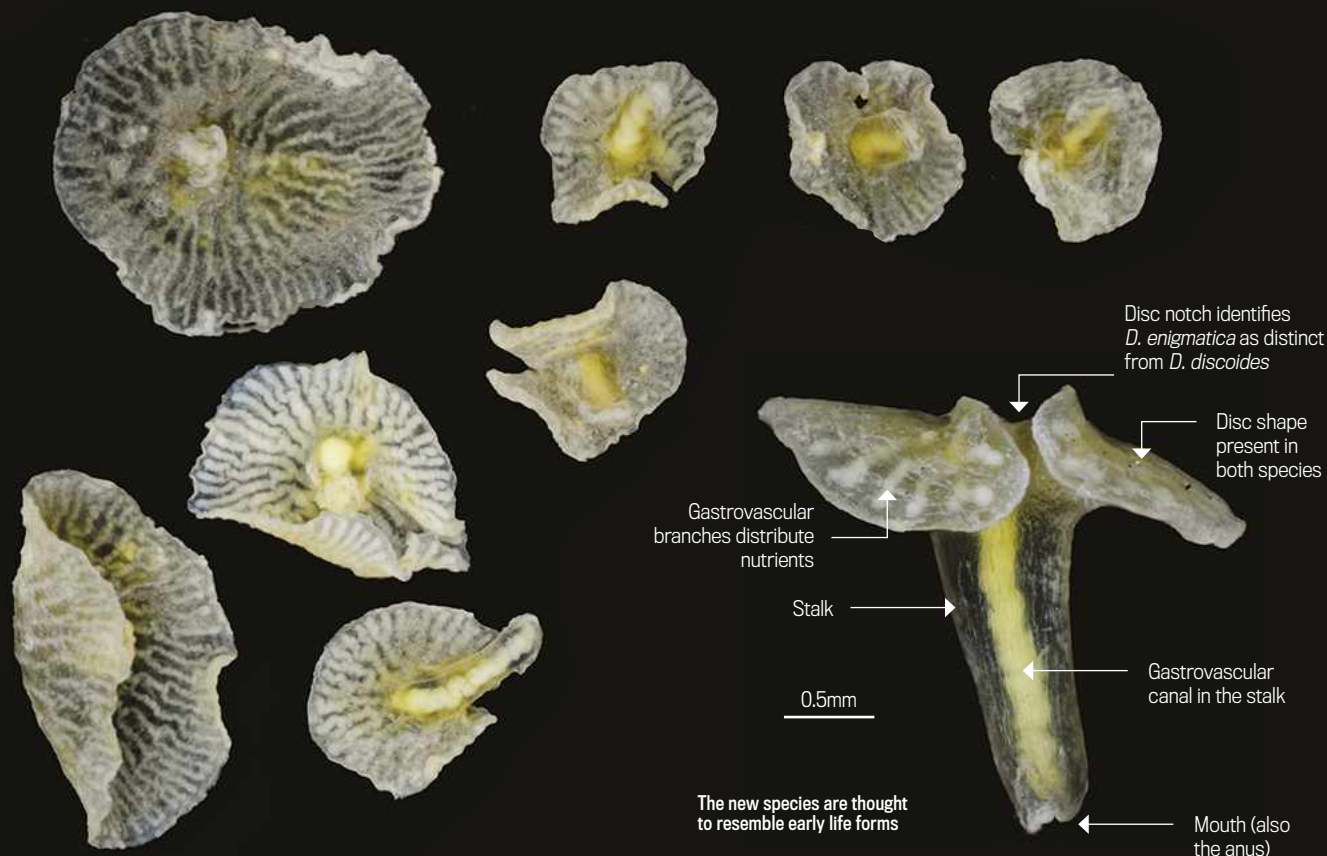
There is, however, one red mist issue I dearly wish someone would sort out: how aircraft stay up in the air. Over a century after the Wright Brothers, this one still provokes furious argument. Some say it’s simply the result of the wing deflecting the oncoming air downward. Others insist it’s the result of the bulging upper surface of the wing forcing the air to move faster over the top than below. Both have their failings – and both can trigger the red mist effect.

I’m currently working with the Institute of Physics to find a really satisfactory explanation that will please everyone. One idea is to hold a competition, like the one back in the 1990s to find the best explanation for what the Higgs particle is all about. But there’s just one problem: who’ll decide which explanation of flight is the right one? ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

BIOLOGY

New oceanic life found



THEY MAY LOOK like the mushrooms sold in posh delis, but you wouldn't want to put these unusual organisms in your risotto. The tiny fungi-shaped life forms are so unusual that researchers at the University of Copenhagen say they do not fit into any of the known subdivisions of the animal kingdom.

They were collected in 1986, at depths between 400 and 1,000m off the Australian coast, but have only recently

been analysed. They were preserved in formaldehyde and stored in ethanol, making them unsuitable for detailed molecular analysis. The researchers say gathering further samples may help them more accurately determine the organisms' relationship to other life.

"Two species are recognised and current evidence suggests that they represent an early branch on the tree of life, with similarities to the 600-million-

year-old extinct pre-Cambrian lifeforms, Ediacara fauna," explains University of Copenhagen researcher Jørgen Olesen.

The new organisms are multicellular and have a dense layer of gelatinous material between the outer skin cell and inner stomach cell layers. Scientists have classified them as two new species in a new genus, *Dendrogramma enigmatica* and *Dendrogramma discoides*, in the new family, *Dendrogrammatidae*.

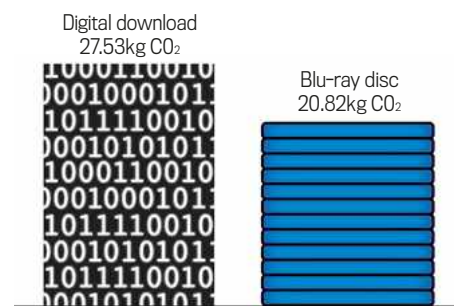
TECHNOLOGY

Discs greener than downloads

IT'S A QUESTION likely to have been asked by every environmentally minded gamer: which format has the bigger carbon footprint, digital download or Blu-ray?

A team led by Kieren Mayers of the INSEAD Social Innovation Centre in France found that Blu-ray discs bought from retail stores are in fact the greener option, as long as file sizes are sufficiently

large. The team estimated total carbon emissions associated with Blu-rays and digital downloads for an 8.8GB file that was played for 232 hours. The bulk of emissions came from playing the game, but there was a significant difference between the two formats. Blu-ray racked up 20.82kg of CO₂, while the upper bound estimate of a digital download clocked in 27.53kg.



The carbon footprint of an 8.80GB game on two formats



EVERYDAY SCIENCE

HELEN CZERSKI

Clouds don't just form interesting shapes - they're huge power stations too

FOR THE PAST 15 minutes I've been staring out of the window, looking up at fluffy white clouds. They're floating eastwards, and though it's calm down here it's clearly rush hour up there. They're shape-shifting as they go. Just now, I saw a frog tip over until it became a human face that turned into a hat. Then I started thinking about it and almost gave myself vertigo. It wasn't the physical scale of the clouds, or the fact that all these tonnes of liquid water are happily floating 3km off the ground. It was the thought of the torrent of energy that all this represents, that's whooshing about above our heads every day.

Imagine a water molecule that's just evaporated from my cup of tea. It's got enough energy to float away from the cup and join the jostling masses of oxygen and nitrogen molecules and others that make up our atmosphere. They're all sharing energy by playing bumper cars - each molecule collides with another one about a billion times each second. Our water molecule finds itself in a puff of warm air, sliding upwards through the atmosphere like an invisible hot air balloon. As the balloon rises, it expands and cools, and the jostling molecules slow down a bit. There is dust in the balloon as well, and occasionally our water molecule settles on to one of the dust particles. But it has enough energy that it soon escapes and joins the bumper cars again.

About 3km up there's a sudden change that betrays some secrets. The molecules have cooled and slowed so much that when our water molecule sticks to a dust particle, it doesn't always have enough energy to escape. This is the start of a liquid droplet, and this water molecule will soon be joined by others. Condensation begins, and a cloud is born. The hidden air packet has revealed itself.

And here's where the energy really starts to play a role. It takes energy for a water molecule to remain as a gas, and when it condenses on to the dust, that energy is given up and makes everything around it warmer. The quantity is vast. Think about the energy your kettle uses to heat 1 litre of water from 0°C to 100°C. To convert the same amount of liquid into gas, it takes five times as much energy as the kettle, even though the temperature doesn't change. And when the water condenses, it gives the energy back. The forming cloud has

"An average cumulus cloud might have 1,000 tonnes of liquid water in it. It's a monstrous amount of energy to play with"



Water molecules from a cup of tea eventually join their friends in the clouds for a game of bumper cars

billions of tiny droplets of liquid water condensing from water vapour, each giving off heat energy. Our hot air balloon is suddenly supercharged with the energy of millions of kettles, so it warms, expands and rises faster, climbing up to the top of a cloud. This one air packet makes a puff - one of those familiar friendly puffs on the tops of cumulus clouds - and then runs out of energy for the time being. An average cumulus cloud might have 1,000 tonnes of liquid water held within it. It's a monstrous amount of energy to play with, and it's only a fraction of the total in the cloud (the rest is gas).

The formation of a cloud lets us glimpse the churning of the atmosphere. That's why these clouds are always changing shape - air is constantly bubbling up from below, briefly becoming visible as it shifts energy around via water, and then sinking back down.

Never mind frogs and faces and hats. Next time I look at cumulus clouds, I'll see them for what they are - a tiny part of the vast engine of our atmosphere. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series is *Super Senses*



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 TRUSTPILOT



Model shown:
ICON-209L T100



INTO THE FUTURE STEPHEN BAXTER

Forty years on from a plan for an interstellar probe, significant challenges remain

FORTY YEARS AGO a group of British visionaries, meeting in London pubs, were trying to imagine a dynamic interplanetary culture a hundred years hence. But they weren't science fiction writers. These were aerospace engineers, and they were trying to figure out who would pay for the ship they were designing: a starship called Daedalus. In November 2014 Project Icarus, initiated by the British Interplanetary Society (BIS), is due to conclude. This is a volunteer international effort to design an interstellar probe using fusion technology.

But Icarus is itself an update of an earlier BIS design effort that ran from 1973 to 1978: Project Daedalus. As it finally emerged, the Daedalus space probe would have been sent on a 50-year uncrewed flyby mission of Barnard's Star. The two-stage craft would have consumed 50,000 tonnes of fusion fuel to deliver a 450-tonne science payload. These are heroic numbers. By comparison, the fuel load of the Saturn V moon rocket massed around 3,000 tonnes. And the energy Daedalus would have expended was more than the total annual energy expenditure of the whole world back in the 1970s.

The Daedalus study had been inspired by a German-American theoretical physicist called Friedwardt Winterberg, who in the early 1970s had sketched a propulsion system based on 'inertial confinement fusion' (ICF). You would fire a pellet of particular isotopes of hydrogen and helium (deuterium and helium-3) into a combustion chamber. There it would be compressed by lasers until it detonated: a miniature thermonuclear bomb. The detonation would shove your ship forward – and you would repeat that operation 250 times per second, for several years, until you reached your cruise speed of 12 per cent of the speed of light.

The Icarus study has shown that 40 years on the challenges remain significant. For one thing the valuable isotope helium-3 is vanishingly scarce on Earth, although it is available in the atmospheres of the giant planets, and perhaps on the surface of the Moon. As for the engineering itself, the National Ignition Facility in California continues experiments on ICF – but, as with other fusion projects, progress is very slow.

The Daedalus engineers didn't want to design a craft that could never be built. So, beyond the fusion engineering, they addressed the fascinating question of what kind of future society might be able to support such a

Helium mining on Jupiter: shall we use the gas to power the Daedalus spacecraft, or inflate billions of party balloons? Decisions, decisions



“A Daedalus probe might be as comparatively cheap as the Apollo Moon programme”

project. In their final report (1978), the Daedalus authors described a future Earth that was populous and energy-hungry. Against a background projected from the then-current 'world energy crisis', they predicted a demand for future energy sources of 'minimal impact on the environment of Earth' – such as nuclear fusion. The authors imagined mining helium-3 from Jupiter with huge balloon-like 'aerostat' extraction factories floating in the Jovian atmosphere. To such a society, a Daedalus probe might be as comparatively cheap as the Apollo Moon programme.

To build a starship would, however, require political will and peace. The authors wrote: 'It seems probable that a Solar System-wide culture making use of all its resources would easily be wealthy enough to afford such an undertaking [as Daedalus], and presumably in order to have reached the stage of extensive interplanetary flight would also have achieved reasonable political stability.' Thanks to Project Icarus we are slowly responding to the engineering challenges of interstellar flight. Forty years on from Daedalus, however, the human factors seem as intractable as ever. ■

STEPHEN BAXTER is a science fiction writer whose latest book, *Ultima*, is published this month by Orion

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SCIENCE AND TECHNOLOGY

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HOW TO TRAVEL **FASTER THAN LIGHT**



ILLUSTRATOR: ANDY POTTS



This month, the movie *Interstellar* depicts humans exploring deep space. **Stuart Clark** investigates the possibilities of rapidly traversing the Universe using wormholes, warp drives and a mysterious substance called negative energy

YOU'RE ALL PACKED and waiting in the departure lounge. You've checked your passport for the umpteenth time, you're wondering what the in-flight film will be, and although long-haul is not your favourite, it will all be worth it when you get there. But you are not going a few thousand miles to reach another continent. Instead, you are stepping aboard a starship that is going to travel a few thousand light-years.

The dream of interstellar travel is one that most of us have had at one time or another. It's a common theme in sci-fi movies: trips to distant worlds, journeys into black holes, or salvation for the human race away from the dying Earth. The latter is the premise of director Christopher Nolan's latest film *Interstellar*, in which a group of astronauts use shortcuts through space and time, called wormholes, in order to find habitable worlds across the cosmos.

The biggest problem encountered when contemplating interstellar travel is the vast distances involved. The nearest star to us is Proxima Centauri, which is 40 trillion kilometres away. That's the number four followed by 13 zeroes! Given such unwieldy numbers, astronomers have created the light-year. A light-year is the distance that a beam of light can travel in a single year and is the equivalent of 9.5 trillion kilometres. On this scale, Proxima Centauri is 4.2 light-years away.

Astronomers choose the speed of light

"I'd have to say that wormholes are a pretty tough proposition"

Stephen Hsu, physicist at Michigan State University

→ because it is the fastest thing in the Universe. Experiments in the 19th and 20th centuries showed that the speed of light appeared to be an absolute limit on how fast you can travel through space.

The fastest spacecraft ever made were the European Space Agency's Helios probes. In the mid 1970s, they flew past the Sun at a speed of more than 70,000 metres per second. That's nothing compared with light, which travels at 300 million metres per second. Even if we could travel at the speed of light, it would still take 4.2 years to travel to the nearest star. And it would just be the nearest star. Most are hundreds, thousands, or even hundreds of thousands times farther.

If we are ever going to make interstellar travel a practicality, we are going to have to find some way of circumventing this absolute speed limit. That's where wormholes come in. "Wormholes are a fundamental topic in general relativity," explains physicist Stephen Hsu of Michigan State University.

MAPPING SPACE

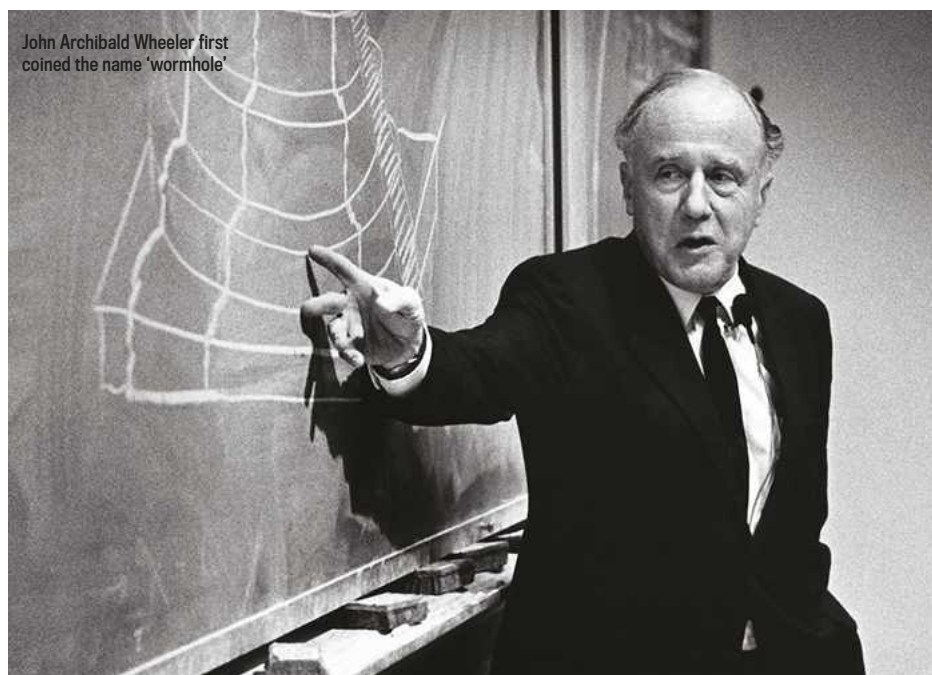
General Relativity is Albert Einstein's description of the Universe. It provides a coordinate system called space-time, in which all celestial objects are placed. Space-time is often described as a continuous fabric that stretches throughout the Universe. When you move around in space-time, you're moving in both space and time. Celestial objects warp this fabric, and while this warping is



Launched in 1974, Helios became the fastest spacecraft

"Wormholes are a fundamental topic in general relativity"

Stephen Hsu, physicist at Michigan State University

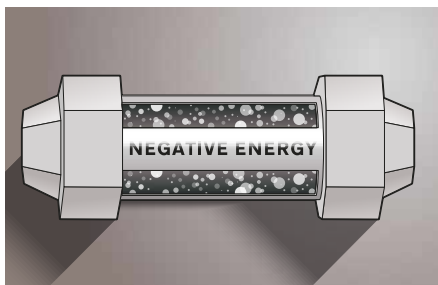


John Archibald Wheeler first coined the name 'wormhole'

PHOTO: NASA/KSC; SCIENCE PHOTO LIBRARY X2; ILLUSTRATOR: AQUITE GRAPHICS

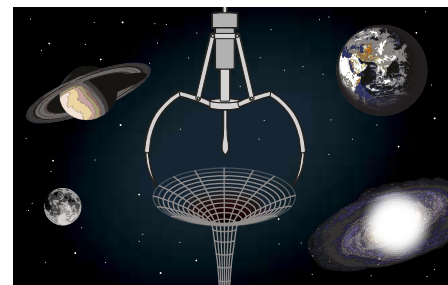
HOW TO BUILD A WORMHOLE

By combining sophisticated technology with a dash of negative energy, we could create wormholes to traverse space and time



1 Get negative energy

The first step is to find a source of strong negative energy to counteract the tendency for a naturally created wormhole to collapse. This energy must be stored in a way that overcomes its tendency to make space-time expand around it. This would involve advanced tech and there's no guarantee that the correct negative energy exists.

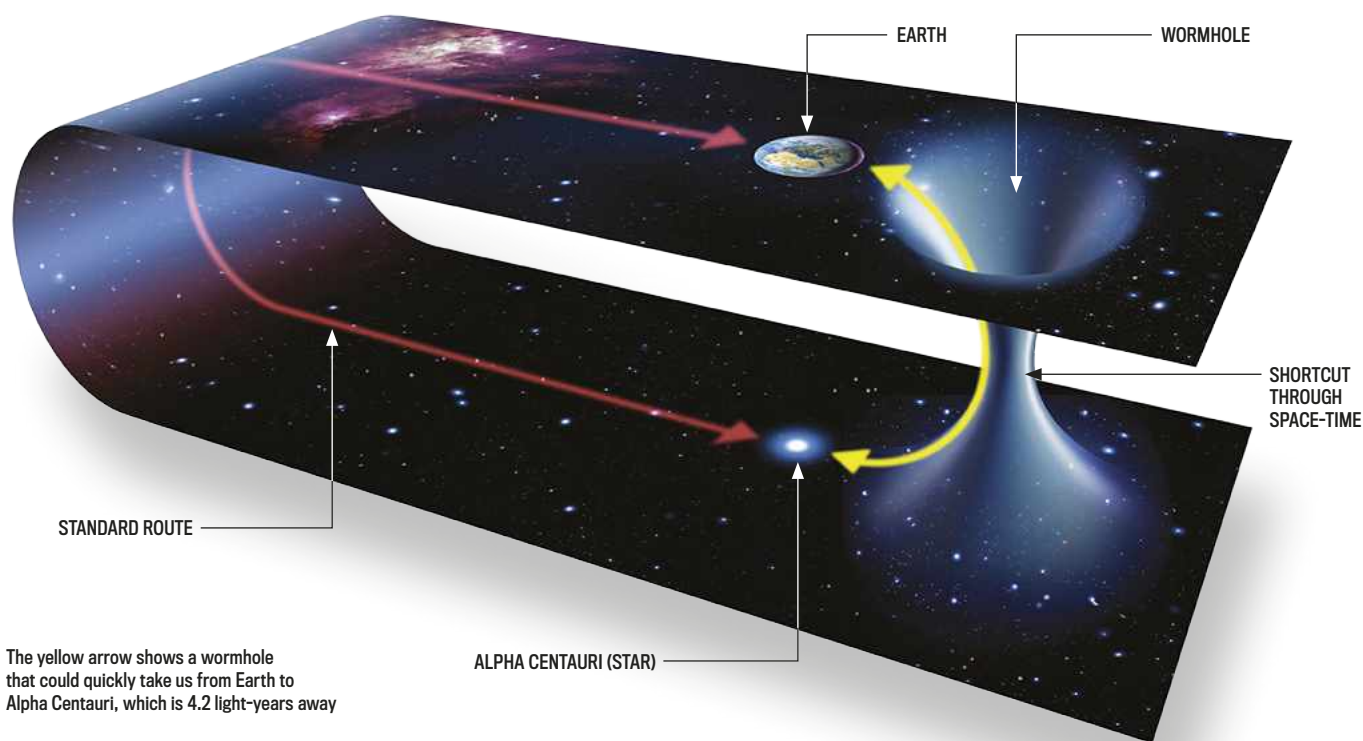


2 Find a wormhole

Wormholes are likely to be constantly forming and disappearing on the Universe's smallest scales. Quantum foam is the space-time continuum seen through an ultra powerful microscope or particle detector. A highly sophisticated piece of technology would have to grab a sub-microscopic wormhole by the throat.

SPEEDY SHORTCUT

Wormholes have been discussed by scientists for nearly a century and could be the secret to hopping through space – the trouble is, it's uncertain if they could definitely be built



largely invisible to us, it creates the force of gravity and deflects rays of light.

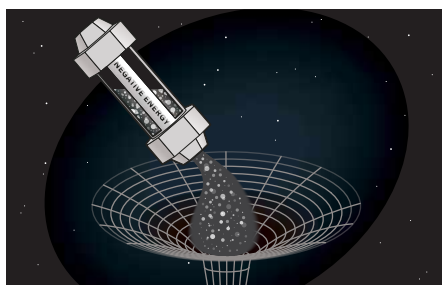
Wormholes are tunnels through space-time; think of them as shortcuts that stop you having to travel the long way round through space. The name was first coined by John Archibald Wheeler in a 1957 article for the journal *Annals of Physics*. Einstein himself investigated the

possibility in 1935 with his colleague Nathan Rosen, while German mathematician Hermann Weyl proposed their existence the decade before.

Based upon the mathematics of black holes, Einstein-Rosen bridges, as the wormholes were called, appeared to be sub-microscopic structures. They also seemed to be naturally unstable. So

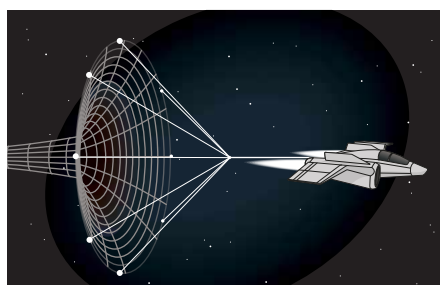
WHAT IS SPACE-TIME?

Space-time is the coordinate system Einstein used in General Relativity. Time is treated as no different from three-dimensional space. No one knows if space-time is a mathematical structure, or physically real. Attempts to detect space-time's structure have failed, but it's still early days.



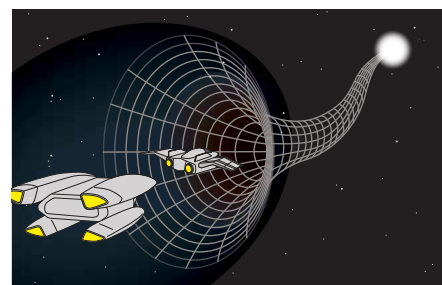
3 Easy does it

Once the wormhole had been stabilised with a shot of negative energy, a space probe would have to be sent through to see where it ended up. If it led nowhere useful, or somewhere dangerous, then it could simply be left to decay away again. But if it formed a beneficial bridge, then the task of injecting more negative energy into it would begin.



4 Shortcut through space

Once the wormhole was large enough, it could begin to be used by traffic. There may also be the possibility of moving the entry and exits into better locations. All that would be needed is some sort of space tug that used the antigravity force of negative energy to 'push' the wormhole's openings into more beneficial positions.



5 Cosmic motorways

Eventually, a wormhole network could span the Galaxy and beyond. It may even be possible to tunnel into other universes, if they exist. Since wormholes are shortcuts through space-time, they may be able to be used as time machines. But you would never be able to go back to a time before the wormhole was created.

→ while it is possible that sub-microscopic wormholes are forming continually, they are collapsing before anything can pass through them.

Skip forward to 1988 and the work of physicist Kip Thorne of the California Institute of Technology. Thorne found that if the right kind of energy could be introduced into the wormhole at the moment of its creation, the tunnel could be stabilised and enlarged, therefore making it traversable. And hey presto: interstellar travel! Except that there is a problem, and it's to do with the energy that's required. "It is unlike anything that we actually know about in the Universe," states Hsu.

The problem is that it has to exert what's called 'negative pressure'. To do that, it must be some kind of negative energy or mass, capable of creating a force of anti-gravity. In 1997, astronomers discovered that the expansion of the Universe was accelerating. They decided that this was happening because space is filled with a kind of negative energy that is causing the expansion to speed up.

They called it 'dark energy', but not even that fits the bill for wormholes. "It's even weirder than dark energy," explains Hsu. Nevertheless, he began calculating the precise details of what this energy would do to the wormhole. It wasn't good news.

The energy would follow the strange laws of quantum mechanics, which operate on the smallest scales. The upshot is that its position and momentum could not be precisely determined, so the wormhole would be 'fuzzy'. "There would be some uncertainty about where or when you would end up if you went through it,"



Stephen Hsu believes something weirder than dark energy is behind wormholes
Below: The *Interstellar* movie poster



A wormhole is a tunnel through space-time - the fabric of the Universe

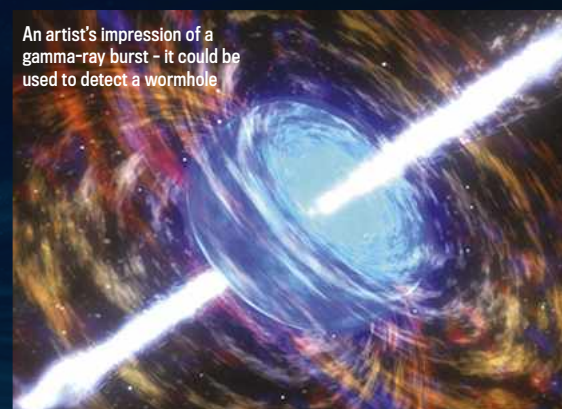
HOW TO FIND A WORMHOLE

Locating a wormhole in the depths of space is a pretty tough proposition, but there are several theoretical ideas about what to look for...

It may be possible to see stars from the other end of the wormhole shining through the conduit. Alexander Shatskiy of Moscow's Lebedev Physical Institute calculated that the negative energy needed to open up the wormhole will push light into a halo coming from the edges of the wormhole.

Shatskiy suggested that a gamma-ray burst (GRB) taking place on the other side of the wormhole could give it away. Astronomers would be able to see a GRB but would fail to identify a host galaxy in which it took place.

Another thought is that the mouth of the wormhole could drift across our line of sight in front of a star. The strong gravitational field



An artist's impression of a gamma-ray burst - it could be used to detect a wormhole



Miguel Alcubierre delighted sci-fi fans in 1994 when he outlined how a warp drive could be manufactured

says Hsu. In other words, yes you could take a shortcut through space-time. But you wouldn't be able to control the destination or the time of arrival.

For Hsu, this all adds up to one result: "I'd have to say that wormholes are a pretty tough proposition and certainly way beyond any technological capabilities that we are going to have in the foreseeable future."

So wormholes may remain the preserve of fantasy. Indeed, their early champion Kip Thorne is a consultant on the *Interstellar* movie. But what about that other bastion of sci-fi: the warp drive?

"It is clear that the theory of relativity is not the last word. But all the rest is speculation"

João Magueijo, professor of physics at Imperial College London

STAR SURFER

In 1994, Mexican physicist Miguel Alcubierre made his name by showing theoretically how a warp drive could be constructed. He solved Einstein's equations to show precisely how a bubble of space-time could be engineered in such a way that a spacecraft could surf this wave at arbitrarily high speeds.

The sticking point is that it again relies on some kind of negative energy to warp space and provide the anti-gravity force to push the spacecraft around.

WHAT IS NEGATIVE ENERGY?

Negative energy is a hypothetical substance that would generate an anti-gravity force. It is linked with exotic matter, another hypothetical substance, which possesses properties that have never been observed in the lab. No one knows if these substances exist, or are just mathematical possibilities.

of the wormhole would first amplify the star's light, through a process known as gravitational lensing. The star would dim as its light disappeared down the wormhole. Finally, the starlight would spike again in another gravitational lens effect, as the wormhole moved off the star. This would be a recognisable signature of a wormhole.

Perhaps the most important aspect of identifying a wormhole is the implication that extraterrestrial beings must exist. A wormhole large enough to be visible is probably only possible because some enterprising – and highly advanced – life form has managed to engineer it.

NASA's Johnson Space Center in Houston, Texas, is home to a small team of scientists and engineers who work in the Advanced Propulsion Physics Laboratory. Under the guidance of engineer and physicist Harold 'Sonny' White, they replicate experiments that others claim show unexpected properties that could be used for future propulsion. The NASA team hit the headlines and controversy in summer 2014 when they appeared to publish results corroborating that an "impossible" drive system could work.

The system was originally called the EmDrive and was invented by British aerospace engineer Roger J Shawyer. Shawyer believes that microwaves directed into a conical cavity can produce a thrust under the right conditions.

His work has been savagely attacked by physicists who point out that it violates the conservation of momentum, an underlying principle in physics. However, a number of other research teams, including that of White, also seem to have measured a thrust in re-constructed experiments. ➔

3 THINGS THAT ARE FASTER THAN LIGHT

We grow up believing that nothing in the Universe can move faster than light, but this trio of physical oddities can beat photons to the finishing line

Cosmic inflation

This is a hypothetical moment in which the Universe became suddenly bigger. For this to have happened, space-time must have expanded at many times the speed of light. No physical laws are violated because the cosmic speed limit only applies to things that move through space-time, not to the movement of space-time. It's unclear whether inflation happened. Nevertheless, the expansion of space is making distant galaxies appear to recede from us at velocities several times that of light.



Cerenkov radiation

The optical equivalent of a sonic boom, Cerenkov radiation occurs when light passes from vacuum into a denser medium, such as water or glass, it slows down. High-energy particles travelling in the same direction often do not slow down as quickly as the light and find themselves travelling faster. They create a shock wave that pushes light out of the way. It is common to see this Cerenkov radiation as a ghostly blue glow around nuclear reactors that are covered in water.



Tachyons

This is a generic name for any particle that travels faster than the speed of light. It is a hypothetical idea that was given its present name in 1967. A particle that travelled faster than the speed of light would violate the known laws of physics unless it had some extremely peculiar properties. If such a particle were possible, it would be able to travel backwards in time, and could never slow down to travel below the speed of light. Sounds exciting, but none have ever been found.



Johnson Space Center:
where scientists investigate
our sci-fi fantasies

→ A press officer from NASA's Johnson Space Center declined *BBC Focus*'s interview request with White but said in a statement, "While research into theoretical faster-than-light travel from a team at the Johnson Space Center has created headlines, this is a conceptual investigation." In other words, don't pack your suitcases just yet.

Advances that could make interstellar travel possible may not just come from

"Travelling between stars is not going to be feasible to us for a very, very long time"

Stephen Hsu, physicist at Michigan State University

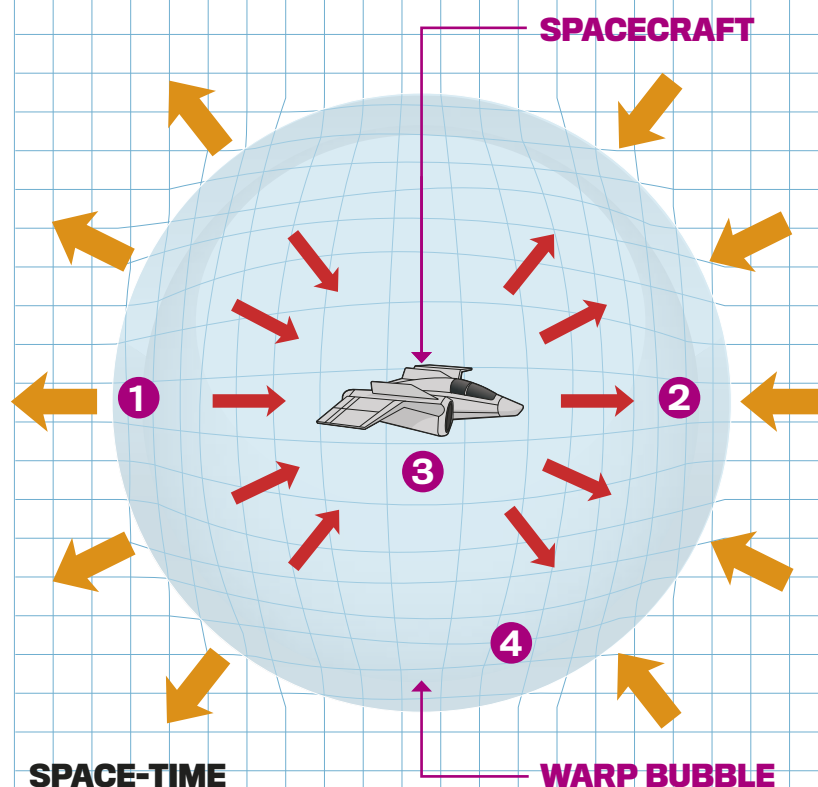
experiments. New extensions of gravitational theories beyond Einstein's General Relativity may show us how to break the speed of light barrier.

"According to existing theory, we should not be able to break the speed of light. But

WARP DRIVE EXPLAINED

Surf through space

The theory of General Relativity makes it appear impossible for anything to travel through space faster than light-speed. But space-time itself does not suffer from such restrictions. A warp drive would be able to curve the fabric of the Universe in such a way that space-time would be contracted in front of the spacecraft, while being expanded behind it. The spacecraft would then 'surf' this movement while remaining virtually stationary in its own little patch of space-time inside the warp bubble. Pretty nifty.



- 1** Hypothetical negative energy would make space-time expand strongly behind the spacecraft.
- 2** Ordinary energy would create a powerfully contracting area of space in front of the vessel.
- 3** The spacecraft sits in a relatively flat region of space-time, 'surfing' the wave.
- 4** The depth of the warp determines the speed with which the spacecraft is carried along.

we are aware that there are limitations to the existing theory and that in reality things might be quite different," says Portuguese physicist João Magueijo of Imperial College London.

Magueijo has been working to advance a brand new theory of gravity that applies when the force becomes extremely strong, such as near a black hole or close to the moment of the Big Bang. Both of these are places that general relativity breaks down.

Magueijo hypothesises that in the moments after the Big Bang, the speed of light would be much higher than here on Earth. As well as solving a number of cosmologically puzzling observations, Magueijo has also pointed out that it could open up highways of interstellar travel.

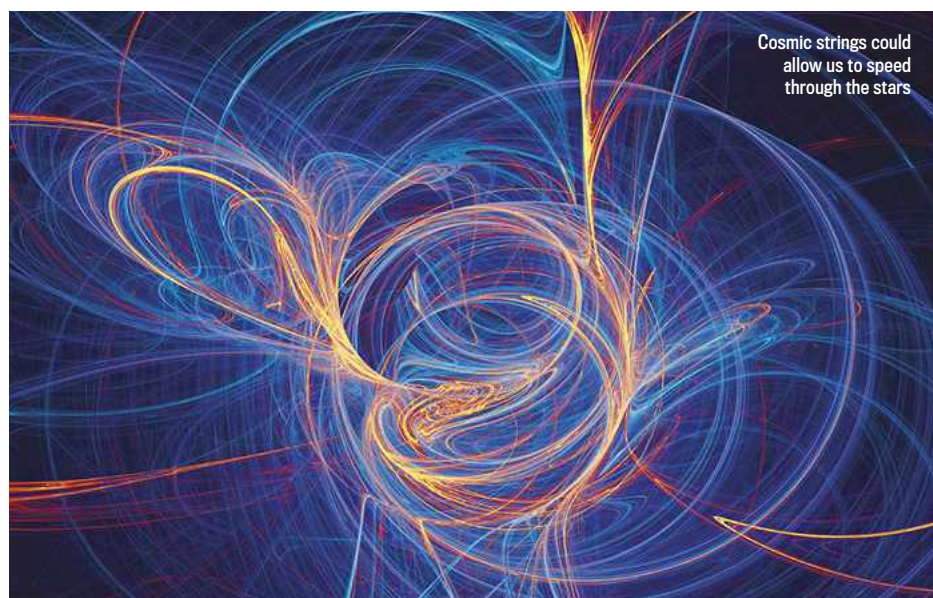
This could be possible because many theories of the early Universe predict a phenomenon called cosmic strings. These are left over from the Big Bang and have

not yet been directly observed. These 'creases' in space-time are boundaries between subtly different regions of space. They are rather like the defects that can occur in crystals. Importantly, they are massive and the speed of light would increase closer to the cosmic strings, and then stay high along its entire length.

There would be nothing to stop a spacecraft positioning itself alongside one of these cosmic strings and using it like an interstellar highway to the stars. The beauty is that you would not have to break the speed of light – you would just need some hefty engines to accelerate the craft.

Nevertheless, such exciting technology is still a long way off from becoming reality, and Magueijo remains very cautious of saying whether it's even possible. "It is clear that the theory of relativity is not the last word. But all the rest is speculation," he tells us.

And so, as Stephen Hsu confirms, we must reluctantly conclude that our dreams of interstellar travel must for now remain confined to the silver screen. "I think the classic *Star Wars*/*Star Trek* way of travelling between stars is not going to be feasible to us for a very, very long time." ■



STUART CLARK is the author of *Is There Life on Mars? The 20 Big Universe Questions*. He tweets from @DrStuClark



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TIME TO
SWITCH OFF?

Your morning TV, your smartphone commute, the office desktop and your home laptop: you probably spend more time staring at a screen than you think. But is it bad for you? **Holly Cave** investigates

TWO WORKERS SIT together at a desk; three-dimensional shapes shimmer in the air in front of them. One reaches into the design, altering it with a fingertip before flicking it over to her colleague. The mist-like apparition moves as they move, switching seamlessly between the air in front of their faces and the interactive table top.

This futuristic scenario is not science fiction, but exists as a working prototype created by researchers at the University of Bristol's





Interaction and Graphics Group. Formed by a curtain of fine water droplets, MisTable's see-through and reach-through 'screens' are not just a spellbinding novelty – it's hoped they could solve many of the health problems associated with today's electronic devices.

DIGITAL EYESTRAIN

Many of us feel the effects of screen use on our eyes. Blurred vision, headaches and burning, itchy, sensitive eyes are some of the host of uncomfortable symptoms captured under the umbrella term Computer Vision Syndrome, or digital eyestrain.

Given the time some of us are now spending focused on a screen, it's perhaps no surprise that this problem is so common. As you might expect, research has shown that digital eyestrain is directly

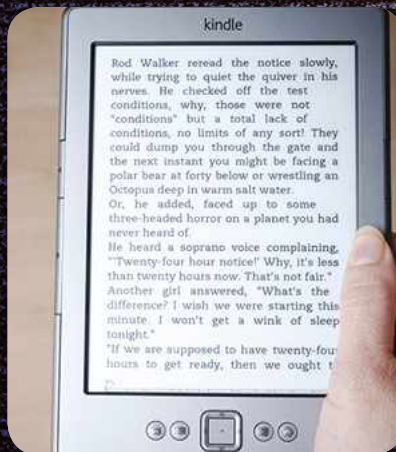
“Some people hold their phones as close as seven or eight inches away. You'd never hold a book that close”

associated with the length of time spent looking at screens – the longer you use them for, the more likely you are to develop the symptoms.

But is staring at a screen any worse than running your eyes over information on the printed page? For certain problems, such as dry eyes, research suggests it is. When we're looking at screens, we tend to stare straight ahead rather than down, as we might when reading a book, resulting in a larger surface area of our eyes being exposed to the drying effects of circulating air. We also seem to blink less often when processing information from screens, compared to paper. This means our eyes are less regularly moistened by tears.

“People are spending hours and hours looking at screens,” says Mark Rosenfield, a vision scientist based at the State University of New York. “Some people are approaching 12 to 15 hours a day on these things. Typically, people simply don't look at printed materials for that long.”

“But I don't know if computer vision syndrome is caused by the screen itself or by the way people are looking at them, for a couple of reasons,” he says. “Firstly, the print often is pretty small – especially



Paper-like screens are less problematic



Never mind the blue screen of death, what about the blue screen of chronic insomnia?

80%

of 'Millennials' (people aged 13 to 32) sleep with their mobile phones next to their bed.

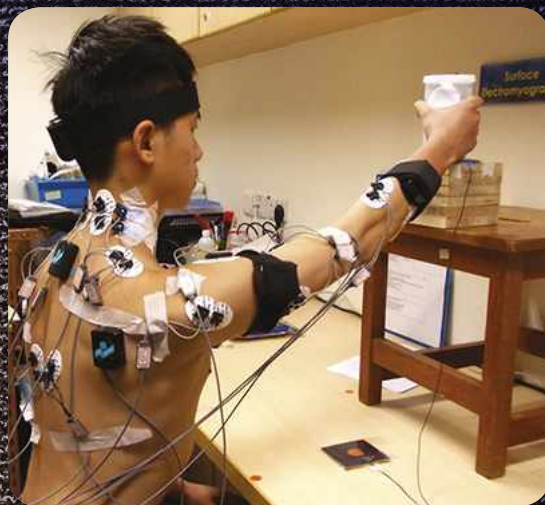


on smartphones – and people tend to hold them at very close distances. We've found that some people are holding their phones as close as seven or eight inches away. You'd never hold a book that close and this means the eye has to work a lot harder than if it was looking at larger print further away.”

He counters that recent reports of screen use causing myopia, or short-sightedness, are as yet unfounded – “though I think kids especially are spending a lot more time looking at screens than they would be reading. So it's possible this does lead to short-sightedness, just by virtue of the length of time they're spending on their devices.”

Of course, anyone who owns an eReader will tell you that an eInk screen is kind to your eyes and will spare you any side effects, and to a degree, they're right. Since eInk doesn't require a backlight to work, it taxes the eye less. Indeed, in the lab,

Monitoring smartphone usage habits at Grace Szeto's laboratory



Physiotherapist and screen use researcher Grace Szeto

researchers repeatedly find that there's no subjective or objective (number of blinks made by the reader) difference in the fatigue experienced while reading an eBook compared to a printed one. But that isn't the end of the story.

Researchers from the Reading Centre at the University of Stavanger, Norway had a hunch that using an eInk screen might be changing our reading habits. In an experiment they gave volunteers a short story to read - half read it on an eReader while the others were given a physical book. A week later they invited the participants back for a simple test: retell the story's events in chronological order. As suspected, the print readers were able to recall the events of the story more accurately than their eReading counterparts. Although it's not clear why the digital readers had a more porous memory, it's clear that



of people using computers for at least two hours a day report eye problems associated with Computer Vision Syndrome, or digital eyestrain.

THE EFFECT ON SLEEP

Not getting your full eight hours? Taking your phone to bed could be the problem

NEUROLOGISTS HAVE KNOWN for years that staring at screens late in the evening can disrupt sleep. Yet more and more of us are taking mobiles and tablets into the bedroom, where we hold them right in front of our eyes for extended periods of time before we try to nod off.

Browsing Facebook on your tablet disrupts your body's circadian rhythm - its ability to "do the right thing at the right time" - says Mariana Figueiro of Rensselaer Polytechnic Institute's Lighting Research Center. Playing our favourite game not only makes us feel alert when we should be winding down, but also fires blue light at our retinas. Shorter in wavelength than the white light produced by lamps, it stops our bodies from producing the sleep hormone melatonin. The pineal gland would normally start to release melatonin into the bloodstream a couple of hours before our typical bedtimes, signalling 'lights out' to our body.

Not noticed this effect? Figueiro's research shows that some people are more sensitive to light than others. Data from her lab suggests that melatonin is suppressed to a greater extent in teenagers than in university students, for example.

And the knock-on effects of delayed and disrupted sleep may stretch far beyond making it hard to get up in the morning. "Long-term suppression of melatonin has been linked to sleep disorders, which in turn have been linked to diabetes and obesity," Figueiro adds. "In animal models, prolonged suppression of melatonin and disruption of circadian rhythms has also been linked to an increased risk of cancer."



Put tablets away an hour before lights out if you want a good night's rest

➔ screen reading seems to be altering our reading habits. In a similar vein, an analysis of reading patterns by San Jose State University, revealed that when faced with an LCD screen, readers bolted around the page, scanned for keywords and only read certain sections. They were using well practised strategies for digesting information rapidly, abandoning the kind of “deep reading” we employ when reading a book. Whether or not these changes have any root in the brain is yet to be seen, but these results do hint at a deeper relationship between screens and our literacy.

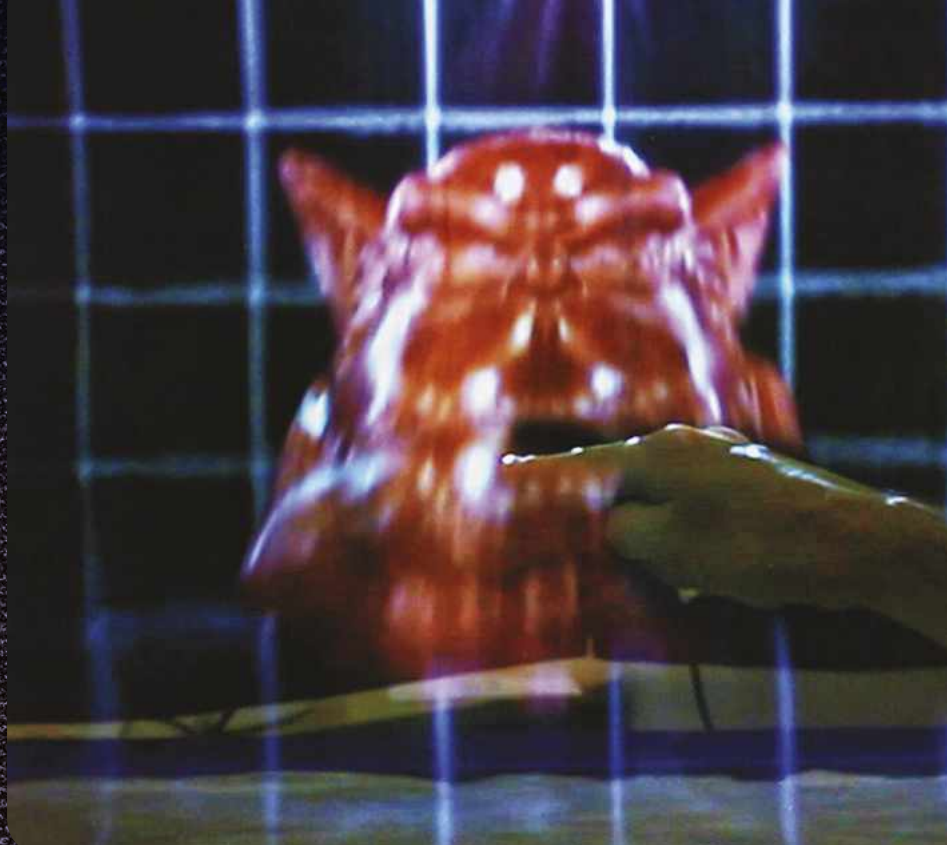
“When it comes to multi-touch devices such as smartphones, the thumb is under a lot of stress”

TOO TENSE

What about the physical effects? If someone tells you they’ve got tennis elbow, it doesn’t necessarily mean that they’ve been sweating it out on the court. Along with carpal tunnel syndrome and tendonitis, it’s just one of the physical problems that can result from using screen-based devices. Pain in the neck is linked to muscle tension, joint compression and poor posture when looking at screens. Wrist and forearm pain is common, too, and Grace Szeto’s research is showing that our increasing use of small touchscreen devices such as smartphones can affect our fingers in particular.

“Problems in the neck and shoulder region are related to static posture, whereas problems in the wrist and finger region are due to the highly repetitive movements performed in using touchscreen devices,” says Szeto, a professor of physiotherapy at Hong Kong Polytechnic University. “When it comes to multi-touch devices such as smartphones, the thumb is under a lot of stress. Repetitive movements can lead to De Quervain syndrome – inflammation in the tendons at the base of thumb. For people who use their index fingers to interact with their phones, then the joints in that finger may suffer increased stress.”

Szeto’s research shows that factors such as screen



17%

of boys spend more than three hours a day playing computer games, according to the GoWell East Study of Physical Activity in Secondary School Pupils in Glasgow in April 2014.



The same study reported that a similar number (16%) spend more than five hours online every weekend.

size, the weight of the device and how it is held all affect the muscles in different ways. So are some people naturally more prone to these problems?

“There is research to suggest that people who tend to have tense muscles, or those with mental stress, may be more affected,” she says. “But this is an association rather than cause-and-effect. People that report pain are observed to have high muscle tension, but it’s difficult to prove which starts first.”

SCREEN BLUES?

It’s been suggested that screen time may damage our mental health as well as our physical health, but the complex psychology involved makes it difficult to analyse.

A 2013 Public Health England (PHE) report looked at the behaviour of children in particular, drawing from several research papers to conclude that “increased screen time and exposure to media (such as bedroom TVs) is consistently associated with reduced feelings of social acceptance, and increased feelings of loneliness, conduct problems and aggression.”

It’s also been suggested in the past that internet usage leads to a decrease in general wellbeing and an increase in depression. But when Erik Wästlund, a psychologist based at Karlstad University,

GripSense is an ergonomic iPad case designed to prevent wrist strain



Developed at the University of Bristol, MisTable is a new kind of interface that aims to reduce problems caused by staring at screens all day

prototype's co-creator Diego Martinez Plasencia. "So some elements in our setup could really benefit this kind of attention-intensive, visual display unit-based work. At the same time, these scenarios rely heavily on the specialisation and previous experience of the workers with this type of interaction, so it is something that will happen slowly and incrementally."

But the good news is that we won't have to wait for a paradigm shift from screens to virtual reality or swirling, *Minority Report*-style interfaces for things to improve. Incremental changes are being made all the time. E-readers, for example, are getting closer and closer to mimicking the feeling of reading from paper. "The clarity of the image on LED screens is getting better too," adds Mark Rosenfield. "Going back 10 years, screens were pretty awful." And manufacturers themselves, such as Microsoft, HP and Amazon, want to improve the situation. Parts of Jay Kim's research, for example, are funded by such companies.

"While there haven't yet been any solutions that have been scientifically validated," says Kim, "many of the problems arise from the fact that there is a lack of tactile feedback on those devices, and because hands and fingers cannot be rested on the touchscreen keyboards. If more robust multi-touch and haptic technologies are developed, allowing people to rest their hands on the screen and get accurate feedback on touch and location, many problems can be addressed and reduced."

Mayank Goel, a computing researcher at the University of Washington, is developing systems which adapt to the user's posture, including GripSense, a pressure- and motion-detecting system, and ContextType, an adaptive text entry system. These ideas could help reduce musculoskeletal problems for touchscreen users, not by changing the screen itself, but by making the device learn the user's natural typing pattern to ensure that they are not forced to extend their hands and fingers to a static location.

"If a keyboard makes it easier for you to type, or if it adapts to your posture, then potentially, you don't need to stretch your hands across big touchscreens," he says. "More research needs to go into exactly how much the user would benefit, but I'm sure that a lot of repetitive stress injuries can be lessened by making our devices more aware of how we're using them." ■

recreated such studies back in 2001, he concluded there was no direct connection between screen time and depression. He thinks the issue is "more about age and adolescence, with the general pattern being that younger people tend to spend more time on the internet and also happen to report lower psychological wellbeing."

But what about working adults? "Always being connected makes it difficult to differentiate between work and leisure time," Wästlund says. "Being in a more or less constant work mode never gives you time to recuperate. And by occupying every dull moment with an e-device, be it with apps, social networks, or news, we never allow ourselves to process and incubate information."

A HEALTHIER FUTURE

Common advice for regular screen users is to get regular eye tests, and while working from a screen to look into the distance, taking breaks every so often. With smaller devices, it's best to hold them higher to avoid neck strain, use both hands, support your forearms and change posture regularly.

Bristol's prototype screen makes this much easier. "These recommendations can be done in MisTable by focusing on the objects behind the partially transparent fog screen," says the

A survey of 2,000 people suggests that those aged under 25 check their phones

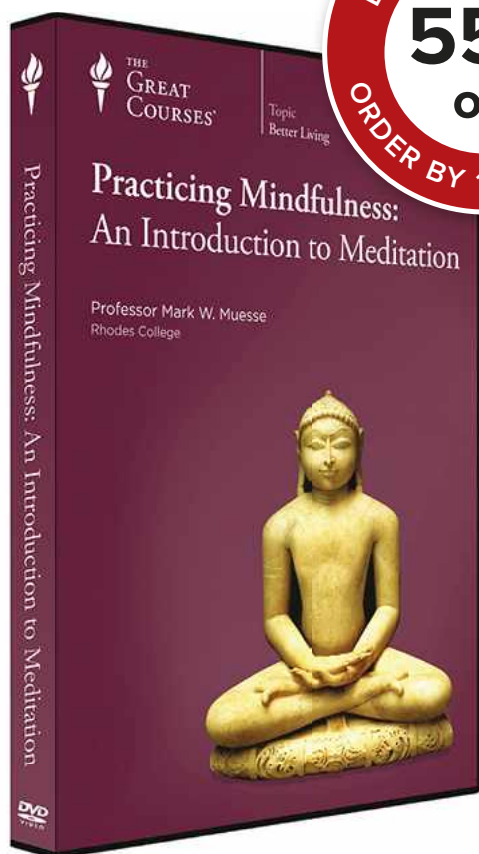


times a day, with

43%

experiencing anxiety when they can't check it.

HOLLY CAVE is a freelance writer and author of the children's book *Really, Really Big Questions About Science*



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6 REASONS YOUR CAT IS WILDER THAN YOU THINK

That purring ball of fluff sitting innocuously on your lap can never be truly tamed. **John Bradshaw** investigates the evolutionary quirks behind one of the UK's favourite pets



PET CATS MAY be domestic animals, but they're not fully domesticated. The cat family – felids – separated off from the other carnivora about 11 million years ago, and apart from size, have not altered a great deal since then, such that even today they are all obviously cat-like. Domestic cats still have much in common with their wild cousins, from the noble lion down to the tiny (and very rare) kodkod, found in Chile. Turn over to find out just how similar your tabby is to a tiger. ➔

**BBC
TWO**

Accompanies an
upcoming BBC Two
about our feline friends



1 YOUR CAT LOVES MEAT

MILLIONS OF YEARS ago, a dozen or so genetic changes took place in the ancestor of all of today's felids, which have locked them into eating meat ever since. All cats, from tabby to tiger, require high levels of animal protein in their diet – protein from plants lacks certain amino acids, such as taurine, that cats need but other mammals (including ourselves) do not.

Cats can't make their own prostaglandins – hormones essential to reproduction – and so need to get these from meat. Compared to other mammals, all cats need large amounts of several vitamins, such as niacin, thiamine and retinol, which are more easily extracted from meat than from plants. And because they don't need to tell the difference between ripe and unripe fruit, they've lost the ability to taste sugars. They have adapted their 'sweet' taste buds for distinguishing between different flavours in meat – which is why pet cats sometimes walk away from food that seems fine to their owners.

This knowledge has only come to light in the past 40 years, benefiting not only pet cats but also the captive breeding of endangered felids such as the clouded leopard. As many of two-thirds of all felid species are endangered.

“The domestic cat is the only felid species in which males are solitary and females are sociable”



2 ONLY 15-20 GENES SEPARATE YOUR CAT FROM WILDCATS

THE DOMESTIC CAT'S DNA was first sequenced in 2007. This has since been repeated for the European wildcat, *Felis silvestris silvestris*, which is first cousin to the domestic cat's ancestor, the Arabian wildcat *Felis silvestris lybica*. The European and Arabian wildcats separated about 200,000 years ago, whereas it has only been 10,000 years since the domestic cat *Felis silvestris catus* emerged as a distinct subspecies. Once the first Arabian wildcat is sequenced, we should be able to pinpoint the crucial differences that make it possible for domestic cats to socialise with us, something wildcats find impossible.

3 DOMESTIC CATS (AND LIONS) ARE THE ONLY SOCIAL FELIDS

MOST CATS LEAD solitary lives, kept apart by the need to monopolise a hunting area. The lion is the only species in which males and females live together in prides, which they can do because they hunt prey that is large enough to feed many lions, not just one. Female cheetahs are solitary, but males sometimes live as a group.

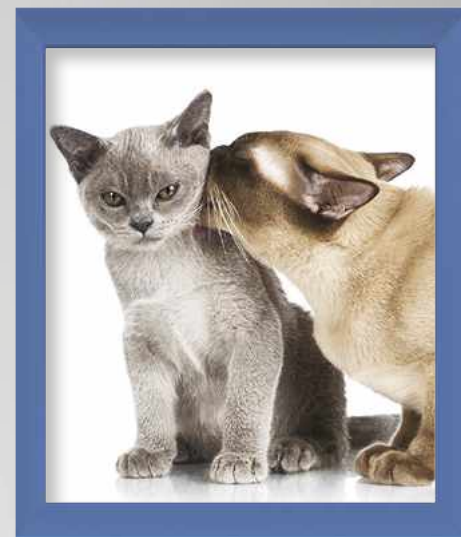
The domestic cat is the only felid species in which males are solitary and females are sociable: mothers and daughters often raise their kittens together. Pet cats show affection for us as they do with other cats – raising their tails upright and attempting to groom us – so perhaps they perceive people as just large, two-legged felids.



4 YOUR CAT'S HUGE EYES INDICATE ITS PREDATORY TENDENCIES

OF ALL FELIDS, only the cheetah specialises in hunting by day, and so has fairly small eyes. Many of the larger cats have slightly larger eyes that are more sensitive than ours, allowing them to hunt by moonlight as well as during the day. But most of the smaller species, including the domestic cat, are mainly nocturnal in the wild. So that they can gather enough light to see by, their eyes are huge relative to their skulls – a

domestic cat's eyes are almost as big as ours. Inside the eye, the retina is about six times as sensitive as ours, and wired to the brain in such a way as to maximise sensitivity, at the expense of sharpness. All felids also possess a reflective layer behind the retina, the tapetum, that further increases sensitivity while at the same time producing their distinctive green 'eye-shine' when caught in a torch-beam.



6 YOUR CAT HAS TWO NOSES

PREDATORS RARELY LIVE in close proximity, and see or hear each other only rarely, so they have to communicate by smell. Lions, tigers and domestic cats deposit urine around their territories, and they also rub their cheeks on prominent landmarks, leaving behind scent from their skin glands. All cats also possess a second 'nose' – Jacobson's organ – purely for analysing the smell of other cats. This lies between the nostrils and the roof of the mouth. The outward sign that it's being brought into play in lions and tigers is a curling of the top lip, a posture referred to as 'Flehmen'. Domestic cats instead they look as though they're going into a brief trance. Muscles around the Jacobson's organ pump a drop of fluid into the mouth, where it dissolves some of the odour being sampled, before being drawn back up into the organ for analysis.

5 WHEN YOUR CAT'S PLAYING WITH A TOY, IT THINKS IT'S HUNTING

CATS WERE ORIGINALLY domesticated to keep mice and rats away from our farms, homes and grain stores, and although nowadays we don't generally encourage our pet cats to do this, inside their heads they're still hunters.

The way they 'play' demonstrates this fact perfectly. When they're playing with small toys, they use the same techniques they use on mice, such as pouncing, and grasping in the mouth.

Larger toys, however, are attacked not with the teeth but with all four sets of claws – reflecting the need to hold a rat, which can be a formidable foe, at arms' length.

Even more revealing is the effect of hunger on play: a pet cat that hasn't eaten overnight plays much more intensely than when it's just had breakfast, as if it believes that ripping apart a felt mouse will actually produce a meal.

JOHN BRADSHAW is a BBC TV presenter and the author of *Cat Sense: The Feline Enigma Revealed*.



READY, STEADY,



By harnessing Nature's ability to use strength in numbers, roboticists can make formidable armies of machines, reveals **Emmet Cole**

THE NATURAL WORLD boasts strength in numbers. Consider the large mounds built by colonies of tiny termites, the complex anthills made by thousands of ants, or the huge ocean swarms formed by tiny krill to improve their chances when confronted by larger predators. In each of these cases, a lone individual could not complete (or possibly even survive) the task, but with hundreds and thousands of identical creatures working together, each playing their part – no matter how small that part is on its own – new capabilities start to emerge.

Roboticists have long been inspired by nature in their designs. As a result, they have given us everything from humanoid robots that look just like people, to tiny drones with the flying skills of winged insects. But can individual robots work effectively together in swarms, like so much of the natural world can?

A team of researchers at Harvard University's School of Engineering and Applied Sciences (SEAS) certainly thinks so. In August, they published a paper in the journal *Science* about a swarm of self-organising robots that can form different shapes on command. The swarm consists of 1,024 simple robots known as Kilobots, each costing around \$20 to make. A single Kilobot is unimpressive compared to today's advanced robots. Just 3cm across, each Kilobot moves on three spindly legs, powered by the same type of simple motor that makes your mobile phone vibrate when you get a call.

But while the Kilobot's specifications may be modest, this makes it ideally suited to the purpose of much swarm robotics research –



Developed at Harvard University, Kilobots have proved a popular tool in robotics research elsewhere



WHAT IS SWARM ROBOTICS?

THE TERM 'SWARM robotics' is used to refer to multi-robot systems of different types and sizes – from small shape-shifting Kilobots to larger Swarm-bots that can pick up and move objects around. Individual robots in swarms are generally quite uncomplicated in design and follow simple rules, and the control of robot swarms is decentralised, which means control of the swarm is not dependent on a single member. Inspired by the swarm intelligence displayed by insects such as ants and bees, swarm robotics builds on computer models of this behaviour developed in the 1990s by Marco Dorigo and others.

So why are roboticists interested in robot swarms? One of the most important benefits is that swarms are more fault-tolerant than a single robot. If an individual robot in a swarm fails, the others will continue working. In some cases, robots in the swarm can even compensate for and correct the errors of a single member. And since there is no 'leader', there is no single point of failure that could cause the whole swarm to fail.

Additionally, robot swarms are scalable, which means robots can be added and removed without new code being required. Robots in a swarm also tend to work in parallel, carrying out several tasks at the same time. Finally, research robots are complicated to design, build and maintain, which makes them expensive. A swarm of simpler robots can provide the same functionality at a significantly reduced cost. Still a relatively new field, swarm robotics is set to grow rapidly in the coming years as electrical components become both smaller and cheaper.



A swarm of robots can form predetermined shapes like the starfish shown above



Harvard fellow and Kilobot creator Mike Rubenstein shows off a swarm of his miniature creations

→ exploring the ways in which simple robots can combine to perform complex tasks they could not perform alone. To get the swarm to form a shape, researchers upload a 2D image of the desired shape to each robot. Special 'seed robots' placed by scientists mark the position and orientation of the shape and remain in position throughout the entire process. An overhanging infrared light sends a single instruction to the assembled swarm, 'Go!'. At that point, each robot uses information from the robots surrounding it to work out approximately how far it is from the seed bot. Those that are farthest away start moving along the edge of the swarm. Once they reach the seed bot, robots can work out their precise position – and communicate that information to other robots within a 10cm radius using tiny infrared sensors. The robots stop moving when two of three conditions have been met: they find themselves within the area designated for the shape, and they have either reached a boundary or touched a robot that has stopped in front of them. Using just these simple rules, the robots form the desired shape. Further, if one of the robots makes a mistake, the algorithm devised by Rubenstein and his colleagues allows the rest of the swarm to correct it.

The swarm is not quick by any means. Shape formation can take anywhere from 6 to 12 hours. But this is the largest swarm of its type ever studied, and future models are certain to be faster. That ant colony wasn't built in a day. The biggest challenge for the Kilobot researchers was building a robot that's cheap enough

"Keep it cheap and simple and build a swarm that's capable of doing interesting things"

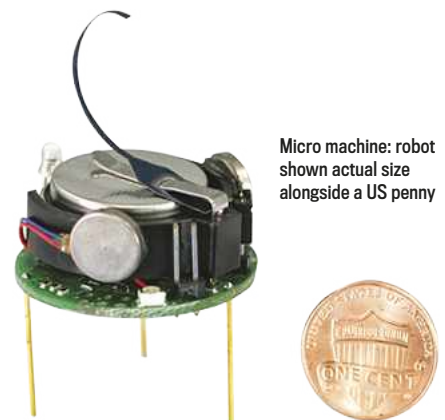
Mike Rubenstein of Harvard University on the primary aims of the Kilobot project

to manufacture by the thousand, but also capable enough to perform worthwhile behaviours, says first author on the *Science* paper, Mike Rubenstein, a post-doctoral fellow at Harvard.

"Those are conflicting abilities – to keep it cheap and simple and to build a robot swarm that's capable of doing interesting things without being complicated."

Kilobots are a great tool for researchers, says Marco Dorigo, one of the world's leading experts on swarm robotics and co-director of IRIDIA, the artificial intelligence lab of the Free University of Brussels, Belgium, who was not involved in the Kilobot project. "We have 120 Kilobots in our lab and use them in our research. They are very simple robots and very cheap, which makes them feasible for researchers with a limited budget. They are also small, which means that you don't need much space for experiments. It was a very good idea to release them."

Robot swarms are ideally suited to tasks that are dangerous, and tasks that call for robots to be distributed over a wide area, says Dorigo. "When the task is dangerous for the robot, you will be glad the system is fault-tolerant. If they break down, the system will show some degradation in the performance but it will still work. And if your task requires you to be in many places at the same time, the swarm is

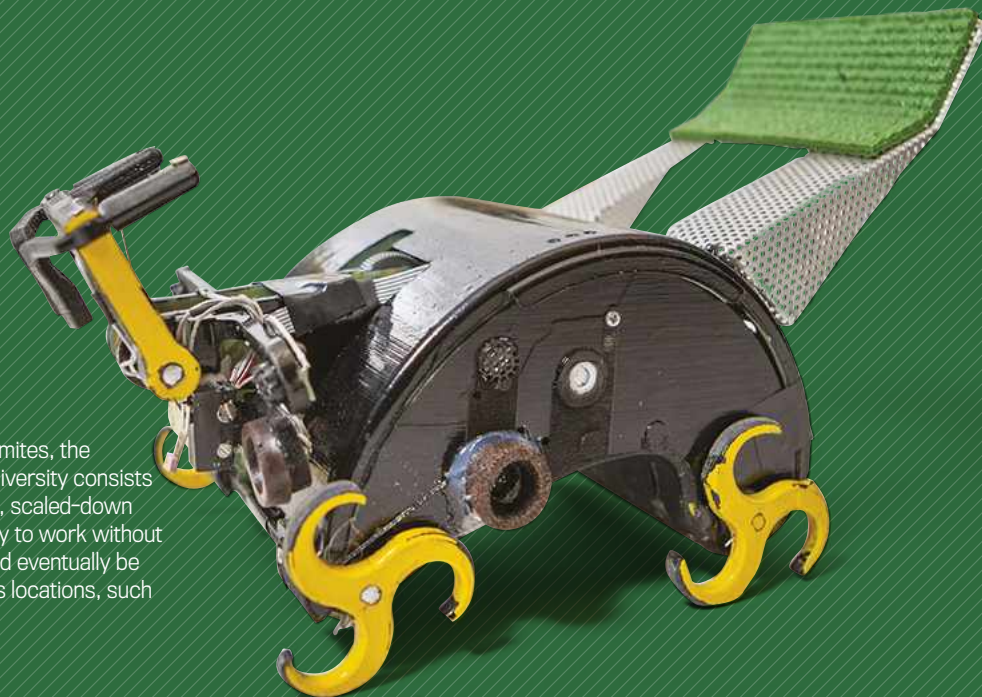


Micro machine: robot shown actual size alongside a US penny

MORE ROBOT SWARMS

1 TERMES

Inspired by the mound-building behaviour of termites, the TERMES robot swarm developed at Harvard University consists of autonomous climbing robots that can build simple, scaled-down architectural structures. The TERMES swarm's ability to work without human supervision means that a similar system could eventually be used for construction work in remote and dangerous locations, such as on the Moon or other planets.

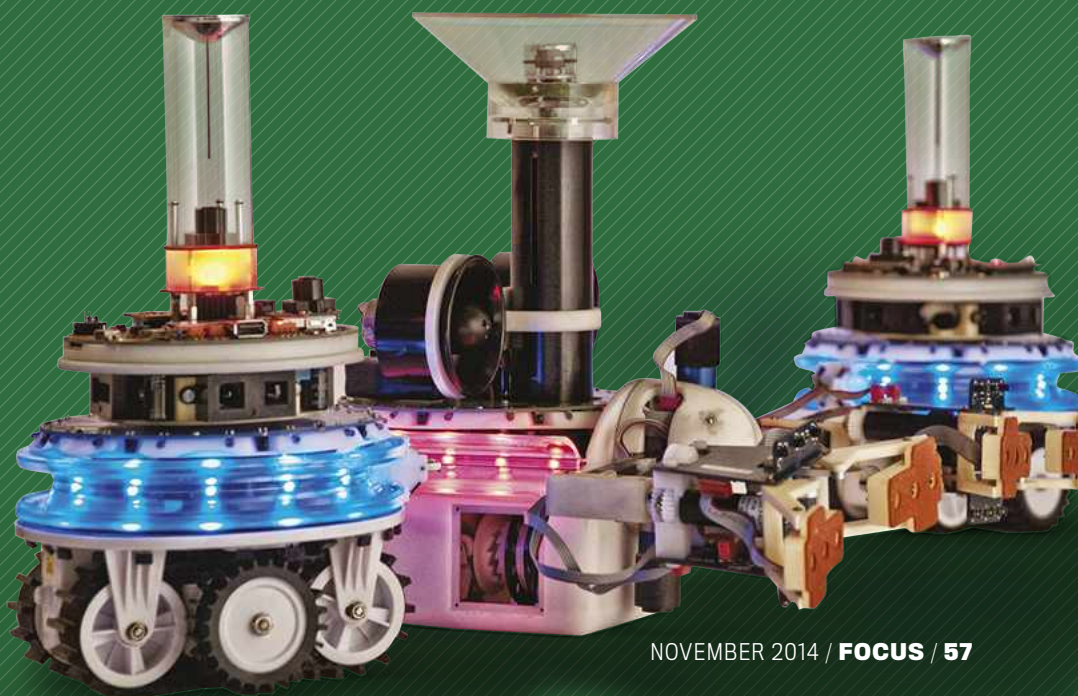


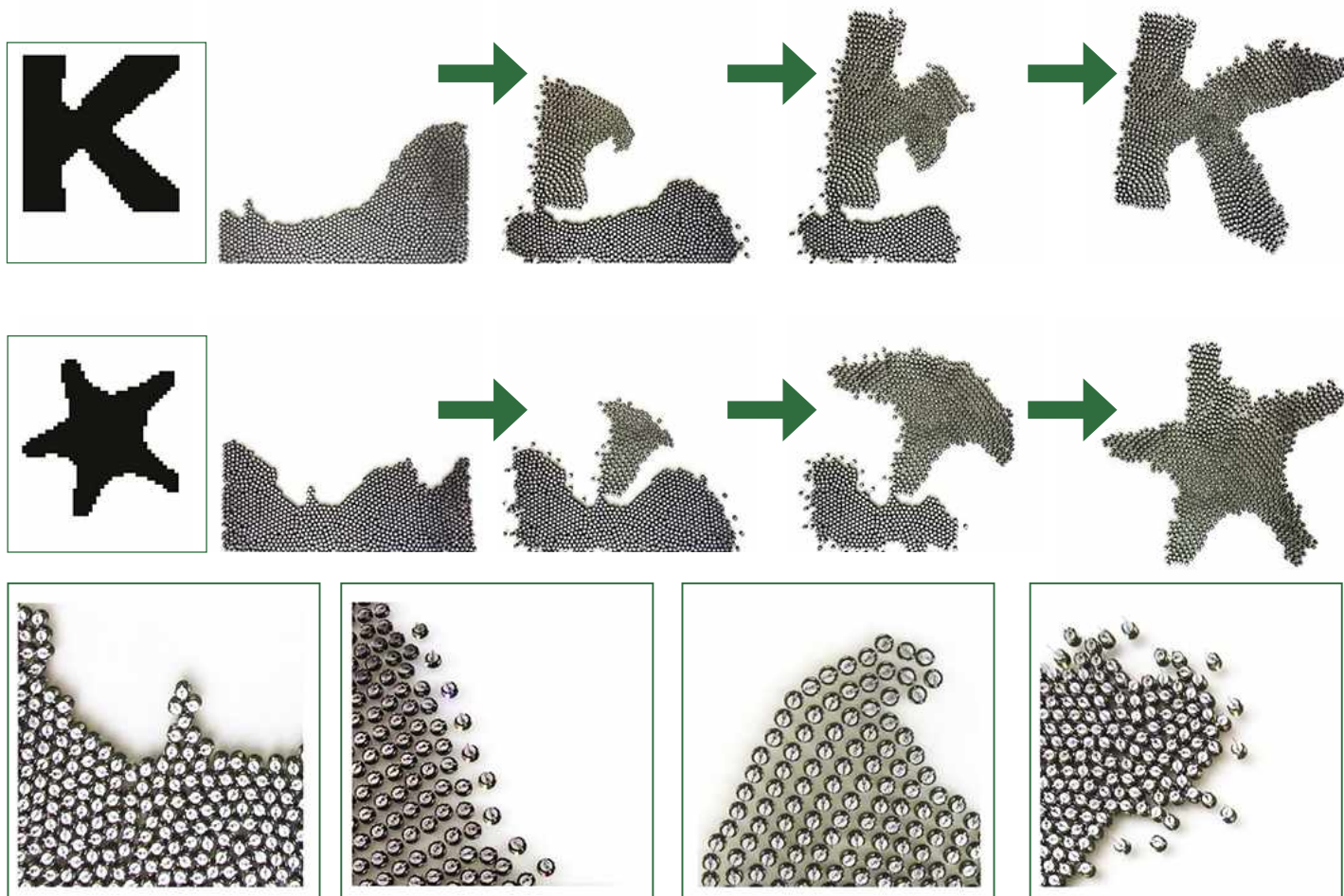
2 ROBOT PEBBLES

Swarm robotics meets programmable matter in the Robot Pebbles project from Massachusetts Institute of Technology. Each cube-shaped robot is just 12mm per side and weighs only 4.0g, but houses a powerful magnet that allows groups of the robots to connect and form complex shapes. The team is currently working on ways to further miniaturise the robots, with the aim of creating what they call 'Smart Sand' - a programmable matter system consisting of intelligent robotic cubes, each measuring just 1mm on each side.

3 SWARMANOID

This is a 60-strong swarm of small, autonomous robots developed by Marco Dorigo's team at Free University of Brussels, Belgium. The swarm consists of three types of robot: foot-bots, hand-bots and eye-bots that can collaborate and combine their different skills to complete specific tasks. Lessons from the Swarmanoid project are being explored in Dorigo's current project, the European Research Council-funded e-Swarm, which is looking at ways to model the behaviour of individual robots within large swarms.





Top: How the robots arranged themselves to form the black 'K' and starfish shapes

Above: Close-up view showing the individual robots in action. They're quite slow - the 'starfish' took nearly 12 hours to self-assemble

➔ better than having a single robot.” Likely applications for swarm robots include search and rescue missions and pollution containment, says Dorigo. Habitat construction – on Mars, for example – is another possibility, but for Dorigo it’s still too early to say how swarms will end up being used. “It’s very difficult to predict because at the moment we are quite far from real-world applications. This is more because of the limitations of the single robot, rather than because of a limitation of the swarm. The individual robots are still too brittle and cannot do much,” explains Dorigo.

BETTER TOGETHER

But can the intelligence of a robot swarm be greater than the sum of its parts? If you measure intelligence in terms of overall functionality, then the answer is yes: a swarm can perform more jobs than a single robot. However, there is no magical extra intelligence that emerges from a robot swarm that cannot be explained in terms of the capabilities of its individual members, explains Dorigo. Emergent (or

“We’re quite far from real-world applications. The individual robots cannot do much”

Marco Dorigo of the Free University of Brussels on the current limitations of swarm robotics

unexpected) behaviours in robot swarms tend to be the result of mechanical and programming errors and lack of foresight on the researchers’ part, rather than any mystical property of the swarm.

In future, however, the intelligence of a robot swarm might exceed the sum of its parts, says Rubenstein. “That’s the hope. We’re starting to be able to get towards something like that, where not only can they be more intelligent but where they can, for example, see things as a swarm that they could not see by

themselves.” Long-term, he’s interested in “the futuristic idea” of building objects using swarms of tiny robots. This is where swarm robotics meets ‘programmable matter’ – matter that can be programmed to change its physical properties.

“The idea is to try to work towards the goal where you could construct tools or other robots made of thousands of little tiny robots. You can build a tool that can adapt to its environment better or recover from errors faster if made of lots of little robots,” says Rubenstein. Along with his colleagues, he is now planning to explore algorithms that can form shapes more reliably and faster. After that, they want to investigate how a swarm could form shapes without any human instructions, by working out the optimal shape for the task at hand by itself. “The algorithm that we released in the *Science* paper was the first that we have done on the full thousand robots. But hopefully it won’t be the last one,” says Rubenstein. ■

EMMET COLE is a technology journalist and a columnist for *Robotics Business Review*

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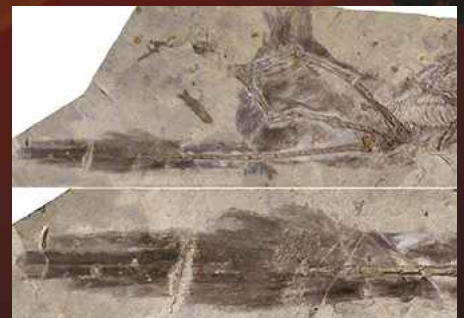
The discovery of more than 40 species of feathered dinosaur has revealed some remarkable details about the evolution of feathers and flight, reveals **John Pickrell**

ONE HUNDRED AND twenty million years ago, in the part of the world we now know as northeastern China, strange creatures shared the swampy forests with early birds and large ground-dwelling dinosaurs. In the dusky light, as the Sun starts to dip below the horizon and nocturnal insects hum to life, an animal the size of an eagle spreads its wings and leaps from a high branch. It's covered in thick grey plumage and at first glance appears to be a bird – but several features pick it out as something

else entirely. Incredibly, it has four wings – feathered hindlimbs as well as forelimbs – and a long tail replete with flight feathers, which it spreads out to provide the largest possible surface area for gliding.

Changyuraptor yangi – described in *Nature Communications* in July – is the largest of a growing group of known feathered dinosaurs that could glide. Its long tail was tipped by 30cm feathers, which may have helped this hefty 4kg flyer control its speed of descent.

The discovery of feathered dinosaurs, such as *Changyuraptor*, are coming thick

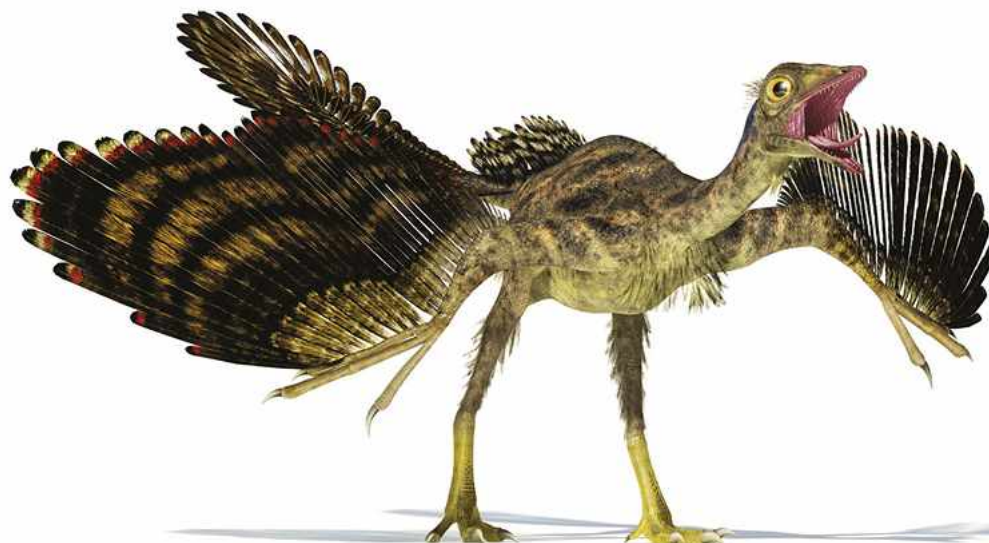


A fossil of *Changyuraptor yangi* (artist's impression above) with remarkable detail of its plumage

PHOTO: L. CHIAPEL/DINOSAUR INSTITUTE/NHM



The world-famous fossil of *Archaeopteryx*, 'the first bird', housed at the Museum für Naturkunde in Berlin, and an artist's impression below



➔ and fast these days. Others announced to the world in 2014 include the small Siberian herbivore *Kulindadromeus zabaikalicus*, and *Anzu wyliei* – labelled a 'cross between an emu and a lizard' by its discoverers and only the second feathered dinosaur known from North America. More recent finds have included a new fossil specimen of the 'first bird' *Archaeopteryx*, and a study which showed how dinosaurs shrank 12-fold over a period of 50 million years in the lineage that led to modern birds.

There is now good evidence that many carnivorous dinosaurs, even fearsome and well-known types – such as *Allosaurus*, *Velociraptor* and *Tyrannosaurus* – had feathers, and that they used them for a variety of functions. Feathers are so

“The creature retained traces of four, long, ribbon-like feathers, which it could have flicked to woo mates”

intimately entwined in our minds with flight that this idea takes some getting used to. Nevertheless, complex flight feathers can't have appeared from nowhere, so it makes sense that the earliest feathers had another purpose entirely.

Since the discovery of the first feathered dinosaur, *Sinosauropteryx* (see p66), in 1996, a great flock of 40 or so feathered species has flapped or scurried to the fore. These fossilised creatures have been found with feather impressions, or with circumstantial evidence in the form of either 'quill knobs' (pits in the bones where the ligaments of feathers attach) or a 'pygostyle' (the bony tail structure to which a fan of feathers attaches in birds).

Nearly all of these species are carnivorous theropods, and the majority are exceptionally preserved specimens from Liaoning Province in northeastern China, although some hail from Mongolia, Germany, North America and Madagascar. In the years following the discovery of *Sinosauropteryx*, it became clear that most

wouldn't have been able to fly – they didn't have fully formed wings or they weren't the right kind of shape. Palaeontologists began to realise that feathers evolved for another purpose entirely and were only later co-opted for flight.

The feathers of many of these animals were simpler in structure than anything we'd recognise as feathers today, and it's likely they were used like the downy fuzz of chicks for insulation. "To start with, feather structures are not all that complicated – they are a coat of simple filaments," says Dr Paul Barrett, a palaeontologist at the Natural History Museum in London. "These animals are small and quite active, they have elevated metabolic rates... and this is a way of retaining heat."

DINO DISPLAYS

After feathers first found a use in insulation, they developed another purpose. In 2007, in Inner Mongolia, Chinese Academy of Science experts unearthed the finely preserved fossil of a bird-of-paradise-sized dinosaur, which they called *Epidexipteryx*, Greek for 'display feather'. These scientists

Mark Norell at the American Museum of Natural History has been studying whether dinosaurs used feathers for elaborate displays



noted in a 2008 *Nature* article: 'Ornamental plumage is used to send signals essential to a wide range of avian behaviour patterns, particularly relating to courtship... It is highly probable that the [tail feathers] of *Epidexipteryx* similarly had display as their primary function.'

The fossilised creature retained traces of four, long, ribbon-like feathers, which it could have flicked and wafted as it danced to woo mates, as birds of paradise do today. This weird dinosaur was a compelling

piece of evidence that early feathers were used for display too.

Other groups of dinosaurs had big 'pennaceous' feathers (the typical modern shape, with a central vane and interlocking barbs running off to either side) on their forearms and tails, which were more obviously used for showing off.

A 2013 study by experts including Phil Currie and Scott Persons at the University of Alberta, and Mark Norell at the American Museum of Natural



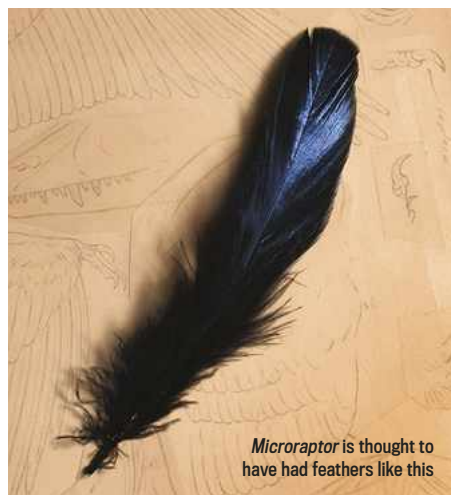
Fossils of *Epidexipteryx* show that it may have used its feathers as a display to attract mates





Recent studies have shown that the four-winged *Microraptor* had iridescent plumage

“Until recently, the consensus was that *T. rex* and other large theropods probably only had feathers as juveniles, if at all”



Microraptor is thought to have had feathers like this



History, provides perhaps the best evidence yet that dinosaurs used feathers for elaborate displays. Oviraptorids are parrot-beaked omnivorous theropods, that had a ‘pygostyle’ tail, where the final few vertebrae are fused to form a ridged, blade-like structure. The researchers found marks on the bones of five different species of oviraptorids, which suggested large muscles that would have allowed the stumpy tail to be flexed and posed in a number of ways. The conclusion was that male oviraptorids likely indulged in tail-shaking mating displays, much as turkeys and peacocks do today.

So there’s good evidence of early feathers being used for insulation and display, but how did they come to find a

function in flight? Eventually, the extra surface area of feathers on the tail and forearms used for display would have offered some lift when jumping or gliding. Then evolution would have started to select for the running or flying functions of feathers, eventually leading to four-winged dinosaurs such as *Changyuraptor* and *Microraptor* that lived in the trees.

Most known feathered dinosaurs are close relatives of birds in the carnivorous theropod group of dinosaurs. Although feathers are only known from a smattering of species across the whole group, the fact that some are early and primitive members and that feathered species are found on many different branches of the family tree, suggests that all theropods were feathered.

DID TRICERATOPS HAVE FEATHERS?

Triceratops and (right) its bristly tailed ancestor *Psittacosaurus*



It's often portrayed with a thick, scaly hide, but the beast may have been covered in bristles

THERE ARE SOME hints that 8m-long, crested herbivore *Triceratops* may have had a bristly covering related to feathers. *Psittacosaurus* is a 1.5m-long, Early Cretaceous member of the parrot-beaked ceratopsian lineage that eventually led to *Triceratops*. Some *Psittacosaurus* specimens discovered in China have revealed plumes of bristles around the tail.

The only skin-impression fossil found for *Triceratops* (which lived in North America near the end of the dinosaur era in the Late Cretaceous) appears to reveal it had bristles, not purely scaly skin as has been long supposed. The remarkable fossil was found by palaeontologist Dr Bob Bakker and is held at the Houston Museum of Natural Sciences in Texas, where he is a curator. We know that *Psittacosaurus* had bristles, so given it is an early member of the lineage that led to *Triceratops*, it seems reasonable to assume that these were passed down.

Despite this, until recently, the consensus was that *T. rex* and other large theropods probably only had feathers as juveniles, if at all. The idea was that huge animals don't need insulation, as they lose heat to the environment very slowly. But the discovery of a series of feathered relatives of *Tyrannosaurus* has turned this idea on its head. The first, *Dilong paradoxus*, was discovered by legendary dinosaur hunter Professor Xing Xu in Liaoning in 2004. As this lightly built,

125-million-year-old predator was relatively small, at 2m in length, its downy covering was not wholly unexpected.

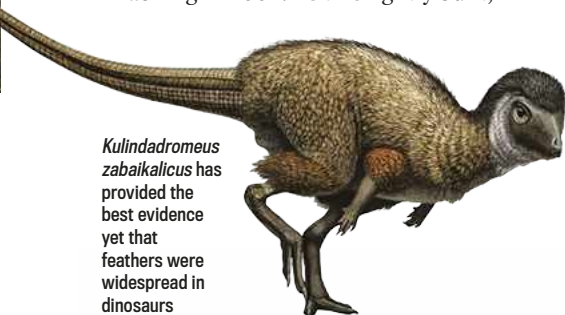
Much more surprising, though, was 9m *Yutyrannus huali* (pictured on p66) discovered in 2012. Also from the Early Cretaceous deposits of Liaoning, this shaggy predator was closer in size to *T. rex* itself. It showed that downy feathers were probably much more widespread among dinosaurs than anyone had expected. *Yutyrannus* is the largest feathered animal ever known to have lived.

A few of the new fossils, however, hint that feathers might have originated much deeper in the dinosaur family tree, not close to the ancestors of modern birds. For example, *Tianyulong confuciusi* was a small bipedal herbivore with a fuzzy covering of fluff. Nothing unusual in that, except it's in the ornithischian group of herbivorous dinosaurs, which are very distant cousins to the carnivorous theropods. Another

ornithischian – *Psittacosaurus*, a small and early relative of *Triceratops* – also had bristle-like structures, which may have been a form of feather.

The new Siberian species, *Kulindadromeus zabaikalicus*, described in July, is the best evidence so far that feathers may have been very widespread across all dinosaur groups. This 1.5m-long ornithischian herbivore may have had three different types of feathery filament, as well as scales on different parts of its body.

Kulindadromeus zabaikalicus has provided the best evidence yet that feathers were widespread in dinosaurs



FLYING REPTILES

There's even the tantalising possibility that feathers originated in the ancestors of animals that gave rise to dinosaurs and their sister group of flying reptiles, the pterosaurs. "Even the filaments of pterosaurs are likely to be a kind of primitive feather," argues Xu, a world expert on feathered dinosaurs at the Institute for Vertebrate



KNOWN TYPES OF DINOSAUR FEATHER



Sinosauropteryx



Caudipteryx



Anchiornis



Archaeopteryx



Confuciusornis

Early birds (*Longirostravis*) perch on one of their large dinosaur relatives (*Yutyrannus*); both species lived in the Cretaceous period



PREHISTORIC PALETTE

Once a mystery, the power of science is starting to reveal the remarkable colours of dinosaurs

AS RECENTLY AS five years ago, experts thought we'd never be able to tell anything about the colour of dinosaurs. Most were painted in greens and browns similar to lizards and crocodiles. Since the discovery of feathered dinosaurs in 1996, the assumption had been that they might have had some of the same variation in plumage that birds do, but few believed this would ever be confirmed. That was until January 2010, when a study led by Professor Mike Benton at the University of Bristol suggested that *Sinosauropteryx* – the first feathered dinosaur discovered – had ginger and white stripes around its tail, something like a ring-tailed lemur. Similar work has now revealed the true colours

of *Archaeopteryx* and four-winged flyers *Anchiornis* and *Microraptor*.

Tiny clues as to the colour of the feathers was found in the structural details of the well preserved fossils of some dinosaurs and early birds. In hair and feathers there are miniscule pigment packages called melanosomes. The way these are stacked or bunched, and whether they are round or oblong, correlates to some of the colours. This has given experts clues as to whether the feathers in fossils were black, brown or red, for example. Iridescent colour is also created by structural features and we can find these in fossil feathers too.



Palaeontology in Beijing. Experts have known for some years that many pterosaurs had a fur-like covering, which perhaps helped them maintain a high metabolic rate for flight, but it's not yet clear if this is related to feathers or evolved independently.

Others aren't so sure that feathers were common across all dinosaur groups. There's no evidence of feathers in most other ornithischians, according to a 2013 study by Paul Barrett of the Natural History Museum and David Evans of the Royal Ontario Museum. "We have lots of skin impressions from duck-billed and horned dinosaurs, and none of them show anything that looks like feathers," says Barrett. This could be because the ancestors of these dinosaurs started off with feathers and lost them, or it could just be that dinosaurs have within their genes the mechanism to easily evolve skin-related structures, he says. "They also have lots of armour and spikes that form in the skin too." It could explain why some groups have feathers, frills or armour and others don't.

The question now is did all dinosaurs and pterosaurs inherit feathers from the same common ancestor, or is it just that the group had a remarkable plasticity to play around with different structures like bristles, quills, fuzz, fluff, ribbons and, eventually, complex and beautiful feathers sculpted for the purpose of flight? Research is ongoing, so hopefully we'll soon know more about these incredible creatures. ■

JOHN PICKRELL is the author of *Flying Dinosaurs: How Fearsome Reptiles Became Birds*



Find out more

Dinosaurs at the BBC Nature website
www.bbc.co.uk/nature/14343366

John Pickrell's *Flying Dinosaurs* site
<http://flyingdinosaurs.net>

The striking ginger and white striped tail of *Sinosauropteryx*



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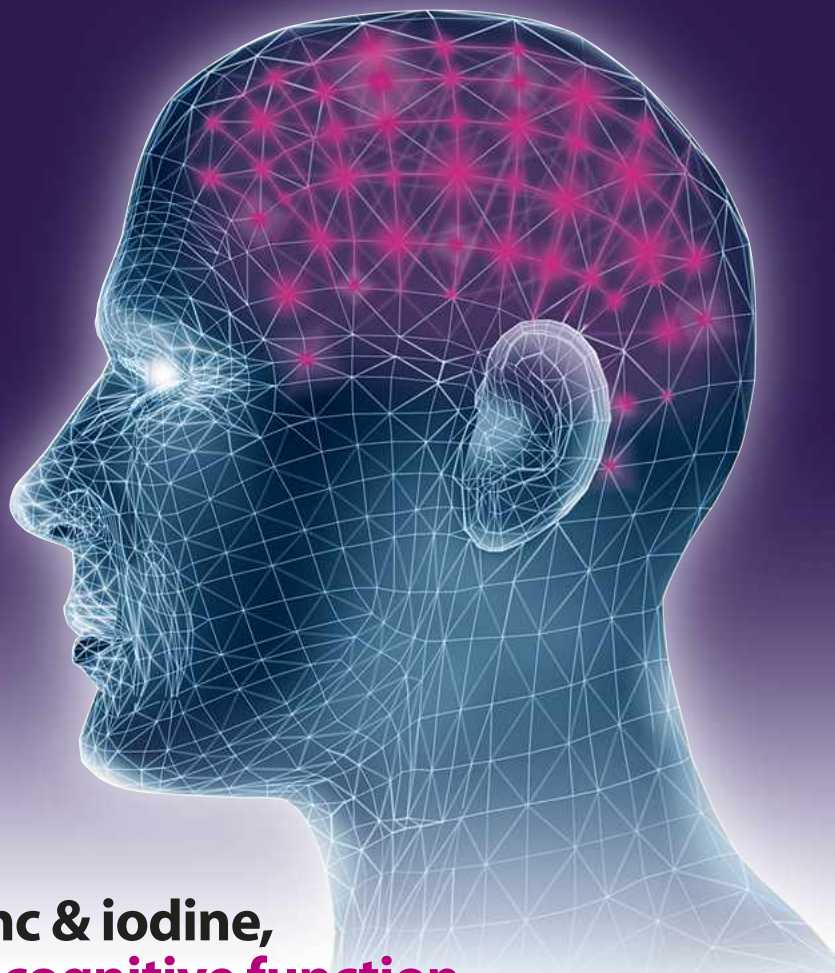
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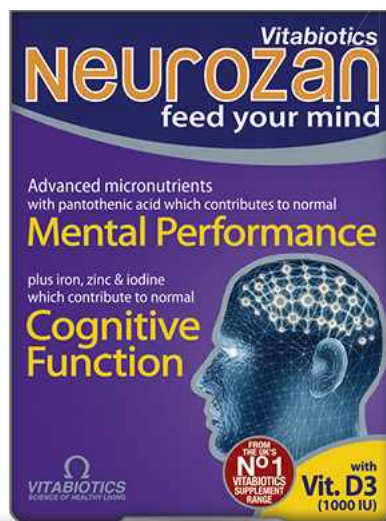
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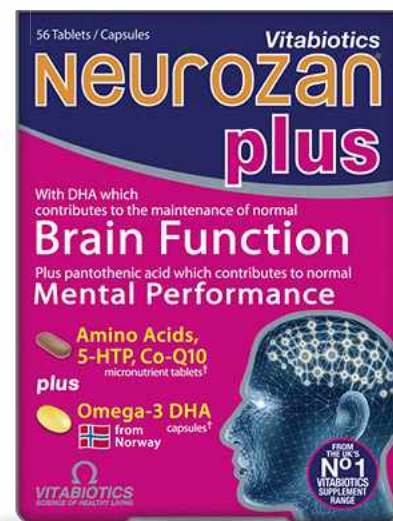
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SCIENCE OF HEALTHY LIVING

Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* 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*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com

or post to *Focus Q&A*, Tower House, Fairfax Street, Bristol, BS1 3BN

Q CHARLIE LEE, MANCHESTER

How does underwater welding work?

A METAL, WATER AND hundreds of amps of current is not a happy combination, and much underwater welding is performed with the welder working in a diving chamber. Even so, wet welding is possible. Special waterproof electrodes protect the diver from the current, while the heat forms bubbles that remove the water from the site of the weld. **RM**

Down in the water deep and low, where all the diving welders go...

PHOTO: BAE SYSTEMS

In Numbers

5.5km

is the height of Martian mountain Aeolis Mons. NASA's Curiosity rover reached the mountain - its primary destination - on 11 September

Q LIZ DENNIS, LONDON

Is the right side of your brain really more creative?

A NO. AT LEAST, not in the popular sense that creative people are more 'right-brained' than logical or analytical people are: a study that scanned the brains of over 1,000 people found no such differences. It is true that different brain areas are specialised for different tasks, including vision, hearing, touch and the control of movements. And the main language areas are in the left hemisphere in 95 per cent of right-handers. But both hemispheres work together in almost everything we do and creativity is a whole-brain process. Painters and sculptors may draw on mathematical and logical ideas as well as visual imagery and words, just as scientists inventing a new theory may do the reverse. **SB**



Contrary to popular belief, most activities use both sides of the brain

Q THEO BARKAS, ATHENS, GREECE

Can subconscious brain activity be measured?

A YES, EASILY. THE problem is not measuring brain activity but knowing what the terms conscious, subconscious or unconscious mean. In the 1950s the EEG (electroencephalogram) was invented, using electrodes on the scalp that revealed waves of activity across the surface. As technology improved, more 'brain waves' were discovered but with no hint that some were conscious and others not. An early, surprising finding was the amount of activity during sleep, and especially during dreaming. Modern scanning techniques, such as PET and fMRI, reveal far more detail,

with increasingly accurate localisation. But how can we tell whether any activity is conscious or not? Many researchers are seeking the 'neural correlates of consciousness'; the special patterns or locations associated with conscious, rather than non-conscious activity. Although this seems to be the Holy Grail of consciousness studies, another possibility is that consciousness is not a property of brain activity at all, but something we attribute to events after they happen. In this case, the difference between 'conscious' and 'subconscious' activity is meaningless. **SB**

Our brains are actually quite active while we're asleep



Q RACHEL CARMICHAEL, READING

Could fossils survive a meteorite impact?

A YES. IN FACT, there might be fossils on the Moon that arrived that way. When a sufficiently large meteorite strikes Earth at the right angle, some of the debris is ejected fast enough to escape Earth's gravity, and is captured by the Moon. Kent University researchers found this year that some fossils could survive both the original impact of the Earth meteorite and then the second one when the debris struck the Moon - but only if they were smaller than 0.04mm across. Nevertheless, this suggests that the Moon could be a good place to look for fossilised plankton, since they will be much better preserved there. **LV**

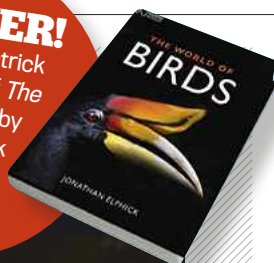


Could this meteorite hold fossil evidence of life on Mars?

QUESTION OF THE MONTH

WINNER!

Jamie Fitzpatrick wins a copy of *The World Of Birds* by Jonathan Elphick (Natural History Museum, £40)



Monarch butterflies congregate to take on water in Michoacan, Mexico

Q JAMIE FITZPATRICK, DUBLIN

Why don't butterflies fly in straight lines?

A BUTTERFLIES AND moths use their wings for many purposes: for flight, as mobile billboards to advertise how poisonous they are, and to create camouflage patterns. So you would expect them to be less adept fliers than insects that have optimised their wing design purely for aerodynamics. But the butterfly's erratic flight is actually an evolutionary tactic that makes it harder for any would-be predators to predict the insect's flightpath. The more poisonous butterflies don't need to carry out these evasive manoeuvres, and as a result these species tend to fly much straighter.

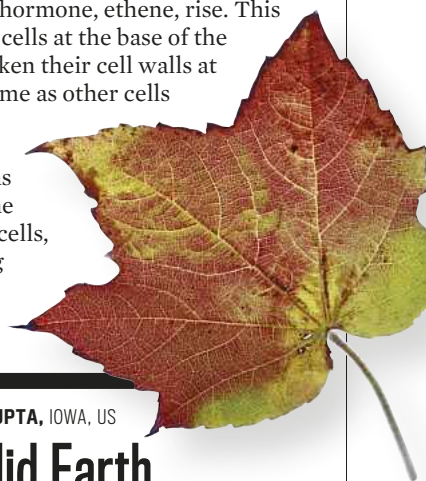
Fluid dynamics simulations that were carried out at Kyoto University in Japan last year showed that butterflies achieve their trademark swoops and tumbles by generating a lot of extra turbulence with each wing beat. And high-speed photography studies undertaken at Johns Hopkins University in Baltimore, US, reveal that they also constantly adjust their centre of gravity by shifting the position of their body and wings.

Monarch butterflies are so good at this that they can effect a 90-degree turn in less than a single body-length. **LV**

Q BARRY CULL, BY EMAIL

What makes deciduous plants start to lose their leaves in autumn?

A DECIDUOUS TREES SHED their leaves as an active process that evolved to conserve resources and protect the tree from being blown over in the windier winter months. The process is controlled by the plant hormone auxin. As light levels and temperatures drop, the flow of auxin to the leaves slows and levels of another hormone, ethene, rise. This signals the cells at the base of the leaf to weaken their cell walls at the same time as other cells expand to break the connections between the weakened cells, like tearing perforated paper. **LV**



Q LALIT GUPTA, IOWA, US

How did Earth get its name?

A EACH LANGUAGE HAS its own name for our planet but they all have one thing in common. Each is derived from a word meaning 'ground' or 'soil' (or sometimes 'universe' or 'creation').

For example, the modern English word 'Earth' derives from the Germanic 'erde', meaning 'ground'. The roots of such words all date from a time when humankind was unaware that Earth is actually a planet. They merely signified the ground beneath our feet, and were adopted for the planet later on. **AG**



Our planet shares its name with the ground we walk on in nearly all languages

TOP TEN

BIGGEST SPIDERS

BY LEG SPAN



1. Giant Huntsman

Length: Up to 30cm
Distribution: Caves in Laos. Other huntsman species are found worldwide



2. Goliath Birdeater

Length: Up to 28cm
Distribution: Upland rainforest regions of northern South America



3. Brazilian Giant Tawny Red

Length: Up to 26cm
Distribution: Tropical South America



4. Brazilian Salmon Pink Birdeater

Length: Up to 25cm
Distribution: Atlantic Forest, Brazil



5. Purple Bloom Birdeater

Length: Up to 22cm
Distribution: Moist forest areas of Colombia



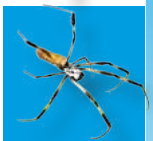
6. Poecilotheria rajaei

Length: Up to 20cm
Distribution: Sri Lanka and parts of India



7. King Baboon Spider

Length: Up to 20cm
Distribution: Most of east Africa, especially Kenya and Tanzania



8. Golden Silk Orb-weavers

Length: Up to 16cm
Distribution: Australia, Asia, Africa, the Americas



9. Brazilian Wandering Spider

Length: Up to 15cm
Distribution: Forests of Central and South America



10. Cerbalus arvensis

Length: Up to 14cm
Distribution: Sand dunes in Israel and Jordan

PHOTO: MICKEY SAMUNI-BLANK/WIKI, RANIL NANAYAKKARA/FLICKR, PETRA & WILFRIED/FLICKR, JOSE LUIS BARTHELD, ANDREAS KAY, VLADEB/FLICKR, J&T REPTILES, STEVE SMITH/FLICKR, TJ PETROWSKI/FLICKR

Q ALEX ROUND, LONDON

What is the biggest ice sheet in the world?



A ICE SHEETS ARE defined as areas of glacier ice that cover an area greater than 50,000km², and there are only two of them in the world: the Antarctic and Greenland ice sheets. At 14 million square kilometres, the Antarctic ice sheet is by far the biggest – eight times larger than Greenland's. **LV**

The Antarctic ice sheet is the world's largest by a huge margin

Q MATTHEW HAYWOOD, BY EMAIL

Do bats get confused by other bats' 'sonar'?



Why find your own way around when you can get a neighbour to do it for you?

A SOME BAT SPECIES have a wide repertoire of available sound frequencies, so the chances of another bat happening to call on the same frequency within earshot are quite low. The Brazilian free-tailed bat will, however, actively switch frequencies if another nearby bat is using a frequency within 3kHz of its own.

But research at the University of Maryland has shown that bats can actually use the echolocation calls of other bats to navigate by eavesdropping. Big brown bats will sometimes stop calling altogether if they are flying close enough to another bat, and just listen for the echo from their neighbour's calls. **LV**

Q TONY WEBB, LANGFORD

Is it possible to remember being in the womb?

A MANY PEOPLE CLAIM they can, or that their toddlers can, but it is doubtful that these are genuine memories. Claims may be based on children imagining what it would be like, or being cued by adults. Most adults can remember events only as far back as the age of three or four. Young children often remember further back, but these early memories generally fade as they grow older.

This is what we should expect from knowing that the limbic system, which is heavily involved in memory, is not fully developed at birth, and that the whole brain changes rapidly in the early years. This is not to say that events in the womb have no effect: there is some evidence that music and voices heard before birth can influence your later preferences. But this is not the same thing as actually remembering life in the womb. **SB**



One day, he'll look back on all this and gurggle like an idiot

Q RICHARD O'NEILL, GLASGOW

Are disposable nappies more harmful to the environment than reusable ones?

A MOSTLY. EIGHT MILLION disposables end up in UK landfill sites every day. We don't know exactly how long they take to biodegrade, but it's likely to be more than 100 years. This means every nappy that's ever been thrown away is still there, and potentially leaking nasty chemicals into the groundwater. But if you compare the carbon footprint of manufacturing disposables with the energy used to manufacture and launder reusable

ones, the picture is less clear. A 2008 study by the Environment Agency concluded that washable nappies are actually responsible for 3 per cent *higher* CO₂ emissions than disposables, per child. But these figures assume that 25 per cent of washable nappies will be dried in a tumble drier. If you dry all your nappies on the line, the balance switches and reusable nappies produce 13 per cent less CO₂ emissions than disposables. **LV**



Q BARRY CULL, BY EMAIL

Could there ever be tree-less paper?



The mainstay of a panda's diet could also be used to make paper

A THERE ALREADY IS. More eco-friendly materials are increasingly used for paper production, including bamboo, banana husks and hemp (the main source of paper in the 19th Century). More esoteric alternatives include 'rock paper' made from ground-up minerals and a non-toxic chemical binder, which also needs less ink for printing. **LV**

Q MEL SIMS, LEEDS

What are the most popular smartphone apps in the world?

A THE MOST RECENT figures I have are from 2013 by the analysts Global Web Index. At the time, there were 970 million smartphone users worldwide. Google Maps is the most popular app of all, followed by Facebook. At number five is Wei Xin. Never heard of it? It's a free instant voice messaging app and it's massive in China. Dominating in such a large smartphone market, Wei Xin is in the global top five despite only being used in China, Malaysia and Hong Kong. **GM**



Outside China, Wei Xin is known as WeChat

Q ROY MUSSELBROOK, RAMSGATE

What's the longest a 'perpetual motion' machine has run so far?



The Beverly Clock has run *almost* constantly for 150 years

A THE IDEA OF a machine that keeps running forever has been around for centuries, with even Leonardo da Vinci and Robert Boyle coming up with proposals. None have proved 'perpetual', however, as energy loss due to effects like air resistance and friction eventually brings them all to a halt.

Arguably the closest we have to a perpetual motion machine is the Beverly Clock in the Department of Physics of the University of Otago, New Zealand. Built in 1864, it's powered by pressure and temperature changes in the surrounding air. As these owe their origin to the Sun's energy and the rotation of the Earth, they could in theory keep the clock going for millions of years. In reality, it has paused a few times when the atmospheric conditions weren't quite right, but it has so far always started up again. **RM**

In Numbers

\$600m

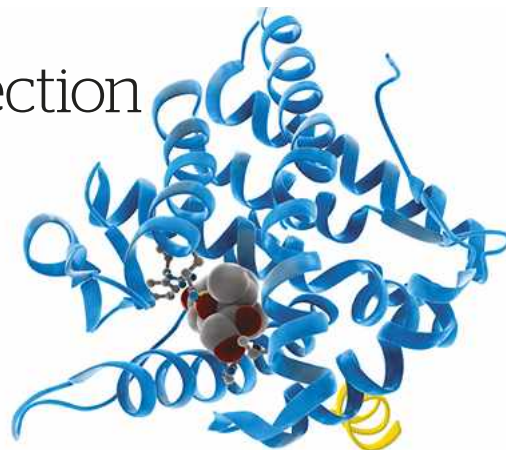
Estimated cost of fighting the Ebola outbreak in western Africa, according to figures from the World Health Organization

Q PAUL STEVENS, LONG EATON

How do anti-rejection drugs work?

A ORGAN REJECTION HAPPENS when a transplanted organ is attacked by your immune system. Anti-rejection drugs interfere with some aspect of this system, and there are three main kinds.

Glucocorticoids are steroid hormones that are produced naturally in the body as part of a mechanism that prevents inflammation from getting out of hand. Adding extra glucocorticoids turns down the thermostat on the body's immune system. Monoclonal antibodies bind to proteins on the surface of T cells (a type of white blood cell). T cells are the worker ants of the immune system and certain monoclonal antibodies will bind to and deactivate them. Finally,



Anti-rejection drugs work by tricking the immune system

there are the drugs that target messenger chemicals in the immune system. Ciclosporin is the best-known of these and works by preventing the production of interleukin 2, a molecule that is used to flag which cells are 'foreign'. **LV**

Q PETER LANG, SALFORD

What's the most distant observed galaxy?

A CURRENTLY, THE most distant (and hence oldest) galaxy known to astronomers is called z8_GND_5296. It was discovered in 2013 using a combination of data from the Hubble Space Telescope and the WM Keck Observatory in Hawaii. Astronomers use a measurement called redshift to determine distance. This galaxy has a redshift of 7.51 – the highest yet discovered – and is an estimated 13.1 billion light-years away. This means we are seeing z8_GND_5296 as it was only 700 million years after the Big Bang. Since the Universe has expanded significantly in that time, z8_GND_5296 will now lie 30 billion light-years from Earth. Not only is z8_GND_5296 a record holder, it is also an oddity. While normal galaxies

like our own Milky Way may produce a couple of new stars each year, z8_GND_5296 has a star-formation rate 150 times greater. The observations have suggested that even more distant galaxies may be hidden in the fog of neutral hydrogen gas prevalent in the early Universe. **AG**

An artist's impression of z8_GND_5296. Best start saving those air miles...



Q Where could the next natural disaster strike?

Around the world, catastrophic events are waiting to happen. **Bill McGuire** reveals where nature is set to wreak havoc next

A WASHINGTON STATE, USA
SEATTLE LANDSLIDE

Seattle: home to Starbucks, grunge and 10,000 houses that could collapse at any minute

MANY OF THE deaths arising from earthquakes are actually caused by landslides. Along with heavy rains, giving a steep slope a good shake is the best way to get it to fail, bringing down any buildings standing on it. There are few places where this threat is greater than in and around the city of Seattle, where a recent study showed that 10,000 homes are perched on steep slopes that could fail during a 'quake. Astonishingly, the research suggests that as many as 30,000 landslides could be triggered across the area when the Seattle Fault next ruptures. This last happened around 1,100 years ago, when a magnitude 7.5 quake caused entire forested hillsides to collapse. With seven earthquake-linked landslide 'storms' identified during the last 3,500 years, an eighth is unlikely to be that far off.

A EAST OF THE ROCKIES, USA
US EARTHQUAKES

Downtown Memphis, Tennessee – enjoy it while you can, because an earthquake could obliterate it tomorrow

THINK AMERICAN EARTHQUAKES, think California. Or maybe not. New hazard maps published by the United States Geological Survey show that nowhere is immune. In its latest assessment of the threat, the USGS warns that 42 out of the 50 states have a reasonable probability of damaging shaking occurring in the next 50 years, with the likelihood described as high for 16 of these. California, Alaska and Hawaii top the chart, but residents of Kentucky, South Carolina and Illinois might be surprised to see their home states flagged too. Of most concern – east of the Rockies – is the New Madrid Seismic Zone, centred on southwest Missouri, which was struck by a series of massive shocks in the early 19th Century. Now home to the cities of Memphis and St Louis, future quakes here on a comparable scale could result in huge damage and loss of life.

A HONSHU ISLAND, JAPAN
MOUNT FUJI ERUPTION

Mount Fuji is showing signs of life – and when it erupts, nearby Tokyo is in serious trouble

MOUNT FUJI IS one of the world's most iconic volcanoes. To the inhabitants of Tokyo, 100km to the northeast, Japan's highest mountain also presents a serious threat. Dormant since 1707, when a major eruption blasted out close to a billion cubic metres of ash and debris, the volcano is showing signs of waking up. Apparently shaken into life by the 2011 Tohoku earthquake and tsunami, increased seismic activity and more active steam vents have encouraged one local scientist to forecast an eruption by 2015. And a study by French and Japanese scientists, which examined how the volcano may have been weakened by the 2011 megaquake, concluded that Fuji now has a high potential for eruption.

BILL MCGUIRE is Emeritus Professor of Geophysical & Climate Hazards at University College London and author of *Waking The Giant*

Planets orbiting Gliese 667C would be heaven for sun worshippers

Q BEN GOODWIN, LEWES

Have we found any planets orbiting triple star systems?

A THERE ARE SEVERAL examples of triple star systems potentially harbouring exoplanets, including the stars 16 Cygni (69 light-years distant) and HD 188753 (151 light-years distant). Perhaps the best studied is a star system called Gliese 667, which is about 22 light-years away in the

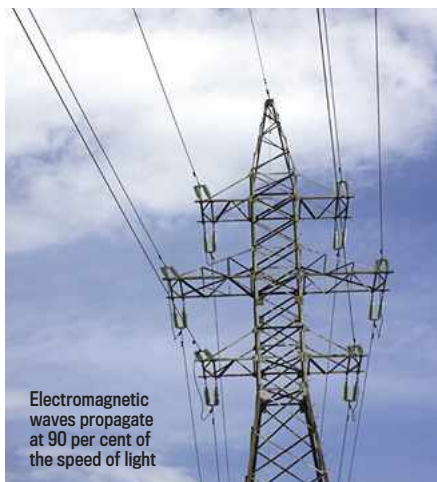
constellation of Scorpius. At least two planets have been found to orbit the third component star of this system, called Gliese 667C. Gliese 667C is a small red dwarf that orbits the other two stars at a distance of 230 AU (that is, 230 times the Earth-Sun distance). From the surface of one of its planets, the nearer star would

appear to be more than five times the size of the Sun as viewed from Earth, whilst the other two stars would be visible in daylight and provide as much light as the full Moon. Interestingly, one of these planets appears to sit right in the star's 'habitable zone'. **AG**

Q CAREL LUCAS, PERTH, AUSTRALIA

How fast does electricity flow?

A DRIFT VELOCITY, THE average speed at which electrons travel in a conductor when subjected to an electric field, is about 1mm per second. It's the electromagnetic wave rippling through the electrons that propagates at close to the speed of light. The dimensions of the wire and electrical properties like its inductance affect the exact propagation speed, but usually it will be around 90 per cent of the speed of light – about 270,000 km/s. **GM**



Electromagnetic waves propagate at 90 per cent of the speed of light

WHAT IS THIS?



KNOW THE ANSWER?

Go to sciencefocus.com/qanda/what and submit your answer now!

LAST MONTH'S ANSWER:

Mark Thomas correctly guessed a dumbo octopus. It was trawled between 500 metres depth and the surface

Q MIKE WARD, BOURNEMOUTH

Are my files safe if I store them in the cloud?

A NO FILE IS 100 per cent safe, whether in the cloud or on your desktop. In the cloud, your files could be hacked, intercepted or lost. Even if the cloud service provider is watertight, someone might be eavesdropping on your web connection when you access your files, or stealing your password with a key logger.

The cloud services I use have built their businesses on securing, encrypting and storing data. I trust them more than I trust myself to keep my files safe. But before I sign up to any service, I check its data protection and privacy policies. Most cloud providers forbid their staff from accessing user content directly, though they may look at metadata such as file names, dates created, file size or location, and your

files may be stored in jurisdictions that require your provider to decrypt files for law enforcement.

If that bothers you, then you should probably stay out of the cloud and just be careful with your own machine. **GM**



Cloud servers: not good for storing embarrassing pics

Q GEOFF PULLIN, CHIPPING CAMPDEN

How many nerves are there in the human brain?



A THERE ARE ABOUT 86 billion nerve cells, or neurones, in a human brain. This number was arrived at in 2009 at Rio de Janeiro University, by taking four adult human brains and dissolving the cell membranes to turn the brain into a cellular soup. Researchers could then count the cell nuclei in a small sample under a microscope and scale the numbers up. **LV**

Q RANDALL BARFIELD, SOUTH CAROLINA

How do insecticides kill insects?

A MOST INSECTICIDES ARE nerve agents that cause uncontrolled trembling or paralysis. These are toxic to other animals, too – organophosphate insecticides like DDT work the same way as chemical weapons like sarin and VX. Other insecticides work by mimicking insect hormones to prevent larvae from turning into adults, or to stop them from making the chitin they need for their exoskeleton. Some are synthetic versions of chemicals that plants make to discourage insects: neonicotinoids are based on nicotine from tobacco plants, for example. **LV**



Secondary smoking is bad for insects, too

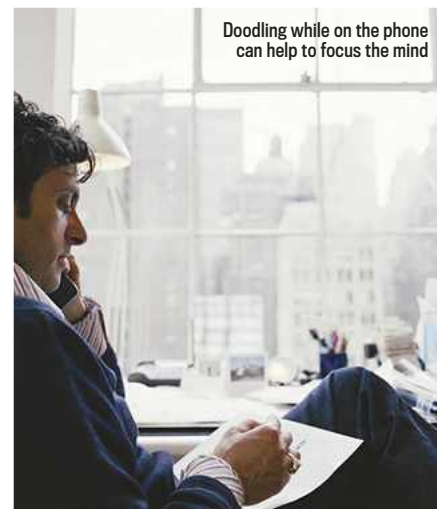
Q TOM KNIGHT, SOMERSET

Why do people doodle or pace up and down while on the phone?

A SOMETIMES DOODLING, PACING, scratching or fiddling with objects can be what are known as ‘displacement activities’. This may be because the call is unwanted, makes us anxious, or because we want to get on with something else.

We should also remember that in natural, face-to-face conversations we typically move a lot, making hand gestures and using our whole body to communicate what we are trying to say. Being deprived of this visual communication channel can be frustrating, and that frustration can lead to unrelated actions, in much the same way that caged animals pace up and down behind bars or that cats suddenly start washing for no good reason.

In other cases the doodling or pacing may function as an aid to concentration. Some people find it easier to think, and not get distracted, if they are walking up and down. Others find that doodling can be creative, helping them to develop their ideas as they speak or even resulting in new ideas. **SB**



Doodling while on the phone can help to focus the mind

NEXT MONTH Over 20 more of your questions answered



For even more answers to the most puzzling questions, see the Q&A archive at www.sciencefocus.com/qanda

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LASCAUX 3.0

PRESERVING PREHISTORIC CAVE PAINTINGS

Laser scanning techniques pioneered for the nuclear industry are being harnessed to create super-accurate copies of Stone Age art, as **Matthew Symonds** discovers

THE DISCOVERY OF the Lascaux cave complex has all the ingredients of a Boy's Own adventure. In September 1940, just a few months after France's surrender in the Second World War, four teenagers entered a natural cleft in a Dordogne hillside. As they ventured deeper into the darkness, it quickly became obvious that they were not the first to have been drawn to this underworld. Daubed on the living rock, in vibrant hues of russet, black, and yellow, were paintings of majestic creatures that had roamed the hills thousands of years before. The boys



PHOTO: SYCPA

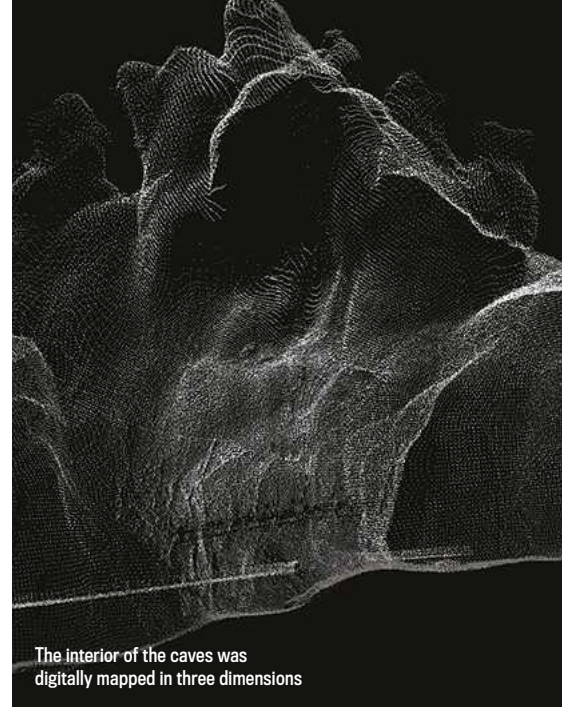
➔ had stumbled across one of the most spectacular decorated caves ever found.

Those first four visitors in 1940 marked the start of a flood. Between 1948, when the cave opened to the public, and 1963, over a million tourists flocked to Lascaux. But inundations of up to 2,000 visitors a day took a toll on the delicate subterranean environment. The combination of artificial lights and crowds breathing out carbon dioxide allowed algae and bacteria to flourish. By 1963 a veil of green algae was attacking the prehistoric paintings and the

decision was taken to close the cave.

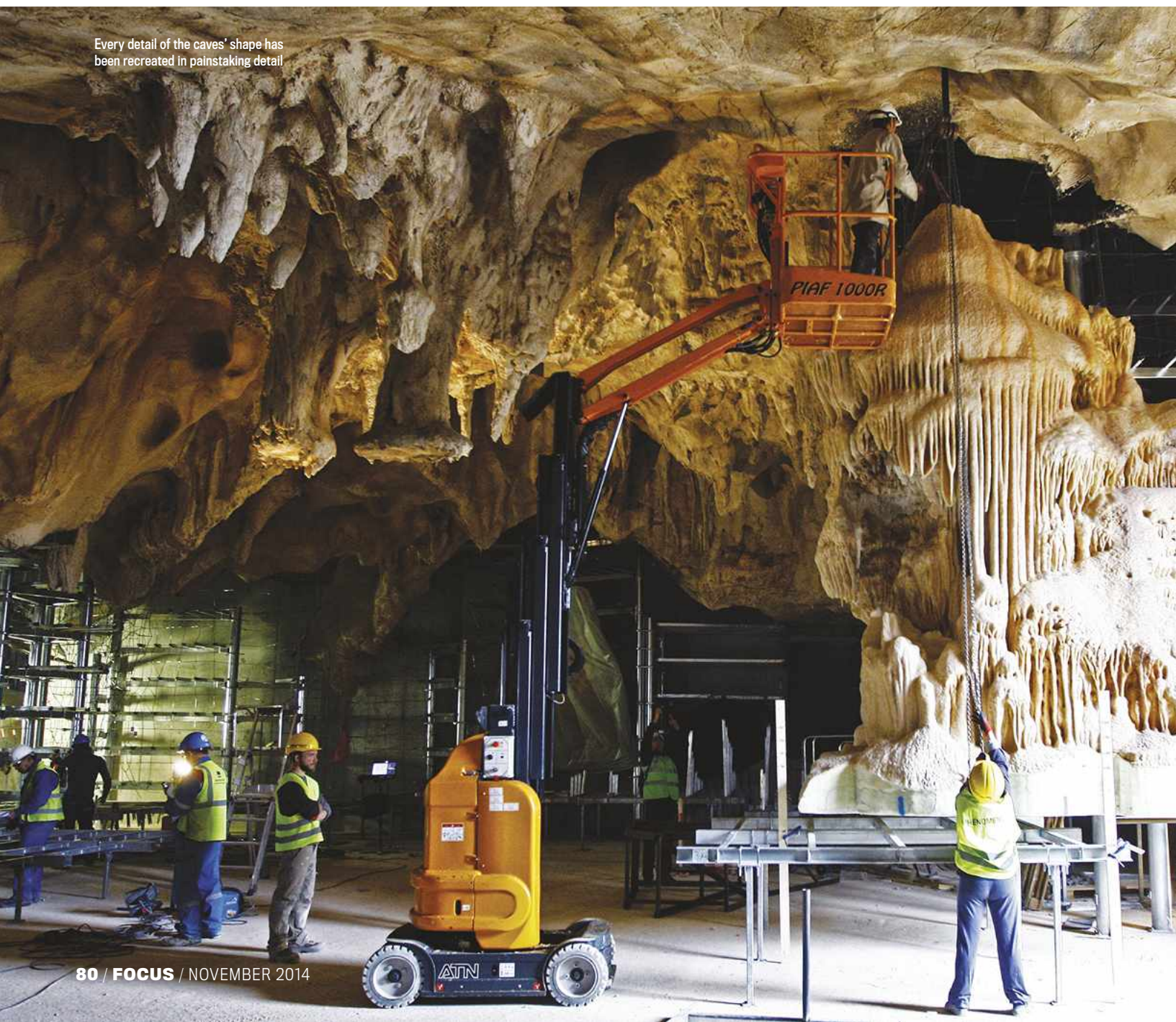
Public appetite for the ancient artwork remained undiminished, though, and so part of the cave was recreated in a nearby quarry. Lascaux 2, as it became known, was a labour of love for Monique Peytral, who spent a decade in the 1970s and '80s manually recording and then replicating a portion of the cave complex. In 2007, work began on creating five facsimiles of sections that did not feature in Lascaux 2, for the Conseil Général – the local council – in Dordogne. Dubbed Lascaux 3, this project employed

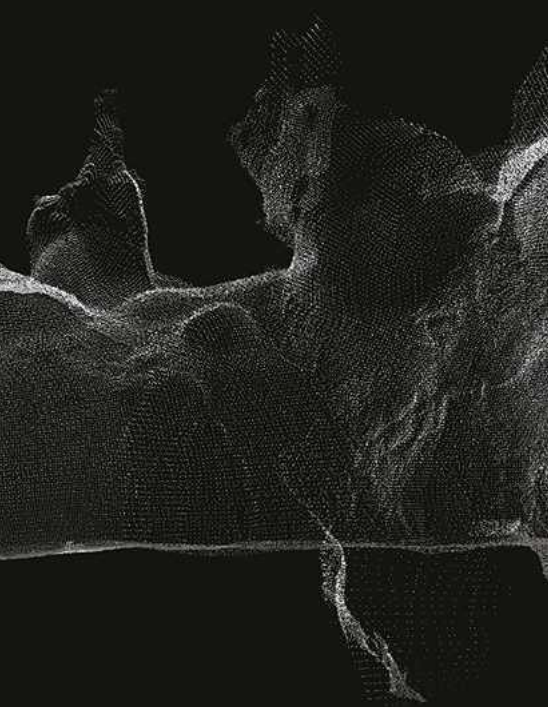
PHOTOS: SYCPA



The interior of the caves was digitally mapped in three dimensions

Every detail of the caves' shape has been recreated in painstaking detail





The stone veil: each section consists of a mineral veneer on a fibreglass frame



“A point cloud could be created, and then worked up into a life-size physical model”

Francis Ringenbach, head of artistic production, Périgord Facsimile Workshop

state-of-the-art technology that Ms Peytral could scarcely have dreamed of.

UNDERGROUND ART

Lascaux 3 drew on a virtual 3D model of the cave, which was captured using a portable scanner that projected a laser beam across the cavern walls. This technique was originally developed as a hands-free way to survey nuclear power stations. When the beam strikes a surface it is reflected back to the scanner, allowing the point of impact to be recorded as a single dot at a known distance. As the survey continues, a cloud of these points builds up, creating a detailed digital model of the scanner's surroundings.

When the survey of Lascaux was complete, the nooks and crannies of its undulating passages and galleries had been recorded to an accuracy of a fraction of a millimetre. The prehistoric artists' canvas could now be simulated with breathtaking clarity, but their handiwork posed a greater challenge, as the paintings are essentially flat. To complete the virtual version of Lascaux, high-resolution photographs of the artwork were layered onto the 3D model.

To craft the five Lascaux 3 panels, this mass of survey data needed to be returned to a physical form. “A point



Installing the framework on which the stone veil is mounted



Mounting the stone veil panels onto the metal framework



While recreating the caves was a high-tech process, the paintings themselves were redrawn by hand

OLD MASTERS

Why the cave paintings were made is a 17,000-year-old mystery

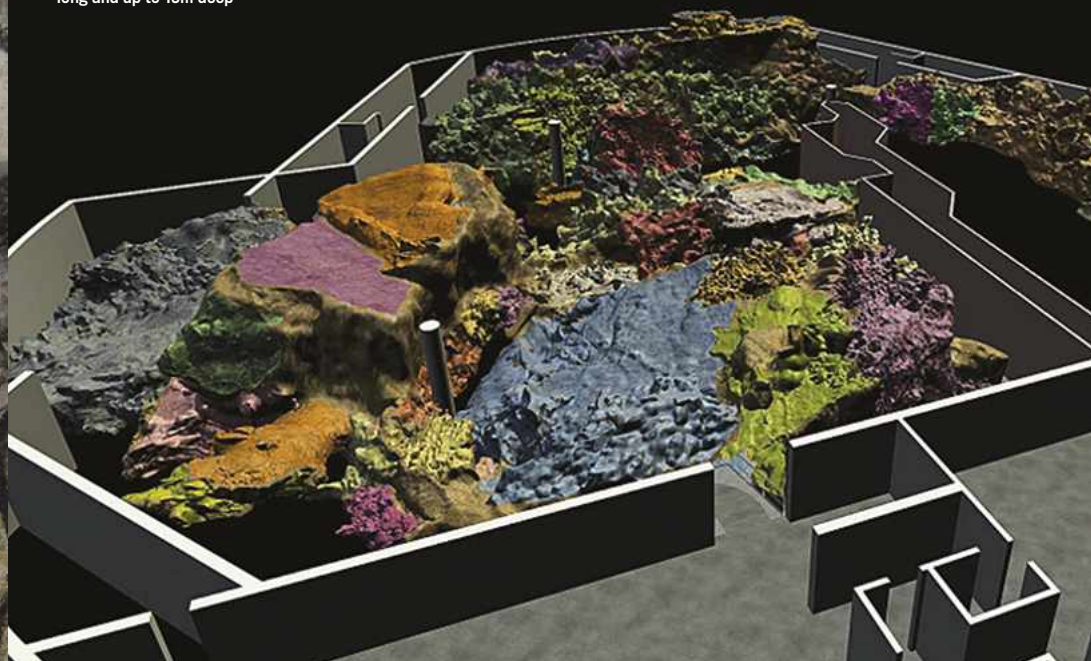
Why prehistoric people transformed Lascaux into an underground art gallery is a mystery. Discarded stone lamps show the artists were able to toil away from natural light, while hollow rocks still bear traces of the powdered pigments used to create their compositions. Radiocarbon dating suggests that the paintings were created about 17,000 years ago. This makes them almost



four times older than the pyramids of Giza, and sets them in the era of the Cro-Magnons: anatomically modern humans living a hunter-gatherer lifestyle in late Ice Age Europe.

Nearly 600 painted animals and a further 500 abstract motifs adorn the walls of Lascaux. Horses are the most common subject, followed by stags and aurochs – an extinct species of cattle – then ibex and bison. Images of predators are in a minority, and banished to remote areas of the cave, suggesting that the animals were not placed randomly within this underworld. The sole painting of a human is a crude stickman. This figure is lying before a charging bison, its guts spilling out after being sliced open by a spear. As these paintings were made thousands of years before the dawn of a written language, we cannot know for certain what they mean.

The cave complex is 235m long and up to 19m deep



“We used the same pigments as the Lascaux artists. The main difficulties were technical”

Francis Ringenbach, head of artistic production, Périgord Facsimile Workshop

Adding the paintings to these panels had to be done the old-fashioned way. A team of artists meticulously copied the ancient originals onto the simulated stone.

“We used the same pigments as the Lascaux artists,” Ringenbach reveals. “The main difficulties were more technical than artistic. Artistically, the aim was to make an exact reproduction. The technical means evolved rapidly, and we were always left somewhat behind by the technological evolution, whereas the artistic part always stayed the same.” In total, each of the five panels took around 1,800 hours to craft.

Unlike Lascaux 2, which lies immobile in its quarry, the Lascaux 3 panels are portable, and are currently the centrepiece of a travelling exhibition allowing audiences around the world to marvel at the skills of Lascaux’s ancient artisans. Rapid obsolescence is, however, a hazard of modern technology. In 2016 Lascaux 3 will be superseded by Lascaux 4, a new, near-complete facsimile of the cave system. Part of a cutting-edge visitor attraction, it will lie at the foot of the hill where four teenagers set off on a grand adventure over three-quarters of a century earlier. ■

The stone veil had to be hand-tinted



The paintings were recreated using the same pigments as the originals



Find out more

www.lascaux.culture.fr

The caves’ official website has a wealth of information regarding their discovery, significance and conservation

MATTHEW SYMONDS is editor of *Current Archaeology* magazine. He can ask for a trowel in five different languages.

PHOTOS: SYCPA

→ cloud could be created, and then be worked up into a life-size physical model called the matrix,” explains Francis Ringenbach, head of artistic production at Périgord Facsimile Workshop, which created the replicas. A high-pressure water jet carved the cave contours captured by the laser scanner into a polystyrene block. Next, a negative impression of the rock face was cast in plastic.

In order to then replicate the texture of the rock accurately, the team developed what they call the ‘stone-veil’ technique. This involves applying a thin coat of clay, powdered limestone and other minerals to the plastic cast. The mineral veneer was then mounted on a fibreglass frame, creating a robust replica rock face that’s less than half an inch thick.

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THE FUTURE OF GADGETS

TECHHUB

EDITED BY DANIEL BENNETT

⬇ THIS MONTH

BILL THOMPSON
The future of electricity
p101

JUST LANDED
Moto 360 smartwatch
p102

ULTIMATE TEST
Cloud cameras
p105



ON THE HORIZON

SAMSUNG GEAR VR

The virtual reality headset
for your smartphone

WORDS: DANIEL BENNETT
Samsung.com

PRESENCE: THAT'S WHAT virtual reality is all about. Feeling as though you've escaped into another world. For most commuters, that sentiment will be wholly relatable: who hasn't daydreamed about sunbathing on a Caribbean beach while crammed into a train carriage? On the face of it, that's what Samsung's new virtual reality headset offers – a device that works with your mobile phone so that you can take virtual trips on the move. But when I strapped in

for a preview of this new headset, it was clear that this new device represents so much more...

You see, Samsung had a little help building its new Virtual Reality headset. The Korean company has been working with the current leaders in virtual reality technology – Oculus Rift. The Rift team, fresh from a \$2bn (£1.2bn) buyout by Facebook, is setting about its plan for world domination. Step one is to find as many technology partners as



Is she watching a movie?
Flying a plane? Catching a
show? Who can say?



➔ possible – to grow the user base from hardcore PC gamers into anyone who owns a smartphone. Step two is to build an app store, which happens to be the first thing to whizz towards you when you wear the Gear VR.

The store is an array of tiles floating in mid-air and it represents the kind of entertainment we can all expect to enjoy in this virtual universe. The first thing that piqued my interest was a Cirque de Soleil performance. After selecting it with the touch panel mounted on the side of the headset, I was suddenly dropped into the audience of a live show. In a couple of seconds, the crowd of journalists around me had disappeared, and I was in the front row at the circus. Acrobats flipped over and around me, and I was mesmerised. Next, I took a chopper ride over Manhattan, followed by a flyover of Yellowstone Park, finishing up by meeting some penguins on a glacier. The only thing stopping me believing I was there was the rest of my senses – there was no wind, no warmth and no cold. They really have the ‘presence’ thing nailed.

Afterwards, I headed over to Oculus Cinema. I didn’t get to watch any films, but I did get to see some trailers – on the Moon. Because the headset takes over your whole vision, the Gear VR can create

a screen of any size it wants, anywhere it wants. I was watching the equivalent of an IMAX screen set up on the lunar surface. It’s so well done that you can see light cast by the screen dancing on the Moon rocks. It sounds cheesy, but I was absorbed – and if you don’t fancy leaving the planet you can always choose to watch it in a plain old cinema.

There were some games, but they paled in light of the wealth of experiences on tap here. If you’re thinking these might all be novelties, there’s reams of new content on the way. For example, Oculus has partnered with Marvel to provide VR users with all the superhuman-powered movies you could ever want, and it’s adapting a bundle of IMAX science documentaries for the official launch.

Since I first tested Oculus Rift over a year ago, virtual reality has come on in leaps and bounds. There’s no motion sickness, no pixelated images – you don’t even need a computer to enjoy it. This is a watershed moment for the technology. The smartphone only became such a huge success because of apps it could run, and now VR has an app store of its own. Now we just need to find that killer app...

DANIEL BENNETT is reviews editor of *Focus*

TECHOMETER

WHAT'S HOT

3D PRINTING

The first zero-g printer has been launched into space. Astronauts aboard the ISS will welcome their new toy, not because they’ve been dying to print iPhone cases but because getting hold of spare parts in space can be troublesome – just ask the crew of Apollo 13. In the long term, 3D printing could be an inexpensive way to upgrade and expand the ISS’s facilities.



WHAT'S NOT

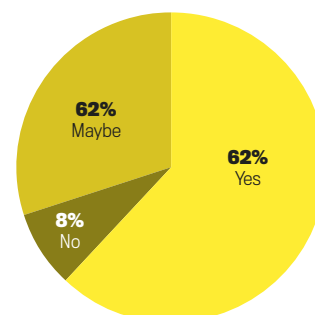
EBAY

Everyone loves a bargain, which is what has drawn hackers to the internet auction site. In recent months, a large number of listings on the site have contained links that harvest passwords. When a user clicks to buy the product they’re automatically redirected to a site that harvests the browser’s password data. According to a BBC investigation, the site has been plagued with malicious sellers for months.



READER POLL

If a smartphone app could offer an eye test, would you use it?



THE NEXT BIG THING

GOING OFF-GRID

WHEN IT GETS dark in rural Uganda, it becomes difficult to do anything. Smelly, dangerous, costly kerosene lamps are one of the few options for lighting a room in your home, but there are no street lamps and no electric sockets to plug lamps into.

Over the last few years, several organisations have been working to install off-grid, solar-powered LED lighting systems in such villages. These projects in some of the world's poorest communities point to a future in which more of us will move away from our dependence on centrally-generated electric power, distributed over high voltage cables and stepped down to the voltages needed by our domestic devices by energy-hungry transformers.

For the last century or so, we've grown used to the idea that electricity is generated in large plants and distributed via a grid of cables to factories, offices and homes. Largely for historical reasons, most of the world's appliances run on 230 volts, with high-voltage distribution systems to get power from the generators to the socket. The result is that

we pay a utility company, plug in our appliances and try not to feel guilty about the impact on the environment, or the inefficiency of the distribution system – around 6 per cent of power generated is lost in distribution. Even those who have photovoltaic systems often end up using inverters to convert the 12-21V they produce to standard mains voltage, even though a lot of devices only need the 12V.

When I'm travelling abroad I typically only need one power adaptor, because everything I take with me charges from the USB ports on my laptop. My wife Katie is an architect and many of her clients ask her to install solar power in their homes. She'd like to see every new building fitted with a separate 12V electrical system, with one or two USB ports integrated into the usual 13 amp sockets. This would remove the need for transformers in plugs and let people power or charge their electronic devices direct from power generated by panels on the roof, keeping the mains feed for the few appliances that need it, like cookers.

I like the idea that off-grid power systems developed for

poor rural communities could show us how to move away from our dependence on mains electricity and fossil fuels. These are communities that never installed fixed-line telephone networks but went straight to cellular. Now we can learn from their experience. We won't all suddenly cut our connections to the grid, tear down the pylons and decommission the

power stations, not least because we still need lots of power for cookers. But locally generated 12V power could reduce the load on the existing system and mean fewer new power stations.



BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service



FROM THE LAB Peek | Eye tests on your iPhone

WHAT IS IT?

An optician's worst nightmare: a low-cost add-on and app for a smartphone that can give you a quick eye test. Peek was built by UK scientists and engineers to help aid workers deal with sight problems in poorer communities.

HOW WAS IT DISCOVERED?

Peek uses an adaptor that attaches to a smartphone, shines a light into your eye and magnifies the image. A special

algorithm then analyses the images. It's able to check your visual acuity, scan for cataracts and warn of the onset of certain types of preventable blindness. It then stores the data so that a patient's visual health can be tracked.

WHEN WILL WE SEE IT?

The Peek app recently won the top prize at the Global Design Forum in London and should be available to buy some time early next year.

Peek could be an invaluable tool for health workers in the Third World



JUST LANDED: MOTO 360

ONE TO WATCH

This is the smartwatch that Apple will have to beat, says Daniel Bennett

What is it?

The first "smartwatch" I'd actually want to buy. So far every smartwatch I've slapped on my wrist has seemed too big, too complicated and just too square. But the Moto 360 is slim, simple and, thank heavens, round.

Why do I need a smartwatch?

Honestly? You don't. But what the Moto 360 can do is make life that little bit easier. For example, if you set off on a route on Google Maps, your watch will vibrate when you reach the next turning and tell you to go left or right – or if you're on a bus, it'll tell you how many stops you've got left to go. If you're hooked into Google Now, it'll give you a heads-up if there's something nearby that might interest you – whether that's a new Japanese restaurant or a sale at a book shop. It'll also ping over any texts, emails and reminders from your phone.

Of course, you can already do all of the above on your phone. But as I navigated the streets of Berlin at its launch, it meant I wasn't reaching into my pocket quite so often, sparing my phone's precious battery life.

What else can it do?

If you're interested in tracking your vitals, the 360 has a built-in heart rate monitor that will passively track your pulse throughout the day – it won't miss a beat. This kind of data is far more useful than simply counting your steps like a lot of other fitness watches do.



MOTO 360
MOTO360.MOTOROLA.COM, £250

You can also choose from a dozen or so different faces for your watch and, with access to the Google Play store, there's bound to be hundreds of options before the year is out. Since the screen is so sharp and bright, it actually does quite a good impression of a traditional watch. This is all just the beginning, though: as the watch makes it into the hands of developers they'll start to make new apps that can take advantage of the hardware. Anyone fancy a music generator that keys into your own heart's bpm (beats per minute)? Give it time and we're sure there'll be one.

What are the downsides?

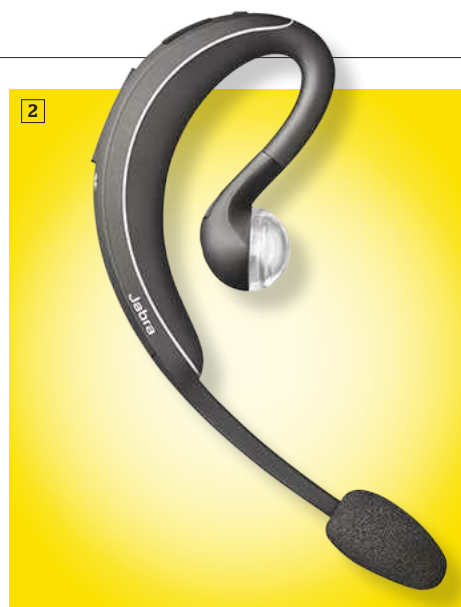
You're going to start needing to charge your watch, every day. Thankfully, Motorola has made this as pain-free as possible. It uses a universal wireless charging system so you can just drop it on the plate supplied or buy any of the wireless charging pads out there. But there is one flaw that some might deem unforgivable:

the display doesn't reach the bottom of the screen. It ends abruptly at a straight edge, just before it reaches the border of the watch face. This leaves an ungainly black patch at the bottom, diminishing an otherwise brilliantly designed product.

Should I buy one?

This is the first smart watch I've considered handing money over for, and if you're excited by tech then this might be worth considering. It's especially desirable because, unlike a large number of smartwatches, you can pair it with almost any new Android phone. But if you're the patient type, it might be worth waiting a year for the second iteration – it's likely to have a longer battery life, more apps and a display that's fully rounded.

DANIEL BENNETT is the reviews editor of *BBC Focus Magazine*



APPLIANCES OF SCIENCE

1 SOUND STAGE

Every rapper and their backing group seem to have their own brand of headphones these days, so it's great to see something a little different. The Mo-Fis include a built-in headphone amplifier, which can be used to make your music sound a lot louder and clearer. It'll take the audio output from your laptop, tablet or even your mobile phone and boost it so all the sound – bass and treble – becomes more distinct.

Blue Mo-Fi headphones
£275,
mofiheadphones.com

2 WIND BREAKER

In much of the UK, blustering wind is pretty much a fact of life. This means the person at the other end of a phone call often sounds like they're being attacked by a giant sheet of cardboard throughout the conversation. To help the citizens of windy nations, the Jabra Wave Bluetooth headset combines a specially designed microphone with smart software algorithms to reduce the noise of wind buffeting against the mic to make calls clearer.

Jabra Wave
£59.99, jabra.co.uk

3 LIFE ON THE EDGE

So far curved smartphones and televisions have been a bit of a gimmick, but the Galaxy Note Edge actually puts its shapely figure to good use. The screen draped over its right side works as an additional toolbar, which doesn't distract from the main display. The extra space can be used to quickly launch your favourite apps, receive notifications, or as a news ticker. There's even a helpful measuring app that'll turn your phone into a £780 ruler, which is nice.

Samsung Galaxy Note Edge
£999 (£782), samsung.com

4 DRONE ZONE

This drone has a 'follow me' mode which turns the IRIS+ into your very own robotic camera man that will follow any Android device with the app installed. A GoPro camera can be mounted to a gimbal so you get the kind of sweeping shots normally reserved for nature documentaries. You can even plot out a course that the IRIS+ will follow while keeping the camera centred on a predetermined 'Region of Interest'.

IRIS+
\$750 (£458 plus P&P),
store.3drobotics.com

5 DAPPER SNAPPER

If you end up taking more photographs with your smartphone than you do with your camera, then this new hybrid device might help make your pictures better. The CM1 is an Android-powered smartphone that has a 20-megapixel sensor and lens, made by camera connoisseurs Leica, poking out the back. This means you'll have full manual control over all of its settings and be able to take great pictures in low light – the kryptonite of most camera phones.

Panasonic Lumix CM1
£749, panasonic.com

6 WATCHFUL EYE

Cycling on the road can leave you feeling vulnerable, so why not have something watching your back? The Fly6 Tail Light is fitted with an HD camera that will record on a loop while you ride. If it detects that the bike is laid down for a while, it'll turn itself off so the footage is saved should you need to look back on it. It's tough enough to survive knocks and bumps and all the circuitry is sprayed with a nano coating to make it completely waterproof.

Fly6 Tail Light
\$159 (£97 plus P&P),
fly6.com

A Startling Memory Feat That YOU Can Do!

"How I learned the secret in one evening. It has helped me every day."

When my old friend John Faulkner invited me to a dinner party at his house, I little thought it would be the direct means of doubling my salary in less than two years. Yet it was, and here is the way it all came about.

Towards the end of the evening things began to drag a bit as they often do at parties. Finally someone suggested the old idea of having everyone do a 'party-piece'. Some sang, others forced weird sounds out of the piano, recited, told stories and so on.



Then it came to Peter Brown's turn. He said he had a simple 'trick' which he hoped we would like. First he asked to be blindfolded. Those present were to call out 25 random numbers of three figures each, such as 161, 249, and so on. He asked me to list the numbers in order as they were called.

Peter then astounded everyone by repeating the entire list of 25 numbers backwards and forwards. Then he asked people to request numbers by their position in the list, such as the eighth number called, the fourth number and so on. Instantly he repeated back the correct number in the positions called. He did this with the entire list – over and over again without making a single mistake.

Then Peter asked someone to shuffle a deck of cards and call them out in order. Still blindfolded he instantly named the cards in their order backwards and forwards.

You may well imagine our amazement at Peter's remarkable memory feat.

"There was really nothing to it – simply a memory feat"

On the way home that evening I asked Peter Brown how it was done. He said there was really nothing to it – simply a memory feat. Anyone could develop a good memory, he said, by following a few simple rules. And then he told me exactly how to do it.

What Peter said I took to heart. In one evening I made remarkable strides towards improving my memory. In just a few days I learned to do exactly what he had done.

"I can instantly recall anything I want to remember"

I was fast acquiring that mental grasp and alertness I had so often admired in men who were spoken of as "brilliant" and "geniuses".

Then I noticed a marked improvement in my writing and conversational powers. What's more my salary has increased dramatically.

These are only a few of the hundreds of ways I have profited by my trained memory. Now I find it easy to recall everything I read. I can now master a subject in

considerably less time than before. Price lists, reports, quotations, data of all kinds. I can recall in detail almost at will. I rarely make a mistake.

What Peter told me that eventful evening was this: "Send for details of Dr. Bruno Furst's Memory Course." I did. That was my first step in learning to do all the remarkable things I have told you about. In fact, I was so impressed that I got permission to publish Dr. Furst's Course myself.

BOB HEAP

"Dramatic Improvement"

"I used to be laughed at in the office here about my poor memory and I must admit with a lot of truth. Since I started your Course my memory has improved out of all recognition!"

Mr. J.W. Sullivan, London S.W.2.

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Mr. P.R. Jordan, (Ship's Officer)

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Please send me your free memory information pack.

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CLOUD CAMERAS

Is your home safe? Are the kids asleep? Is the cat in yet?
Jamie Carter tests four wireless motion detection or 'cloud'
cameras that can detect movement in your home



PHOTO: THESECRETSTUDIO.NET

WHILE WE LIVE in an era of low crime, the UK's Inspectorate of Constabulary recently found that some forces ask burglary victims to turn detective and investigate their own crimes.

Cue these off-the-shelf cloud cameras. Just put the camera on a wall or hard surface, attach it to Wi-Fi, and see what it sees via a smartphone app. They all have night vision and motion detection; as soon as they sense movement, most of these cameras send you an email, a text message or an alert

on your smartphone. You then open an app and watch what just happened. Whether it's a thief caught red-handed or Tiddles coming through the cat-flap, a cloud camera gives you live and recorded video of your home.

We've reviewed four one-camera packages, but they're all modular systems so you can easily add extra cameras to watch multiple rooms.





PHILIPS IN-SIGHT M120 HOME MONITOR

£129.95, works with iOS and Android, philips.co.uk

OFFERING GOOD VALUE and using the slickest app of all, Philips' In-Sight M120 is a cloud camera that's easy to use, but does come with some unexpected costs.

Its technical highlight is arguably HD video, with its 1,280x720 pixel resolution footage bright and smooth even at night, but it's the In-Sight+ app that makes this product a standout. Set-up is a cinch, with the app generating a QR code on a smartphone that just needs to be held up in front of the In-Sight M120's camera lens to link to a home Wi-Fi network.

The camera itself is small but stable, and is flexible enough to point at a specific area of a room. The app offers live streams and

even conversations with whoever's at home, but it's only possible to send a maximum 14-second recorded voice message.

The app will send you a message whenever the camera detects movement, but the videos it records are locked away in a cloud account that costs €99-€299 per year to access, depending on how far back you want to go – either seven or 30 days. That means you're paying quite a high price to watch what could just be your dog jumping on the sofa, though a single subscription does give full access for up to 16 people.



SWANNSECURE NVW-470

£399.99, works with iOS, Android and Windows, swann.com

AS WELL AS an outdoor-grade 1,280x720 resolution HD camera that must be fixed to a wall, the NVW-470 includes a seven-inch tablet for taking around the house. That tablet can be attached to a TV via an HDMI cable for truly big-screen security, but it's not much fun to operate: it uses an ancient form of Windows and has a low resolution 1,024x600 pixel touchscreen that's also the least responsive we've tested in years. Setting it all up is also long-winded and complicated.

The SwannView Link app for smartphones and tablets offers live streams of video as well as access to motion-detected sequences, which are saved to

the included 8GB microSD card, so there are none of the monthly charges that the Philips and Belkin cloud cameras demand. Since cameras can easily be added to the NVW-470 – even the app is designed to allow the viewing of four streams simultaneously – this makes a good option if you're set on expanding. However, the tablet proves an expensive drawback; video looks better through the app both during the day and in night-vision mode, and all settings for the system must be done via its poor touchscreen. If the SwannView Link app played a bigger role, the NVW-470 would be much less painful to use.





BELKIN NETCAM HD+

£129.99, works with iOS and Android, belkin.com

OFFERING EXACTLY THE same video quality as the Philips (1,280x720 pixels), Belkin's NetCam HD+ adds the ability to take remote snapshots of your home. The NetCam HD app uses Wi-Fi Direct for an easy set-up, with the camera quickly finding its way onto a home network. The night vision mode works well, as does a two-way microphone for conversations; the app's live feed page includes a speech button that you press to talk.

The NetCam HD+ is sensitive to both motion and sound, which sends alerts to your email address. It's possible to share that live feed with others, see a timeline of movement detections,

and view, share and download both videos and photos from the cloud – but only for a price. The latter requires a subscription to Belkin's NetCam Cloud+ Premium service, which is free for 30 days but then costs £7.99 a month or £79.95 a year.

NetCam HD+ is the most future-proof of all the cameras here. It's compatible with Belkin's WeMo range of smart home products including LED lights, a switch and the Crock-Pot smart slow cooker. So any motion detected by the NetCam HD+ could trigger a hi-fi, flashing lights... or a casserole. It's a smart home concept that's both bizarre and intriguing.



D-LINK DCS-942L

£89.99, works with Windows, Mac OS, iOS and Android, dlink.com

HERE'S A DECENT budget option, though this camera isn't the easiest to use. Set-up means connecting the DCS-942L to a Wi-Fi router using a cable and desktop software rather than an app, but Wi-Fi is configured easily enough and the mydlink app – which displays live streams and recordings – is reasonably slick. Video quality isn't the most detailed, though the non-HD 640x480 resolution pictures do have a higher frame rate than most. Using the app to have two-way conversations, watch (and even record on a schedule) live video and take photos is easy, but not stealthy. With the night vision mode come flashing LED

lights, which could disturb whoever's at home. Like the SwannSecure, the DCS-942L ignores the cloud to instead record all video to an included 16GB capacity micro SD Card stored in a slot in the camera's side. Alerts about motion detection are sent by email, while videos can be viewed via the app with no restrictions, which is a great reason to go for the DCS-942L, though set-up is tricky and the software looks dated. Best viewed as a solution for desktop or laptop computers, the slightly dated DCS-942L will appeal to those wary of the cloud or not keen on cloud storage fees, and not addicted to a smartphone.



THE STRUCTURE OF HUMAN CELLS

BY KATHERINE NIGHTINGALE

The invention of the microscope kick-started a scientific journey of discovery into the world of the very small that culminated in our understanding of the building blocks of the human body

W

HEN PEOPLE THINK of scientists, they often think of people in white coats peering down microscopes. That's no surprise – the microscope has been instrumental to finding out what's inside us. The first microscope came from the Dutch city of Middelburg

around 1590. This was a time of great interest in the power of lenses, whether for spectacles, magnifying glasses, telescopes or microscopes. Some would use these new technologies to gaze into the heavens. Others peered inwards, instead staring into the 'microcosmos', the world of the cells inside us.

During the 1600s, scientists began to study all kinds of materials under their microscopes. Not least of these was Robert Hooke, who in 1661 was passed a royal commission to study insects. Hooke set about designing a new type of microscope for the job. With its three lenses, it magnified objects by 50 times.

He studied insects and materials, producing brilliant technical drawings for his *Micrographia* book, published in 1665. *Micrographia* also holds Hooke's most significant contribution to cell biology. When peering down his

microscope at a thin sheet of cork, he saw what appeared to be many empty spaces bound by wall-like structures. Reminded of the small rooms in which monks dwell, he named them 'cells'.

Perhaps drawn to microscopy after seeing Hooke's studies of fabrics, Dutch tradesman Antonie van Leeuwenhoek became adept at

grinding lenses, making them with such precision that he could magnify objects to 270 times their size. His microscopes used just a single, tiny spherical lens, and gave him unprecedented access to the hidden world.

In 1675 he found single-celled lifeforms – now called protozoans – in drops of rainwater, and in 1683 he studied his own tooth scrapings and found bacteria, tiny moving beasts he named animalcules ('little animals').

Cells are generally transparent, making it difficult to discern their contents, even with improved microscopes. Van Leeuwenhoek is the first thought to have used cell 'stains', adding saffron to muscle cells to increase the contrast between cell components. Together Hooke and van Leeuwenhoek are credited with discovering cells, a feat which would have been impossible without their microscopes.

THE LIFE WITHIN

Humanity had found cells, but what were they? It was the discovery of their first component that would bring about a deeper understanding of their role, and what Hooke's dead cork



A louse clinging to a human hair is one of the remarkable images that features in Robert Hooke's *Micrographia*



This artist's impression of a human cell shows organelles surrounded by cytoplasm and a membrane

> IN A NUTSHELL

Harnessing the power of microscopes enabled scientists to explore a world invisible to the naked eye and discover that plants and animals are comprised of cells. Technological advances then meant we could learn how cells work.

→ cells had in common with van Leeuwenhoek's little animals.

Even though many others must have spotted it, it was the Scottish botanist Robert Brown who first named and described the cell nucleus – the control centre – in orchid cells in 1831. We now know that the nucleus contains the chromosomes of DNA and is the seat of power from which our genes regulate the rest of the cell.

A few years after Brown named the nucleus, in 1837, the German scientist Theodor Schwann was having lunch with a fellow German researcher, the botanist Matthias Schleiden. Their conversation turned to the nucleus,

which had so far been seen only in plants. Schleiden had observed that new plant cells seemed to come somehow from an existing nucleus. Schwann, who had been studying animal cells, remembered seeing structures that could well be nuclei.

Excited, the pair rushed to Schwann's laboratory to look at tadpole tissue. There were the nuclei: animals must be made of cells too. Both scientists wrote up their findings, with Schleiden describing cells as the 'building blocks of life', and Schwann stating: "All living things are composed of cells and cell products." It may seem obvious now, but this 'cell theory' was revolutionary:

all life from algae to aardvarks, bacteria to begonias, was made of cells.

The subsequent decades of the 19th Century, as microscopes improved, were fertile times for discovering the components of cells, and teasing apart the differences between the cells of animals, plants and bacteria.

Hooke, when coining the term cells, had technically discovered the cell wall in 1665. Human cells don't have a cell wall like plants and some bacteria, but they do have a cell membrane, a layer of lipids (fatty molecules), proteins and other components. Though it was clear that something must surround animal cells, it wasn't until 1855 that the doctor

THE KEY EXPERIMENT

Sometimes major scientific discoveries happen by chance, as Albert Claude found when he stumbled upon a key organelle while searching for a virus in the cells of a chicken

MUCH WAS KNOWN about the cell by the time that Albert Claude performed his key experiment of developing cell fractionation in 1930. But looking down a microscope was quite different to being able to separate out the parts of the cell to study them individually.

Claude developed cell fractionation while trying to isolate a virus, called Rous Sarcoma Virus, from chicken tumours. To do this he gently mashed up the tumour cells with a mortar and pestle (or sometimes a commercial meat grinder) to break the membranes and release the cell contents. He then put them in a tube and spun them in a centrifuge, the force of which speeds up the settling of heavier particles to the bottom of the tube. By successively spinning and extracting the sediment, the components of the cells are separated by size.

Claude found what he was looking for: a virus made of Ribonucleic acid (RNA). Good scientists run 'control' experiments too. In this case, Claude needed to show that the virus was present in only the tumour cells, and not healthy chicken cells. But when he repeated the process, he found that healthy cells also had similar RNA-rich particles in them. He named these mysterious organelles 'microsomes', discovering for the first time an organelle that researchers using a light microscope simply wouldn't have spotted.

Albert Claude serendipitously discovered microsomes, a cell organelle, when searching for a virus using a centrifuge



Robert Remak found a way of hardening the membrane so he could see it clearly.

Seventy per cent of the volume of the cell is cytosol, a colourless liquid that is mostly water, plus salts and organic molecules. Together with components called organelles, cytosol makes up the cell's cytoplasm – everything in the cell membrane aside from the nucleus. Around 1835 the French biologist Félix Dujardin saw this 'life substance' in single-celled animals and named it sarcode (meaning 'the flesh of the cell').

In the mid-19th Century life was made a little easier for the nascent field of cell biology. Until this point a variety of natural dyes such as iodine, cochineal and van Leeuwenhoek's saffron had been used to stain cells. But in 1856, a young assistant chemist named William Perkin produced mauve, the first synthetic dye. Though not designed for cells, it was the first of many useful synthetic dyes.

INTERNAL ORGANELLES

Many cellular metabolic processes take place in the cytosol, but some occur in dedicated organelles. One of the best-known organelles is the mitochondrion, now known as the cell's 'powerhouse' because it produces a molecule that is used as a source of chemical energy. It's possible that mitochondria were first seen in muscle cells by the Swiss physiologist Albert von Kölliker in 1857. But it was Richard Altmann, in Germany in 1894, who established that they were organelles and called them 'bioblasts'. They were renamed mitochondria by the German cell biologist Carl Benda in 1898.

Another organelle was discovered as a direct result of cell staining, and is also the only one to bear the name of its discoverer. In 1897 Camillo Golgi discovered an organelle called the Golgi apparatus in a makeshift lab he'd set up in a small hospital kitchen. It was there that he developed the 'black reaction' in which cells are impregnated with silver nitrate, highlighting their contents under the microscope. The Golgi appeared as a fine network inside the cell, and we now know that it is involved in the packaging up of proteins and lipids made by the cell.

As the 20th Century dawned, most of the large components of the cell had been spotted and named. However, really getting to grips with what each part of the cell did was going

CAST OF CHARACTERS

The great minds who harnessed cutting-edge technology of the time to explore cells



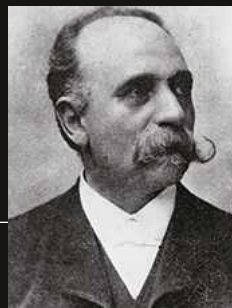
Robert Hooke (1635–1703) contributed to fields as diverse as architecture, palaeontology and astronomy. He was an English researcher born in the Isle of Wight and known for his difficult manner and rivalry with fellow researcher Isaac Newton.



Antonie van Leeuwenhoek (1632–1723) was a Dutch draper and amateur researcher. Son of a basket maker, he was an unlikely scientist, but his skill led to him producing some of the most advanced microscopes of his time, and the discovery of single-celled organisms.



Theodor Schwann (1810–1882) was a German physicist born in the town of Neuss. He was most productive early in his career, making discoveries in digestion, the nervous system and metabolism, before turning his attention to theology later in life.



Camillo Golgi (1843–1926) was an Italian doctor and researcher. He concentrated his work on the nervous system though he also strayed into malaria research. Many of his discoveries are named after him, as is the village of his birth.



Albert Claude (1899–1983) moved to the United States in 1929. He was a Belgian cell biologist who served for the British Intelligence Service during World War I, and was rewarded with a medical education in Belgium despite not having the required qualifications.

TIMELINE

The advent of the microscope enabled biologists to explore the inner space of the human cell



Robert Hooke's *Micrographia* is published, in which he describes using a microscope to find boxy structures in a thin slice of cork and coins the term 'cell'.

1665



Antonie van Leeuwenhoek uses his powerful microscope (pictured) to discover 'little animals' – single-celled organisms – in rainwater, followed by bacteria from his own tooth scrapings in 1683.

1675

Matthias Schleiden and Theodor Schwann discuss the recent discovery of the nucleus and realise that both plants and animals must be made up of the same basic units: cells.

1837



1897

Camillo Golgi discovers the Golgi apparatus in nerve cells using the 'black reaction', his own staining technique which involves impregnating cells with silver nitrate (pictured).



Albert Claude develops the technique of cell fractionation in an attempt to isolate a chicken virus. He discovers ribosomes and isolates mitochondria in the process.

1939



Claude and colleagues produce the first electron microscope image of a cell (pictured), which George Palade describes as "cell biology's birth certificate".

1945

➔ to take more than looking. As the Belgian cell biologist Albert Claude said in his 1974 Nobel lecture: "Until 1930 or thereabout, biologists, in the situation of astronomers, were permitted to see the objects of their interest, but not to touch them; the cell was as distant from us as the stars and galaxies."

PEERING DEEPER

At the same time, the tool that had been their window into cells – the light microscope – was coming to the end of its usefulness, unable to resolve objects smaller than the wavelength of light.

Two techniques developed in the first half of the 20th Century would come to the rescue, revealing structures invisible to the light microscope, confirming previous findings, and working out the biochemical role of organelles. The first of these, cell fractionation, allowed scientists to get their hands on cellular components. Developed in 1930 by Albert Claude at the Rockefeller Institute in the United States, it involved mashing up cells and then using the process of centrifugation to separate their subunits (see 'The key experiment', p96).

The second essential technique was electron microscopy, invented by German engineers in 1931. Physicists were already using the technology, but it was Claude who brought it into the realm of biology. Electron microscopy uses a beam of electrons as a source of illumination and can resolve much smaller objects than traditional microscopes because the wavelength of an electron is much shorter than that of a photon (a packet of light). In 1943 Claude began working with one of the few electron microscopes in the United States to look at subcellular particles produced by cell fractionation. In 1945, his lab was the first to use an electron microscope to image a whole cell. George Palade, who shared the Nobel Prize in 1974 with Claude and the Belgian researcher Christian de Duve, later called this image (see left) the "birth certificate" of cell biology.

Claude's lab was able to combine these techniques to determine what mitochondria do; they may have been observed and named in 1894, but it was only once they had been isolated that researchers could find out their function. He found that they contained many enzymes (proteins that act as catalysts) associated with the chemical

NEED TO KNOW

Key terms to help you understand the workings of cells

1 CELL

The basic unit of life – everything is made up of cells. Human cells have genetic material containing a nucleus and membrane-enclosed organelles, all in a watery substance called the cytosol and surrounded by a cell membrane.

2 EUKARYOTIC

A type of cell which has a nucleus and membrane-enclosed organelles. Plant, animal and fungal cells are eukaryotic, as are some single-celled organisms.

3 ORGANELLE

A component of the cell that has its own specialised function, in much the same way that an organ plays a specific role in the body. They are often separated from the cell by their own membrane.

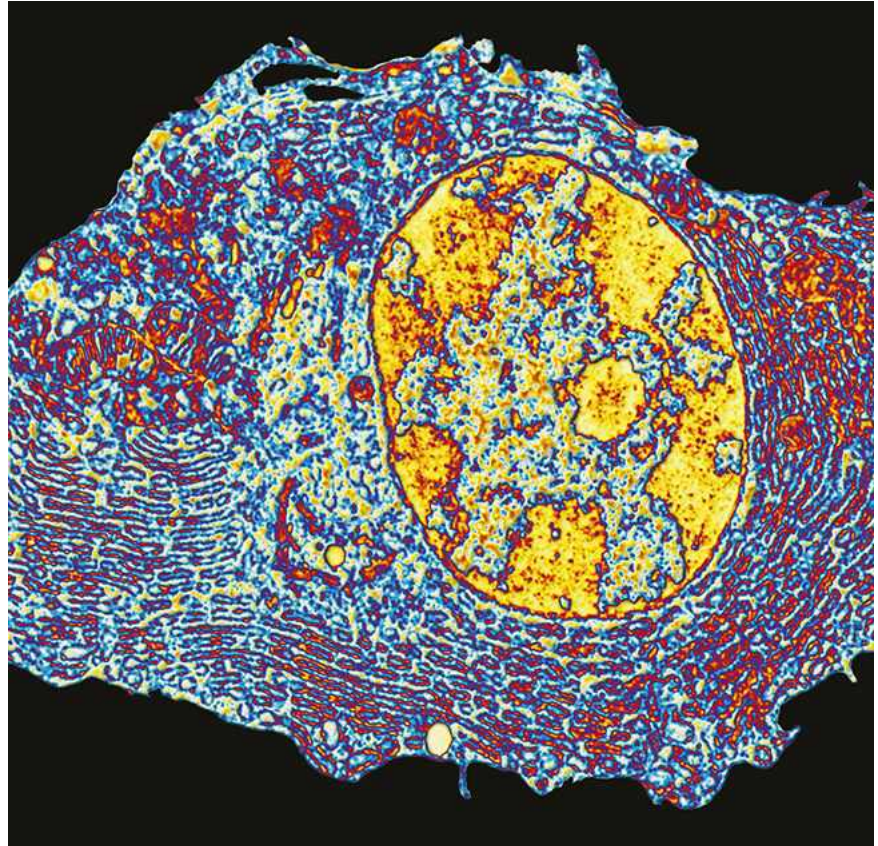
4 PROKARYOTIC

A type of cell with no nucleus, mitochondria or other membrane-enclosed organelles. Most prokaryotes are single-celled organisms, such as bacteria.

process of respiration, and that they are indeed the cellular power plants. He also used characteristic dyes to conclude that the organelles in his test tube were the same that had been seen under the microscope.

Also in 1945 Claude, along with colleague Keith Porter, used electron microscopy to discover the endoplasmic reticulum (ER), a large membranous system within the cell that is involved in producing proteins and lipids, and transporting them around the cell. The net-like structure had initially been spotted in 1902 by the Italian scientist Emilio Veratti, but the idea was discarded by the scientific community at the time.

In 1946, George Palade joined Claude's lab and began to refine many of his techniques. It was Palade who realised that the microsomes that Claude had discovered in his key experiment can be part of the ER. He renamed them ribosomes in 1955, and



A cross-section of a human cell taken with an electron microscope reveals the nucleus (large oval centre) surrounded by cytoplasm. This is filled with the endoplasmic reticulum (ER) - seen as a pink network

found that they produce proteins. We now know that the membrane of the ER joins up with the outer membrane of the nucleus, providing a highway along which DNA is translated into proteins. Part of it, the 'rough' ER, has ribosomes attached, and another, the 'smooth' ER, produces lipids.

WASTE DISPOSAL

Christian de Duve, a Belgian researcher born in England during World War I, took these new techniques further by discovering an organelle without using a microscope – he didn't even have one in his lab at the time. In 1949 de Duve discovered lysosomes – the waste disposal unit of the cell – by accident when researching insulin in rat liver cells. He used cell fractionation and then biochemical tests to determine that the cell's cytoplasm contains numerous lysosomes – membranous particles of enzymes playing a role in cell communication and energy metabolism, as well as breaking down cellular components.

Researchers have discovered much more about the cell since the mid-20th century. But it's fair to say that today's

cell biologists are more preoccupied with how the components work together than finding new ones. They tease apart the relationships between these cellular subunits – how they talk to each other to keep the delicate equilibrium of the cell's workings in check; how they behave in certain circumstances, and how this knowledge can be exploited to develop drugs and other treatments.

It is now possible to watch living cells go about their business, using the modern versions of van Leeuwenhoek's saffron to watch specific parts of the cell in action. Today's image of the cell is dynamic – a high-definition film to the 17th century's hand-drawn sketch. ■

KATHERINE NIGHTINGALE is a science writer with a degree in molecular biology

Find out more



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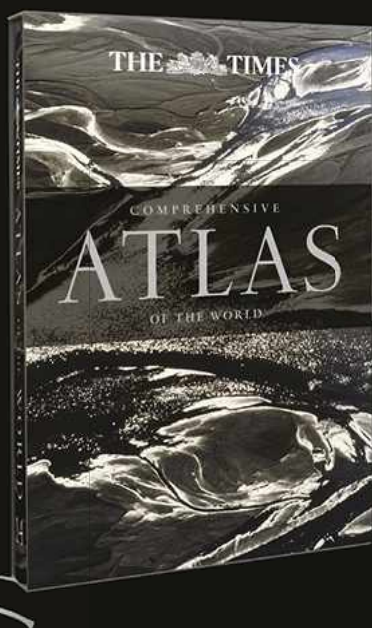


Listen to 'The Cell', an episode of Radio 4's *In Our Time* on the discovery of cells and how they work with Melvyn Bragg.
<http://bbc.in/PPBRoS>

THE TIMES COMPREHENSIVE ATLAS OF THE WORLD

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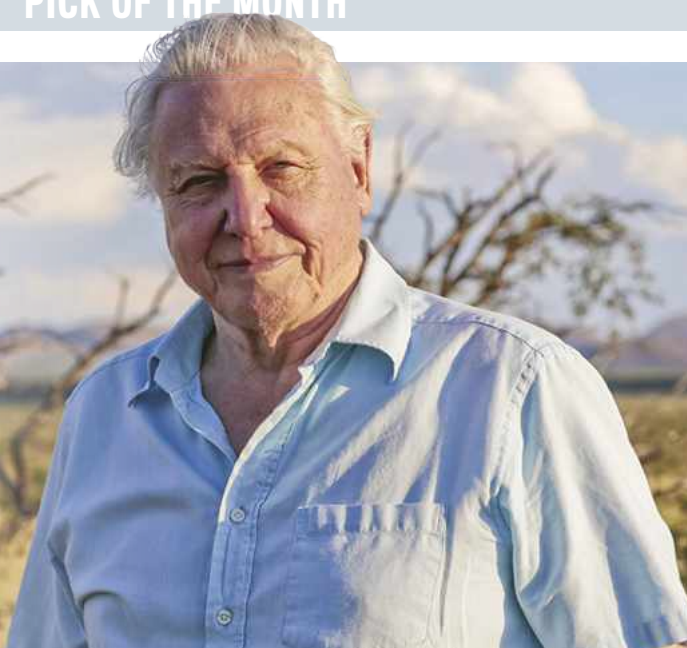
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PICK OF THE MONTH



Life Story

David Attenborough looks at how similar natural imperatives apply right across the animal kingdom



➔ WE OFTEN SAY life's too short, but spare a thought for the mayfly. Once they reach adulthood, some species of this ephemeral insect have only a few minutes to find a mate and reproduce before they die. At the other end of the scale, bowhead whales are thought to live for up to 200 years, lurking beneath Arctic waters as generations of humans pass them by.

Existence on Earth can be poignantly fleeting or astonishingly enduring, but there's one thing that all creatures have in common: they must graft out that existence from the minute they're born. It's this struggle for life that's at the heart of Sir David Attenborough's latest series: *Life Story*.

Life Story follows this universal journey over the course of six episodes. Arriving into the world, surviving childhood, meeting a partner, finding a home, climbing the social ladder, becoming a parent: it's a story that resonates with most of us. But while the meaning of our lives is open to interpretation, nature, as Attenborough demonstrates using case studies from many different species, has just one ultimate goal: continue the bloodline, propagate those genes and ensure your kind survives.

This being an Attenborough series, we're treated to some goosebump-inducing sequences along the way, all shot in breathtakingly detailed ultra HD. A newly hatched barnacle goose chick leaps 400 feet off a cliff to find food; a young meerkat comes face to face with a cobra; an Indian tiger cub watches helplessly as her father is chased away by a rival.

But amid nature's violence and chaos, we also see the lighter side of life. In Papua New Guinea, a flame bowerbird woos his lover with an outrageously flamboyant courtship display, while in Japan, a tiny pufferfish sculpts a crop circle in the sand to impress his sweetheart. And just wait till you see the Indonesian octopus that's learned to escape from enemies by hiding in a coconut shell and gleefully rolling along the sea floor.

Wildlife series don't come much more epic, emotional and heart-wrenching than this.

JAMES LLOYD



Life Story airs on BBC One this autumn – see *Radio Times* for full details of dates and times

DON'T MISS!



Wonders Of The Monsoon

A new series looks at the global impact of these rain-bearing winds. **p102**



Manchester Festival Of Science

3D printing is just one topic you can explore at this city-wide event. **p105**



The Copernicus Complex

The Sun may not revolve around us, but have we taken the idea that we are 'not special' too far? **p106**



WATCH

TV, DVD, BLU-RAY & ONLINE
WITH TIMANDRA HARKNESS

31 OCTOBER

UFO: Alien Invasion

National Geographic, 9pm



APTLY FOR HALLOWE'EN, a documentary on the spookiest UFO sightings. Eyewitnesses report lights in the skies, while official records leave some questions open. The last audio recording from the cockpit of pilot Freddie Valentich describes seeing strange lights and an unidentified craft hovering above him. Valentich was never found.

NOVEMBER

Meet The Psychopaths

Channel Five, 6pm



SOME ESTIMATES SUGGEST there are over two million, mostly undiagnosed psychopaths in the UK. For some, their impulsive nature and lack of remorse just leads to career success and dwindling party invitations; for others, it's the path to violent crime. This three-part documentary asks how you can spot psychopathy in others – or yourself.

9 NOVEMBER

Rosetta: Comet Landing

National Geographic, 8pm



IT'S BEEN IN space for 10 years, chasing a comet across the Solar System. Now Rosetta faces its biggest challenge: to rendezvous with an uneven, erratically moving, duck-shaped blob of dirty ice as it tumbles towards the Sun, venting vapour as it goes. Success could mean unlocking the secrets of how our planet formed and life began.

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Radio 4

EDITOR'S CHOICE



What you can't see in this picture of a massive storm is the enormous teacup

OCTOBER

Wonders Of The Monsoon

BBC Two, 8pm

REJOICE, VIEWERS WHO were hoping for a new *Wonders Of...* series! It may not feature Cox, cosmology or cosmonauts, but it does promise five hours of spectacular television.

There's more to monsoons than heavy rain. For a start, the name actually refers to the wind that brings its distinctive weather to a region stretching from the Himalayas to Australia. That area is home to over half the world's population, and the annual patterns of drought and rain have shaped the cultures and beliefs of the region's

diverse peoples. Wildlife, too, has evolved to survive in these extreme conditions. Baby orangutans make themselves umbrellas from leaves, and caterpillars protect themselves with poison drawn from trees.

Unforgiving weather also makes for some strange partnerships: between shrews and carnivorous pitcher plants, and between people and wild creatures. From stockbrokers to tiny insects, everybody and everything that lives in the path of the monsoon finds their lives shaped by its power.

BRIAN COX

INTERVIEW

BY TIMANDRA HARKNESS

Britain's pre-eminent science presenter is back with a new series, *Human Universe*, in which he examines our place in the cosmos

Q What's the idea behind the *Human Universe* series?

The challenge with cosmology is: how do you ground it? How do you make those ideas relevant beyond science? I think they are relevant, but cosmology has a history of being extremely challenging. Science should be the framework within which philosophy should operate. This series is saying: what is the current framework? And then, of course, you're into masses of opinion about what that means.

Q Did you learn anything new while you were making the series?

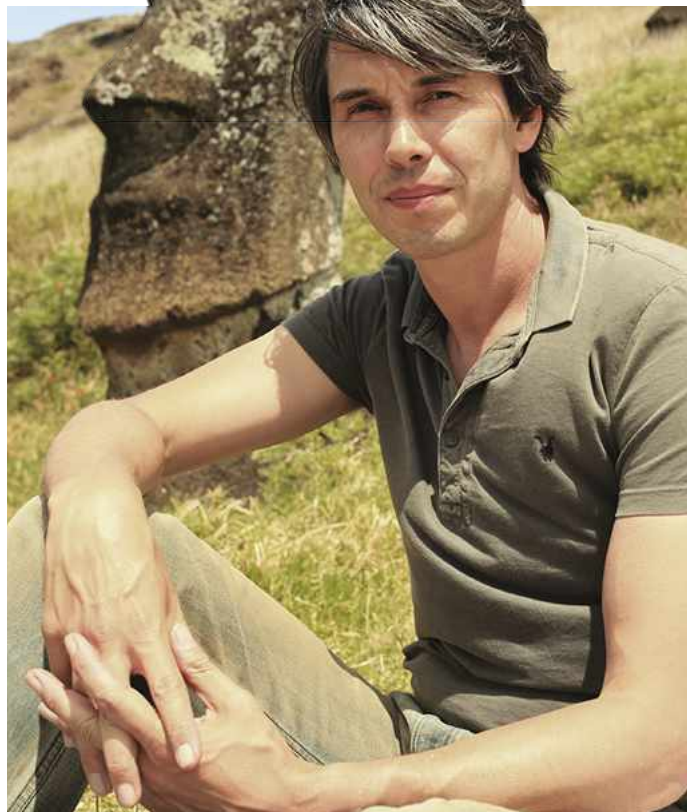
I didn't know a lot about human evolution and it's an extremely contentious area, because the evidence is difficult to come by. It's difficult to talk about events that happened a million years ago or two million years ago, so I found that very interesting.

Q Which filming location meant the most to you?

I really wanted to go back to Ethiopia. I was there a long time ago, when we filmed *Wonders Of The Solar System*, and always felt I had some unfinished things to say. Also the Soyuz landing was a terrific thing to see – and a bizarre experience because only two of us filmed it. Everybody else got stuck in the snow. The Russian army said, 'You can get in with us. You're not supposed to, but you can – but only two of you.' So that whole sequence in Kazakhstan is just me and the cameraman.

Q Is *Human Universe* something of a new direction for you?

It's my favourite series that I've done. I explicitly didn't want to call it 'Wonders of' something because we've made three of them. That format for me was just getting boring. The big innovation for me is how do you get the presenter out of the documentary? Those human moments where we go away completely and let other people talk was a new idea, and I think it works – it frames the ideas. There's a man who says, "Your ears are the past, your eyes are the future." It's exactly what we wanted to say about the idea of building a spacefaring civilisation. You need to build knowledge from generation to generation, and he said it in about three lines. So we thought, 'Why would I say it?'



In a bid to master the 'stonny face', Cox sought help from an expert

Q Is it hard to portray ideas on screen?

There's a simple choice: do you want to do them in an illustrative way – like making the stone tool in the first episode – or should I just sit down and say it? You can make it into a big sequence with lots of shots, like in Petra, talking about the rise of civilisation. Or you can just sit down, like I do in Ethiopia, to talk about an unbroken chain going back to our ancestors in the Rift Valley.

Q Is TV more open to difficult ideas than when you made your first series?

You develop trust, I think. As soon as you start offering opinions, people don't agree with those opinions, but that's good. Why shouldn't television be challenging?

Q How do you think the audience will take it?

All you can do, I think, is do something that you personally like. I think you're almost doomed to fail if you try to second-guess what an audience wants. It might be that the audience would prefer *Wonders Of...* part 4, but I don't want to make that – I want to make something else!



LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

STARTS 27 OCTOBER



US marines exercising at Camp Bastion

Trauma: A Brief History

BBC World Service, 6.30pm

WAR BRINGS CONSTANT innovation in ways to kill people, but also in ways of keeping them alive. Dr Kevin Fong travels to Afghanistan and into history, from the trenches of World War One to Camp Bastion, for this two-part exploration of trauma medicine. The programme is part of the Discovery strand.

28 OCTOBER

Click

BBC World Service, 6.30pm

LIVE FROM THE opening of a new permanent exhibition at London's Science Museum that's all about the age of information comes this special edition of the weekly technology programme. Gareth Mitchell reports on the exhibition and the week's technology news.

ONLINE

What If Africa Was The New Hub Of Global Science?

bbc.co.uk/programmes/p01613y7



SIX PROGRAMMES EXPLORE the current state and future prospects of science in Africa. At a science festival in Uganda, students and researchers discuss what science can do for health and agriculture - and what Africa can do for science. First broadcast in March 2013.



NOVEMBER

Hot Gossip

BBC Radio 4, 11am

BEEN CAUGHT READING a gossip magazine? It's OK! Evolutionary psychologists say gossip has important social functions. In this two-parter, Geoff Watts investigates the history, science and sociology of gossip, scandal and rumour. Sounds good (but don't let on that it was us that told you).



Geoff Watts: gossip-monger

NOVEMBER

The Life Scientific

BBC Radio 4, Tuesdays, 9am

PROFESSOR JIM AL-KHALILI continues his friendly chats with prominent scientists. Guests include Professor Sally Davies, Chief Medical Officer for England, on 11 November. A haematologist specialising in sickle cell disease, she now has to advise on topics from Ebola to obesity.



TOUCH

SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

Anatomy 4D

iOS 6 or later, iPhone/iPad/iPod touch, Android 2.2, DAQRI, free



DAQRI IS AN augmented reality pioneer, and one of its most impressive tech showcases is Anatomy 4D, an AR app that gives you a virtual tour of the human body. Print out the supplied picture of a human body, lay it on a flat surface and aim your camera at it, and Anatomy 4D will display a 3D computer rendering of the body and its various organs. You can then zoom in and out, change the viewing angle by moving your phone around the

target, and selectively view particular systems in the body, such as the skeletal, lymphatic or respiratory system.

Theodolite

iOS 4.3 or later, iPhone/iPod touch, Hunter Research & Technology, £2.49



THEODOLITE IS ANOTHER augmented reality app. This one's a digital viewfinder that provides users with an impressive data overlay that's reminiscent of military heads-up displays. Using your camera's internal

sensors and GPS, the app combines numerous navigational tools such as a compass, inclinometer, rangefinder and mapping features. Users can also take geotagged photos and videos, while in-app purchases include the ability to share your location with a team, and more precise geodetic data packs. It's ideal for outdoors types, sportsmen and serious surveyors alike, and a Theodolite HD version is also available for iPad users.

Sky Map

Android 1.5 or later, Sky Map Devs, free



A FORMER GOOGLE project that has now been released to the open source community, Sky Map provides users with an interactive map of the night sky right on their Android device. Using a combination of location data and your phone's internal sensors, the app displays star charts precisely aligned to wherever your phone or tablet is pointed, displaying the names of stars, constellations, planets and other celestial objects. A 'Time Travel' feature lets you roll back time to see what the night sky looked like on a

particular date, and you can also toggle a night mode so as not to ruin your low-light vision.

KATE RUSSELL is a technology journalist and BBC Click presenter



VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

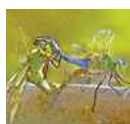


18/19 OCTOBER

Battle Of Ideas

The Barbican, London, battleofideas.org.uk

THE BARBICAN HOSTS a festival of debate including talks on flooding, animal consciousness and space exploration.



24 OCTOBER

Rules Of Attraction

Royal Institution, London, 6.30pm, £12, rigb.org

THROUGH WORKSHOPS, LIVE music, films, demos and talks, discover the science of sexual attraction – chemical bonds, gravitation – and what makes us fall in love.

25 OCTOBER

Objects In Time

Royal Observatory Greenwich, London, 12pm-4pm, £15, rmg.co.uk

DR MAREK KUKULA looks at the science behind everyday objects. Includes a clockwork workshop and a sci-fi writing masterclass.

25 OCTOBER

Dark Skye Star Party

Clan Donald Centre, Isle of Skye, 5.30pm-9pm, £12.50, darksky-skye.com

LEARN HOW TO capture galaxies on camera with *Stargazing For Dummies* author Steve Owens and astrophotographer Sue Daly. Plus, there's a pop-up planetarium, and a chance to see how explorers navigated by the stars.



FROM 25 OCTOBER

Six Networks That Changed Our World

Science Museum, London, free, sciencemuseum.org.uk

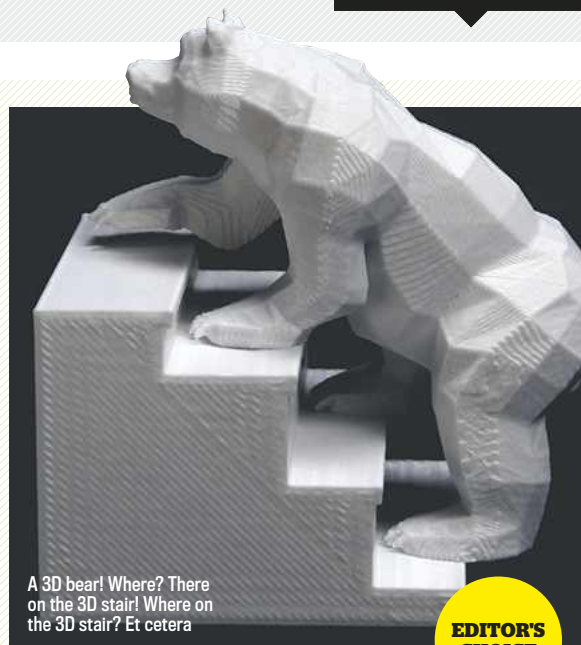
TAKE A RIDE on a time machine through 200 years of technological advances which shaped the connected world we live in today.

30 OCTOBER

Sextants To Satellites And Beyond

National Maritime Museum, London, from 11am, free, rmg.co.uk

DISCOVER HOW TIMEKEEPING has evolved from Harrison's clocks 300 years ago, via satellite navigation, to quantum timekeeping.



A 3D bear! Where? There on the 3D stair! Where on the 3D stair? Et cetera

EDITOR'S CHOICE

23 OCTOBER - 2 NOVEMBER

Manchester Festival Of Science

At venues across Manchester, mostly free, manchestersciencefestival.com



IF YOU FANCY making fire from ice, creating square bubbles or building an erupting volcano, then head to this 10-day festival. Scattered across the city are all sorts of events: talks, workshops, comedy shows. There are plenty of highlights. Astronomer Mark Thompson discusses all things galactic, from satellites to supernovas and from parsecs to planispheres. A 3D printing exhibition looks at the groundbreaking design of everything from beautiful art pieces to replacement body parts. And there's the chance to do hands-on experiments, like making a jelly baby scream.

31 OCTOBER

Lates At Life: Halloween

Life Science Centre, Newcastle, £7.50, life.org.uk

FRANKENSTEIN 4D MOTION ride, access to all exhibits and no kids. What more could you want from Halloween?



5 NOVEMBER

What If?

Royal Institution, London, 7pm, £12, rigb.org

SUBTITLED 'SERIOUS SCIENTIFIC answers to absurd hypothetical questions', this talk will appeal to fans of the Ig Nobel Prize.

12 NOVEMBER

We've Overdosed

Royal Geographical Society, London, 7pm, £30, intelligencesquared.com

ANTIDEPRESSANT USE HAS doubled in the UK in the last decade, while Ritalin use for hyperactivity has tripled. Join this discussion looking at the roles of science, psychiatrists and Big Pharma.

PHOTO: TEDDY LLOYET, RAIN RABBIT/FLOCKR



READ

THE LATEST SCIENCE BOOKS REVIEWED

H Hardback **P** Paperback

The Copernicus Complex

The Quest For Our Cosmic (In)Significance

Caleb Scharf

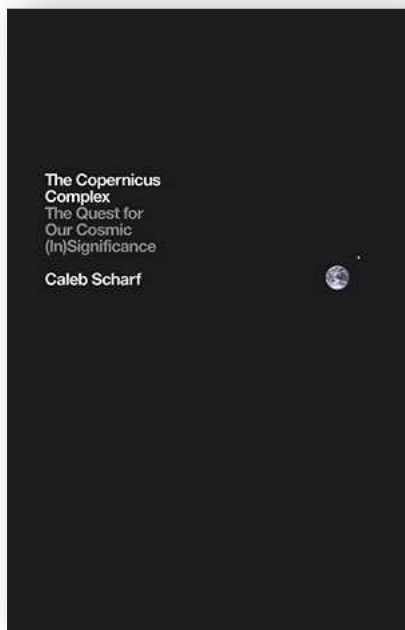
Allen Lane **H** £20

ONE QUESTION ABOVE all others towers over us when we contemplate the Universe: "are we alone?" It's been the subject of intense debate for centuries. We used to think we were at the centre of the entire Universe, with the Sun, the planets and the stars revolving around us. That changed when Copernicus correctly placed the Sun at the centre of the Solar System, and it was realised that the stars were other suns. Suddenly, Earth was relegated to being just another planet around just another star.

In his latest book, astrophysicist Caleb Scharf suggests we're still feeling the hangover from this wrench in our understanding. In the intervening centuries, the Copernican principle has extended our mediocrity beyond the Solar System, stating that we're not in a special position in the Universe either. But, says Scharf, this has taken a stranglehold on our thinking. So *The Copernicus Complex* is a manifesto for an update in our thinking, in light of what we've been finding out about stars, life and other planets in the last few decades.

Take the search for exoplanets. Many of the early planet hunters expected to uncover carbon copies of our own Solar

"Early planet hunters expected to uncover carbon copies of our own Solar System"



System – after all, we're not special. Yet the truth exploded that notion. There are giant, gassy planets orbiting astonishingly close to their parent stars, planets circling multiple stars, and an abundance of super-Earths – giant, rocky worlds for which we have no Solar System equivalent. It's also possible that we live at a special time in the Universe's history. In one sobering passage, we're informed that star (and planet) formation is happening at a rate that's just three per cent of what it was billions of years ago. Perhaps we're lucky to have sprung up when we did.

Scharf serves up a well-constructed argument, seamlessly flitting between deep philosophy, the latest astronomical findings and good old-fashioned storytelling. A particular highlight is when he recalls standing atop a Chilean mountain, gazing up at the boundless sky and contemplating the very origins of life.

In truth, there is nothing really new here. But if you're looking for an entertaining and well-written introduction to the latest ideas about where we come from and whether we're alone, this is a great place to start.



COLIN STUART is an astronomer and co-author of *The Big Questions In Science*

MEET THE AUTHOR



Caleb Scharf

What have exoplanets taught us about our own place in the cosmos?

We've now detected evidence of over 4,000 potential exoplanets. On the one hand, this tells us that planets are incredibly abundant. But at the same time, we find that our Solar System is in a slightly unusual club.

For example, the orbits of the planets in our Solar System are more circular than in many systems, and our system doesn't contain some of the more abundant planet types such as super-Earths. If you put all the characteristics together, it looks like we live in a one-in-a-hundred kind of place. But we don't know whether this is related to the existence of life here.

Now we have an idea of some of the conditions needed for life, can we look for those conditions elsewhere?

Absolutely. Here on Earth, biology has put a big fingerprint on the planet – it has affected the chemistry of the atmosphere, the surface environment, and the way the planet responds to seasonal changes. So we can look out for these 'biosignatures' on exoplanets.

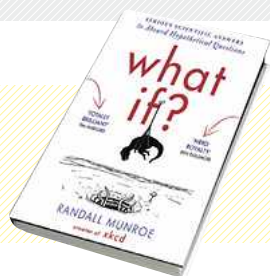
So what was your conclusion after writing the book: is the Earth special?

I think we may well be unique, but not exceptional. There could be lots of other planets out there with lots of life, some of which might be equally complex and sophisticated – but just very different. This is a way to reconcile the idea of cosmic mediocrity with the evidence that there are special things about the Earth. There may be lots of equally special places out there.



MORE ON THE PODCAST

Listen to the full interview with Caleb Scharf at sciencefocus.com/podcasts



What If?

Serious Scientific Answers To Absurd Hypothetical Questions

Randall Munroe

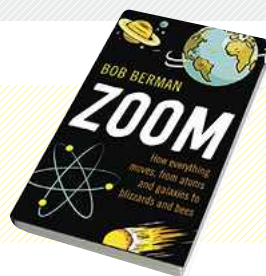
John Murray **H** £14.99

IN GEEK CIRCLES, webcomic XKCD is the epitome of cool. Now, creator and ex-NASA roboticist Randall Munroe turns his attention to (sometimes weird) questions posed by XKCD readers, such as 'If we all disappeared, how long before the last light went out?' and 'From what height could you cook a steak just by dropping it?'

Munroe lets his imagination run wild, taking us on a fantastic journey of thought experiments and poignant reflections through the lenses of physics, maths, biology, history and humanity. Collecting the best of his weekly blog, each answer is a treat packed with facts, logic, wild (yet rational) speculation, wry nerd humour and stick figure cartoons. A tour around Munroe's brain takes even the most oft-heard of questions - "What would happen if all humans jumped at the same time?", "What if I have just one soulmate?" - in surprising directions. Yet what shines through most is the author's incredible curiosity about the world and his ability to spin a fine yarn around it. It's like a trip up the scientific Amazon with the Indiana Jones of knowledge.



MUN-KEAT LOOI is a science writer and co-author of *Big Questions In Science*



Zoom!

How Everything Moves, From Atoms And Galaxies To Blizzards And Bees

Bob Berman

Oneworld **P** £8.99

FROM THE ATOMS around us vibrating trillions of times a second to the distant galaxies that whoosh 150,000 miles farther away in a heartbeat - everything, it seems, is on the move. In *Zoom*, US writer Bob Berman takes us on a journey to explain how the world works, from the formation of sand dunes to the majestic movement of the aurora borealis.

Berman interweaves a formidable number of facts through the book that light up every page. Bamboo can grow at 39 inches a day; an empty mayonnaise jar contains enough energy to boil away the Pacific Ocean; some types of bacteria can travel 100 times their own body length in a second. It all adds up to an entertaining read, leaving you in no doubt about how incredible life and the Universe we live in really are.

Indeed, there seems to be little untouched, with Berman closing with how quantum entanglement - dubbed "spooky action at a distance" by Einstein - implies that something, whatever it is, can even travel in zero time. As Berman himself puts it: "Everything moves; it has always moved; it is its nature to move."



MICHAEL BANKS is the news editor of the journal *Physics World*



A Buzz In The Meadow

Dave Goulson

Jonathan Cape **H** £16.99

THIS IS OSTENSIBLY the story of how Goulson, one of Britain's leading entomologists, bought a ruined French farm for a song and set about renovating it and observing the wildlife of its beautiful meadow. Power tools catch fire due to idiosyncratic wiring, much wine and cheese is consumed, and there's a narrow escape when hunters pepper the author with lead shot - all pretty familiar stuff. What makes this a worthy sequel to *A Sting In The Tale* (Goulson's surprise bestseller about bumblebees) are the insights we get into the secret lives of the insects, plants and other species found on the farm's 33 acres. There's a lot of sex - for instance, we learn about a bizarre plant disease called campion smut, in which a fungus makes flowers change sex, and about the phenomenal fecundity of male deathwatch beetles, who in the act of ejaculation transfer up to 20 per cent of their bodyweight to the female in one go.

Goulson brings obscure biological experiments to life and turns complex ecology into a real page-turner, ending with 65 sobering pages that highlight some of the damage we are collectively wreaking on the natural world.



BEN HOARE is features editor of *BBC Wildlife Magazine*



How We Got To Now

The History And Power Of Great Ideas

Steven Johnson

Particular Books **H** £20

WE'RE CONSTANTLY TOLD that innovation is vital to our future health, wealth and happiness, but how does it come about? Is it inspiration, perspiration or something more complex? Steven Johnson tackles this question by looking at six innovations that have shaped our modern world: glass, refrigeration, audio technology, sanitation, time measurement and lighting.

As he shows, a lot of the neat and tidy stories about how innovation happens are just plain wrong. For example, lots of inventors beat Edison to the design of the light bulb - he was just the first to make it really good. Johnson also highlights how

one innovation often triggers many more. The invention of printing sparked increased demand for spectacles, which in turn led lens-makers to the development of the telescope and the microscope.

While he has an ear for a great anecdote, Johnson's writing style veers between the academic and the populist, and some of his analysis is less than lucid. Still, by the end, you'll almost certainly have learned something new.



ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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MINDGAMES

Test your knowledge with our Big Quiz set by **James Lloyd**

1 A cave engraving found in Gibraltar may be the best evidence yet for Neanderthal art. What symbol does the etching resemble?

- a) A hashtag
- b) A question mark
- c) An asterisk

2 Complete the recent headline: '_____powered battery could charge your phone'

- a) Urine
- b) Sweat
- c) Saliva

3 Which fictional character was recently sent into space aboard a Japanese micro-satellite?

- a) Hello Kitty
- b) Godzilla
- c) Mario

4 This odd-looking critter is a baby aye-aye lemur being weighed at North Carolina's Duke Lemur Center. To which island are lemurs endemic?

- a) Mauritius
- b) Majorca
- c) Madagascar



This fella is endangered on its home island of...

5 This otherworldly image is a close-up of which creepy-crawly?

- a) Bed bug
- b) Human flea
- c) Deer tick



6 According to psychologists at King's College London, what could predict a child's future intelligence?

- a) Their drawings
- b) The length of their earlobes
- c) Their parents' jobs

7 Recent research at the University of Exeter has refuted what commonly held belief?

- a) That magpies steal shiny objects
- b) That bulls are enraged by the colour red
- c) That goldfish have a three-second memory

8 Astronomers have mapped the huge supercluster of galaxies to which the Milky Way belongs. They've dubbed it 'Laniakea', but what does this mean in Hawaiian?

- a) Exquisite sky
- b) Celestial sphere
- c) Immeasurable heaven

9 Computer scientists from Birmingham University have developed a robot capable of what?

- a) Polishing your car
- b) Loading your dishwasher
- c) Taking out your rubbish and sorting your recycling

10 Complete the recent headline: 'Spending less time _____ could be the key to living longer'

- a) Sitting down
- b) Phoning friends
- c) Watching TV

11 The world's last known passenger pigeon died 100 years ago. What was her name?

- a) Mabel
- b) Maggie
- c) Martha

12 Scientists have discovered the most complete giant sauropod dinosaur skeleton yet. Roughly how much did the *Dreadnoughtus* weigh?

- a) 20 tonnes
- b) 40 tonnes
- c) 60 tonnes

13 This snazzy Soviet dog spacesuit recently went up for auction. What was the name of the Soviet dog who in 1957 became the first animal to orbit Earth?

- a) Lisichka
- b) Laika
- c) Lenin



More puzzles online



Try solving puzzles from the BBC quiz *Only Connect* hosted by Victoria Coren online at <http://bbc.in/1vCOzuY>

QUIZ ANSWERS

HOW DID YOU SCORE?

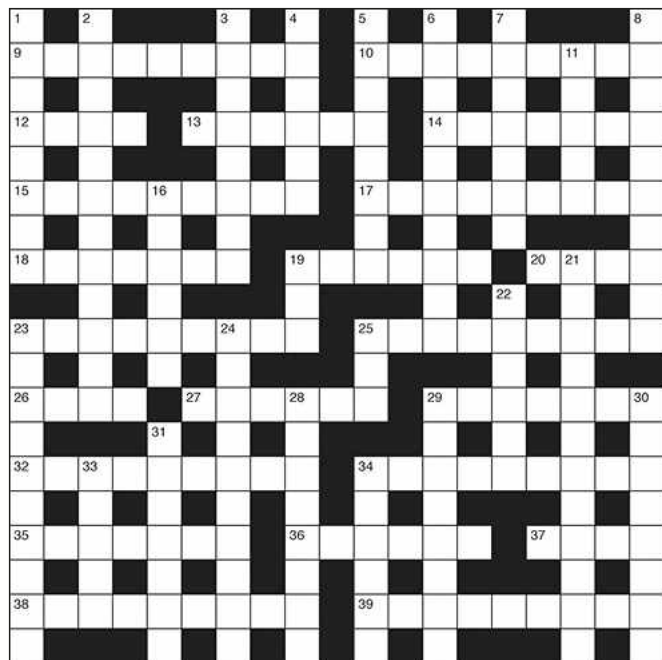
0-4 DOG'S DINNER

5-9 DOGGED EFFORT

10-13 TOP DOG

1a, 2b, 3a, 4c, 5b, 6a, 7a, 8c, 9b, 10a, 11c, 12c, 13b

FOCUS CROSSWORD No 170



ACROSS

- 9 Skid like an amphibious aircraft? (9)
- 10 Fruit, seafood and beer have double phosphorous (4,5)
- 12 Weight of potassium oil varies (4)
- 13 Salt and chalk, a line going round (6)
- 14 Rust makes old exit have trouble with keys (7)
- 15 Lint used in location of aphids (5,4)
- 17 Sealed window weighing virtually nothing (9)
- 18 Tip over during journey in current (7)
- 19 Doctor rings graduate first for building material (6)
- 20 Stuttering at start of operation (1-3)
- 23 Denigrate feathers, to a degree (9)
- 25 Rushing to perplex bat (6,3)
- 26 Cure using colour (4)
- 27 Jack gets a shilling for every mineral (6)
- 29 Finally, a moderate paint (7)
- 32 Flier and warmonger pursue good score (5-4)
- 34 Soothing and helpful about married university student (9)
- 35 Writer has lost out in trifle (7)
- 36 Starving country loses area (6)
- 37 Horse throwing up dust (4)
- 38 MongOOSE has one, using one munch (9)
- 39 Clean the beach to have fun (9)

DOWN

- 1 Fun incentive to get delphinium (8)
- 2 Energy from America or Russia, say (7,5)
- 3 Digital protection dossier carried in handbag (4,4)
- 4 Points to identical seeds (6)
- 5 I'm chased around port (8)
- 6 Room for experiment (10)
- 7 Mother will get a kiss and I'll get a bone (7)
- 8 Abandon reported connections to cat (6,4)
- 11 Called after parking collision (5)
- 16 Prioritising the first one in anger (6)
- 19 Last word from the cricket (3)
- 21 Woman gets fellow ordering free Latin gear (12)
- 22 Creature has article to mail off (6)
- 23 I had returned with exciting insulator (10)
- 24 Asian range of anorak may develop answer (6,4)
- 25 Confirmation about tree (3)
- 28 Heard to store underwear in nickel silver (8)
- 29 Monkey adds note of flavouring (8)
- 30 Remedy against treasure (8)
- 31 Last character gets directions to rent outsome hops (7)
- 33 Ravine starts to give up large calcium hexagons (5)
- 34 Hurry to take in new nationality (6)

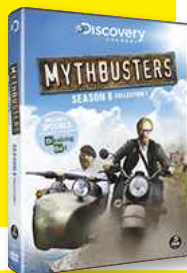
SOLUTION TO CROSSWORD No 167

Sue Corvett, Stephen Millard, Peter Haworth, Phil Cooper and Kathy Humphrey each solved issue 271's puzzle and receive a copy of *Finding Longitude* (Collins, £20).



WIN! MYTHBUSTERS SEASON 8

The first five correct solutions drawn will each win a copy of *MythBusters Season 8* (Discovery, £17.75). Entries must be received by 5pm on 13 November 2014. See below for more details.



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Post entries to *BBC Focus Magazine*, November 2014 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to november2014@focuscomps.co.uk by 5pm on 13 November 2014. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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HOLLYWOOD SCIENCE

Life extension in **DRACULA UNTOLD**

THIS MONTH, HAVE your garlic and rosaries at the ready as *Dracula Untold* hits the big screen and the Prince of Darkness reveals his secrets of eternal youth: cleanse, exfoliate and moisturise... and suck the life blood from innocents. But vampires, it seems, could be on to something if recent research is anything to go by.

In May 2014, two groups showed that young blood can help reverse the ageing process, but the blood came not from virgins, but from rodents. In what sounds like a scene from the Hammer House of Horror, Saul Villeda from the University of California and colleagues physically joined pairs of old and young mice together so they shared each other's blood supply. Old mice pumped with young blood sprouted more connections in a memory-related brain region called the hippocampus, Villeda found. And when young blood plasma was injected directly into old mice, it improved their memory. "It takes six months or more off the ageing process," says Villeda. If it worked the same in humans, that would be equivalent to 20

"Young blood can literally reverse the problems that occur in the old brain"

years. "There's something about young blood that can literally reverse the problems that occur in the old brain," he says. Meanwhile researchers at Harvard showed that chemicals in young blood can increase muscle strength and endurance in older mice. It's possible the effects could extend to humans. Suddenly black pudding is starting to look appetising.

The real-world findings help explain how made-up vampires manage to stay youthful for millennia (it's refreshing to find fiction underpinned by sound science), but vampires aren't the only ones able to stall the Grim Reaper. Bats, of which there are many in *Dracula Untold*, also enjoy unexpectedly long lives. One species, Brandt's bat, can live for a staggering 40 years – 10 times longer than predicted for an animal of its small size. Perhaps bats add years to their life by dining on the blood of hapless cows.

The hunch is that young blood contains molecules that 'waken' dormant stem cells in the recipient, which then start dividing to produce replacements for damaged and dying cells. So rather than endorse vampirism, or 'haematophagy' to give it its proper name, the hunt is on to identify these rejuvenating molecules and 'bottle them' in the form of new anti-ageing therapies. If researchers have their way, ageing could be slowed and vampires could find themselves swapping blood for a healthy diet and a handful of pills. It'd certainly take the edge off future vampire films, but if all else fails there's still one way to stay young – just be Justin Bieber. ■



HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

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