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Q&A
- Why does hair go grey?
- Can fish catch colds?
- Could a brain survive without a body?



GENERATION EARTH
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WELCOME TO FOCUS



THIS COULD BE the last ever issue of *Focus*. If one interpretation of the Maya calendar is correct, the world will end on 21 December, 2012. Well, I don't believe it and I trust you don't either. That said, there are plenty of apocalyptic events that *could* happen this month. Science writer and BBC presenter Alok Jha heads for cover on p35, with his guide to how you can survive them.

Focus itself is a survivor – the magazine we know today was launched 20 years ago this month in the UK. On p58 we examine the science and technology covered in that very first issue, and find out how it's evolved since – and where it's going in the future. And on Facebook this month we'll be delving through more issues from the archives. Go to www.facebook.com/sciencefocus and click 'Like' to help us celebrate our anniversary in style.

Some of the most exciting steps forward are being taken in the quantum realm: not just quantum computing but a quantum internet and other advances besides. Former *Focus* editor Paul Parsons looks at the world of the very small and the very strange on p46.

There's much else inside: our article on human attraction accompanies an episode of *Dara O Briain's Science Club*, and there are seasonal gift ideas aplenty in our gift guide (p42) and Tech Hub (p83). Enjoy!

Graham

Graham Southorn, Editor

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APPEARING IN THIS ISSUE...



Alok Jha

Best known as a science correspondent for *The Guardian*, Alok is popping up as a TV presenter this year on *Dara O Briain's Science Club*. He is also the author of *The Doomsday Handbook: 50 Ways The World Could End*.



Cherry Lewis

Dr Lewis is an honorary Research Fellow in the School of Earth Sciences at the University of Bristol. Her book on geologist Arthur Holmes, *The Dating Game: One Man's Search For The Age Of The Earth*, was published in 2000.



Paul Parsons

A former editor of *Focus* and theoretical cosmologist at the University of Sussex, Paul is no stranger to the bizarre world of physics. This month, we asked him to look into the emerging technology of quantum computing.



Dan Read

When *Top Gear* magazine's special projects editor isn't actually driving, you'll find him writing about life behind the wheel. That made him the perfect person to investigate the latest trends in car technology.

WANT TO SUBSCRIBE? Just fill in the form on p30 and you'll get a free book or DVD – and save 32 per cent off the cover price to boot!

EXISTING SUBSCRIBERS Turn to p30 for an exclusive interview with geneticist **Steve Jones**

COVER: MAGICTORCH

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THE QUANTUM REVOLUTION IS HERE

How strange subatomic effects are being harnessed to transform the internet, computing and medicine

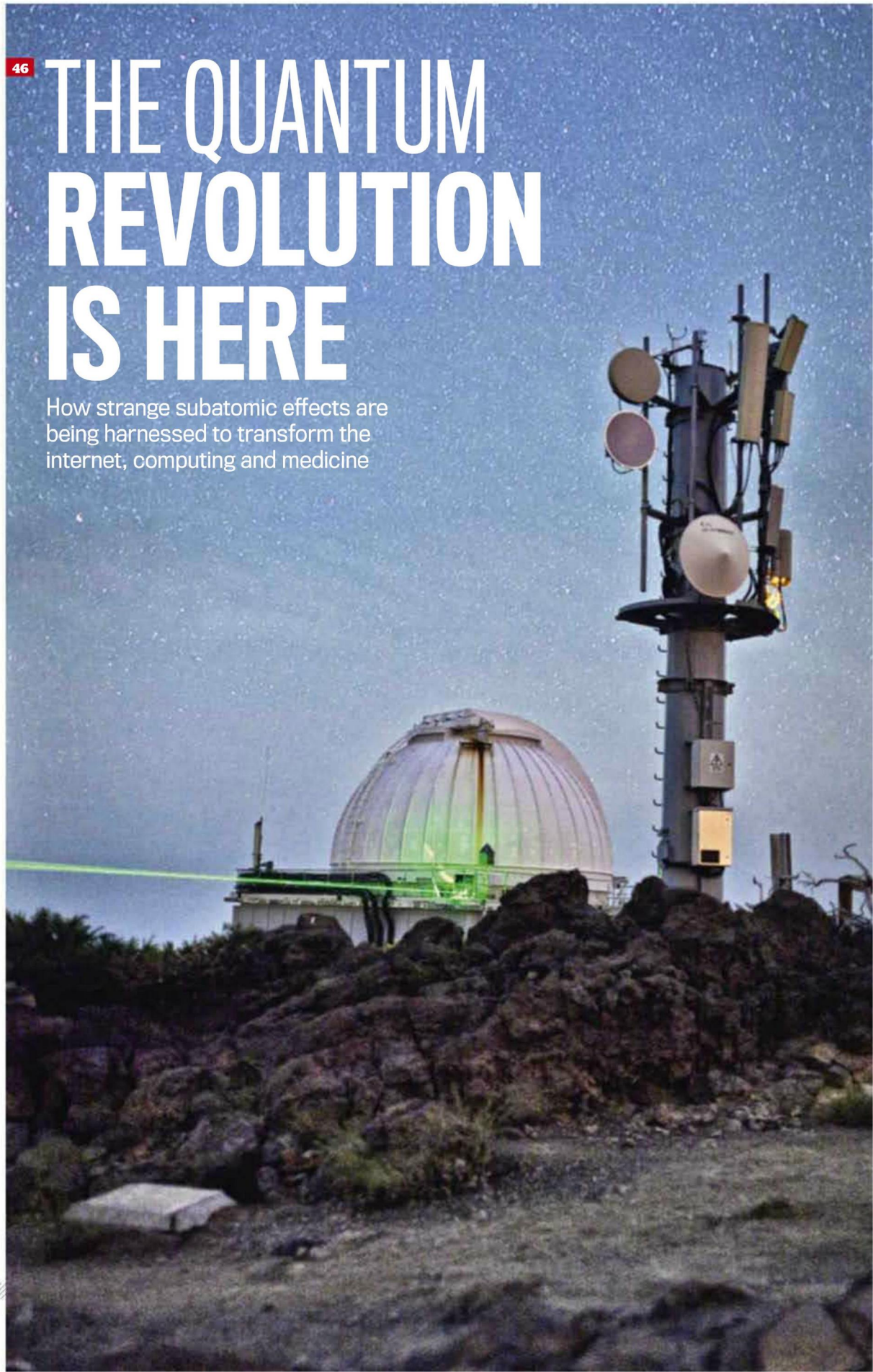
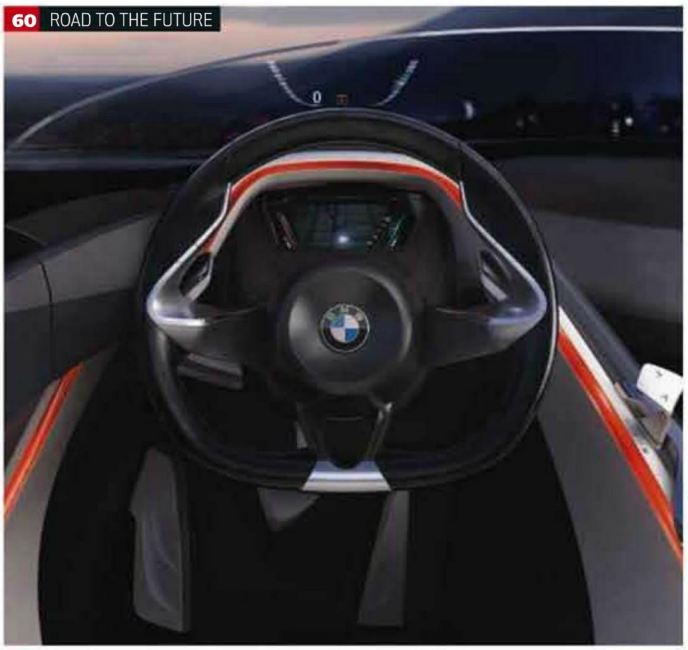


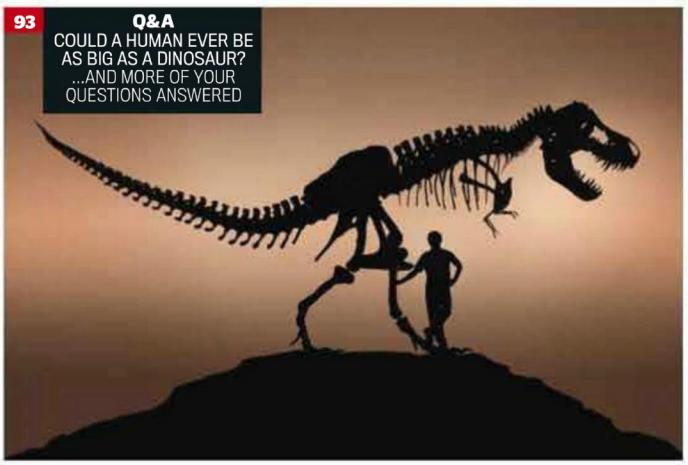
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Wowdass

Awe-inspiring images from the world of science

MegaPixel



Dressed to thrill

WHEN AUSTRIAN SKYDIVER Felix Baumgartner jumped out of his capsule 24.2 miles (39.0km) above Earth, there was one thing keeping him alive – his space suit. The temperature around him was -60°C and there was little oxygen to breathe. Low air pressure meant that, without his pressurised attire, fluids inside his body could have turned into gas.

But the suit also had to be flexible enough for Baumgartner to get into the right position before opening his parachute. "For over 40 years we've been designing space suits for people in the sitting position," said Daniel McCarter from David Clark Company in Massachusetts, which made the suit. "We have made huge advances in elbow and knee joints," says McCarter. "We're doing all kinds of R&D projects on advanced suits for the future – for commercial spaceflight as well as suit concepts for the Moon or Mars."

McCarter watched from mission control in Roswell, New Mexico, as Baumgartner hit a speed of 1,343km/h (834mph), breaking the sound barrier before safely touching down.

PHOTO: RED BULL


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Flake physics

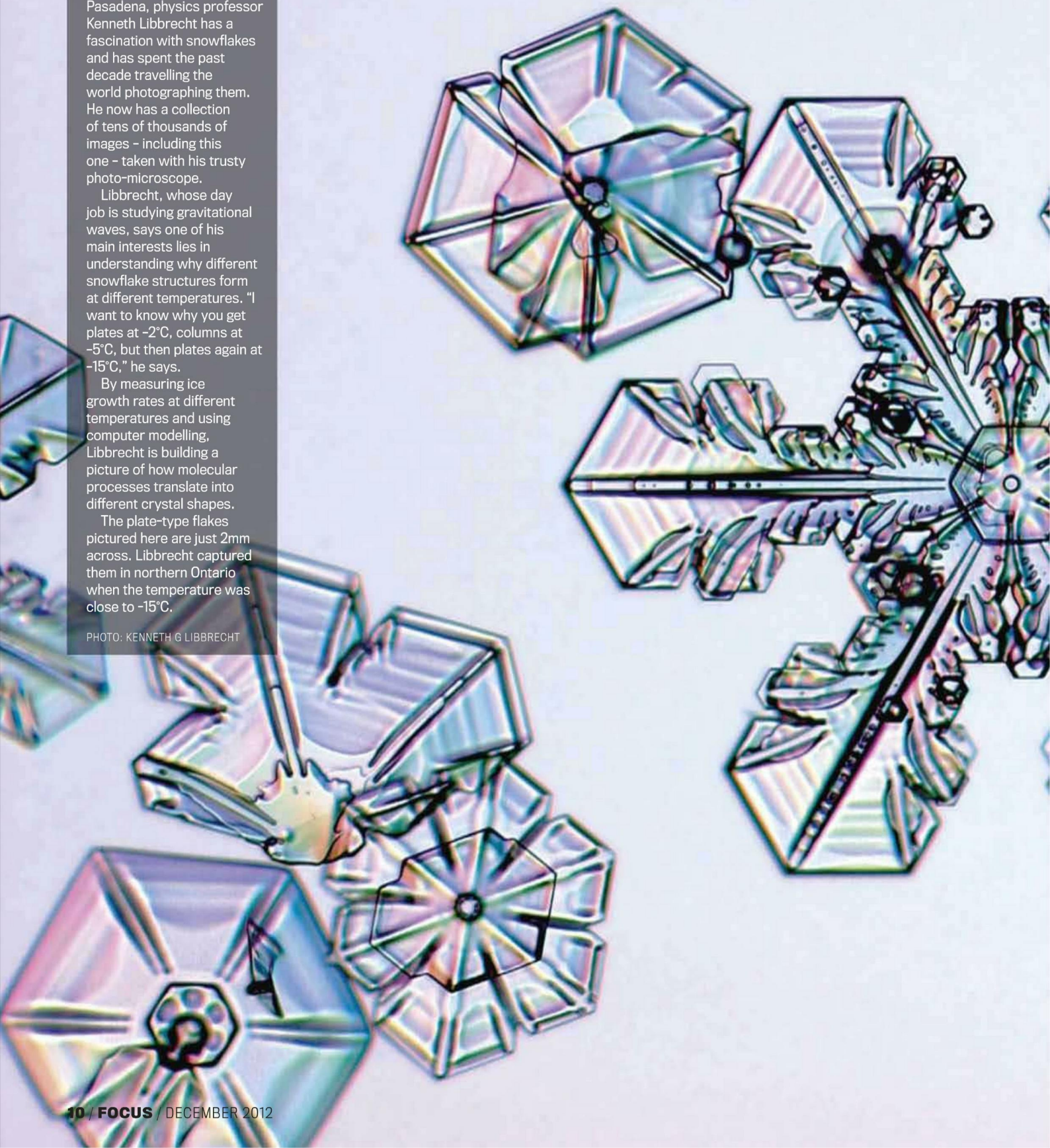
THOUGH BASED AT the California Institute of Technology in sunny Pasadena, physics professor Kenneth Libbrecht has a fascination with snowflakes and has spent the past decade travelling the world photographing them. He now has a collection of tens of thousands of images – including this one – taken with his trusty photo-microscope.

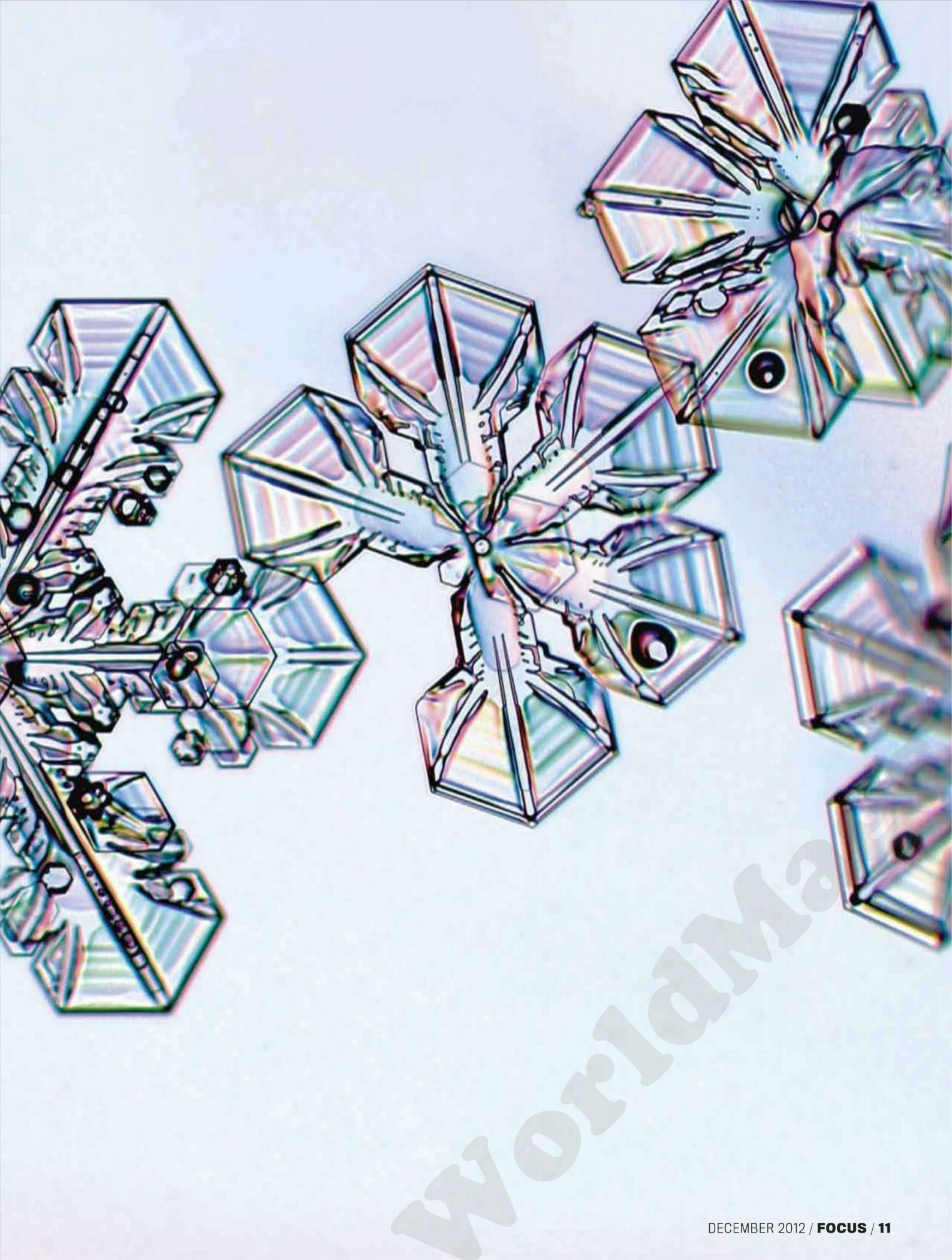
Libbrecht, whose day job is studying gravitational waves, says one of his main interests lies in understanding why different snowflake structures form at different temperatures. "I want to know why you get plates at –2°C, columns at –5°C, but then plates again at –15°C," he says.

By measuring ice growth rates at different temperatures and using computer modelling, Libbrecht is building a picture of how molecular processes translate into different crystal shapes.

The plate-type flakes pictured here are just 2mm across. Libbrecht captured them in northern Ontario when the temperature was close to –15°C.

PHOTO: KENNETH G LIBBRECHT





WorldMags



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Rock bands

THE STRIKING LINES running through the hills of the Zhangye Danxia Landform Geological Park in China look like they've been painted on. But this remarkable landscape tells the story of 20 million years' worth of geological activity.

"This area would have once been a lake," says Professor John Underhill, an expert in stratigraphy at the University of Edinburgh. "During colder, wetter climes the lake would have been full and iron would have been deposited into the sediment, creating the red banding. During hotter periods the lake would dry up and the iron would have been leached from the ground leaving behind the white bands."

You would normally only see this visual record of the country's fluctuating climate by drilling into the ground, but these beds have been lifted up and tilted by tectonic processes. More recently, rainfall and water drainage has sculpted the exposed landscape into the sharp peaks and valleys seen today.

PHOTO: REX



REPLY

Your opinions on science, technology and our last issue



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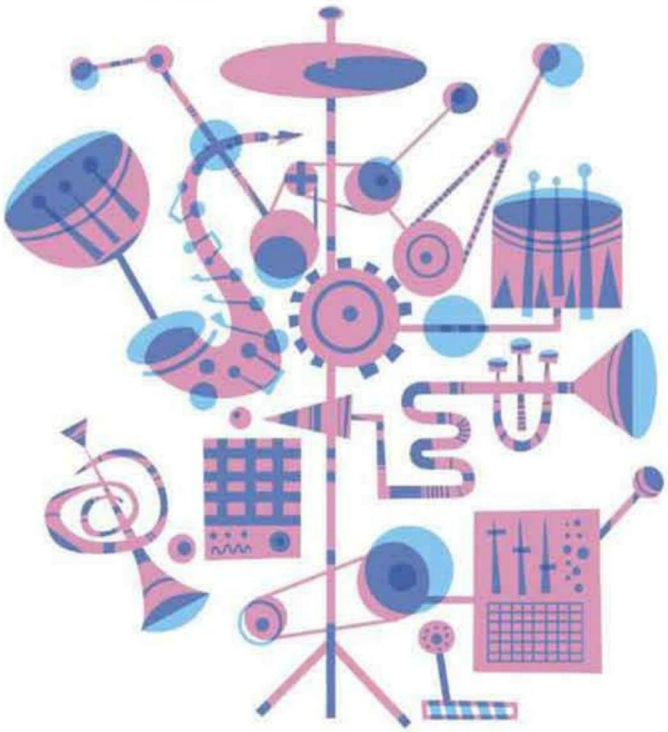
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Letters may be edited for publication

MESSAGE OF THE MONTH



Computer vs Beethoven

Speaking as a musician, I instantly found it hard to believe Stephen Baxter's declaration that computer software could write a piece of music apparently by Chopin or Beethoven (September, p26). Having listened to these experimental pieces it seems to me that they are 'predicted' by utilising a set of strict new rules and patterns applied to an original piece of music, rules which are so definitive that they would not have been laid down by the original composer. Scientifically, we must treat creativity as a complex physical process, but unless the exact workings of Beethoven's brain become miraculously clear to us then we have no hope of emulating the uniqueness that came with each new piece composed.

These experiments cannot avoid sounding like a simple mish-mash of previous works, a 'copycat' quality that is noticeably absent in real, ingenious Beethoven. The process exemplified here is a process of simple replication, not stylistic, digital innovation.

Chris Bond, London

Write in and win!



Chris wins a copy of *Can We Travel Through Time?* by Michael Brooks (Quercus, £8.99). Send us your views to win next month's prize.

Light speed ahead

I found Professor Close's article on the speed of light (November, p96) very interesting because the history of its measurement is one of the central arguments in the development of modern physics. However, one aspect of the story was not mentioned and that is the effect of gravity on the propagation of light. In the early part of the 20th Century, Eddington and others believed that gravity slowed down light. Many contemporary publications avoid mentioning the effect of gravity on the speed of light. There is also the Shapiro gravitational time delay, which is possibly due to the fact that the path of the light is curved and hence longer. Because of these ideas I'd like to know more on the history of the gravitational effect on light.

Ron Harrison, Loughton, Essex

Thanks Ron, we'll be taking a closer look at gravity in the New Year. - Ed

Unhackable apps

As identified by last month's edition (The Ultimate Spy, p55), one important feature of our national security is the General Communications Headquarters, which monitors and intercepts communications between criminals. These require extremely skilled technicians and programmers to break the latest codes and ensure our country's continued protection. In a BBC documentary, one such worker identified a key skill for this being developed by the time he was 10.

Currently some technology giants, such as Apple and Microsoft, are promoting the idea of closed, 'unhackable' applications which prevent people from experimenting with the systems. It is exactly this sort of experimenting that our defenders and scientists of the future need to hone their skills. Companies such as Google openly release code, and their flourishing Android operating system is a prime example of the power of open source technology. The Raspberry Pi is another great example of a device

ILLUSTRATION: LAUREN GENTRY

that enables people to experiment with technology. We need inventions and changes and hiccoughs in design and code to allow people to learn. These sorts of things cannot be exposed by closed-source applications.

Apple and Microsoft should beware that they are encouraging an increasingly 'hack-free' future and therefore a more dangerous and unpredictable one.
Harry Tanner, Hampshire

Secret scrambler

I believe that I saw an article on Alan Turing in *Focus* 2012. The article revealed that Turing had developed, for want of a better term, a secret voice scrambler that was portable. Technical details were revealed, such as the fact that he mixed the voice signal with random noise. He gave a number to each sampled point and then added another number to that by modulus arithmetic. If you ran that article could I get a copy of it?
Robert Lloyd

Our article on Alan Turing's legacy (July, p40) didn't mention this invention, but there is a fascinating document online about it. See www.turing.org.uk/sources/delilah.html

Early man sketched

I have drawn all three skulls featured in the September issue of *Focus* (The Secrets Of Human Evolution, p35). Drawing is something I fell in love with after being inspired by Prof Alice Roberts. She was kind enough to look at my sketchbook at the Cheltenham Science Festival and introduced me to some of her illustrators.
Hannah West



Hannah's sketch of the skull of *Australopithecus afarensis*

Winners

Congratulations to Shelley Mee (Kent), who won a 32-inch Sony TV in our recent online competition at sciencefocus.com

YOUR COMMENTS ON OUR FORUM

On www.sciencefocus.com/forum, we asked:
Are there lessons to be learned from Felix Baumgartner's skydive?

M Paul Lloyd Baumgartner went straight up and down and only reached some 1,200km/h – pretty fast but hardly the 27,000km/h he would have been travelling at had he descended all the way from space, with the subsequent friction heating causing him to burn up. If this sort of project is going to be anything more than a publicity stunt then they have to look at ways of taking it to the next level and design some sort of personal heat shield that will allow an astronaut to de-orbit safely.

Thinker I'm just worried what effect a heat-resistant uniform would have in an emergency situation. If a space shuttle/module comes into orbit ready for descent to Earth and something goes wrong, they have to get it back to Earth on their own. If there's a handy little Eject button there, would it not increase the chances of using it, even if the shuttle could be brought down somehow?

nemisis1960 As a heat shield was developed for the Shuttle, could the same technology be used for a space suit? As I remember they used ceramic tiles, but maybe a lighter but equally durable material could be manufactured?

Powerman So taking everything on board it ends up looking like one big publicity stunt. Disappointing, isn't it?

Shadowwolf I don't see why that diminishes the event. It costs money and they were willing to get behind it and risk their image. Sponsorship doesn't diminish an amazing feat like this, and we get all the data and questions that arise over it.

MikeG Given the amount of helium it took to make this attempt, and the increasing scarcity of this non-replenishable resource, these records are likely to stand.

FOCUS
SCIENCE AND TECHNOLOGY

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DISCOVERIES

News and views from the world of science

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BLAME IT ON THE OCEANS

Why a warm phase in the North Atlantic Ocean is the cause of our wet summers

GM FOODS DEBATE

Is it time we were more receptive to GM food's benefits?

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EXPANSION EXPLORED

Will the Spitzer Space Telescope shed new light on dark energy?

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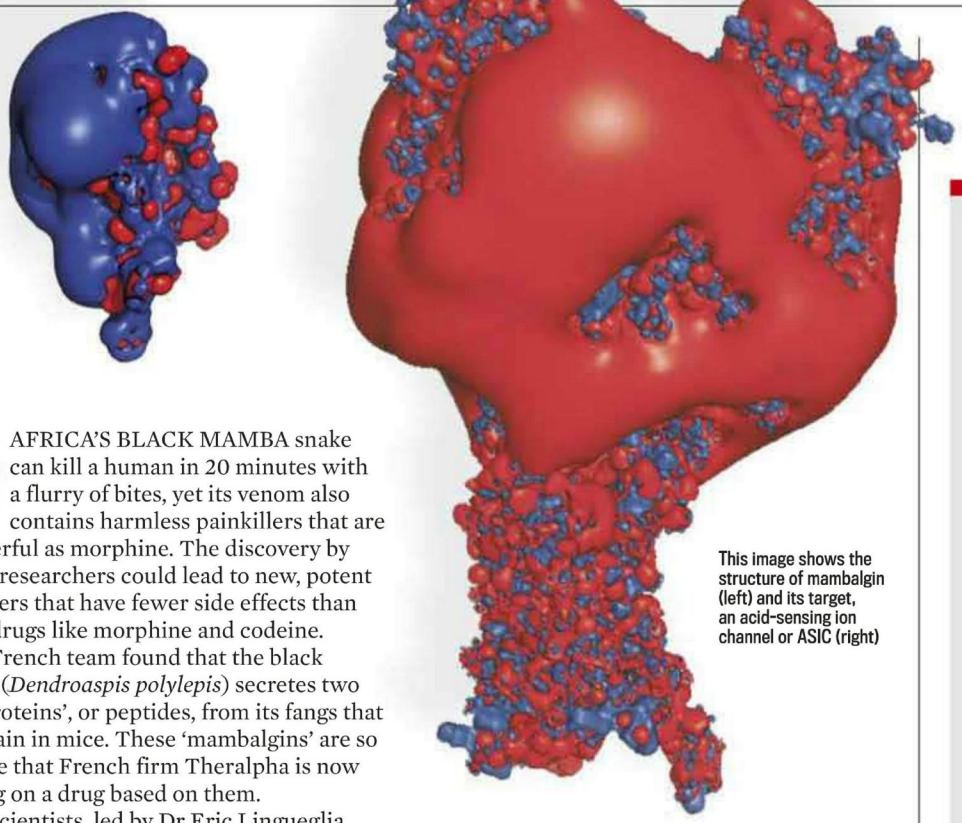
THE BIG STORY

Venom: the painkiller of the future

Snake's deadly fang cocktail could yield new drugs

The black mamba's fangs contain a deadly poison, but also a powerful analgesic

PHOTO: GETTY, NEODAA / UNIVERSITY OF DUNDEE



This image shows the structure of mambalgin (left) and its target, an acid-sensing ion channel or ASIC (right)

AFRICA'S BLACK MAMBA snake can kill a human in 20 minutes with a flurry of bites, yet its venom also contains harmless painkillers that are as powerful as morphine. The discovery by French researchers could lead to new, potent painkillers that have fewer side effects than opiate drugs like morphine and codeine.

The French team found that the black mamba (*Dendroaspis polylepis*) secretes two 'mini proteins', or peptides, from its fangs that block pain in mice. These 'mambalgins' are so effective that French firm Theralpha is now working on a drug based on them.

The scientists, led by Dr Eric Lingueglia at the Institute of Molecular and Cellular Pharmacology in Valbonne, were hunting for alternatives to opiate drugs. Patients can grow tolerant to them, requiring higher doses, and develop side effects such as nausea. Yet only a trickle of new drugs have been brought out over the past decade to treat pain.

"The interesting thing is that the potency of the mambalgins is similar to morphine, but the way they act is different," says Lingueglia. Morphine binds to molecules on the surface of nerve cells called opioid receptors, but mambalgins work on ion channels – key components of the nervous system that regulate the flow of ions across cell membranes.

Lingueglia's team screened more than 50 venoms from different species of animal, searching for molecules that target ion channels. Lingueglia found that mambalgins bind to and block specific acid-sensing ion channels (ASICs) involved with pain transmission. Mice injected with mambalgins could withstand painful, but harmless, hot water on their paws and tails twice as long as untreated animals.

Venoms work by combining the effects of a cocktail of molecules, so not all components are harmful. It's not clear why black mamba venom includes pain-killing mambalgins – Lingueglia says it may simply be a by-product of the fast evolution of the venom, or they may be useful. "They may, for instance, give time for other toxins and enzymes to do their job, by making the prey less worried."

The medical use of venom is a burgeoning field of research. Several hundred proteins have been purified from snake venoms and are being considered for treatments. The French team has worked out the building blocks – the amino acids – that make up the mambalgins, as well as the genes behind them. "Now we can produce the mambalgins using bacteria or chemistry," says Lingueglia.

EMMA DAVIES



ANALYSIS

Richard J Lewis

Associate Professor at the Institute for Molecular Bioscience at the University of Queensland, Australia

"PAIN IS OFTEN poorly treated because the mechanisms responsible for it inside the body and associated drug targets are poorly understood. Peptides in venoms have helped to define some recently identified drug targets, including ion channels in the spine which are targeted by omega-conotoxins in the venom of fish-hunting cone snails.

Acid-sensing ion channels (ASICs) are known to contribute to inflammatory pain – pain caused when immune cells enter an area. But the specific subtypes involved in conducting pain signals around the body were unclear. This discovery of a new ASIC blocker from black mamba venom helps us to understand the roles these subtypes play, and has revealed that different combinations of ASICs underlie the origin of pain.

The most immediate benefit of this research is that it has not only revealed a peptide that could potentially be used medically, but also new targets to relieve pain in a broader sense. What remains to be seen is to what extent ASIC channels contribute to different painful conditions, including neuropathic and cancer-related pain. It also needs to be investigated whether ASIC channels can synergise with existing analgesics for better pain relief."

TIMELINE
The painful story of venom research

1960s
Scientists identify molecules in Brazilian pit viper venom that can be used to treat high blood pressure. These form the basis of new drugs.

1986
Stanley Cohen and Rita Levi-Montalcini (right) win a Nobel Prize for identifying a protein called nerve growth factor from work on snake venom.



1989
A compound in Japanese pit viper venom is found to prevent blood clots forming. Now, similar compounds are used as research tools.

1999
A heart drug called tirofiban is approved. The drug is based on powerful anti-clotting agents derived from African saw-scaled viper venom.

2005
A drug called exenatide is approved for type II diabetes. It contains a version of a protein derived from the saliva of the Gila monster.



2012
Molecules in the venom of the black mamba that block pain are identified, providing an insight into the mechanics of pain in the body.

WHAT DO YOU THINK?
Let us know your thoughts at facebook.com/sciencefocus

PHOTO: NATURE, JEFF SERVOS, PRESS ASSOCIATION



A warm North Atlantic Ocean is to blame for the rainy summers the UK has been experiencing

Meteorology

Warm seas = wet summer

THE WASH-OUT summers the UK has had over the past few years can be blamed on a warming in the North Atlantic Ocean since the mid-1990s. But despite this discovery, meteorologists are unable to say when the wet summers are likely to end.

The North Atlantic alternates between relatively warm and cool phases that can each last for decades. The current warm phase was preceded by a cool phase from 1964-1993, which followed a warm phase from 1931-1960. Now, climate scientists at the University of Reading have found that warm North Atlantic phases are associated with milder, wetter summers across northern and central Europe and hotter, drier summers around the Mediterranean. A cool Atlantic makes for dry summers in northern Europe.

Changes in the temperature of the Atlantic are tied to shifts in the pattern of salt and freshwater, the winds and tides and also, possibly, man-made greenhouse gases. But the new research focused on the statistical link between ocean temperature and weather. Although the exact mechanism remains unclear, higher Atlantic surface temperatures warm the air above, shifting the jet stream – the fast-flowing air current high up in the atmosphere. This summer, the stream was further south than usual, allowing weather systems bearing rain to cross over the UK.

So when will the North Atlantic cool? "That's the million-dollar question," says Prof Rowan Sutton, lead author of the study. "It could happen in a couple of years, it could be a decade or more. We think it's potentially predictable, but we're not capable of making accurate predictions at the moment."

JAMES LLOYD

1 MINUTE EXPERT
Element 113

What is it?
It's one of the 'superheavy' elements, which do not occur naturally and can only be made in a particle accelerator or nuclear reactor. Most are highly unstable and decay after a fraction of a second.

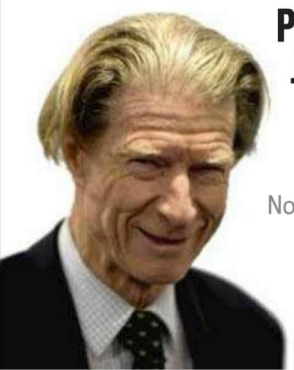
Why is it in the news?
A team at the RIKEN Nishina Centre for Accelerator-Based Science in Japan say they have proof of having made an atom of element 113, and are claiming the right to name it. Since 2003, the physicists have been bombarding the metal bismuth with zinc atoms in the hope of creating an atom with 113 protons and 165 neutrons. As well as the atom recently created, they thought they had made it twice before, the first time being in 2004.

So what happened?
The expert body that decides whether a new element has been officially created wasn't convinced. As 113 decays quickly, spotting it is a question of detecting the right decay products, and proof can be hard to come by.

What happens now?
The RIKEN team thinks it has a strong case, but it's down to the committee – a joint US and Russian team is also claiming naming rights.

EMMA DAVIES

WHO'S IN THE NEWS?



Professor Sir John Gurdon

University of Cambridge biologist and Nobel Prize winner

What did he say?
After learning he had been awarded the 2012 Nobel Prize for Physiology or Medicine for his research on stem cells, he revealed that he keeps one of his old Eton school reports over his desk. The report, which dates from 1949, says: "I believe he has ideas about becoming a scientist; on his present showing this is quite ridiculous."

So why did he keep it?
Gurdon told reporters: "When you have problems like an experiment that doesn't work, it's nice to remind yourself that perhaps you're not so good at this job after all."

What was his Nobel for?
In 1962, at Oxford, he showed that if the nuclei of cells from adult *Xenopus laevis* frogs were transplanted into eggs of that species that have had their nuclei removed, the eggs would still develop. This showed the DNA had not altered as the frog matured, suggesting that an adult cell could be converted back into an embryonic cell. These can transform into any other kind and so could re-grow damaged tissues – a prospect being investigated today.

PHOTO: PRESS ASSOCIATION, CORBIS



PHOTO: GETTY

HOT TOPIC

Should restrictions on GM food be loosened?

A COW HAS been genetically modified so it produces milk lacking a protein that lies behind some allergic reactions. Beta-lactoglobulin is present in cow's milk but not in human milk, and can cause diarrhoea and vomiting in some toddlers. But now it has been eliminated from the milk of a cow in New Zealand using a technique called RNA interference.

Back in 2006, scientists at AgResearch in New Zealand found that a short piece of genetic material called microRNA interferes with another genetic chunk, messenger RNA, which carries the instructions to create beta-lactoglobulin. So they added DNA that encodes the production of this protein-blocking microRNA into cow embryos. Out of roughly 100 embryos, one calf produced milk free of beta-lactoglobulin.

Ironically, the researchers are unable to taste the milk from their hypoallergenic cow – drinking it is prohibited under New Zealand law. In fact, almost no genetically modified animal has been approved for consumption by regulatory authorities around the world. Is is time for that to change?

WHAT DO YOU THINK?

Let us know your thoughts using the hashtag **#hottopic** at **twitter.com/sciencefocus**, and on **facebook.com/sciencefocus**

Your Tweets and Facebook posts

Jack Wickham: *It's all food, it makes no difference whether it's GM or not. The restrictions should be in the testing and production, not in who can eat what.*

Ben Davies: *I worry about the long term effects of messing with nature, could it bite us in the backside in years to come?*

Mark Thomas: *People should man up. GM food is needed if we're to feed the world in the future.*

Alex Mason: *Like everything, it's about choice: if you don't want to eat GM food, you don't have to. As for me, I think it's ridiculous to mistrust it.*

WHAT THE PAPERS SAY

HENRY GEE

The latest research from leading science journals



Insects have been thinkers for a long time

Next time you swat a wasp, spray plants for greenfly or treat your pets for fleas, consider that all these creatures are insects – the most successful, diverse and numerous of all animals, with bigger brains than they are often credited with.

Insects are members of a larger group, the arthropods, which also includes lobsters, barnacles, spiders, mites, scorpions and centipedes. All wear their skeletons on the outside and have rather sinister 'compound' eyes, behind which lie complex, calculating brains.

These brainy arthropods pose an intriguing question. Recent work has shown how insects evolved from fellow arthropods the crustaceans, in the same way that we land vertebrates evolved from fish. Today, the closest relatives of insects among crustaceans are water fleas such as the *Daphnia* that we feed to pet fish. But water fleas have simple eyes, connected to simpler brains than most insects. So does this mean that insects started off with small eyes and brains and had to evolve their more complex mental faculties?

Enter Dr Xiaoya Ma of the Natural History Museum in London and her colleagues. In research just published in *Nature* they have been looking at a Chinese fossil arthropod from the Cambrian Period (488-542 million years ago). The fossil, which looks like the nightmare you might have after eating live scampi and is blessed with the impossible name of *Fuxianhuia*, is so well preserved that you can see not only its stalked eyes, but also, preserved as a delicate film of iron mineral, its brain.

Now, the brains of modern insects are divided into three parts. The part at the front is connected to those large, pitiless compound eyes, the better to make sense of these creatures' visual world. The second is connected to the antennae – organs of smell and touch. In modern insects, the third section looks like a bit of an afterthought. But crucially, the brain of *Fuxianhuia* looks every bit as complex – as 'evolved' – as the brains of any extant crustacean or insect. In fact, this ancient creature had a brain that looks just like the brains in most modern insects and crustaceans.

So rather than insects once having simple brains, as *Daphnia*'s brains would appear to indicate, it seems that insects would have had their cerebral skills from the outset. This shows that *Daphnia*'s tiny brain in a whole new light – it's simply a specialism. After all, how much does a water-flea really have to think about?

All this means that insects have had their brains for a long time – far longer, in fact, than we *Homo sapiens* have been around to swat them.

Henry Gee is a palaeontologist and evolutionary biologist, and a senior editor of the journal *Nature*

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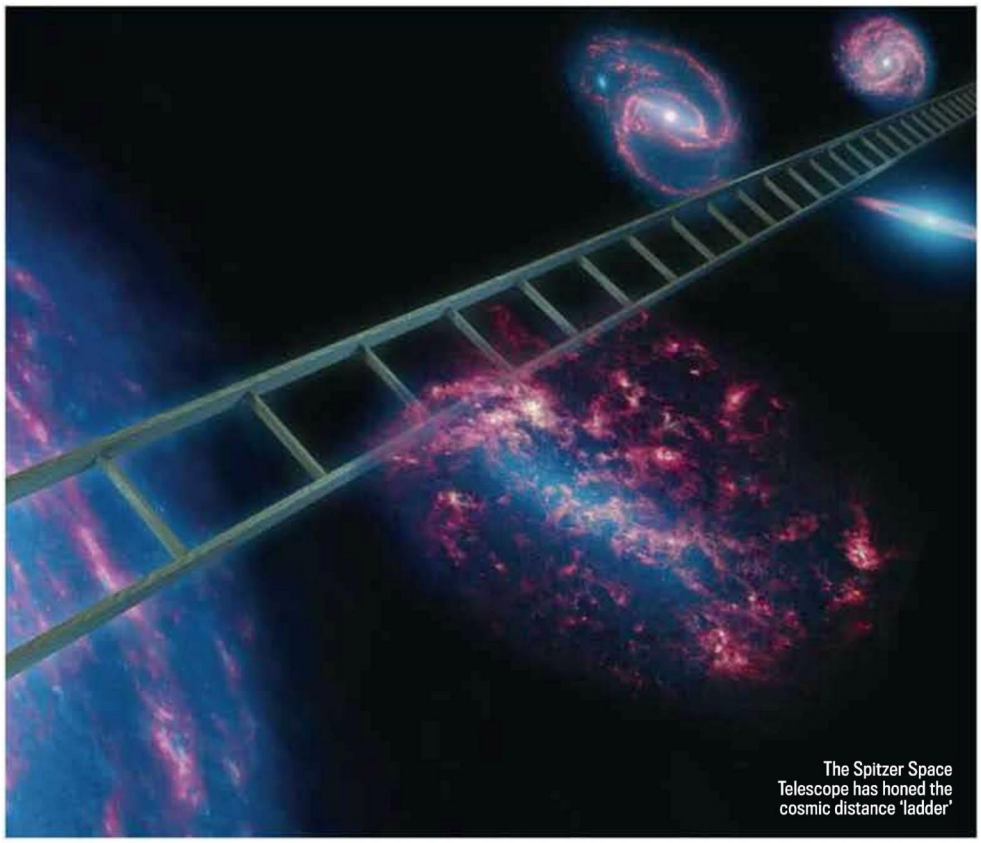


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The Spitzer Space Telescope has honed the cosmic distance 'ladder'

Physics

Universal expansion find provides dark energy clue

ASTRONOMERS HAVE MEASURED how quickly the Universe is stretching apart more accurately than ever before. The measurement, by NASA's Spitzer Space Telescope, provides an insight into the age of the Universe and the nature of the stuff that's causing it to expand – dark energy.

Distant galaxies move away from us faster than closer ones, and the 'Hubble constant' tells us exactly how much faster. Astronomers in the US have calculated it to be 74 kilometres per second per megaparsec, with a megaparsec being about three million lightyears. The figure allows researchers to calculate the age of the Universe by tracing the expansion back from the present day to the Big Bang.



Dr Wendy Freedman of the Carnegie Observatories in southern California

To come up with this new measurement, astronomers used Spitzer to observe unusual stars, known as cepheid variables, that brighten and dim like clockwork. The longer a cepheid takes to brighten and dim, the more naturally bright, or luminous, it is. And the bigger the difference between this intrinsic brightness and how bright it appears to us, the further away the star is. In effect, cepheids act as cosmic yardsticks, and observing the rate at which these objects move away from us shows the Universe's expansion rate.

"It's exciting that we were able to use Spitzer to tackle fundamental problems in cosmology: the precise rate at which the Universe is expanding at the current time as well as measuring the amount of dark energy in the Universe from another angle," says Dr Wendy Freedman at the Carnegie Observatories in California.

The Universe is expanding thanks to dark energy – a mysterious stuff which is yet to be identified. Knowing the expansion rate helps to narrow down what dark matter may be.

KELLY OAKES

PHOTO: NASA, TYLER KEILLOR, CARNEGIE OBSERVATORIES ILLUSTRATOR: ALAN WARDLE/ANYFORTY

DIGITAL WORLD

Science on the web

WHY STRING THEORY

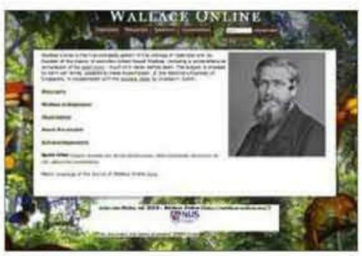
whystringtheory.com

The controversial theory that says everything in the Universe is made of tiny vibrating strings is not the easiest to get to grips with. Why String Theory will give you the story so far, together with the latest musings on whether the theory is right, or even testable.

WORKS OF ALFRED RUSSEL WALLACE

wallace-online.org

He may not be as famous as his contemporary Charles Darwin, but 19th century naturalist Alfred Russel Wallace's contribution to science was arguably as great. Now you can see for yourself, as his collected works – books, articles, manuscripts and illustrations – have been made available online.



Mathematician Samuel Hanson reveals the stories behind the numbers in Relatively Prime

RELATIVELY PRIME

relprime.com

This is a series of audio documentaries by American mathematician Samuel Hansen that tell the stories behind mathematics. One episode showcases useful mathematical tools you didn't learn about in school; others tackle artificial intelligence, music and more.

BEYOND THE VISIBLE

webbtelescope.org/webb_telescope/science_on_the_edge/beyond_the_visible

The James Webb Space Telescope will give us an unprecedented view of the cosmos in infrared light. Infrared can cut through dust clouds to reveal star nurseries, and tell us about the atmospheres of alien worlds. This video explains what the new super-scope will see.

KELLY OAKES

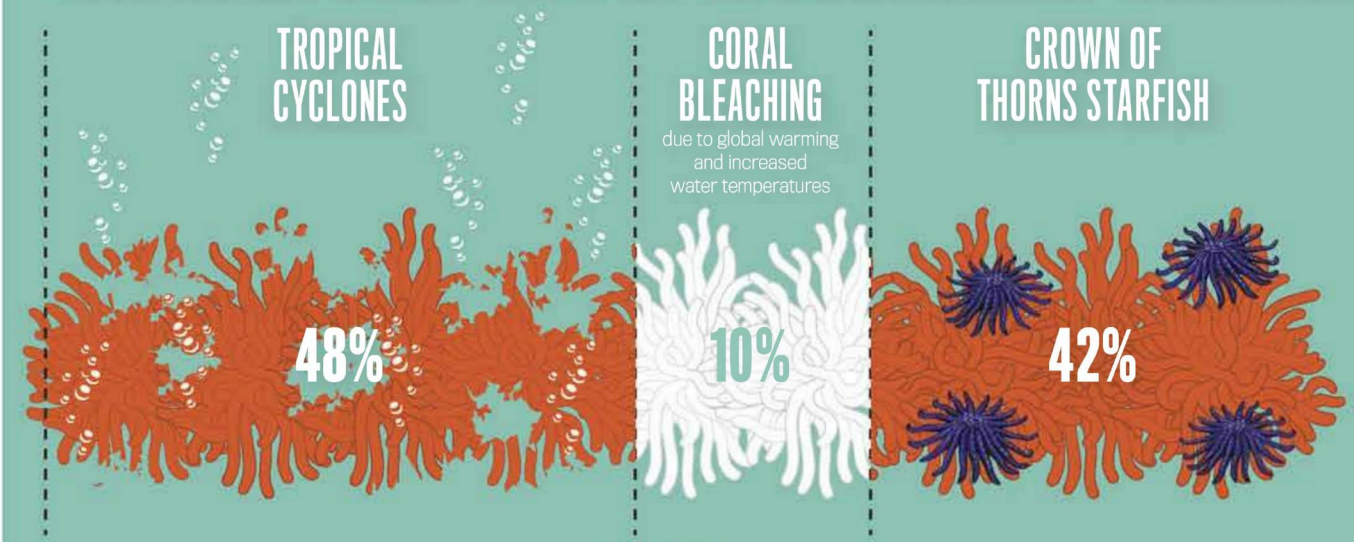
GRAPHIC SCIENCE

Seeing research differently

CORAL KILLERS ARE UNMASKED

After more than 2,700 days at sea, marine scientists have published the most comprehensive study to date of the health of a coral reef. Researchers from the Australian Institute of Marine Science and the University of Wollongong have spent the last 27 years examining the Great Barrier Reef and revealed the culprits behind its worrying rate of decline. Their investigation was partly carried out by manta-tow sampling, in which a diver is pulled behind a boat to perform a rapid visual survey. Data on cyclones, bleaching and starfish numbers were then crunched using statistical models to attribute losses to different causes.

THE MAIN CULPRITS OF BARRIER REEF DECLINE





OVERALL DECLINE IN GREAT BARRIER REEF CORAL COVER 1985-2012: 50.7 PER CENT

"We can't stop the storms, but perhaps we can stop the starfish. If we can, then the reef will have more opportunity to adapt to the challenges presented by rising sea temperatures and ocean acidification."
John Gunn, CEO of the Australian Institute of Marine Science

NEWS IN BRIEF

Vampire dinosaur found

A dwarf dinosaur with 'vampire' fangs that is thought to have lived in South Africa 200 million years ago has been identified. The fossil carrying *Pegomastax africanus* was found in the 1960s, but the specimen inside has only now been described in the journal *ZooKeys*. The beast was probably a plant-eater, so its sharp canines were most likely used for fighting.



Pegomastax africanus **stood no more than 60cm (2ft) tall and was vegetarian**

Asteroid hits Manchester

Tiny pieces of the Itokawa asteroid, returned to Earth by Japan's Hayabusa mission in 2010, have been sent to a team at the University of Manchester for analysis. The researchers are from one of 11 teams selected to receive particles from the Hayabusa sample, which is unique because, unlike a meteorite, it hasn't been exposed to Earth's atmosphere.

Men on the brain

Bearing a son can alter a woman's mind. Examining the autopsied brains of dozens of women, researchers at the Fred Hutchinson Cancer Research Center in Seattle found male DNA in 63 per cent of the brains, most likely transferred from a male foetus during pregnancy. The impact of this 'microchimerism' is currently unclear.

PATENTLY OBVIOUS

Inventions and discoveries that will change the world with James Lloyd



Virtual reality takes to the air

WELCOME ABOARD THE aircraft of the future. Can we offer you a virtual environment to go with that gin and tonic? How about a Hawaiian beach... or maybe a Martian sunset? Future air passengers may well do much of their flying in just such a tranquil setting, thanks to a new invention by aircraft manufacturer Airbus Operations in Germany.

The company has been granted a patent for a system that projects images and films onto the walls and ceilings of commercial aircraft. The technology combines individual pictures to create a continuous overall image, which is then displayed using a special projector to immerse passengers in a virtual environment. It also takes account of the cabin geometry, pre-distorting the images so that they appear undistorted to the viewer when cast over the frames of windows and overhead luggage holders.

The aim of the projection system is to give passengers the impression that the plane's interior space is more generously proportioned, with a seamless, spacious view. After all, a 24-hour flight can get a little claustrophobic after a while.

Patent application number: US 8277053

Hives hum with health

A BEE LOVER has developed a system that eavesdrops on hives and analyses the sound of their buzzing to monitor the colony's health. Dr Huw Evans in Newcastle analysed the audio signatures of colonies in different states and found that a humming frequency of 250Hz, for instance, indicates a swarm is imminent.

Once the hum is recorded and analysed, data can be fed back to the keeper on a tablet computer.

Patent application number: GB 2489435

Neanderthals learned from modern humans

SOPHISTICATED TOOLS AND ornaments were made by Neanderthals in France more than 40,000 years ago, a new study suggests – possibly revealing a cultural exchange with modern humans. Known as the Châtelperronian artefacts, the items were found among Neanderthal remains at Grotte du Renne, but other research suggested they could have been made by modern humans before sinking into the strata.

To settle the debate, a team led by Professor Jean-Jacques Hublin at Germany's Max Planck Institute for Evolutionary Anthropology performed radiocarbon dating on collagen from the finds. They were found to be between 41,000 and 44,500 years old and, since there was no evidence for major mixing between the layers of rock, they were likely to have been made by Neanderthals. The artefacts were produced after modern humans had arrived nearby, so Neanderthals may have learnt craft skills from us.

JAMES LLOYD



Neanderthals may have used knowledge from modern humans to make these tools

THEY DID WHAT? Hamsters 'duplicated' in a copier



What? At Bristol and Yale universities, psychologists showed 5- and 6-year-olds a scientific-looking machine that included two metal boxes wired with dials, and flashing lights. A hamster was placed in one box and after a brief delay, the second box buzzed. The lids of both boxes were then lifted, revealing an identical hamster in the second box.

What happened next? Before the 'duplication', the children were told the first rodent had a blue heart. They were also invited to whisper their name into its ear. Afterwards, they were asked if the 'copy' also knew their name and if it, too, had a blue heart.

What was the result? Two-thirds of children thought the first hamster's physical properties – such as its blue heart – had been replicated in the second, but that mental attributes were less likely to have been replicated.

Why was this done? The experiment explored children's views on identity. It seems 5- to 6-year-olds see the mind and body as two distinct things.

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Zoology

Froggy 'flick knives'

A FROG WITH a finger that can shoot out a combat-ready spike sounds like the stuff of comic books. But an amphibian that lives in the Amami islands of Japan has been found to carry such weaponry. Dr Noriko Iwai at the University of Tokyo was investigating the false fifth finger of the Otton frog, *Babina subaspera*, and found the spike is only deployed by the males – and not just for its original purpose of anchoring to a female. "The pseudo-thumb may have evolved for mating, but it is clear they're now used for combat," says Iwai. "The males demonstrated a jabbing response with the thumb when they were picked up, and the many scars on the male spines provided evidence of fighting."

Iwai says more research is needed to look at how the pseudo-thumb evolved.

Astronomy

Meet Earth's newest neighbour

FINDING PLANETS AROUND other stars has become fairly commonplace in astronomy. But when the star system involved is our Sun's nearest neighbour, Alpha Centauri, the discovery still causes a stir.



Alpha Centauri is only 4.3 light-years away and the planet found orbiting one of its three stars is nearly Earth-sized, with an estimated mass 1.13 times that of our planet. "This is the first planet with a mass similar to Earth found around a star like the Sun," says Dr Stephane Udry at Geneva university. "But it may well be just one planet in a system of several."

Other discoveries have shown that if a star is orbited by a small planet, it is likely to host others. So the Alpha Centauri system could easily have a planet within its habitable zone, the distance from a star at which water can exist on a planet's surface – often considered a prerequisite for life.

But finding such a planet would take years to confirm. It is unlikely the planet that's just been discovered will be occupied – it is so close its star, Alpha Centauri B, that its surface will be scorched.

Nonetheless, the discovery of an Earth-sized world orbiting Alpha Centauri B is an incredible feat in itself. Although the star is close to our Sun in astronomical terms, it's still 41.3 trillion km away. The world was detected because of the tiny wobble its gravity causes its star to make – movements of no more than 51cm per second. These shifts were detected by a telescope at the La Silla Observatory, Chile.

JAMES LLOYD

NEWS IN BRIEF

In the trees

Exactly when primates began to live in trees, as most do, has never been clear. But palaeontologists have now identified some ankle bones as belonging to *Purgatorius*, the earliest primate, which lived around 65 million years ago. They show that the animal's foot had a wide range of motion – indicative of a life lived in trees. The bones were found in fossil beds in Montana.

All-new Apollo science

Lunar samples brought back by the Apollo 11, 16 and 17 missions suggest the Sun is the source of water in lunar 'soil'. Lunar regolith contains tiny glassy grains called agglutinates which contain 200–300 parts per million water. Dr Yang Liu at the University of Tennessee found that the ratio of two hydrogen isotopes in the water closely matches that in solar wind.



Some 40 years on, lunar material from the Apollo missions is still revealing new secrets

DNA's expiry date

DNA has a half-life of 521 years, new research shows. In that time, half the bonds between the DNA's nucleotides will break down. Palaeontologists examined 158 bird bones, ranging in age from 600–8,000 years, to assess the rate of decay. They found that even in ideal conditions, every bond would be destroyed in 6.8 million years – which rules out cloning dinosaurs.

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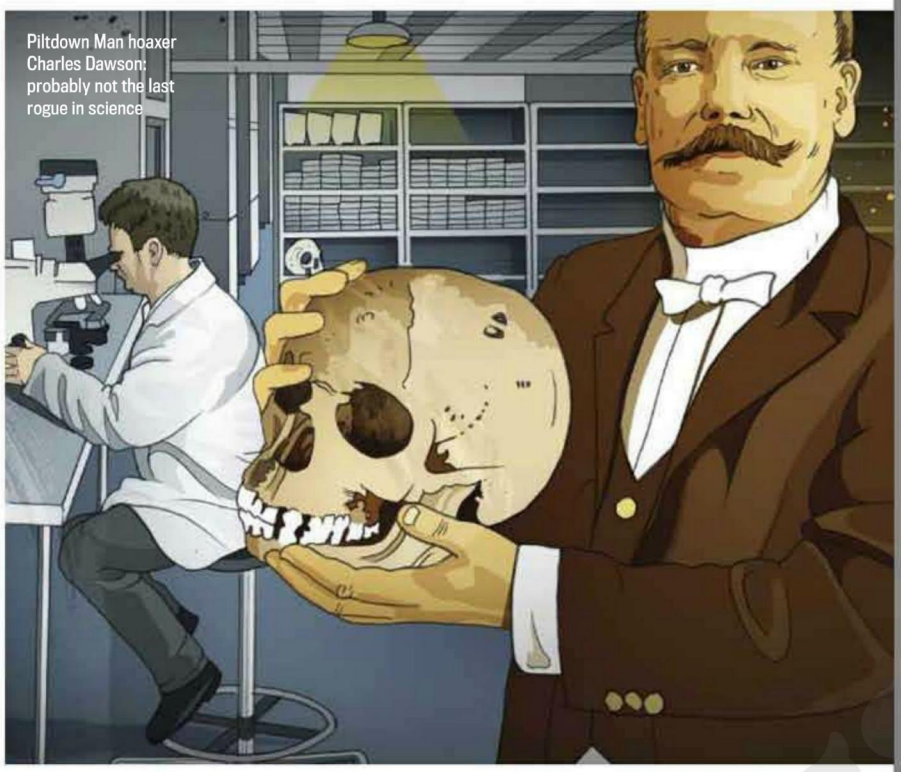
ROBERT MATTHEWS

SPECTACULAR BREAKTHROUGHS CAN expect a lot of scrutiny. But more ho-hum research is much more likely to be taken on trust. People in authority rarely respond well to being fooled. If they discover the perpetrators, they usually feel honour-bound to teach them a lesson. Which is ironic, as the key lesson usually lies in understanding why they were fooled in the first place.

Exactly a century on from the most famous scientific hoax of all time, just how much has the scientific establishment learned from the experience? For as former US president George W Bush famously tried but failed to put it: fool me once, shame on you; fool me twice, shame on me.

That notorious fooling took place on 18 December 1912, where a packed meeting of the Geological Society of London was told of an astounding discovery made in a gravel pit near Piltdown, East Sussex. A local solicitor and amateur archaeologist named Charles Dawson unveiled parts of the skull and jawbone of a previously unknown ancestor of modern humans. It was later named *Eoanthropus dawsoni* in Dawson's honour, but is better known as Piltdown Man.

Dawson claimed to have been given fragments of skull some years earlier by workmen at the pit. He persuaded Sir Arthur Smith Woodward, a leading expert on fossils, to accompany him on a search for more – which Dawson duly discovered along with half a lower jawbone. Sir Arthur, convinced that the fragments were a 'missing link' between humans and apes, set about putting them together to prove his point. Not everyone was convinced by the end result, but the authority of Sir Arthur and his followers won the day. Not until the early 1950s did it become clear that the Piltdown fragments consisted of the skull of a medieval human and the jawbone of an orangutan.



Piltdown Man hoaxer Charles Dawson: probably not the last rogue in science

"A century on from the most famous scientific hoax of all time, just how much has the scientific establishment learned from the experience?"

By the time the scandal broke, Dawson – who has long been regarded as the culprit – was dead, and so unavailable for being taught a lesson. Was he just a fraudster determined to make a name for himself by fooling the great names in the field? Or was he, as some have suggested, trying to teach the scientific community a lesson about the dangers of getting the facts to conform to beliefs? Research by Dr Miles Russell of Bournemouth University has revealed dozens of other fakes in Dawson's collection of 'discoveries', which suggests he was a career fraudster rather than a scientific cynic.

Either way, the scientific community tends to treat the whole episode as something that happened a long time ago, and which could not happen today. But the continuing exposure of scientific fraud suggests otherwise: last year a Dutch psychologist was found to have published at least 30 peer-reviewed papers based on imaginary data.

More worrying is the fact that some of these dodgy claims are in the scientific literature for years before someone smells a rat. That gives the lie to the idea that the scientific process itself, with its demand for replication, is up to the task of stopping latter-day Dawsons. Part of the reason it fails is because of the fragmentation of modern science. As it has soared into ever more rarefied research, ever fewer people are qualified – or have the time – to replicate new claims.

All of which highlights an awkward truth about modern science. As it gets ever more complex and esoteric, progress becomes ever more reliant on that hopelessly unscientific notion of trust. Scientists have no choice but to rely on other researchers to be honest. Not just honest about their work, but also about resisting the temptation to make the facts fit their beliefs. That is the true significance of what Dawson revealed to the scientific establishment that evening a century ago. ■

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

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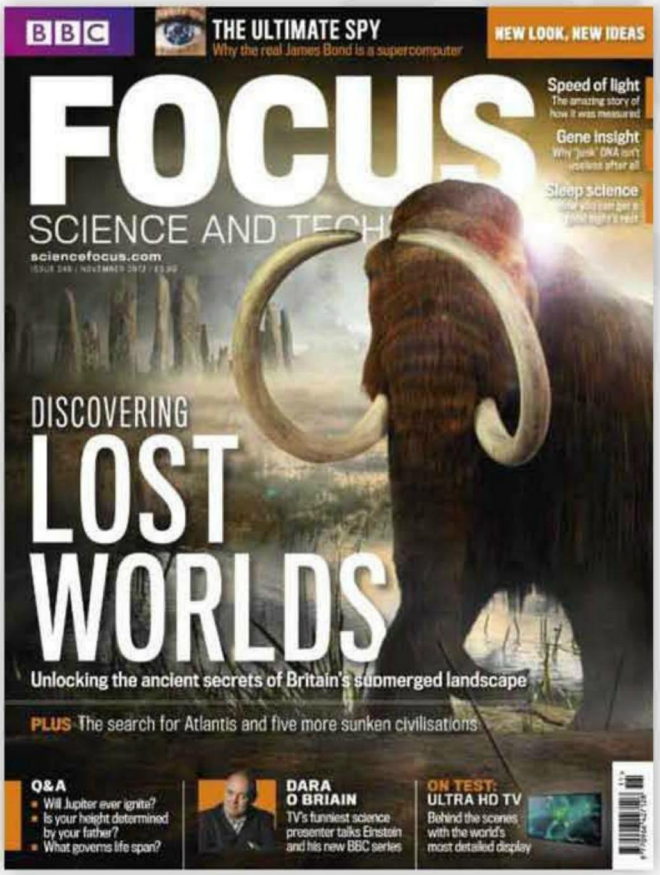
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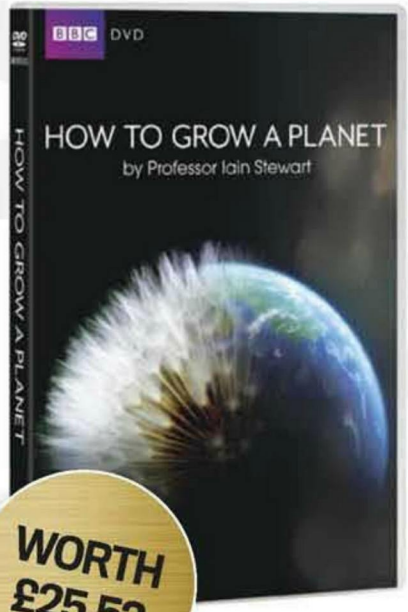
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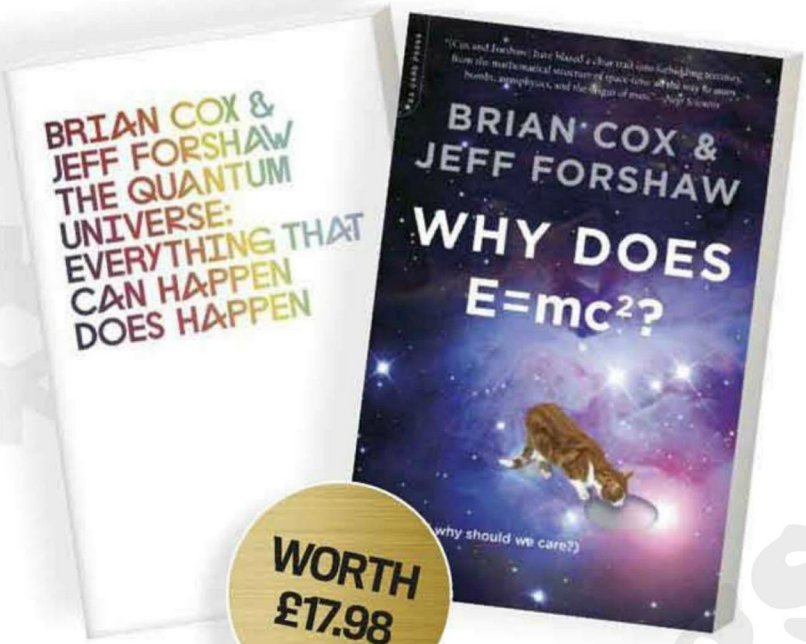


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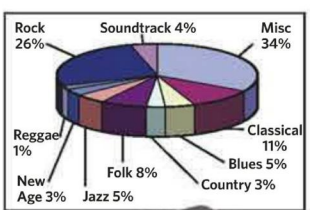
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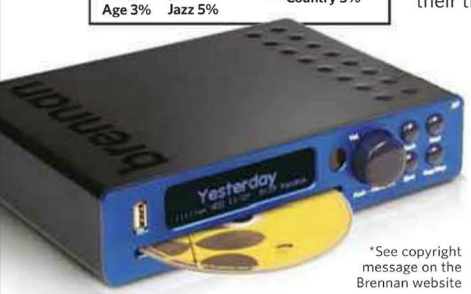
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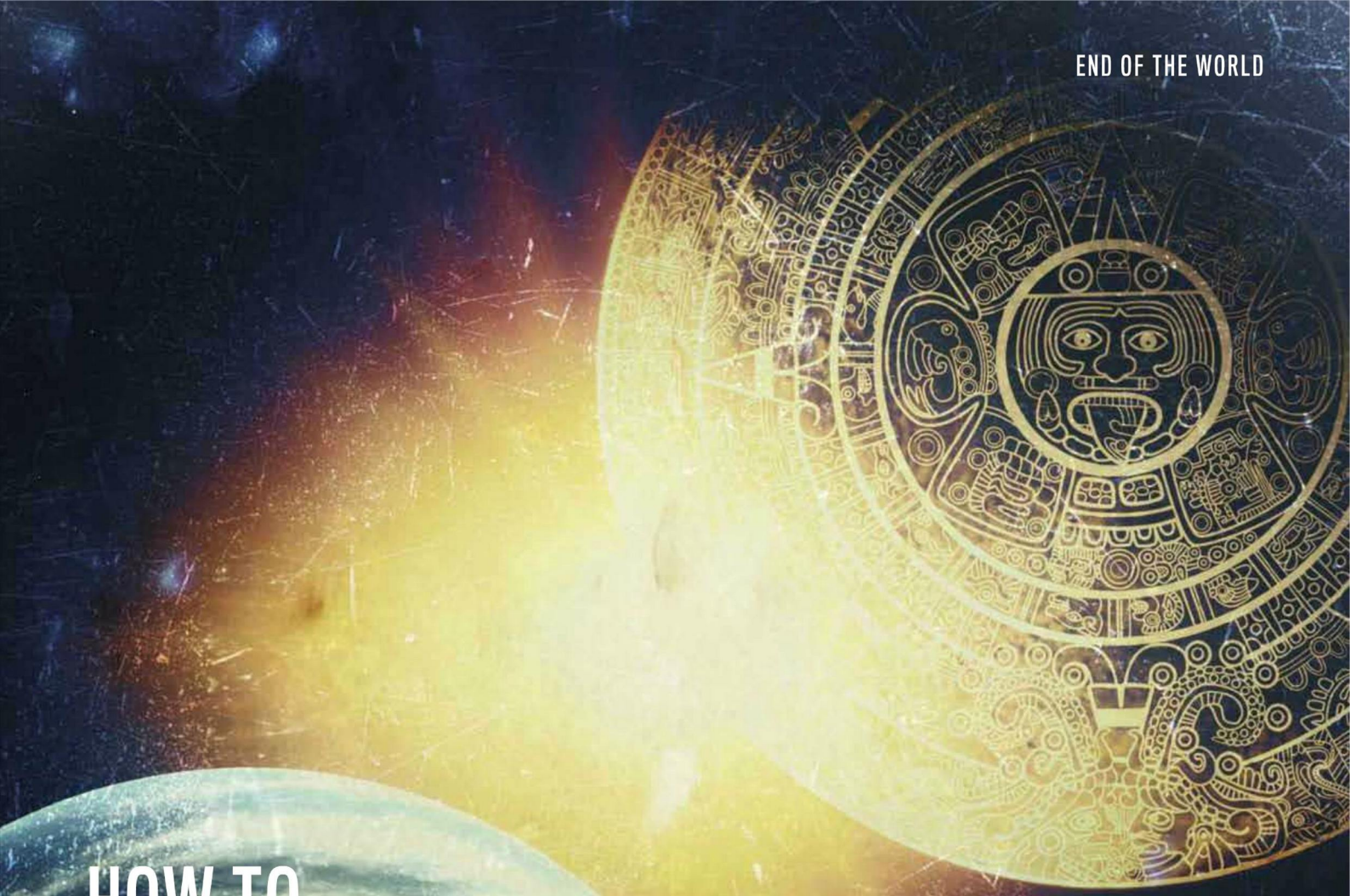
The face behind the Brennan JB7

Martin Brennan has worked with Sir Clive Sinclair and Lord Alan Sugar and has designed over 20 silicon chips in his career. Ever since CDs were invented Martin longed for a CD player that would hold his entire disorganised CD collection.

He wanted something as simple to use as a light switch but at the same time something that would let him find a particular track without leaving his armchair.

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HOW TO SURVIVE...

THE END OF THE WORLD

The Maya apocalypse of 21 December 2012 may be just a myth, but a global catastrophe really could happen this month. **Alok Jha** prepares for the end of mankind

SOME BELIEVE AN apocalypse is on its way. Rather unfortunately, the next time we're due a good old smiting is 21 December, which is when the ancient Maya's cyclical calendar runs out. Of course, if you really think a series of devastating natural disasters will occur in the run-up to Christmas, you probably haven't been reading *Focus* for very long. Both scientists and scholars of the Maya have debunked the theory, and the explanation is mundane. Our own calendar ends on 31 December every year, but it doesn't mean the world will blow up at midnight.

But don't breathe a sigh of relief just yet, as there's still a chance that the world really will end this month. From nuclear war to killer viruses, we reveal the ways in which the human race could be wiped out. We've stated the scientific probabilities and, for a bit of fun, asked bookmakers William Hill for their odds. Perhaps not surprisingly, anyone betting on one of these scenarios won't enjoy odds of millions to one. We only hope they survive to collect their winnings. Read on to discover the most likely catastrophes.

PHOTO: THINKSTOCK MANIPULATION: CHRIS STOCKER.CO.UK

ASTEROID IMPACT

A massive strike would result in dust clouds and world-shaking tremors

Odds of human extinction: 50-1*

*All 'Odds of human extinction' are provided by bookmakers William Hill, based on the likelihood of an event causing the end of mankind by 2050

EXTINCTION SCENARIO

A GIANT SPACE rock hurtles toward us, turning into a fireball before slamming into our planet's surface. Every animal, plant or building within a few hundred kilometres is vaporised by thousands of degrees of intense heat generated on impact. Earthquakes, storms and tsunamis then batter areas further away.

The worst, though, is yet to come: the enormous impact – not to mention the fires it creates worldwide – will throw so many particles into the air that the dust will block out the Sun. Kiss goodbye to growing food for at least a decade. This has happened many times throughout Earth's history, most famously 65.5 million years ago, when an asteroid over 10km wide hit Chicxulub in Mexico, an event that killed the dinosaurs.

Anywhere within a few thousand kilometres of the impact site would suffer from the resulting shock waves, debris and devastating earthquakes. Outside this 'kill zone', you might be protected from the immediate effects. "Shelter will help people survive an impact, although nothing will help if you are too close," says planetary scientist Dr Matt Genge of Imperial College London. "The problem, however, is that the exact location of collision is unlikely to be known accurately until a few days or hours before impact."

So you'll be glad to hear that NASA has been watching out for huge, potentially world-ending space rocks for some time now. "These large objects would be capable of causing global problems if they should hit, but none have been found to pose a serious future threat," says NASA astronomer Dr Don Yeomans, author of *Near-Earth Objects: Finding Them Before They Find Us*. To date, NASA has identified 94 per cent of all nearby objects more than 1km wide, and almost 40 per cent of those over 140m have also been discovered.

SURVIVAL STRATEGY

COULD WE DO anything about a giant asteroid on a collision course with Earth? Dr Yeomans is hopeful. One solution is to ram it with a high-velocity spacecraft well in advance, which could change the asteroid's speed and trajectory by a small – but large enough – amount. "So that when it was predicted to strike the Earth in 10 or 20 years' time, the asteroid's altered orbital position would allow it to miss the Earth by a wide margin."

If there was an asteroid on its way now, your best bet is to watch your Twitter feeds and check websites for the latest information on where the space rock will strike. You'll then be in with a chance of catching a plane to the other side of the planet. Otherwise, find yourself a cave or nuclear bunker to hide in and hope for the best. And make sure you take food supplies to last until the dust clouds clear.

Given NASA's tracking of near-Earth objects and other astronomical surveys, the chances of dying in a humanity-ending asteroid impact are very low – around one in 4.3 million. For comparison, your chance of dying in an aeroplane accident are around one in 30,000; falling foul of a fatal road accident is around one in 90. Nonetheless, mankind might have to bat away a giant space rocks one day: an asteroid the size of the one that wiped out the dinosaurs hits Earth fairly regularly, every 100 million years.

But assuming that we're still around when a giant space rock next slams into the Earth, take heart from the fact that it wouldn't take many of us to repopulate the planet. "A human population could recover even if it were cut to only a couple of hundred individuals," says Dr John Hawks, an anthropologist at the University of Wisconsin-Madison. "I expect we would have a very good chance of recovering – even from a population of a dozen."

"The exact location of collision is unlikely to be known accurately until a few hours before impact"

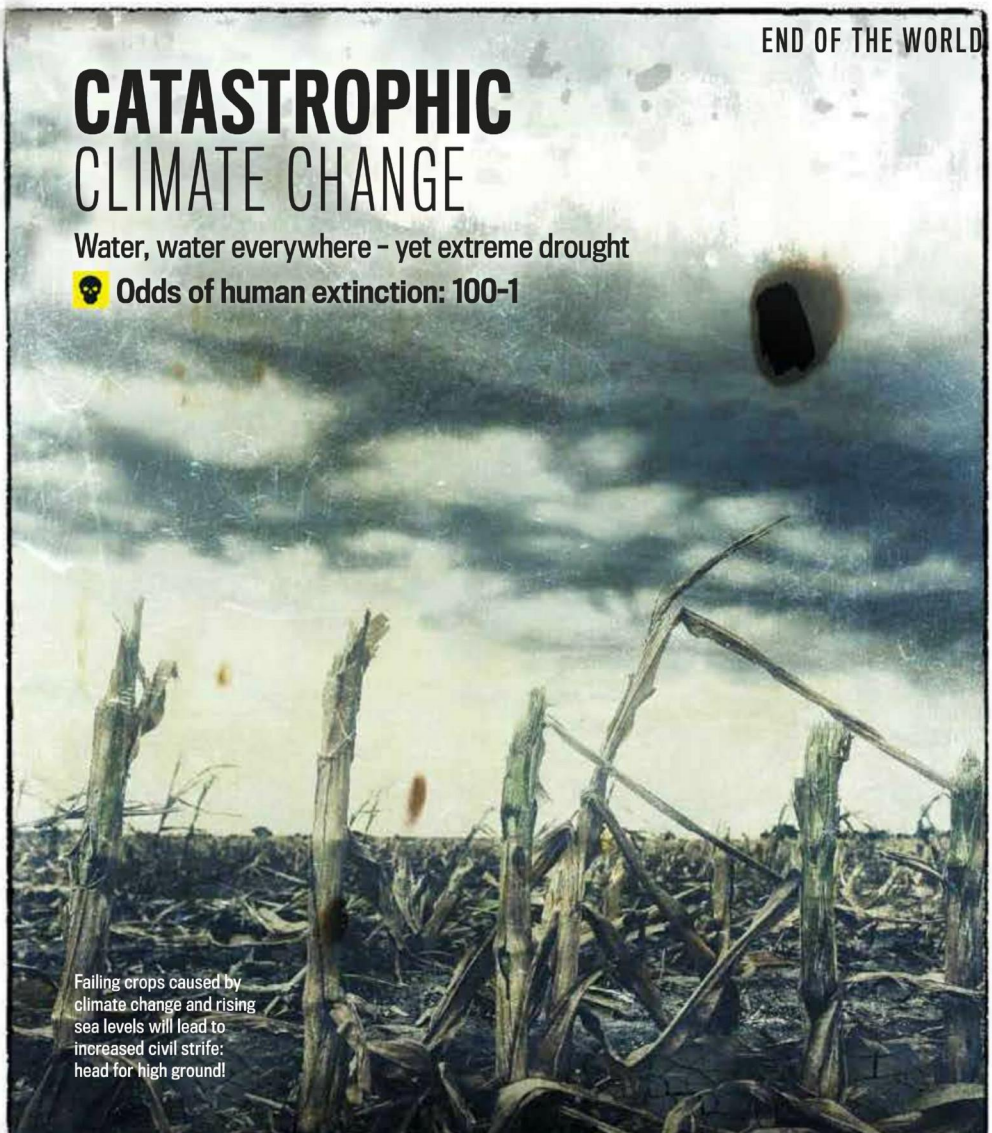
Dr Matt Genge, planetary scientist at Imperial College London.

PHOTO: THINKSTOCK, GETTY MANIPULATION: CHRIS-STOCKER.CO.UK

CATASTROPHIC CLIMATE CHANGE

Water, water everywhere – yet extreme drought

Odds of human extinction: 100-1



Failing crops caused by climate change and rising sea levels will lead to increased civil strife: head for high ground!

EXTINCTION SCENARIO

THE INTENSITY AND devastation caused by recent extreme weather – floods, winds and droughts – seem to be happening more regularly and coincide with global warming. Predictions from climate scientists suggest that, by the end of this century, temperatures could on average rise by several degrees. In future, the general trend will be that dry areas become drier, and wet areas wetter.

In the worst case scenario, the complete melting of the polar ice caps would lead to a global rise in sea level of over 70m. "In the most extreme case, all coastal communities would be deep underwater," says geohazards expert Professor Bill McGuire of University College London. South and south-east England would become an archipelago of small islands, while countries such as Bangladesh and the Netherlands would be lost beneath the waves.

Dry areas far from the coastlines, meanwhile, would get even drier: the south-western USA is already entering a permanent state of drought, while the Gobi desert in China is expanding by more than 3,000km^2 per year.

SURVIVAL STRATEGY

ENVIRONMENTAL CHANGES EXTINGUISHING the entire human population is unlikely, but maintaining civilisation as we know it would be very difficult. Severe climate change would create a mad scramble for land and resources. War, civil strife and mass migration would be widespread. It might be a good idea to preemptively buy yourself a plot of land away from cities and the coast. Oh, and try to build your home on high land, to avoid flooding from nearby rivers.

The last time the world experienced extreme warming – 6°C more than today, during the 'Palaeocene–Eocene thermal maximum' 55 million years ago – living things underwent significant changes in lifestyle. "Crocodiles swam in Arctic waters and there were palm trees in parts of Siberia," says McGuire, who describes environmental catastrophe in his book *Waking The Giant*.

To survive a world of extremes, we would have to adapt quickly. "Climate change, resource depletion and land degradation may bring big problems as soon as 2030," says McGuire. "By this date we will need 50 per cent more food and energy to sustain the forecast global population."



Check Twitter and the web to see where an asteroid is likely to strike so you can get out of the 'kill zone' in good time



GLOBAL PANDEMIC

A deadly disease that could infect us all

Odds of human extinction: 16-1

EXTINCTION SCENARIO

OUR CONNECTED WORLD has made it easy to travel to distant locations – but it's also made it easier than ever to spread disease. In 2009, a strain of the H1N1 influenza virus emerged in Mexico and, thanks to air travel, spread across the world in a matter of days. The World Health Organisation (WHO) declared it a pandemic, and for several months the world was on edge at the prospect of large-scale deaths from a bug for which no-one had yet created a cure.

In the end, although H1N1 swine flu did kill thousands of people, it didn't turn out to be 'the big one' – the deadly disease that would worry an epidemiologist, a modern version of something like the 1918 Spanish flu. Within six months, this influenza pandemic had killed around 50 million people, most aged 20 to 45. And that was when travelling between countries took days or weeks – imagine a virulent strain spreading across the globe in the hours it takes to fly from Beijing to London.

A pandemic could start anywhere, but according to Professor Richard Coker of the London School of Hygiene and Tropical Medicine (LSHTM), some places are more likely than others. "A large fraction of the world lives in East or South East Asia," says Coker, who studies emerging infectious diseases and is based at the National University of Singapore. "Due to farming and market practices in these countries, there tends to be slightly higher levels of contact with domestic animals, such as poultry and pigs. Most experts think that this is the most likely region."

SURVIVAL STRATEGY

WHEN PUBLIC HEALTH officials declare a pandemic, quarantine is often a useful way to stem the spread of the disease. But this wouldn't be effective if people are able to transmit the disease before they show signs of illness. With SARS (severe acute respiratory syndrome) for example, transmission mainly occurs from very sick people who can be identified and quarantined to stop infection.

At the other extreme is HIV, where untreated people can be infectious for a decade before they become ill. "It's likely that a pandemic will originate from a pathogen that's transmitted via the respiratory route, through droplets," predicts Professor John Edmunds, head of infectious disease epidemiology at LSHTM. "But as HIV has shown, 'slower' pandemics may be transmitted through other routes."

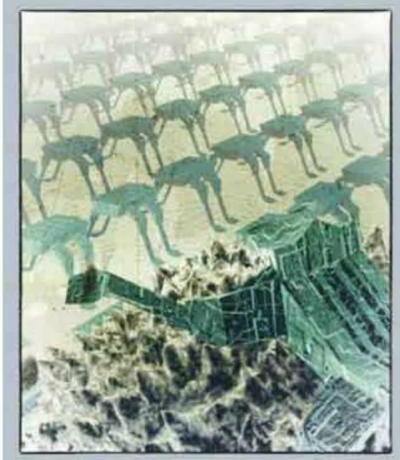
Hiding could help you escape infection, but not for long. Remote islands might sound like a sensible place to sit out a pandemic, but even these are well connected nowadays: the H1N1 swine flu virus was first identified in April 2009, and the first cases were reported on the Falkland Islands just three months later.

The risk of another pandemic is almost certainly close to 100 per cent. But whether it will be a nasty disease such as SARS, or relatively mild like H1N1 flu, is difficult to predict. Authorities such as WHO have action plans for when they sniff the start of an outbreak – the challenge is how much money they can invest in studying the potential spread and treatments of the many different diseases.

PHOTO: CORBIS, SCIENCE PHOTO LIBRARY X2, GETTY MANIPULATION: CHRIS STOCKER.CO.UK



FUTURE THREATS



Prepare to be assimilated into grey goo

GREY GOO

In his 1986 book *Engines Of Creation*, nanotechnologist K Eric Drexler suggested that an army of self-replicating nanobots might destroy the world. Tough, omnivorous robotic 'bacteria' could, for example, out-compete real microbes and spread like blowing pollen, replicate swiftly, and reduce the biosphere to dust in a matter of days. Given that we still struggle to control living organisms, if we aren't prepared, then these tiny, dangerous and rapidly spreading replicators could be hard to stop. The result would be a featureless world of 'grey goo' within days.

But how likely is this scenario? Drexler himself has played down fears in subsequent years, and a report by the Royal Society dismissed grey goo as unlikely. A study by molecular engineering firm Zyvex Technologies found that replicating nanoscopic devices of the type in a grey goo scenario would produce so much heat that they'd become easily detectable – and stoppable.

ROBOT UPRISING

Modern machines may seem mundane compared to the super-smart robots that retro science-fiction stories led us to expect would exist by now, but that won't be the case forever. And technical challenges aside, there's no reason to believe that artificial intelligences won't match or surpass humans soon enough. Experts believe that, later this century, robots with our mental power will appear that will be able to copy themselves into millions or even billions of descendants. Would this robot army help us meet global problems such as climate change or disease? Would it decide that people are a waste of space and resources? Doomsday could be triggered by accident. Perhaps the first super-smart AI will be given a benign challenge, such as a maths puzzle, but then go gung-ho in its attempt to solve the problem by incorporating the entire planet – including us – into a global calculating device.



Red eyes aren't normally a good sign when it comes to robot armies



Aliens may simply decide to level the place; how nice of them

ALIEN INVASION

Contact with extraterrestrials would be one of the greatest moments in the history of humanity. But would aliens be benevolent? They might be wise and want to share information with us, or they might see Earth as no more than a filling station – mining our resources on their way to some galactic destination. Or they might ignore us, but accidentally leave behind a virus or toxic waste that kills all life on Earth. Those worried about alien contact include physicist Stephen Hawking, who thinks the outcome of a visit might be the same as when Columbus landed in America, which Hawking notes "didn't turn out well for the Native Americans".

You won't have to run for cover just yet. Astronomer Frank Drake, the father of the Search for Extra-Terrestrial Intelligence (SETI), reckoned that thanks to increasing computing power, detecting the first signal from a distant source might only be 30 years away.

THE DEATH STAR

How the end of the Sun will eventually destroy our planet



5 BILLION YEARS

In 5 billion years the Sun will run out of hydrogen fuel, expand to dozens of times its present diameter and turn into a red giant (pictured). Our planet will orbit at the edge of this giant star and any life would have to eke out an existence on a world whose atmosphere and oceans have since boiled away, and where radiation bakes the surface.



6 BILLION YEARS

The situation will get worse as the Sun starts to die. Although it doesn't have enough mass to explode as a supernova, our star will still explode, ejecting its outer layers to form a planetary nebula, leaving behind a white dwarf (pictured). Blazing at a temperature of 10,000K, the Sun will be the size of Earth and yet contain half of its present mass – a teaspoon of it would weigh a tonne on Earth.



7 BILLION YEARS

The light from the Sun will become 100 times brighter on Earth than it is today, and the white dwarf will appear as a pin-prick in the sky. Its intense radiation would tear apart any molecular bonds on Earth. Even rocks would disintegrate into clouds of free atoms. Eventually, the white dwarf will lose its remaining energy and turn into a lump of stellar ash: a brown dwarf (pictured).

PHOTO: SCIENCE PHOTO LIBRARY X3, BARCROFT MEDIA MANIPULATION: CHRIS-STOCKER.CO.UK



After nuclear war, you may find yourself trying to survive somewhere like the irradiated Ukrainian town of Pripyat, abandoned after the Chernobyl disaster

NUCLEAR ARMAGEDDON

Mutually assured destruction from atomic bombs

Odds of human extinction: 20-1

EXTINCTION SCENARIO

IF YOU FIND yourself about to face a nuclear explosion, with the harmful radiation travelling towards you at the speed of light and shock waves a few minutes behind, running away would be pointless. "You cannot outrun an atomic blast," says Professor Geraldine Thomas, a molecular pathologist at Imperial College London. "So accept your fate if you're within about 500m."

If the world's thousands of nuclear bombs were all detonated at once, the millions of people within a few miles would die instantly from the heat of the blasts. Around the world, billions more would be killed as the surface of the planet becomes a cold, dark and dry place. Plants would die due to lack of sunlight, which would be blocked by the smoke from fires caused by nuclear explosions. The effects could last a decade or more, as the soot particles circulate high in the atmosphere.

With the Cold War over and mutually assured destruction less likely, it's easy to expect that the worst predictions of nuclear destruction are fiction. But computer models of a regional conflict between India and Pakistan, for example, show that detonating their nuclear weapons could release enough smoke to devastate global agriculture for years, leading to widespread loss of life outside those two countries. According to atmospheric scientist Richard Turco, detonating between 50 and 100 bombs – just 0.03 per cent of the world's current nuclear arsenal – would throw enough soot into the atmosphere to create climatic anomalies unprecedented in human history.

SURVIVAL STRATEGY

IF YOU DO survive the initial blasts, move away from the explosion site and reduce radiation exposure by not drinking contaminated water. Radiation is only dangerous in high doses and when it comes into contact with our cells.

Humans are already adapted to low-dose radiation exposure, which we get through food, rocks in the ground and cosmic radiation. And, as Thomas points out, there's no evidence to suggest that future babies born to bomb survivors would be unduly affected: "Tales of mutant species following radiation exposure have been widely exaggerated." ■

ALOK JHA is a presenter on the BBC Two programme *Dara O Briain's Science Club* and author of *The Doomsday Handbook*

Find out more

If you're interested in the Maya and the apocalypse, pick up *BBC History Magazine*'s Christmas issue, on sale 4 December

Radio 4's *Infinite Monkey Cage* on global disasters: www.bbc.co.uk/programmes/b00vxygx



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Christmas gifts for science and tech lovers



FOR BOOKWORMS

1 More Than Human

This portrait of the animal kingdom is a feast for the eyes. Every page will stop you in your tracks, whether it's a close-up of a spider's spinneret or a portrait of a pensive panda. It might be light on science but it more than makes up for this with the quality of the images. Wildlife lovers will go ape for this one... it's the cat's pyjamas!

£40, Abrams

2 Universe: The Definitive Visual Guide

Summing up the entire Universe in one (very hefty) book is no mean feat, but it's one that the editor, Astronomer Royal Martin Rees, has pulled off. Incredible images jump off the page, articles are accessibly written and lively graphics help explain denser topics. A great introduction to cosmology.

£30, Dorling Kindersley

3 The Where, The Why And The How

To prove that science can be beautiful, this book pairs researchers with artists to explain broad topics in science, ranging from how stars are born to how squirrels remember where they bury their nuts. While the scientists explain these mysteries, the artists try their hand at visualising the subjects. We just feel sorry for the artist who was given the job of illustrating dark energy...

£15.99, Chronicle Books



FOR AMATEUR PHOTOGRAPHERS

1 Samsung Galaxy

This 16-megapixel compact camera is crammed with smart features. It's loaded with the Android smartphone operating system and so has access to all of its apps. This means there's heaps of photo editing software available, so you can crop, apply effects and edit images on the go. It also comes with a 3G connection so you can upload your images directly to Facebook or Flickr wherever you are.

£399, samsung.co.uk

2 Pentax K-01

This year has been all about compact system cameras: small snappers with interchangeable lenses that let you take DSLR-quality pictures. In our summer test, this blocky shooter won us over with its unique styling, phenomenal photo quality and ease of use. It's a little on the bloated side, but Pentax offers some wafer-thin lenses to make up for it.

£432.99, pentax.com

3 Autographer

Take your pictures in a whole new way. This wearable 5-megapixel camera with a wide-angle lens uses a clever algorithm to decide when to take pictures, and snaps away while you enjoy your holiday. Each time it takes a photo, it attaches metadata including your GPS location, the temperature, light levels and more.

£299, autographer.com



FOR MUSIC LOVERS

1 Parrot Ziks

These are the most high-tech headphones money can buy. There's Bluetooth connectivity, noise-cancellation and a built-in microphone. The right earcan houses a touch panel that changes the volume and track, and they also come with a smartphone app that lets you simulate the sound coming at you from different directions. They sound great, too.

£349, parrot.com

2 Pure Sensia 200D connect

Is this the ultimate radio experience? Podcasts, web radio, DAB and FM are all accessible through the Sensia's touchscreen interface. You can stream music from your PC or Mac over your home Wi-Fi or listen to music from your mp3 player, and there's Facebook and Twitter integration, too. Rumour has it the next model will even cook you a hot dinner...

£249, pure.com

3 Sonos

Despite some new competition, Sonos still sets the standard for multi-room, wireless speaker systems. If you want to play different tracks in different rooms at different volumes – all controllable from your smartphone or tablet – then this is the gadget for you. This year, Sonos has added a sub to its speaker family if you want to add some meaty bass to the mix.

Basic system £259, sonos.com







FOR COMMUTERS

1 Asus Eee Pad Transformer Prime

Tablets are a perfect way to kill time when you're travelling. But once you reach your destination, it's a little tricky to get work done with just a touchscreen. The Transformer adds a keyboard and mousepad to the equation to make tasks like editing and writing documents faster and more precise.

£599, asus.com

2 Jabra Soulmate

Beef up the sound coming from your laptop, tablet or phone with the help of this portable Bluetooth speaker. Its rubber sole, which sets it apart from other travel speakers, stops it from vibrating when you crank up the volume. It also comes with a handy carry case that, while keeping it safe from dirt, sand and splashes, lets the sound out without muffling it.

£149, jabra.com

3 Garmin nüvi 3490LT

If you're driving every day, then you really need a dedicated Sat-Nav to help you get there quickly and cheaply. This Garmin will not only show you traffic-jammed routes, it will also warn you about them on your Android smartphone before you leave the house. There's even an eco drive mode that takes all the different variables into account to steer you towards the most fuel-friendly trip.

£249, garmin.com







FOR THE KIDS

1 Raspberry Pi

This little circuit board is an entire computer that costs under £30. You'll need to learn a bit of coding to use it, but if you're willing to do that then the Raspberry Pi can be the main ingredient in any number of incredible projects. We got as far as making a media streamer for the home, but the more adventurous have even managed to turn it into a small satellite destined for outer space.

£29.95, raspberrypi.org

2 Wii U

If the Nintendo Wii was anything to go by, then its successor will be the top item on every kid's wish list this year. Family-friendly motion-control gaming is still on offer, but the Wii U also adds a tablet-like controller so the kids can keep playing while the adults watch TV. See our verdict on page 86.

£249, nintendo.com

3 LeapPad2

If you've got a tablet computer and a small child at home, the chances are you probably won't want the two to meet. The LeapPad acts as a buffer – it's a fully functional, toughened touchscreen tablet crammed with educational software and games for kids that's relatively inexpensive to buy (compared to an iPad repair bill, that is).

£72, leapfrog.com







FOR COUCH POTATOES

1 Planet Earth/Frozen Planet

Sit back and take in spectacular views of the ends of the Earth with this Blu-ray boxset. In case you've been living in a nuclear bunker since the Cold War and haven't heard of either, these Attenborough-narrated documentaries send film crews all over the planet to capture the majesty of the natural world.

£33.99, bbcshop.com

2 LG 47LM960V

Despite the rather dull name, this sleek, aluminium-bodied TV was one of the best bits of tech we tested all year. It's loaded with smart apps, has sharp 3D images and includes a motion-controlled remote that's fun and simple to use. Our favourite feature is the split vision mode, which displays two distinct images at once in two sets of 3D glasses – great for gaming.

£749, lg.com

3 Humax DTR-T1000

Meet the successor to Freeview. YouView is the new TV service that takes all the catch-up TV from the terrestrial channels (like 4OD and BBC iPlayer) and conveniently puts them all in one place. The set-top box also comes with a hard drive for recording your shows, and soon you can expect Sky programmes on a pay-per-view basis.

£299.95, youview.com

ADVERTISEMENT

THE TOP20

Choosing a home cinema system is a potential minefield that must be negotiated with great care or safely avoided by letting experts guide you. If you want to end up with a system that, as a minimum, meets your expectations in terms of picture and sound quality, reading magazine product reviews and choosing the recommendations, five-star favourites or best buys can only ever be part of the answer at best. Looking for the cheapest price and having a system delivered to your door, even with a 'knowledgeable' friend to help set it up, is a well-trodden path to disappointment.

There is a bewildering choice of components on the market today and also different ways in which components can be installed and connected together. Which sort of visual system do you go for? Projector and screen, or plasma, LCD or LED TV? 3D or non-3D? Full 1080p capability is now the only sensible choice but the appropriate source components, such as a Blu-ray player, need to be part of the equation. The sound performance of a system is also hugely important, even more so if you will be listening to music, or music DVD's, through the same system. If so, you need an amp that approaches the performance of a decent 2-channel hi-fi amp, which is not that easy to find. Having an amp with the right inputs for the best connectivity is essential but you will also need to decide on a 5.1 or 7.1 speaker system, passive or active sub and, crucially, where they will be sited for the best results. In short, it's complicated and very fertile ground for getting it wrong.

ACHIEVING POTENTIAL

To select a system, you could choose a collection of 'Best Buy' components in the hope that they will be a great combination. Maybe, but probably not. You could buy a pre-packaged all-in-one system from one manufacturer. This is almost certainly not the best route either as you will miss out on enormous potential. From informal surveys conducted, it appears highly likely that **the majority of home cinema systems selected and installed on a DIY basis (that is without professional input) are performing at way below their optimum level.** To compound matters, most are also ill-matched to the room in which they are installed and are, in reality, the wrong system. Without considerable knowledge or experience, high quality home cinema is not a suitable DIY activity. Our aim must be to buy a home cinema system that will provide an excellent picture quality plus an audio delivery that will match, or even better, the commercial cinema experience. It must be exciting, reliable and deliver true value for money.

WHAT AND WHERE TO BUY

To ensure a home cinema system is right for you, where do you start? Here's an important tip ...**don't** start with **WHAT**, start with **WHERE**. There's only one way to give yourself the best chance of getting it right first time, and that's through a specialist AV dealer. It's possible you have preconceived ideas that put you off visiting one. Although you would welcome the advice and guidance, you don't know the technical jargon. You don't want to be talked down to. Your friend has said they only sell expensive gear and they're not interested if you don't have a big budget. They're expensive. These are just myths.

Most specialist AV dealers are running their business because, above all, home cinema is their hobby. They spend a large portion of their time comparing systems to get the best possible results. They know the component combinations which don't gel together and, conversely, they know the combinations which give the best performance within a given price range. Very importantly, they know how to get a system working to its optimum. But they all also know the system must suit **you**.



> "...Our aim must be to buy a home cinema system that will provide an excellent picture quality plus an audio delivery that will match, or even better, the commercial cinema experience."

So good you'll believe you're there!

GUIDE

TO BUYING HOME A CINEMA SYSTEM



BUYING OR BEING SOLD TO?

There are dealers around, web based or otherwise, who will sell you anything you are willing to pay for. They may be a bit cheaper but that's all they offer. Now there's a carefully selected group of long-established specialist dealers who are totally committed to putting the customer first. Their idea of 'selling' is to discuss your requirements, offer their advice, give you the best options, then play the systems for you and allow you to be the judge. You'll probably be surprised and, almost certainly, relieved to discover how easy it is to see and hear the differences between components and between systems. You'll be able to make a clear and informed decision about what to buy.

The story doesn't end there. These shops won't abandon you once you've put your hand in your pocket. They won't leave you to set up the system you've selected as best you can. They'll install it in your home, make sure it performs to its best, and ensure you're entirely happy with the way it works. Why? Because a high proportion of these dealers' custom comes through people who have bought from them before, either directly or by recommendation. It's vital to them to get it right for you.

GETTING THE BEST DEAL

Unless you've got money to burn, you'll be living with your new system for years. Most of these dealers offer much longer equipment guarantees than provided by the manufacturer, a very worthwhile benefit, but it also makes it in the dealer's interest to ensure high build quality and reliability. Maybe you could save a few pounds by buying piecemeal but you'll lose out on the overall package. As far as the dealers are concerned, they believe that taking care of their customers properly is a far better way of doing business than just handing over boxes.

LISTED BELOW ARE 20 OF THE BEST AV SHOPS IN THE COUNTRY

They have been selected because they are known to do an excellent job in guiding customers towards home cinema systems that will provide years of superlative performance and total satisfaction.

SOUTH

Chelmsford RAYLEIGH HI-FI SOUND & VISION
216 Moulsham Street. 01245 265245
www.rayleighhifi.com

Kingston-upon-Thames INFIDELITY
9 High Street, Hampton Wick.
020 8943 3530
www.infidelity.co.uk

Maidenhead AUDIO VENUE
36 Queen Street. 01628 633995
www.audiovenue.com

Norwich MARTINS HI-FI
85-91 Ber Street. 01603 627134
www.martinshifi.co.uk

Rayleigh, Essex RAYLEIGH HI-FI SOUND & VISION
44a High Street. 01268 779762
Custom Install Dept.
01268 776932
www.rayleighhifi.com

Southend-on-Sea RAYLEIGH HI-FI SOUND & VISION
132/4 London Road. 01702 435255
www.rayleighhifi.com

Tunbridge Wells KENT HOME CINEMA
69 London Road, Southborough.
01892 535007
www.kenthomecinema.co.uk

LONDON

Ealing AUDIO VENUE
27 Bond Street. 020 8567 8703
www.audiovenue.com

N1 GRAHAMS HI-FI
190a New North Road. 020 7226 5500
www.grahams.co.uk

SW11 ORANGES & LEMONS
61-63 Webbs Road, Battersea.
020 7924 2040
www.oandlhifi.co.uk

SW20 O'BRIEN HI-FI
60 Durham Road. 020 8946 1528
www.obrienhifi.com

MIDLANDS

Coventry FRANK HARVEY HI-FI EXCELLENCE
163 Spon Street. 024 7652 5200
www.frankharvey.co.uk

Nottingham CASTLE SOUND & VISION
48/50 Maid Marian Way. 0115 9584404
www.castlesoundvision.com

Solihull MUSIC MATTERS
93-95 Hobs Moat Road. 0121 742 0254
www.musicmatters.co.uk

NORTH

York SOUND ORGANISATION
2 Gillygate. 01904 627108
www.soundorg.co.uk

CEDIA BADA

The majority of the above dealers are members of one or both of the major trade organisations, BADA or CEDIA.

STAR QUALITIES

VALUE FOR MONEY ★★★★★
SERVICE ★★★★★
FACILITIES ★★★★★
VERDICT ★★★★★

TOP 20 UK SPECIALIST HOME ENTERTAINMENT DEALERS
QUALITY ASSURED ★★★★★

Warnings

THE QUANT REV

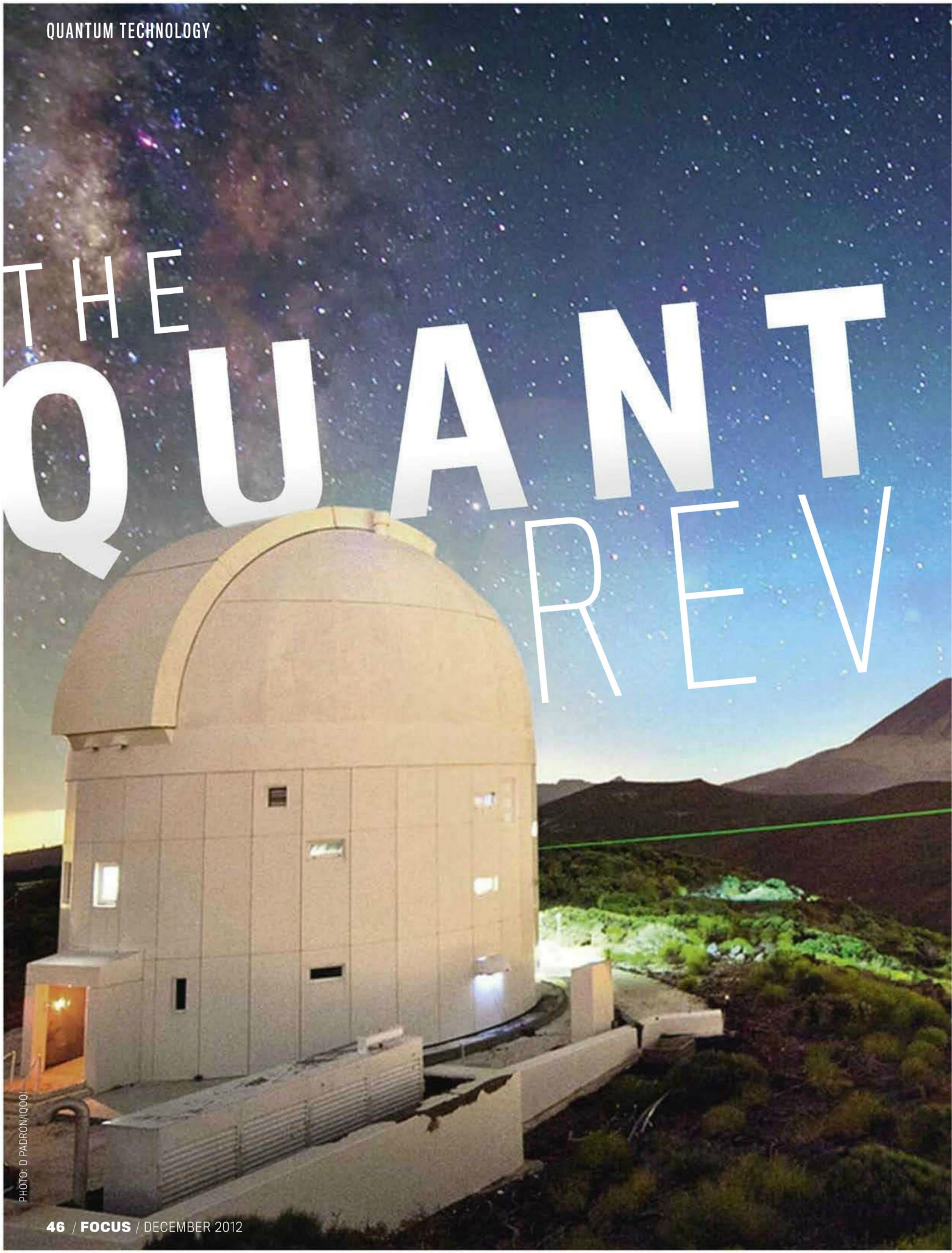


PHOTO: D. PADRÓN/IOQI

UM OLUTION IS HERE

Physicists are harnessing weird subatomic phenomena to build ultra-fast computers and transform the internet. **Dr Paul Parsons** looks at how quantum technology will change the world you live in

A laser beam containing entangled photons is received by ESA's Optical Ground Station on the island of Tenerife. The quantum information has travelled 143km from the island of La Palma

Quantum theory has revolutionised physics. Since it burst onto the scene a little over a century ago, it has overturned the way we think about subatomic particles and the interactions between them. Now there's a new quantum revolution brewing – one that's set to give us technology that can perform feats that were once unimaginable.

Experimental quantum computers are already buzzing away in labs around the world. And Canadian company D-Wave Systems has started marketing the D-Wave One, which it describes as 'the world's first commercially available quantum computer' with a price tag of $10,000,000 (£6.2m). However, some critics have questioned whether it has all the properties of a full quantum computer.

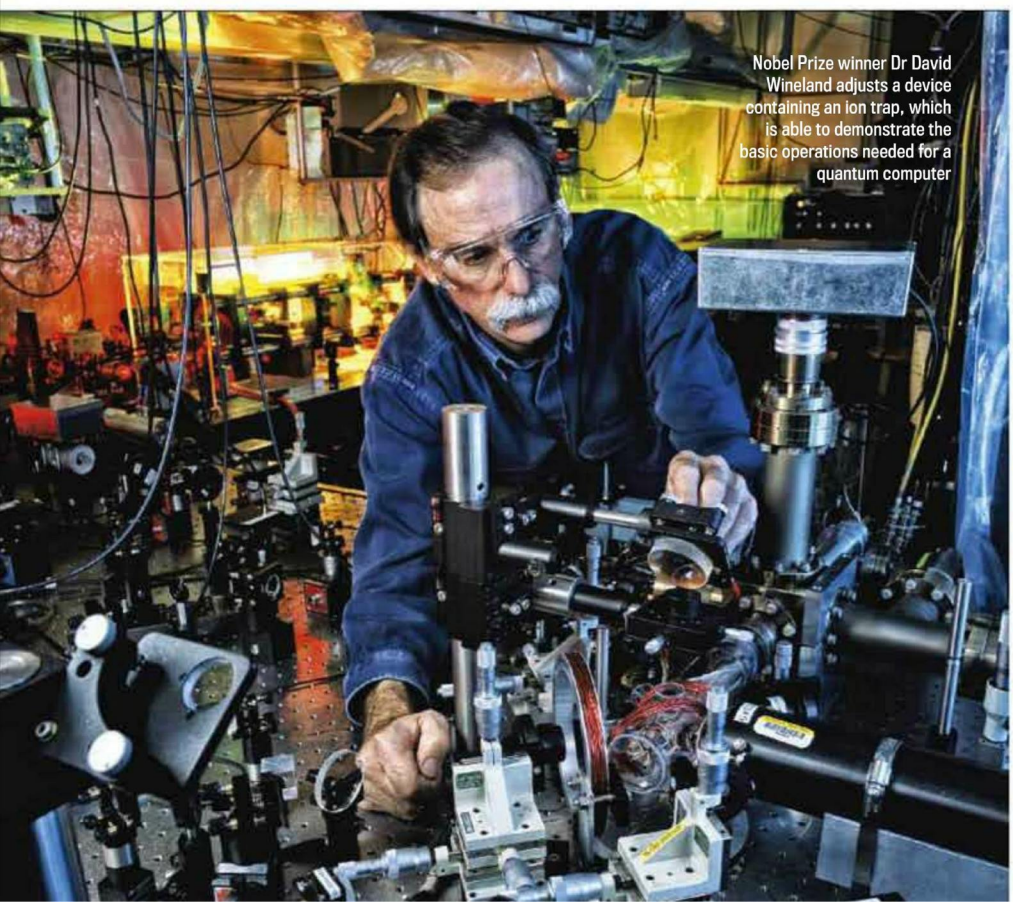
But it's not just computers that will be transformed by harnessing quantum phenomena, the weird behaviour of the subatomic world. In recent months, huge strides have been taken towards the development of a 'quantum internet'. Such a network would let you Google for web pages exponentially faster than you can on a classical computer, make new types of games possible, and provide absolutely secure eavesdropper-proof communication so you would never need worry about casting your bank details into cyberspace again. Add to this cameras that could take pictures of things they can't see themselves and new techniques for developing drugs, (see 'The appliance of quantum science' on p50) and it seems quantum technology is coming of age.

It is perhaps a reflection of this that two physicists, Professor Serge Haroche at Collège de France and École Normale Supérieure, both in Paris, and Dr David Wineland at the National Institute of Standards and Technology in Colorado have both been awarded the 2012 Nobel Prize in Physics for their work on quantum technology.

Subatomic particles lose their quantum properties as soon as they interact with the outside world – something that's made quantum phenomena difficult to study. But working separately, Haroche and Wineland managed to measure and control particles when they were exhibiting quantum behaviour for the first time. With their electric fields and mirrors, they paved the way for others to experiment with tiny quantum particles and, most importantly, put them to use.

"It's a machine with fundamentally new abilities. It can do things a classical computer can't"

David Deutsch, Visiting Professor at University of Oxford's Department of Atomic and Laser Physics



Nobel Prize winner Dr David Wineland adjusts a device containing an ion trap, which is able to demonstrate the basic operations needed for a quantum computer

PHOTO: GEOFFREY WHEELER/NATONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, SCIENCE PHOTO LIBRARY X3

QUANTUM DREAMS

It was back in the 1970s when David Deutsch, an Oxford-based mathematician and physicist, realised that quantum phenomena could revolutionise computing. Down in the quantum world, physics is very different to our everyday experience. Particles do funny things, like being in two states at once (called superposition) and appearing to be somehow connected. In the latter, one particle will do the opposite of the other, even when separated by a large distance, in an effect known as 'entanglement' (see 'Weird world of quantum physics', right).

The fundamental unit of information inside computers, the bit, can take a value of 1 or 0. Deutsch realised that a bit made from a quantum particle, such as a photon of light, could be a 1 and a 0 at the same time thanks to superposition. String eight of these 'qubits' together and you have a 'qubyte' that represents every number between 0 and 255 simultaneously.

If you can build a machine to process these quantum bytes, then all 256 different numbers can be crunched in one fell swoop instead of one by one – leading to a dramatic improvement in speed. It's the power of such 'parallel processing' that gives quantum computers the edge over their conventional counterparts. "It's a new kind of machine with fundamentally new abilities," says Deutsch. "It's able to do things that the classical computer can't."

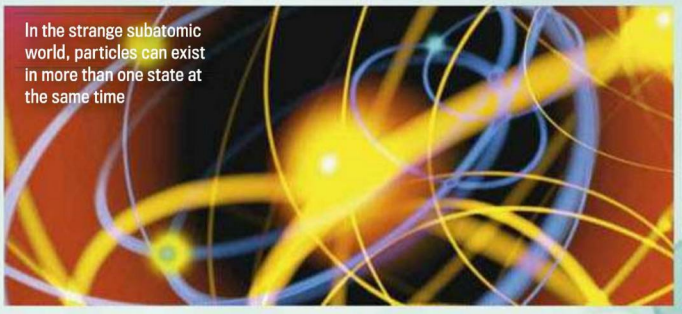
Deutsch published his work on the theoretical underpinnings of quantum computers in 1985 and it wasn't too long before applications began to emerge. In 1994, computer scientist Peter Shor, then working at Bell Laboratories in New Jersey, wrote the first program to run on a quantum computer. 'Shor's algorithm' is a set of instructions that enables a quantum computer to factorise large numbers – that is, to split a number into two smaller values which give the original number when multiplied together. This is easy for small numbers like 21 (7x3), but factorising a very large number – say, one with 150 digits – would take an ordinary computer millions of years. Shor's algorithm, running on a quantum computer, can do it in a few minutes.

WEIRD WORLD OF QUANTUM PHYSICS

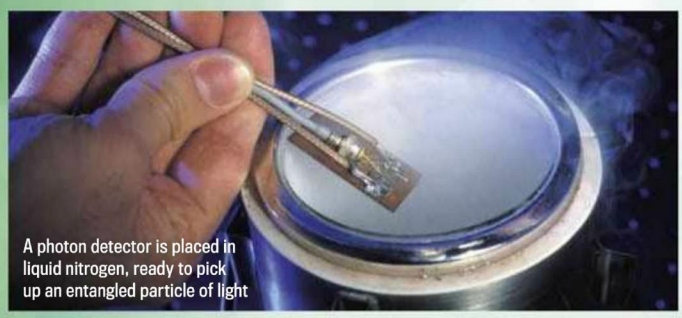
In the subatomic realm, mind-bendingly strange things happen

SUPERPOSITION

One of the strangest properties of subatomic particles is that they can exist in two or more states at the same time. An electron, for example, can be in one of two states determined by its spin. Quantum spin is very loosely analogous to spin in the everyday sense except that in the quantum world it's 'quantised', being allowed to take just one of two values, denoted 'spin up' and 'spin down'. Each of these configurations is a 'state' of the electron. But an electron can exist in a mix of these two states. And that's how they're used to record a qubit of information, with 'spin up' representing '1' and 'spin down' as '0'.



In the strange subatomic world, particles can exist in more than one state at the same time



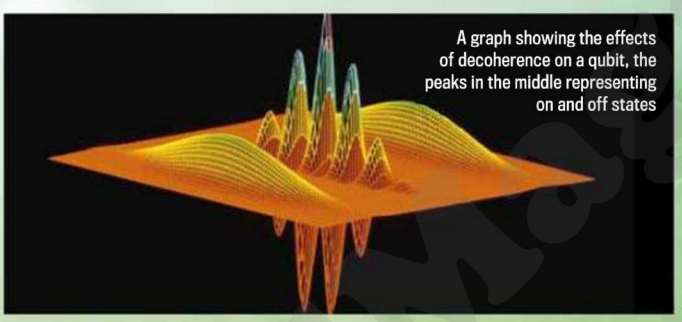
A photon detector is placed in liquid nitrogen, ready to pick up an entangled particle of light

ENTANGLEMENT

Einstein called it 'spooky action at a distance'. Subatomic particles can become linked and remain linked no matter how far they are separated – one particle doing the opposite of the other. Two entangled particles taken to opposite sides of the Universe would exhibit a kind of faster-than-light communication between each other: measuring the state of one would instantly determine the state of the other. This entanglement will allow information to be communicated over vast distances. However, the entangled channel has to be supplemented by a classical signal which can never exceed the speed of light.

DECOHERENCE

Older physics text books will tell you that a quantum particle exists as a wave only until someone measures it, at which point the waviness is destroyed and it becomes a 'classical' object. Some physicists disapproved of the subjective picture this conjured up. We've since discovered that *any* interaction with the outside environment is enough to make a particle in a quantum state turn classical. Physicists refer to this process as 'decoherence', and it's a major headache in the development of quantum communication systems in which the quantum state of photons must be preserved as they travel along miles of fibre-optic cable.



A graph showing the effects of decoherence on a qubit, the peaks in the middle representing on and off states

HOW DOES THIS STRANGE STUFF HAPPEN?

As weird as they are, the predictions of quantum theory have been proven in countless experiments. What's less clear is how those strange phenomena come about. One idea is that our Universe is just one of many, leaved together like pages in a book. So when we say that a particle can exist in more than one state at once, that's because the different versions exist in different universes. Or when there's decoherence, that's because the parallel universes have peeled apart such that the quantum interference between them shuts off.

If this is true, it would mean that a quantum computer is so fast because its parallel processing power comes from harnessing copies of itself in other universes.

THE APPLIANCE OF QUANTUM SCIENCE

It's not just computers and the internet that will benefit from subatomic supercharging



Full colour TV

The quality of the display in a light-emitting diode (LED) TV is pretty good. But a far-superior display technology is now under development, and at its heart are objects known as 'quantum dots'. Each one is a bundle of quantum particles, manufactured to have specific properties – it's essentially a designer atom. In existing displays, every pixel contains a red, green and blue LED, each lit to a different brightness to compose a limited range of colours. Quantum dots, however, can be designed to emit pure colours – not just those based on RGB – making for a richer viewing experience.



Drug design by computer

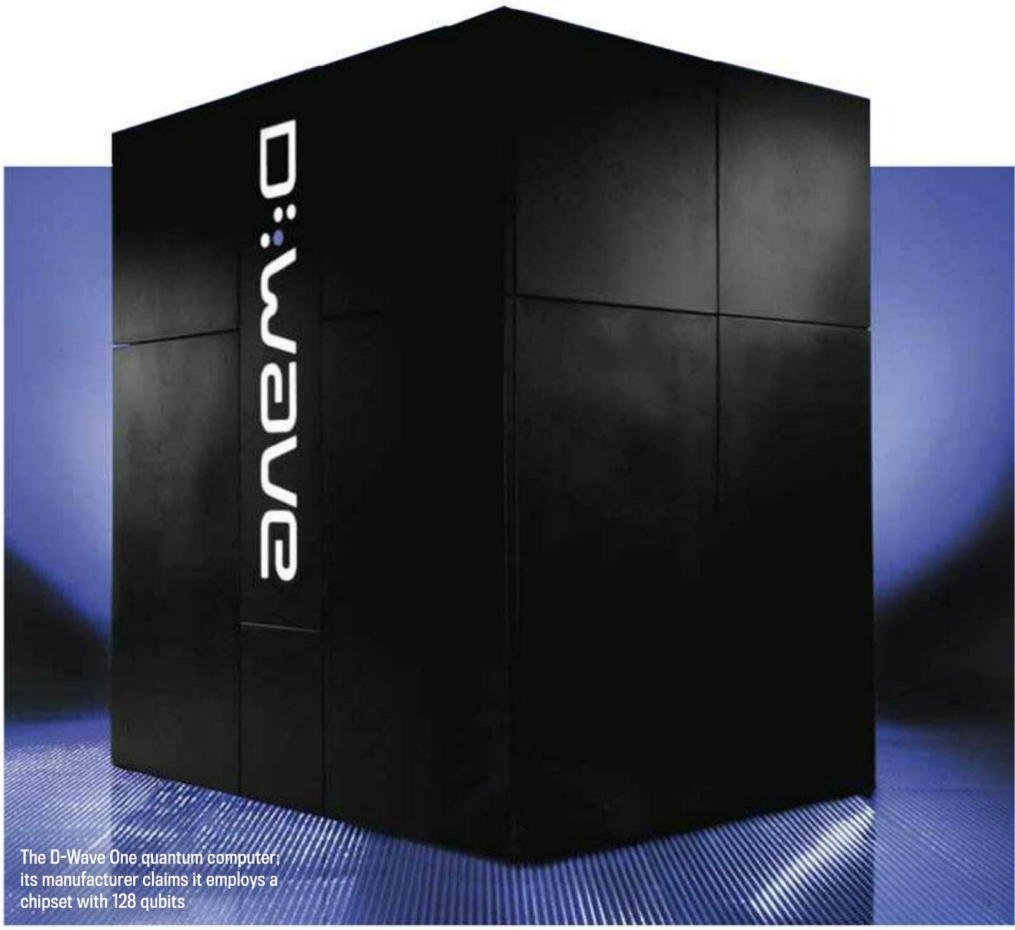
If you want to calculate the behaviour of a marble rolling down a hill, one way is to simply roll a marble down the hill and measure its speed and position as its goes. Now scientists are turning to quantum technology to do the same thing when designing clinical drugs. The properties of a drug are determined by its chemistry, which in turn is fixed by the quantum structure of its molecules. Calculating the properties of complex drug molecules from quantum theory is a formidable challenge, but using controllable qubits it's possible to simulate molecules and then read off their chemical properties directly.



The 'magic' camera

Imagine a camera that can take shots of things that it's not pointing at. Just such a device has been developed by researchers at the University of Maryland and the US Army Research Laboratory. A special flash bulb creates pairs of entangled photons. One photon in each pair goes into the camera, while the other is directed toward the subject using a laser or a system of lenses and mirrors. Because of the link between the particles, the photons in the camera form an image of whatever is illuminated by their entangled partners. The technology could enable satellites to take images through cloud.

PHOTO: SCIENCE PHOTO LIBRARY X2, THINKSTOCK X2, BALTIMORE SUN, D-WAVE SYSTEMS, ALLATKA/WIKIPEDIA



The D-Wave One quantum computer; its manufacturer claims it employs a chipset with 128 qubits

This discovery sent security experts into panic mode. Every time you make a financial transaction online, your details are encrypted using a system that relies on the difficulty of factorising big numbers. Your bank picks two numbers, multiplies them together and sends you the resulting big number. You can use this big number, called the 'key', to encrypt your transaction, but decrypting it requires knowledge of both numbers. So even if someone else knows your key, they have to be able to factorise it in order to access the transaction. Up until recently, this was extremely hard. But if a hacker with a quantum computer can now do it in minutes, then e-commerce could grind to a halt.

ULTIMATE SECURITY

Luckily, as well as presenting the problem, quantum technology also offers a solution. At around the time Deutsch was publishing his findings on processing quantum information, a team led by IBM researcher Dr Charles Bennett demonstrated how banks could use quantum information to transmit encryption keys in a way that's absolutely uncrackable.

It relies on the fact that qubits are notoriously fragile – the slightest interaction with the surrounding environment causes them to collapse into an ordinary bit with a definite value of 1 or 0. This happens because of a phenomenon called decoherence (see 'Weird world of quantum physics', on p49). It means that an eavesdropper trying to intercept a message transmitted as a stream of qubits must inevitably alter the message. A transmitter and receiver could therefore check that no one has tried to intercept their communications by interspersing the message with a test signal. Any discrepancy in it would mean that the key had been intercepted.

"There are several banks that use the secure communications of quantum networks"

Professor Steve Bleiler, of Portland State University

In 2007, Swiss company ID Quantique used just such a quantum encryption protocol to transmit electronic ballot slips during the Geneva federal elections. Since then, the technology has been rolled out to financial institutions and online security firms. "There are now several banks that, between their branches, use the absolutely secure communication that quantum

networks offer," says quantum physicist Professor Steve Bleiler, of Portland State University. "Expect to see more and more of this particular feature as a way, for example, to fight identity theft and fraud."

The development of larger-scale quantum networks is also gathering pace. In September 2012, physicists from the University of Waterloo in Canada reported how they were able to set up a quantum link between the Canary islands of La Palma and Tenerife – a distance of 143km (89 miles). Photons were entangled on La Palma before a high-powered laser fired one of them to a receiving station in Tenerife. Shifting the state of a photon on La Palma, such as its polarisation, then shifts the state of the photon in Tenerife. Such 'teleportation' enables data to be transferred over great distances.

The fact that the photons were beamed through free space means the technique could be used to exchange secure information with moving vehicles. In September, German researchers led by Sebastian Nauerth at the Ludwig-Maximilians University of Munich zapped infrared laser pulses from an aircraft flying at a height of 20km and a speed of nearly 300km/h to a receiving station on the ground, sending quantum keys stored in photons along the path. It wouldn't take too much development for military aircraft to start using quantum communication to transmit surveillance data. And in the longer term, data could be transmitted to and from satellites using quantum teleportation to create an ultra-secure global communication network.

A QUANTUM INTERNET

Yet today's internet is more than just computers connected together. In between the connections are 'nodes', where signals travelling across the network can be read and then 'routed' to their correct destination. Doing this with qubits is tough, again because of decoherence. Steering qubits through a network with classical nodes would mean the qubits would have to interact with the nodes, and this would destroy their delicate quantum state.

Researchers at the Max Planck Institute of Quantum Optics (MPQ) in Germany recently made progress with this problem. In September this year, they demonstrated the world's first ever quantum network nodes. The network consisted of 60m of fibre optic cable, along which qubits could shuttle back and forth, piggybacking on photons of light. Punctuating the network were quantum nodes – individual atoms on which qubits could temporarily be stored. Having a quantum storage medium at the node – a single atom – means the photons can be stored without destroying their quantum state, before being relayed onwards.

Even web search engines look set to get a boost from quantum technology. In June 2012, research at the University of Southern California demonstrated how quantum computers could be used to speed up search engines. The experiment didn't involve an actual quantum machine. Instead, the team ran a simulation of a quantum processor on a classical computer, proving that parallel processing would allow a quantum processor to run a Google search exponentially faster than a classical machine. "We showed that Google's PageRank algorithm, if it were to run on a quantum computer, would compute the ranking of pages faster than is possible using classical computers," says Professor Daniel Lidar, who directed the project.

Rolling out a quantum internet will nevertheless be a gargantuan task. While beaming lasers through the air is the only option with satellites and aircraft, a far more stable option in most instances would be fibre-optic cables, which would reduce the chances of decoherence. So a quantum internet would require thousands of kilometres of dedicated fibre-optics to be laid.

Bennett at IBM thinks the considerable cost of this infrastructure means the quantum internet will most likely operate alongside, rather than replacing, the classical web. "Quantum communication will be used for special purposes, like sharing cryptographic keys, and quantum computing will be used in those few situations where it gives a significant speed advantage: factoring large numbers, some kinds of search, and the simulation of quantum systems," he says.

But if Bleiler at Portland State University is right, Bennett may be underestimating the demand for quantum communication. Bleiler thinks commerce may be the ultimate driver for the quantum internet, making use of the security and ultra-fast searches it offers. A quantum internet could be up and running sooner than you think. ■

TODAY'S QUANTUM TECHNOLOGY

The power of the subatomic is already being harnessed



Ultra-accurate clocks

Atomic clocks (pictured) are the most accurate timepieces we know – losing just a billionth of a second every day (compared to about 0.02 of a second for a typical quartz wristwatch). Their accuracy derives from the known frequency of microwaves given off as electrons in an atom of the isotope caesium-133 hop from one energy state to another. The microwaves have a frequency of 9,192,631,770 waves per second (Hz) – each time this number of waves from the atom passes a detector, the clock knows to tick on by one second.



Powerful magnets

Pass an electric current through a coil of wire and, as proven by 19th Century British physicist Michael Faraday, it generates a magnetic field. The bigger the current you can send through the wire, the bigger the field – use a superconducting wire and the field generated can be enormous. This is how superconducting magnets work. Superconductivity is an effect caused by quantum physics – enabling electrons, the carriers of electric current, to slip unimpeded through certain materials. Superconducting magnets are used in particle accelerators and in super-fast 'maglev' trains (pictured).



Body scanners

Magnetic resonance imaging (MRI) is a technique for taking pictures inside the human body, which is less damaging than an X-ray. The patient is subjected to a powerful magnetic field. Because the quantum particles of atoms, the nuclei, carry a positive electrical charge, they respond by snapping into line with the field. This in turn makes the nuclei create their own rotating magnetic fields, which the MRI scanner can detect. These rotating fields carry information about the type of tissue being scanned and its distance from the magnet in the scanner. A computer can then construct an image of the patient's interior.

Dr Paul Parsons is the author of *How To Destroy The Universe* (Quercus, £9.99)

Find out more

BBC one Prof Jim Al-Khalili discusses quantum computing with Dallas Campbell on *Bang Goes The Theory*: http://bbc.in/wqStBw

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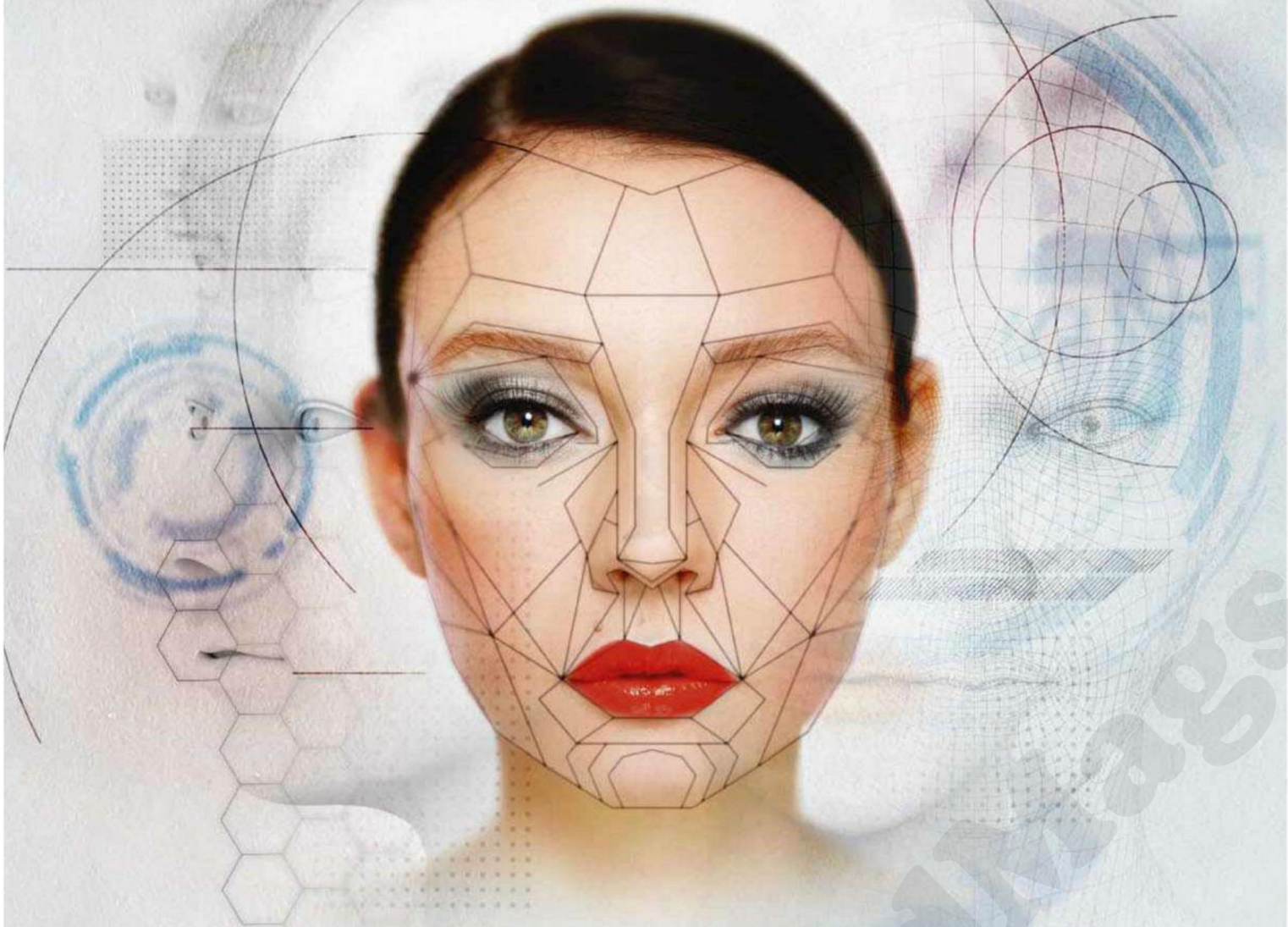


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BEAUTY AND THE GEEKS



We find some facial features more attractive than others, but why? **Zoe Cormier** investigates the science behind the perception of beauty

BBC TWO

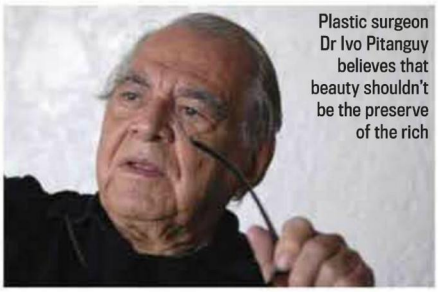
Watch Attraction, an episode *Dara O Briain's Science Club* on BBC Two this month

ILLUSTRATOR: JUSTIN METZ

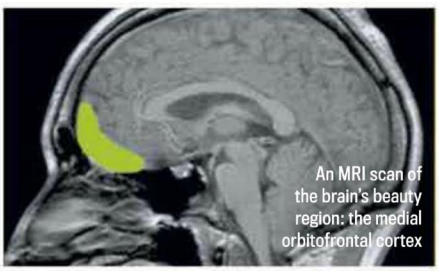
FOR DR IVO Pitanguy, charity isn't only about providing food or housing, but beauty too. The Brazilian doctor has spent 40 years performing *pro bono* plastic surgery on the poor of Rio de Janeiro out of a firm conviction that changing physical features shouldn't be the privilege of the rich.

Such an attitude might seem superficial, but it's an ancient belief. "Attractiveness affects every component of human life," says Professor Randy Thornhill, a biologist at the University of New Mexico. "Since the Greeks, we've understood that we make constant judgments about people based on how attractive they are, and this impacts how we interact with them." The mythical face of Helen of Troy launched a thousand ships and the story resonates for a reason: beauty has undeniable power.

So what exactly is it that makes a face beautiful? The 18th Century philosopher Edmund Burke defined beauty as "some quality in bodies, acting mechanically upon the human mind by the intervention of the senses". And according to Semir Zeki, professor of neuroaesthetics at University College London, "Two-thirds of this definition is about the contribution of the brain."



Plastic surgeon Dr Ivo Pitanguy believes that beauty shouldn't be the preserve of the rich



An MRI scan of the brain's beauty region: the medial orbitofrontal cortex

Zeki studies how we appreciate beauty, which includes brain scans that reveal one region – the medial orbitofrontal cortex (mOFC) – that becomes active when we experience something beautiful, whether it's a piece of music or a work of art. "This isn't to say that there is a 'beauty spot' in the brain," notes Professor Zeki. "But this does mean that the brain possesses a mechanism to perceive beauty, regardless of the source."

The brain also includes an area of the cortex that's specialised for recognising the sight of faces: the 'fusiform face area'. Neuroscientists have observed that individual nerve cells in a monkey brain will fire signals in response to seeing a face. It's likely that appreciating beautiful features involves activating both the mOFC and fusiform face area.

SEXY SYMMETRY

So why do we find some faces beautiful, but not others? Randy Thornhill, an expert on the evolution of sexual interactions, says it's because an animal's physical features advertise whether its body – and ultimately its genes – are of good quality. "Beauty is a promise of function," he says.



PHOTO: GETTY, NATUREPL.COM, BRIDGEMAN ART LIBRARY, ALAMY, ANTHONY LITTLE/ALITTLELAB.COM X2

They might look the same, but the image of a member of the Tanzanian Hadza tribe on the right has been doctored to be more symmetrical. Psychologist Anthony Little found that the tribe subconsciously preferred this face over the original on the left, suggesting that people in developing countries at risk of parasitic infection are predisposed to find symmetry attractive

"The brain has a mechanism to perceive beauty"

Semir Zeki, professor of neuroaesthetics at University College London

Before an animal chooses a mate, it assesses whether a prospective partner has 'good genes', which it does by gleaning clues from its appearance (see 'The evolution of beauty', opposite). Animals are able to use these external characteristics as an indirect measure of genetic quality because disease – especially infection by parasites – can lead to organisms growing in an asymmetric way: in other words, they look lopsided.

Thornhill's extensive research on insects shows they prefer to pair with mates possessing symmetrical bodies. And since his first study on facial symmetry in humans in 1994, psychologists have published hundreds of papers that consistently show that subjects prefer pictures that have been doctored to look more symmetrical. This includes photos of real people – altered to iron-out subtle differences between the two halves of their face – and computer-generated images of fictitious faces.

Like other animals, humans also seem to use facial symmetry to figure out whether a potential partner has good genes for fighting infection. People in developed countries rarely encounter debilitating parasites, but they remain a burden in the Third World, and research suggests that those who live in regions with a high risk of infection are predisposed to find symmetry attractive. In a study by evolutionary psychologist Dr Anthony Little of the University of Stirling, Scotland, members of the Hadza tribe in Tanzania exhibited a stronger preference for symmetry than people in the UK.

In another study, Little found that showing test subjects disgusting images – such as photos of dirty toilets or rotting meat – led them to prefer symmetrical faces even more, implying that there's some kind of biological urge to choose mates that can resist disease.

Attractive symmetry has implications for modern mating rituals too. Thornhill has found that women have a strong preference for facial symmetry during the fertile phase of ovulation, while Little has revealed that we should avoid trying to find a high-quality partner while

THE EVOLUTION OF BEAUTY

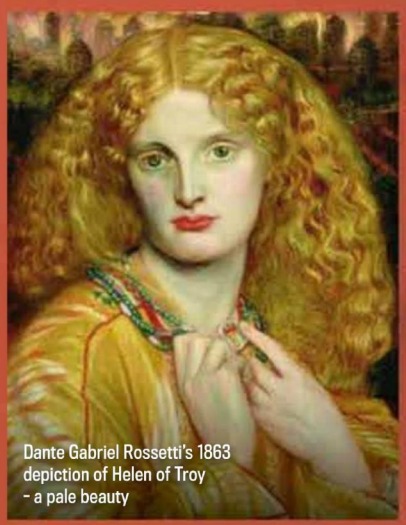


Attractive symmetrical zebra finches sire more offspring

WHY IS BEAUTY A DESIRABLE FEATURE?

Evolutionary biologists like Randy Thornhill explain that 'beautiful' features – such as clear skin, bright eyes and shiny hair – are a rough indicator of an individual's ability to reproduce. Good looks are a sign of good genes. Symmetrical features are associated with a strong immune response: parasite infection can cause animals to grow in a lopsided way. Symmetry therefore suggests that an individual has an immune system that's been strong enough to fight infection. Reproducing with a mate that has symmetrical features will in turn make good-looking offspring with a similarly strong immune system.

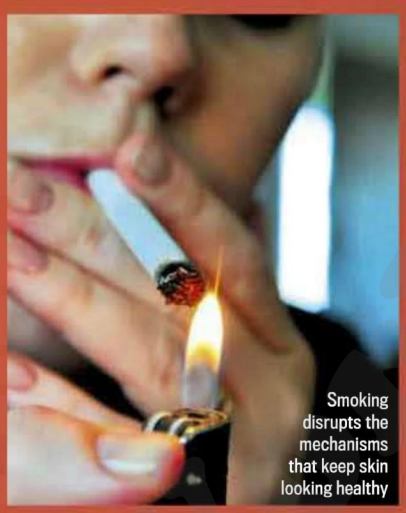
Research from across the animal kingdom has shown that attractive males sire more progeny: attractive male zebra finches have more grandchildren, for example, while female peafowls give preferential treatment to the offspring of attractive males, investing more energy and nutrients into eggs fertilised by those males.



Dante Gabriel Rossetti's 1863 depiction of Helen of Troy – a pale beauty

HAVE HUMAN PREFERENCES EVOLVED?

The ideal qualities of a 'beautiful' face can vary between different cultures, and tastes for particular facial features seem to have changed over time. Half a millennium ago, the rich were probably attracted to pale skin because it was a sign of affluence and luxury – of a life spent indoors. "If you go back and look at what was written about beauty, it's difficult to tell if writers of the day were simply reporting their own impressions, or what they thought people preferred," says University of St Andrews psychologist Dr Lisa DeBruine. "There's not a lot of good research about how things have changed throughout human history or across different cultures – much information is simply the opinions of old white guys." And as DeBruine points out, it's impossible to tell whether preferences for what's considered 'beautiful' have changed. Although the evolution of facial features can be seen by comparing old skulls, faces don't fossilise.



Smoking disrupts the mechanisms that keep skin looking healthy

WHY AREN'T WE ALL BEAUTIFUL?

If 'sexual selection' drives animals – including humans – to choose attractive mates with good genes, why haven't ugly individuals been weeded out of the gene pool? The answer is that genetics is somewhat of a lottery: the result of random mutations means there will always be winners and losers, and some of us are simply lucky to be born with genes that allow attractiveness. But the environment can also affect our physical features. Our behaviour and lifestyle choices – such as smoking, drinking and a bad diet – can all dull someone's naturally good looks.

Nature can also be influenced by nurture. A study by Dr Anthony Little of the University of Stirling showed that attractive features are also a sign of a healthy upbringing: adults who suffer childhood trauma have less symmetrical faces. "Symmetry is a sign of developmental stability and the ability to resist environmental stressors," says Dr Little.

"Research has overshadowed the idea that beauty is an individual preference"

Dr Lisa DeBruine, a psychologist at the University of St Andrews



Dr Lisa DeBruine's research has shown that women find male faces that have been warped to have more feminine features (top) less attractive than their more masculine equivalents (bottom)

PHOTO: L M DEBRUINE

under the influence of alcohol: beer goggles reduce our ability to detect symmetry.

Humans exhibit 'sexual dimorphism' – men and women look distinctly different. Individuals of one sex tend to prefer certain physical features that are considered attractive when they're possessed by the other sex: large eyes, small chins and high cheekbones are feminine, for instance, whereas pronounced eyebrows, large chins and broad cheeks are masculine.

Psychologists at the University of California, San Diego, even claim to have calculated the ratios for a perfect feminine face: a vertical distance between the eyes and mouth that is 36 per cent of the face length, while the horizontal distance between the eyes should be 46 per cent of a face's width. This isn't because there's anything inherently beautiful about 36 and 46 per cent, but because faces made up of average ratios are judged to be the most beautiful. What's more, if you change these average figures by travelling abroad, for instance, your brain will adapt. "People can recalibrate preferences quickly to adjust to the average traits they see in the population around them," explains Dr Anthony Little.

But some characteristics of beauty haven't been studied as much, particularly complexion. "Skin colour and texture far outweigh the importance of symmetry," argues Professor Dave Perrett, head of the Perception Lab at the University of St Andrews in Scotland. He found that people with higher levels of pigments called carotenoids, which give more golden tones, are consistently rated as more attractive. It might explain our obsession with suntans.

SUBJECTIVE BEAUTY

"People used to believe that beauty lies in the eye of the beholder, but research has overshadowed the idea that beauty is an individual preference," says Dr Lisa DeBruine, a psychologist at the Face Research Lab at the University of St Andrews. "But we still differ in what we prefer, so many of us in the field are now interested in understanding why different people like different things."

DeBruine's research on personal preferences has shown, for instance, that we don't fancy individuals who look like ourselves. When a heterosexual woman is shown images of men with similar features to her own, she'll rate them as unattractive – what psychologists believe is an instinctive reaction to a 'virtual sibling' that could prevent inbreeding. Intriguingly, it doesn't apply to faces of the same sex: a heterosexual woman will rate women who look similar to herself as more beautiful, especially if the woman already rates herself as attractive.

Taken together, these studies show that although features such as symmetry should be attractive to all, personal taste is important. "It's kind of comforting to think that there really is no such thing as the ideal beauty," says DeBruine. ■

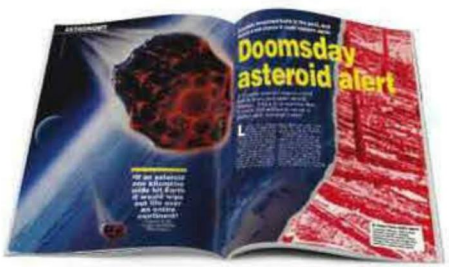
ZOE CORMIER is a freelance journalist and science writer based in London

Find out more

BBC TWO *Dara O Briain's Science Club* covers attraction this month on BBC Two: *www.bbc.co.uk/bbctwo*


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FOCUS AT







ASTEROID IMPACTS

THEN: "A sizeable asteroid impact could kill millions and cause untold damage. NASA is so worried it wants $50 million to set up a global early warning system. Yet to date, astronomers have catalogued just 200 near-Earth asteroids of any size. The fact is, despite the real danger posed by Earth-approaching asteroids and comets, few astronomers are searching for them."

NOW: Space rocks large enough to end humanity upon impact, such as the 10km+ asteroid that killed the dinosaurs, are rare, occurring once every 100 million years. But smaller strikes would still be capable of destroying a city. In 1908, a 45m-wide object exploded over Tunguska, Siberia, with a blast 1,000 times more powerful than the Hiroshima bomb. Today, astronomical organisations, collectively called Spaceguard, scan the skies for near-Earth objects with orbits that bring them perilously close to our planet. As of 30 September 2012, 853 near-Earth asteroids over 1km have been discovered by NASA's Near-Earth Object Program.



NEXT: "The combination of the Large Aperture Synoptic Survey Telescope in Chile and a space-based near-infrared telescope should enable the discovery of more than 90 per cent of all near-Earth objects 100m in diameter or larger, as well as thousands of smaller objects. By 2032, we will have a much better understanding – and awareness – of objects approaching Earth."
DR DONALD YEOMANS, astronomer and manager of the NASA Near-Earth Object Program

TELEWORKING

THEN: "Computer technology should mean millions of jobs no longer need to be tied to offices. Two or more people thousands of miles apart can hold a meeting using videoconferencing equipment. You need a clever little box called a codec (coder/decoder), a video camera, a modem and a screen to display the image. Information is sent via phone lines."

NOW: According to 2011 figures from the Office for National Statistics, 'teleworkers' make up 6.4 per cent of the UK workforce. Videoconferencing systems are common, and many people use Skype. Suitable Technologies sells 'telepresence robots' that roam the office while you control them from home, while Double Robotics will soon offer a self-balancing iPad-toting robot.



NEXT: "Remote presence is the future. I've lived that way for three years; in 20 years, it'll be everywhere. The next big step is a device that has simple arms. Wi-Fi everywhere will allow these devices to roam freely."
DALLAS GOECKER, electrical engineer and teleworker at Suitable Technologies

SAVING BUILDINGS

THEN: "After 800 years, time is running out for the tower of Pisa. Unless its progressive tilting can be stopped, this famous monument will collapse. The Italian government has called on some of the world's most eminent engineers and conservationists to produce a rescue plan."

NOW: The 56m tower of Pisa started leaning while it was being built: foundations on one side were too soft to support its weight. By the 1990s the tower had tilted to an angle of 5.5°, but a restoration project had stabilised the foundations by 2001, stopping the tower's southward movement. It now only tilts by about 4°, and should be stable for another 300 years.



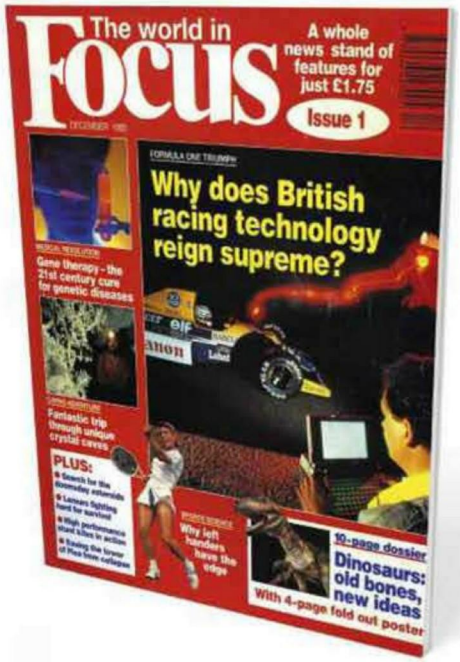
NEXT: "Big Ben's tower has been inclining northwards by about half a millimetre each year. But at that rate, we will not need to stabilise it before 2032. I've heard that the Taj Mahal is subsiding, and that the marble is degrading due to pollution, so that could be a good candidate for stabilisation."
PROF JOHN BURLAND, expert in soil mechanics at Imperial College London

"You need a little box called a codec, a video camera, a modem and a screen"

Focus gets to grips with new-fangled 'videoconferencing' technology, 1992

PHOTO: STEVEBOXALL.COM

20





To celebrate 20 years of *Focus*, we look at stories from our first issue to see how science has changed, and ask experts to predict the next two decades...







AEROGELS

THEN: "Safe Emulsion Agar gel (SEAgel) is one of a family of new materials called aerogels, made up of microscopic bubbles of air trapped in a lightweight substance. They look like being one of the key materials of the 1990s. Some, called 'frozen smoke', are lighter than air and could be used as insulation in fridges and freezers, which currently use ozone-destroying CFCs."

NOW: Invented by chemical engineer Steven Kistler in 1931, these synthetic materials, in which gas replaces the liquid in nanoscopic pores, haven't really taken off yet. As effective thermal insulators, aerogels are currently used in spacesuits, skylights and blankets. Until recently, aerogels have been based on carbon, aluminium oxide, agar jelly or, most commonly, silica. But in August 2012, NASA chemists announced that they'd managed to make silica aerogels more flexible using plastic-like polymers, and developed a new 'polyimide aerogel' that's 500 times stronger than silica types.



NEXT: "Aerogels made of different substances – beyond just the 'blue' silica type – will be ubiquitous in our daily lives. Ultralight vehicles will incorporate strong aerogels to extend range, reduce energy requirements and dampen noise. Multifunctional varieties will enable new battery and fusion concepts, and make human spaceflight less expensive. Aerogels will be working behind the scenes – we won't even realise they're there."
DR STEPHEN SEINER, materials scientist and founder of Aerogel Technologies

GENE THERAPY

THEN: "Gene therapy is a potent new treatment. It goes to the roots of our humanity – our genes – aiming to correct flaws that cause inherited diseases and other previously incurable disorders. This is the medical revolution of the 21st century. Many scientists believe that the first disease to benefit from gene therapy will be previously incurable forms of cancer."

NOW: The aim of gene therapy is to replace a mutated, faulty gene with a working version. Current approaches use a vector – often a modified virus – to deliver the therapeutic gene into the cell so it can be incorporated into a patient's DNA. The major challenge is to insert the gene into the genome so it's switched on without side-effects for other genes, and fixes the genetic defect in every diseased cell. Relatively unsuccessful until the mid-2000s, clinical trials since have shown that gene therapy can treat disorders of the nervous and immune systems, various cancers, blood disease and blindness.



NEXT: "Gene therapies will be part of mainstream medicine: for some diseases they'll complement recognisable treatments such as chemotherapy for cancer or antiviral therapy for AIDS. Most excitingly, gene therapy will be an effective and widely available treatment for diseases that are currently incurable or of devastating severity, including neurological and blood diseases."
PROF ADRIAN THRASHER, president of the British Society for Gene and Cell Therapy

ELECTRIC CARS

THEN: "Commercial electric cars are a step closer after high-energy sodium-sulphur batteries powered an electric car to a world distance record. In Swiss trials, a two-seater Horlacher Na-S Sport, which has a 27-horsepower motor, drove 340 miles non-stop at an average speed of 74.4mph. The batteries have twice the power density of common lead-acid batteries. Once sodium-sulphur batteries are widely available, viable electric cars may not be far behind."

NOW: The chemicals in rechargeable batteries have different electrical properties with different benefits and drawbacks. Lead-acid batteries were invented in 1859, but their high-surge currents mean they're still used in cars' starter motors. When it comes to electric vehicles, such as the cars built by Tesla Motors, you need batteries with a high energy density and low self-discharge. Sodium-sulphur batteries have a high energy density, but operating temperatures of over 300°C make them impractical for cars. Today's electric vehicles use costly lithium-ion batteries, like the ones in rechargeable gadgets.



NEXT: "Today it is virtually impossible to build an electric car with a range greater than 200 miles, because the batteries are simply too heavy. But exciting developments in lightweight lithium-air batteries have the potential to increase this range to over 500 miles, enabling widespread adoption of electric vehicles."
PROF PAUL V BRAUN, expert in materials science at the University of Illinois at Urbana-Champaign

ROAD TO THE

Cars that run on pure air or shape-shift for easier parking are part of a new motoring revolution. **Dan Read** gets behind the wheel

YOU COULD BE forgiven for thinking that British roads aren't a particularly pleasant place to be. Drivers in London waste an average of 54 hours every year sitting in congestion and other British cities fare even worse, according to data company INRIX. Drivers in Manchester, for instance, while away an average of 72 hours behind the wheel each year going absolutely nowhere.

Our motoring woes don't end there. In the UK, we collectively consume enough fuel to fill 19,600 Olympic-sized swimming pools every year and fuel prices continue to rise. Then there's the noxious stuff that comes out of our exhaust pipes.

But advances in materials, sensor technology and artificial intelligence promise to transform the car over the next few years. Imagine a vehicle that can shrink to squeeze into the tightest of parking spaces, one that can 'see' around the corner to spot potential hazards or one that can even drive itself.

Over the next few pages, *Focus* takes a look at the kind of car you could be driving tomorrow.

PHOTO: HIRIKO.COM

THE CAR THAT... FOLDS

A shape-shifting vehicle that can make itself shrink



IF YOU COULD design a car to fit perfectly into a city, what would it look like? That was the question researchers at the Massachusetts Institute of Technology (MIT) Media Lab asked back in 2003. Over the following years a team of designers, urban planners and even architects began to tackle it. They set themselves two targets: to create a car that could fit into tight parking spaces, and to make it easier than ever to manoeuvre.

The result of their deliberations is the CityCar – an all-electric, two-seater that can fold in the middle when it's being parked, making it just 1.5m long. It is so short when it's folded that up to three of them can fit end-to-end into one parking space. "This is not a traditional vehicle," says MIT designer Praveen Subramani. "From the start we wanted to achieve something different, so we began rethinking the basic architecture of a car."

The MIT team dispensed with the traditional engine, transmission and gearbox, instead developing 'robot wheels' that each have their own electric drive motor and steering motor, as well as suspension and braking. The wheels rotate up to 120° so the car can slip into parking spaces sideways and spin on its own axis.

The repositioning of the inner workings leaves space for the folding mechanism. The CityCar is effectively split into two sections: the front passenger compartment and a rear module housing the batteries. By sliding the front half up against the rear section using two small actuators in the linkage between each end, the wheelbase contracts. This can be done with the occupants on board, although it might feel like being tipped off an armchair.

Driving the CityCar will take some getting used to. "We decided upon a drive-by-wire system, so there was no need for a steering wheel," says Praveen. In other words, there is no mechanical linkage between the steering and throttle controls, with commands being sent to the robot wheels electronically. The traditional steering wheel is replaced by something resembling an aircraft control yoke. The lack of a steering column means the driver and passenger can get in and out through the windscreen that swings upwards.

In 2010, Basque company Denokinn began working with MIT and helped turn a half-scale model into a full-size car, the 'Hiriko', the Basque word for urban. Next year, Hirikos will hit the streets of Vitoria-Gasteiz near Bilbao for a trial scheme. "The current plan is to start small-scale production in the next year and a half," says Praveen. Fleets of Hirikos will be deployed in cities and available to hire, much like the 'Boris Bikes' in London. Alternatively, they would cost €12,500 (£10,000) to buy and the batteries would be leased.

FUTURE

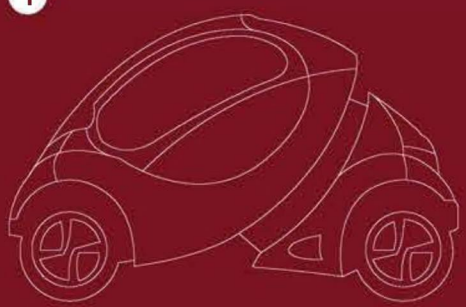
HOW IT WORKS

The engine, transmission and gearbox that clutter a traditional car are dispensed with so the vehicle can fold in the middle and squeeze into tiny parking spaces.



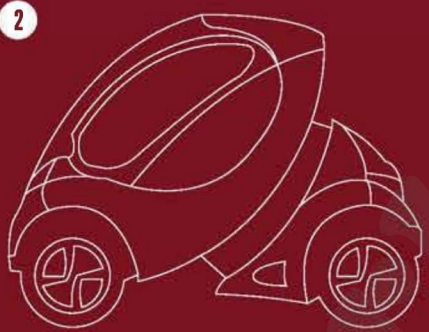
THREE STEPS TO STRESS-FREE PARKING

1



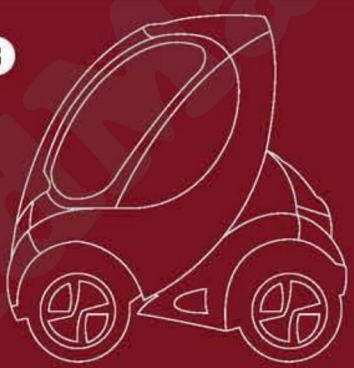
The CityCar is split into two halves: a front passenger section plus a rear module housing the batteries. When extended, the total length of the car is 2.5m.

2



Two electric actuators slide the front section up against the rear portion, rolling the front wheels towards the ones at the rear.

3



When the front wheels have rolled back as far as possible, the CityCar is just 1.5m long. The driver can exit through the windscreen, which opens up.

THE CAR THAT... DRIVES ITSELF

Scanning the road and making its own decisions, the Google car can navigate through traffic

IN RECENT YEARS, various car manufacturers have begun experimenting with driverless vehicles. Ironically, it's a company typically associated with the internet – Google – that's furthest ahead with its plans. Its prototype, incorporated into the Toyota Prius, has already covered 300,000 development miles – mostly in Nevada and California where the state governments have passed laws allowing driverless cars on the streets.

The Google car uses a 64-beam laser mounted on the roof, which scans the surroundings and imprints a 3D terrain mesh on the car's brain. Four radar sensors in the bumpers read the road and alert the car to pedestrians, traffic or any other unpredictable obstacles. There's also a front-facing camera in the top of the windscreen, programmed to detect traffic lights and street signs. The car's position is constantly plotted via GPS and wheel motion sensors.

Once the data has been stirred together, commands are sent to the throttle, brake and steering systems. According to Google co-founder Sergey Brin, we could see production versions on the road "in five years or less".

But Google isn't alone. Engineers at Stanford University in the US, for instance, have been working with electronics experts at VW to develop an Audi TTS that can drive itself, taking data from sensors in the production car and combining it with information from a GPS system. The autonomous Audi successfully negotiated the challenging Pikes Peak hill climb in Colorado.

"We want to better understand a vehicle's limits and be able to safely control it at those limits," says Joseph Funke, a research assistant at Stanford. "In the short term, these concepts can improve existing safety systems working alongside the driver and in the long term could translate to safer autonomous cars."

Even if driverless car technology hits the roads soon, there are other issues to consider. "The potentially limiting factor is the legality of a consumer autonomous vehicle. For example, who's at fault if a driverless vehicle gets in an accident? Groups at Stanford are looking into this as well, but I am not sure how that will play out," says Funke.

HOW IT WORKS

Data from lasers, a camera, GPS and sensors are combined to allow the car to negotiate roads without any driver input.



The sensor cluster on the top of the Google driverless car scans the environment before a computer translates the data into commands

PHOTO: GOOGLE ILLUSTRATOR: JASON LEE

THE CAR THAT... RUNS ON AIR

It's zero emission and can be refuelled in two minutes with the stuff you breathe

THE IDEA THAT a car could run on air and emit only pure air out of its exhaust pipe sounds a little far-fetched. But French company MDI has developed an engine that does exactly that and built a car around it, the AirPod.

The physics involved is simple. A compressed gas in a confined space is a way to store energy. When the air is allowed to expand, energy is released that can do work. In MDI's engine, air moves pistons up and down rather than an explosion generated when small amounts of fuel are injected.

But there are a few major obstacles to making a practical compressed air car, such as the issue of driving around with a large tank of highly compressed, potentially explosive gas. Safety concerns were addressed with the invention of an air tank made from carbon fibre and thermoplastic, designed to split with a hiss rather than shatter with an explosion.

Cleverly, the engine is reversible, so could act as a compressor to fill the air tank when driven by an external electric motor. "Or you could fill the tank in under two minutes from a special air station," says Cyril Negre, engineer and son of MDI's founder. "But of course, compressing the air in the first place requires energy. If this is powered by renewable energy, the CO_2 cost would be zero."

MDI's plans for the AirPod are advanced. "The car and engine are ready to go, and we want to sell it by the middle of next year," says Negre. Car company Tata has also signed a deal to develop the engine for its own cars in India.

HOW IT WORKS

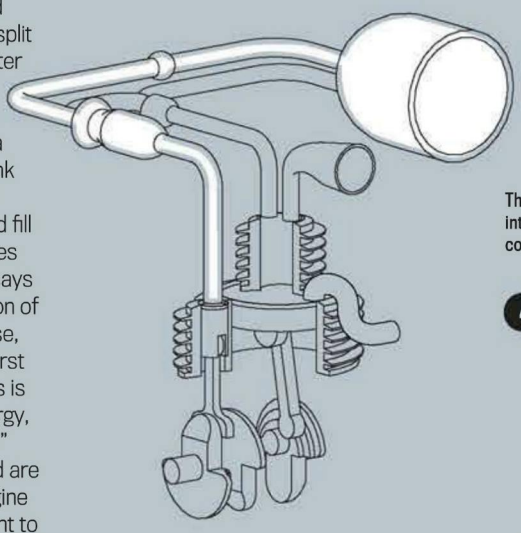
The force of rapidly-expanding air drives the engine's pistons. With no hydrocarbons being burned in the engine, there's no pollution to come out of the exhaust.



In a world of rocketing fuel prices, the AirPod could be a way to keep us on the roads

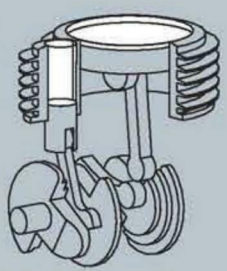
FOUR STEPS TO AIR POWER

1



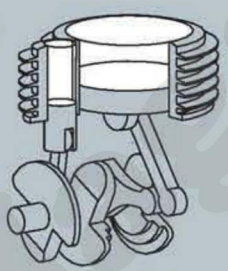
About 260 litres of air is compressed into a super-strong carbon fibre and thermoplastic tank at a pressure of around 258 bars.

2



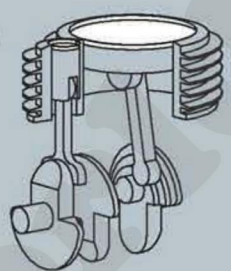
The air is then fed into a pair of interconnected cylinders that contain two pistons.

3



The air entering the first cylinder creates a force on the first piston – just like the explosion phase of a regular petrol engine. This turns the crankshaft, providing the physical drive of the engine.

4



When the first cylinder's piston reaches full extension, the leftover air forces its way through to the second cylinder, which also helps drive the crank.

THE CAR THAT... SEES ROUND CORNERS

A series of 'eyes' and an ability to talk to other cars make for an incredibly safe vehicle

IMAGINE A CAR that detects the world around it – that builds up a 360° picture of the road and even knows what's around the next corner. At the Geneva motor show last year, BMW unveiled the Vision ConnectedDrive Concept, a car that can do exactly that.

This car has sensors and cameras in the headlamps and taillights – 'eyes' front and back. As you drive along, they read your surroundings, giving warnings of pedestrians stepping into the road or white vans approaching rapidly from behind. Antennae in the car's wing mirrors are hooked up to a wireless network, which enable it to talk to others on the same network – warning, for instance, of other cars approaching a junction too quickly.

How to link cars to one another and the internet effectively is a challenge scientists at MIT in the US have been wrestling with. They have developed systems that not only allow cars to exchange data rapidly, but also enable them to link to Wi-Fi hotspots and relay data before the connection is lost. "If you try to connect your phone to a Wi-Fi network, something in the order of 13 messages have to go back and forth," says Professor Hari Balakrishnan at MIT. "By developing software in the Wi-Fi nodes [cars], we have been able to do that work in under 400 milliseconds."

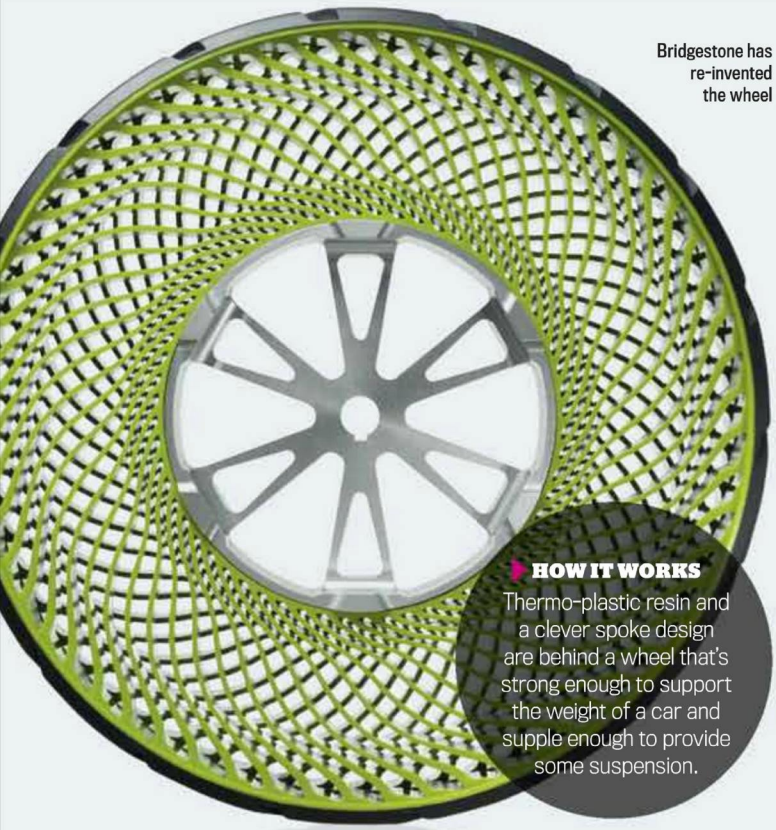
The data from the cars can then be analysed to provide useful information to drivers so they can cut their travel times, as well as driving more safely and economically. "You could relay information quickly to people's mobile phones. But I think the best way to provide information is in a weekly feedback report. Over a month or so, you might also have rebates or rewards for people who drive safely," says Balakrishnan.

HOW IT WORKS

Sensors packed into the headlights and taillights sense danger, while links to other cars provide warnings of potential accidents.



The dashboard of the ConnectedDrive can warn you of a car approaching too quickly from around a corner



Bridgestone has re-invented the wheel

HOW IT WORKS

Thermo-plastic resin and a clever spoke design are behind a wheel that's strong enough to support the weight of a car and supple enough to provide some suspension.

PLUS... THE AIR-FREE TYRE

How punctures will become a thing of the past

AIRLESS TYRES HAVE been around for a while. We've seen them on golf carts, construction vehicles and NASA's Curiosity rover. But while making them work at low speed is one thing, putting them on our roads is more difficult. Friction at the road surface generates a lot of heat, which rules out metal or simple plastics. And because a car partly relies on a cushion of tyre air, removing it could place greater demands on suspension.

But tyre manufacturer Bridgestone has a solution. "We developed a system of spokes made from thermoplastic resin," says Gert Meylemans, a project insider. "These radiate outwards from a lightweight aluminium hub, and form the 'wall' of the tyre," he says. "Importantly, each layer of spokes runs in a different pattern to the last and each is curved. This helps distribute the load." Around the outer layer, the tyre has a band of rubber for the tread.

Still in development on electric vehicles in Japan, engineers are working on increasing the tyre's weight tolerance – tweaking the spoke patterns so it can work with much heavier cars.

So with high-tech tyres, new materials and added computing power, the car of tomorrow is just around the corner. ■

DAN READ is special projects editor for *Top Gear Magazine*

Find out more

BBC NEWS See the Google driverless car in *Click*: www.bbc.co.uk/i/b01n7zmn

PHOTO: BMW, BRIDGESTONE



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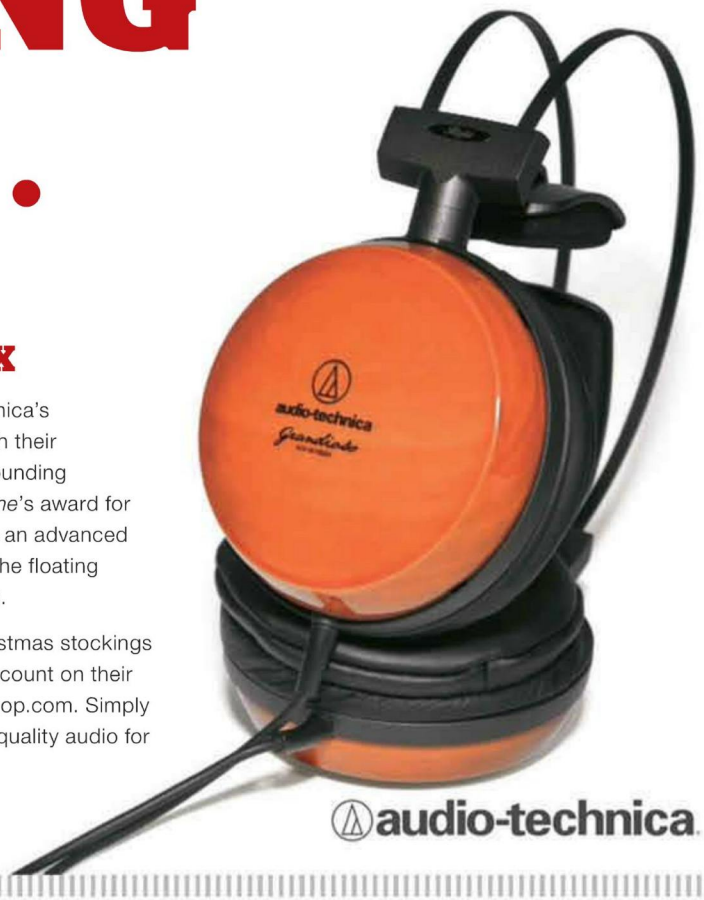
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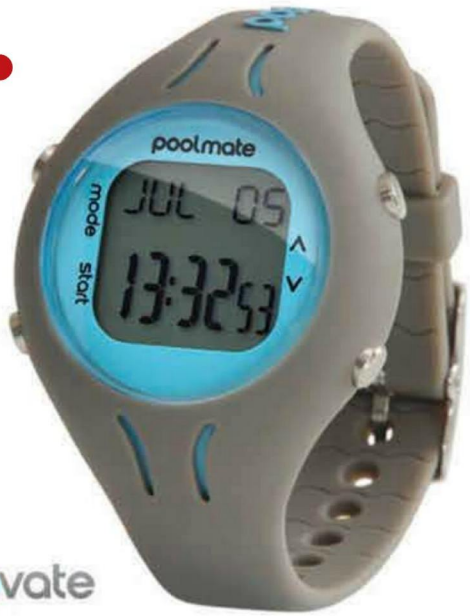


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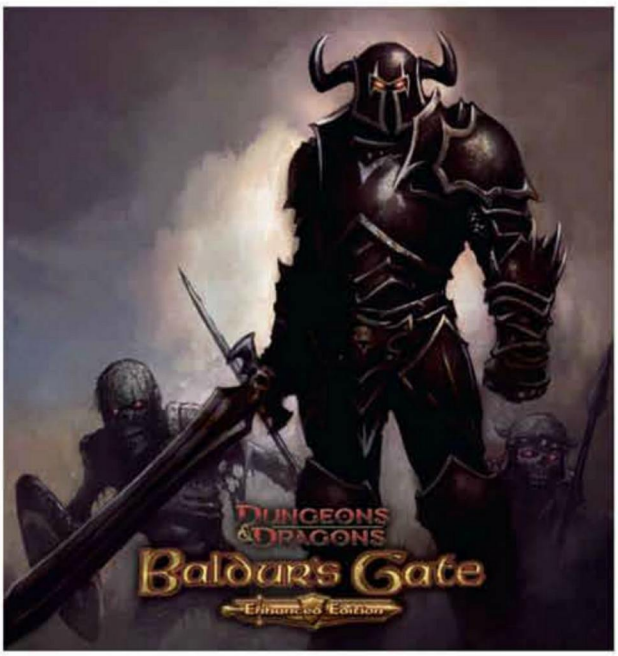
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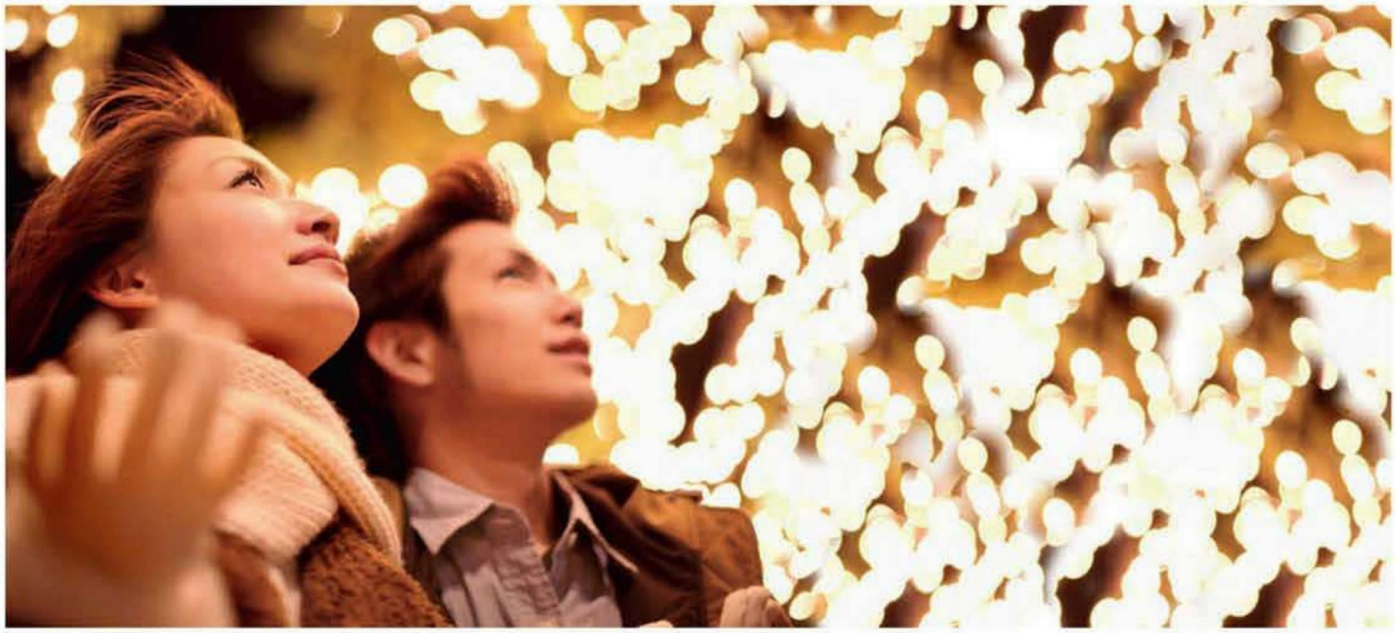


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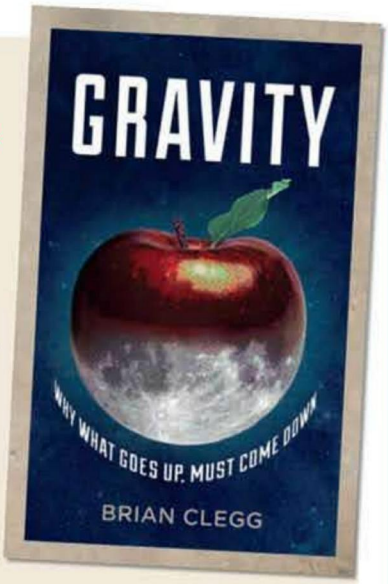


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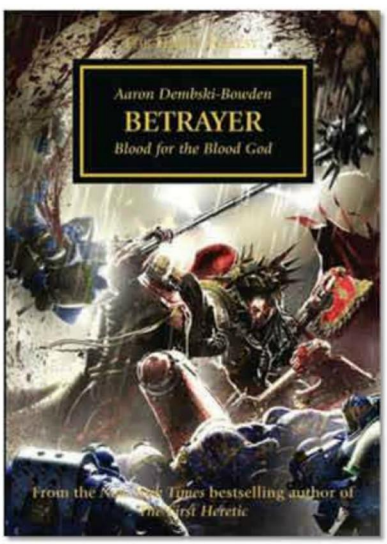
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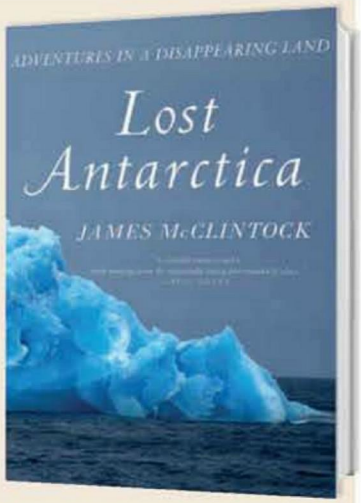


***Betrayer* is exclusively available from blacklibrary.com and Games Workshop Hobby Centres. Check out the full range here:**

blacklibrary.com/horus-heresy

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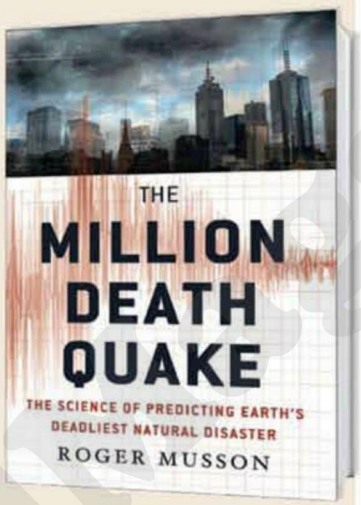
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– Bill Gates

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touchscreengloves.co.uk



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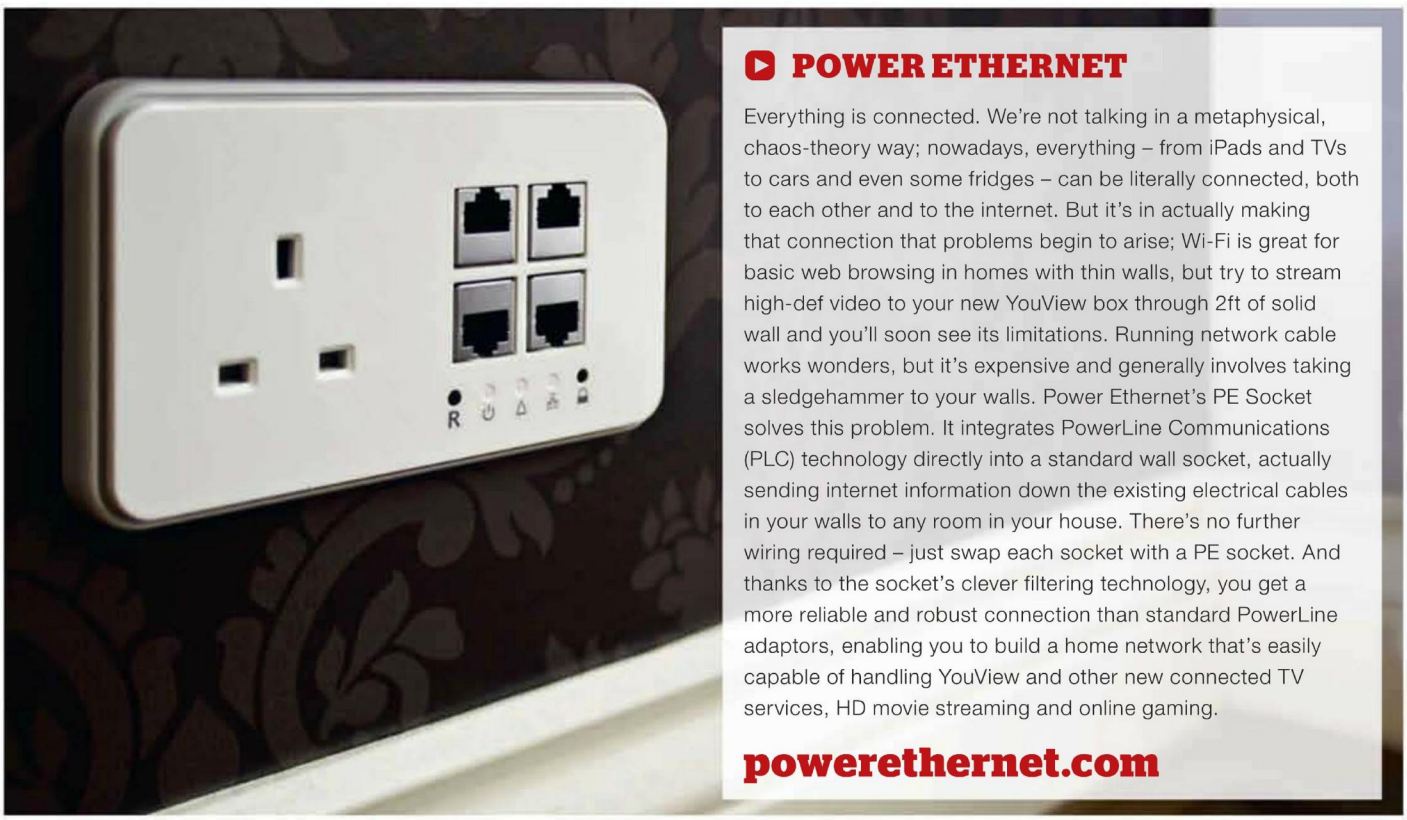


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touchability.co.uk



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Everything is connected. We're not talking in a metaphysical, chaos-theory way; nowadays, everything – from iPads and TVs to cars and even some fridges – can be literally connected, both to each other and to the internet. But it's in actually making that connection that problems begin to arise; Wi-Fi is great for basic web browsing in homes with thin walls, but try to stream high-def video to your new YouView box through 2ft of solid wall and you'll soon see its limitations. Running network cable works wonders, but it's expensive and generally involves taking a sledgehammer to your walls. Power Ethernet's PE Socket solves this problem. It integrates PowerLine Communications (PLC) technology directly into a standard wall socket, actually sending internet information down the existing electrical cables in your walls to any room in your house. There's no further wiring required – just swap each socket with a PE socket. And thanks to the socket's clever filtering technology, you get a more reliable and robust connection than standard PowerLine adaptors, enabling you to build a home network that's easily capable of handling YouView and other new connected TV services, HD movie streaming and online gaming.

powerethernet.com



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THE FUTURE OF GADGETS

TECH HUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

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Gaming edges ever nearer to total immersion with the Oculus Rift virtual reality headset

ON THE HORIZON

OCULUS RIFT

Virtual reality headsets debuted back in the early '90s, when the film *The Lawnmower Man* gave the world a glimpse of the future. And then... everything went a bit quiet. Well, now virtual reality is about to become every gamer's reality, thanks to the Oculus Rift.

It's the most advanced headset to date and crucially it won't break the bank. In fact, experts are tipping it to be the first VR headset that could have mass appeal.

The first thing you'll notice when you wear the Rift will be its field of view. It's massive. While other headsets show a screen floating in the distance – a bit like sitting at the back of an empty cinema – this one drops you right in the action. Previous attempts at a VR headset have only offered a 40° field of view, but the Rift gives you 110°, which is more like having a front row seat in the cinema. And it's all in stereoscopic 3D thanks to a dedicated screen for each eye.

Immersion is the goal here. The headset tracks the movement of your head so that you can look around virtual worlds. Its creators say there'll be zero lag between your movements and those of your virtual character, which will be pivotal in creating a truly convincing virtual reality experience. If they can



Wearing a mask in your living room is a fairly embarrassing prospect, but the proposed look of the Rift is suitably cool

achieve this, the Rift will truly distinguish itself from predecessors and make for an unparalleled gaming experience.

And it looks like the Rift might deliver. Gaming luminaries like John Carmack (creator of *Doom* and *Quake*) and Gabe Newell (the man behind *Half-Life*) have had their first play with the prototypes and have been whole-heartedly getting behind the project and offering their support. Indeed, Carmack has tailored a version of first-person shooter *Doom 3* for the device, while the team behind online mech sim *Hawken* (previewed on p117) has developed a special cockpit view for use with the Rift.

The initial funding came from Kickstarter and the reaction was nothing short of phenomenal: it hit its $250,000 (£154,808) target in one day, and so far has raised almost 10 times that sum. When it goes on sale towards the end of next year, we anticipate that the headset will cost around $300 (£185), which is the price of an early version that's being sent to developers.

At this price, the Rift could alter the gaming landscape. "It's going to completely change the way people make games and how we play them," says Peter Firth, an analyst at The Future Laboratory, a trend-forecasting consultancy. "Virtual reality headsets have cost around $20,000, so for the Rift to come in at a few hundred dollars is unprecedented. It's similar to what we've seen with 3D printers: the early models are prohibitively expensive, but as the technology improves, the price comes down."

Game changer

The Rift is part of a new wave of virtual or augmented reality gear. Sony has launched its £800 HMZ-T1 Personal 3D Viewer, and Google will unleash its Project Glass specs in the next couple of years. Sony's viewer is for movies, while Project Glass promises to bring online connectivity to your everyday vision. This leaves the Rift to clean up when it comes to games. With plenty of industry buzz and technical advancements that leave the competition behind, we can't wait to see if it heralds a new era of gaming when it's released next year.

WWW.OCULUSVR.COM

JOE SVETLIK is a technology news reporter for CNET and TechRadar

ILLUSTRATOR: LAUREN GENTRY

TECHOMETER



WHAT'S HOT

FASTER WI-FI

The first products carrying the new Wi-Fi standard – known as 802.11ac – will be on sale this month from the likes of Netgear, D-Link and Belkin. With a name like '802.11ac' you'd be forgiven for thinking 'so what?', but these new routers will be technically able to ferry data around your house 10 times faster than current Wi-Fi kit. All new Wi-Fi-enabled devices, like laptops, tablets and smartphones will start to carry the new chipsets early next year.

WHAT'S NOT

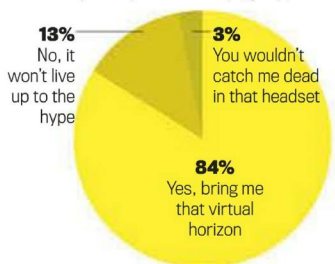
3D TV

Both Sony and Samsung have admitted that sales of their 3D TVs have been disappointing this year. Although more 3D TVs have been bought this year – perhaps because almost all new sets carry the technology – consumers haven't adopted 3D as quickly as the industry had hoped. Fergal Gara, the head of Sony UK, said that since the tech isn't popular with consumers right now, they'll be focusing on other avenues, like their new 4K resolution TV.



READER POLL

Is virtual reality the future of entertainment? Here's what our readers have said so far. Add your opinion at http://j.mp/oculuspoll





EARLY ADOPTER

BILL THOMPSON

How to create order from digital chaos

The other week I went to a party with my son's high-end camera and filled an eight gigabyte memory card with photographs. As a result I've now got another 300 photos to upload, review and label.

It will probably never happen. I've imported them into iPhoto and created an 'event', but I haven't even had time to look at them all, let alone tag the people or places, so they can't be indexed or searched.

It isn't just photographs. My hard drives and memory cards are stuffed with files whose names may once have been meaningful, like '2012 FIAT IFTA', but are unlikely to remain so for long, adding to the digital debris that surrounds us all.

This is not just a challenge for me, as I try to keep on top of work, friendships, family life and day-to-day admin, but a challenge for the wider internet society. If we don't find ways to keep track of the things we are creating and storing digitally, then we are in as much danger of losing our connection to the past as the librarians of Alexandria proved to be when Julius Caesar burned the place to the ground in 48BC.

The answer is metadata, or 'data about data'. Tags, descriptions, catalogues and indices are the only way that we can track the vast amount of data we all generate and the only way you – or future digital archaeologists – are going to find the photos from last year's holiday in Budapest or that important letter to your brother.

The sad reality is that the only way to ensure that your personal digital life is properly catalogued is to do it yourself, because nothing but self-discipline can sensibly rename thousands of images named IMG_0001.JPG through to IMG_9999. However, it



would be nice to get some help from the same tools that created the problem.

Happily, help is at hand. My music library is a mess, in part because the CD details are not accurately associated with the files when I rip a CD I've bought, and I can't be bothered to add it myself. However, new cloud-based music services like Amazon's Cloud Player and Apple iTunes Match try to identify the music that you provide them by searching their massive databases. In the process they clean up the catalogue data, and there's hope that we might be able to do something similar with our personal information. Services like Mendeley are already trying to do something similar for academics and researchers, by creating reference libraries as research is carried out.

Facebook and Google+ already offer to identify people in your photos as you upload them, and though the tagging only lives on the social networks, the software could be more widely distributed. For example, Samsung's new Galaxy III smartphone offers to identify faces in your photos once you've taken them.

The privacy implications of having everything scanned and indexed by third parties are horrendous and we shouldn't assume they can be overcome easily, meaning that an organised life might come at the cost of privacy. Who knows, there might even be scope for a whole new service industry offering 'digital cleaning' to iron out wrinkles in your metadata, as well as your shirts.

Then again, we might find the world a less interesting place if we lost those serendipitous discoveries that lie at the source of creative imagination. Perhaps we shouldn't seek order everywhere after all.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

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Visit our forum at sciencefocus.com/forum

COMING SOON

3 MONTHS

BASIC BAND



Forget using a pedometer to keep track of your health, the Basic Band combines a heart rate monitor, accelerometer, thermometer and a galvanic skin response sensor to accurately monitor your health. It enables you to see how well you're sleeping, how many calories you're burning and even how things like coffee or exercise affect you during the day. *Mybasis.com*

+ **Vaio Tap 20** This 20-inch touchscreen desktop PC can be unplugged and carried around your house like a giant tablet. *Sony.co.uk*

+ **Lytro** The camera that lets you select your focus *after* the shot is taken. *Lytro.com*

6 MONTHS

PEBBLE WATCH



The Kickstarter-funded Pebble watch connects to your iPhone or Android smartphone. Its E-ink display can be customised with a host of apps and it alerts you to incoming calls and emails by vibrating. Oh, and it also tells the time! *http://getpebble.com/cart*

+ **Intel Clovertrail** Codenamed Clovertrail, Intel's new generation of mobile processors will power next-generation laptops and tablet computers, giving them longer battery lives and faster interfaces. *Intel.co.uk*

+ **Nest** A thermostat that could slash your bills. It adapts to your habits to heat your home economically. *Nest.com*

9 MONTHS

WINDOWS 8 PHONE



Now that Microsoft has its own tablet, named Surface, about to hit shelves, the computing giant will want to build on its ecosystem based around Windows 8. A number of 'inside sources' at chip manufacturers have revealed that a Microsoft branded phone is in the works. *Microsoft.com*

+ **Project Glass** Messages, maps and information from the web will all be overlaid on top of your view with Google's new vision for the internet. *J.mp/projectglass*

+ **Xbox 720** Leaked documents, Microsoft job vacancies and one controversial eBay auction, all point to a release next year for the console that's been codenamed 'Durango'. *xbox.com*

JUST LANDED

CONTROL FREAK



Nintendo's new console arrives for Christmas, boasting HD graphics and a hefty touchscreen controller – but is it any good? Neon Kelly plays with the Wii U

How is this a step up from the Wii?
The Wii U is the most powerful machine Nintendo has ever produced. It's also the company's debut HD console and the first to offer an online service in the same vein as the PlayStation Network or Xbox LIVE. But never mind all that: the main talking point is the new tablet controller.

The Wii GamePad is like a cross between an iPad and a standard twin-stick device. It's less sexy than Apple's supermodel but surprisingly light and solidly made. The controller's hand-grips are further apart than we're used to, and the pad ultimately feels like a collection of familiar elements arranged in an alien configuration.

What is the tablet used for?
In many cases the GamePad simply serves as an additional screen, displaying information that might normally clutter the space on your TV; expect to see a lot of interactive maps and inventories. More exciting is the option to use it as your main window on the action: if your flatmate wants to watch *Come Dine With Me*, you can surrender the TV and continue playing on the pad's 6-inch display. However, at the moment only select games are supporting this feature.

Nintendo is banging the drum for something it calls 'asymmetrical gameplay'. This involves one player using the GamePad while their friends wield Wii Remotes. In *Rayman Legends*, for example, the GamePad player takes on a guardian angel role, using the touchscreen to raise or lower bits of the level.

What is it like to play?
While we're all used to HD graphics these days, it's surprisingly pleasing to finally see Mario and co looking all smart and crisp. There's also much to admire in the early takes on asymmetric play, too. *Nintendo Land* finds the tablet player controlling a ghost who remains invisible to everyone else, and it's oddly satisfying to play separately.

As with the original Wii, many launch games have a tendency towards gimmickry, using the touchscreen for novelties that will soon lose their lustre. *Zombi U* may be the first game to let us rummage in a virtual backpack on the GamePad, but that's hardly something we've all been waiting for.

Read up on individual games before you open your wallet, because in the early days there's bound to be a lot of shovelware.

Should I get one?
Many of the Wii U's launch titles can also be played on the Xbox 360 and PS3, while the big exclusives – *Bayonetta 2*, and a 3D *Mario* effort – feel far off. You should bide their time until Nintendo proves its case.

The Wii U boasts some impressive tech, but there's no equivalent to the original Wii's *Wii Sports* – no single game that sells the machine's potential. The first Wii was instantly iconic; as strange as the GamePad may be, it feels far less revolutionary.

NINTENDO WII U
£249, WWW.NINTENDO.CO.UK

NEON KELLY is deputy editor at Videogamer.com

THE FIVE BEST LAUNCH GAMES



Nintendo Land
Use the GamePad to steer an invisible ghost, Samus's gunship, or a mob of Pikmin in this minigame collection.



New Super Mario Bros. U
Mario is back. Get stuck and a chum on the GamePad can build platforms for you.



Mass Effect 3
BioWare's sci-fi opus is one of 2012's classics... and now the GamePad lets you issue commands to your team.



Zombi U
A survival horror effort set in London. Use the tablet to access your backpack and unlock doors.



Assassin's Creed III
Action-adventure in 18th Century America, with the tablet serving as a radar in naval battles.



APPLIANCES OF SCIENCE

1 CRASH DUMMY

In the event of an impact the ICEdot helmet sensor sends a signal to your phone – which will hopefully still be in one piece – letting it know that you've been in an accident. 'What's the point in that?', you may ask. Well, the phone's app will then send data from the sensor, which includes the force of the crash in Gs and your GPS location to your selected emergency contacts.

ICEdot Crash Sensor
Icedot.org; TBC

2 EMPEROR'S CLOTHES

This unique case creates a vacuum seal around the bits of your iPad that are vulnerable to water, leaving the screen completely bare. This means that you can use your tablet underwater – well, let's be honest, in the bath – without sacrificing the touchscreen's responsiveness or brightness. We've tried one and it does work, but we have to warn you, it's only for the very brave.

LifeProof nüüd case
www.lifeproof.com; £93.10

3 GREEN FINGERS

Some foliage will always brighten up a home, but there are those of us who can't deal with the responsibilities of owning a fern, which is where this self-sustaining plant pot comes in. Just add batteries and fill the water tank, and the Click and Grow box will release fertilizer and water according to a strict schedule. Titchmarsh had better watch out.

Click and Grow
Clickandgrow.com; from $23.88 (£14.79)

4 MAGIC WAND

Remember universal remotes? While they promised god-like omnipotence over your household tech, there was always the danger of turning your stereo on every time you wanted to change the TV channel. Logitech has rectified this, by adding Wi-Fi, Bluetooth and USB connectivity. It's also replaced most of the buttons with a touchscreen, plus it learns your favourite channels and settings.

Logitech Harmony Touch
Logitech.com; £199.99

5 HOT DESK

The super-fast transfer speed of USB 3.0 has enabled a new type of product called the 'Windows To Go' drive. The idea is that you can plug this into any computer running Windows 8 and it will start your very own session of the operating system, complete with all your personal preferences, security settings and files. It's able to read data at 250MB/s.

Kingston DataTraveler WorkSpace
Kingston.com; price TBC

6 REVERSE ENGINEERING

Millions use the Instagram app to make their pictures look like they've been taken with an instant camera. So it was only a matter of time before a physical add-on that actually turns your iPhone into a facsimile of a vintage Polaroid camera was made. And here it is, the Impossible Instant Lab. It turns digital images into physical ones at your iPhone wherever you are, complete with '70s filters.

Impossible Instant Lab
the-impossible-project.com; price TBC

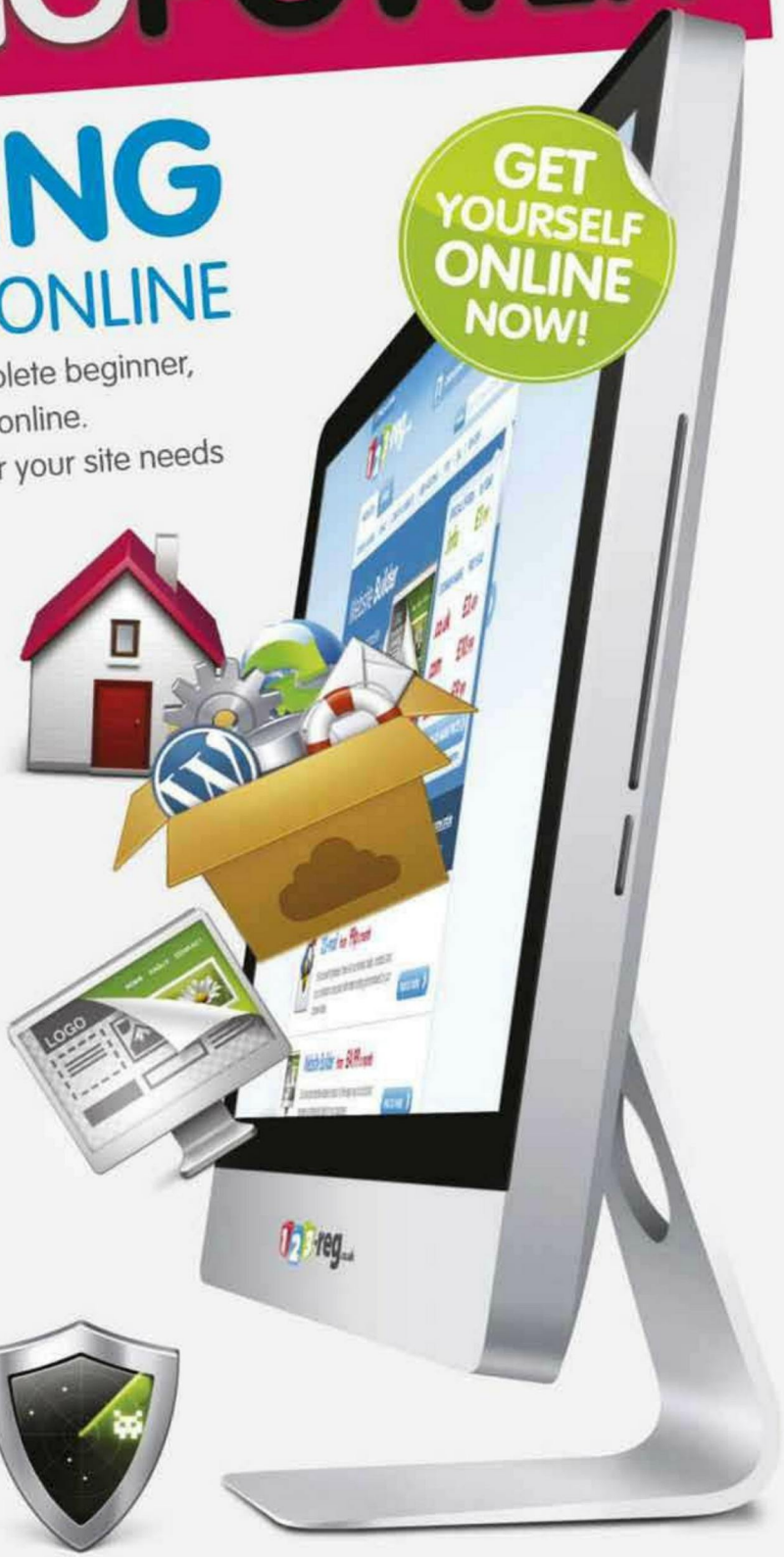
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ULTIMATE TEST

EREAD ALL ABOUT IT



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In addition to books, most eReaders now let you view a broad range of document formats, including PDFs, Word docs and html pages, and most will do some limited web browsing. Newspapers, magazines and other periodical titles are also increasingly bringing out subscription services for eReader users.

WHY DON'T I JUST BUY A TABLET COMPUTER?

Unlike traditional LCDs, electrophoretic (E-ink) displays are built for reading. They're designed to work entirely with ambient light, making them as easy to read as real paper. Because there's no backlight, their batteries will last for weeks, and long reading sessions won't tire your eyes.

PHOTO: STUDIO4PHOTO.CO.UK

WorldMags





KOBO GLO

Kobo.com, £99.99

This might look like just another Kindle clone at first glance, but as soon as you pick it up, the Glo takes on a personality of its own, far removed from the Kindle's shadow. Its textured plastic back may look odd but it feels more secure when holding the device. The customisable home screen that allows you to view your library of downloads by their artwork is a breeze to use, and the same is true of the cross-platform apps which work seamlessly to let you pick up on your phone or tablet where you left off on your eReader. Kobo's store is pretty extensive too, with millions of books available, many of them for free; however, accessing those from external sources such as Project Gutenberg is less than intuitive. And frustratingly, despite being set up for newspapers and periodicals, the store still has no content.

As for the flagship Glo feature, which lights up the screen in front of the image to make it easier to read in the dark – well, it does the job. The Kobo lets you control how bright you want it, and will turn it off to spare the battery if you accidentally leave it on. But personally I'd rather just turn a light on...

FOCUS RATING ■■■■□

SONY READER

Sony.co.uk, £119

In a world where buttons are in short demand, Sony has dug its heels in, offering not one but five to assist with navigation on its latest touchscreen Reader. And surprisingly, even ardent touchscreen evangelists will find it difficult to deny that they help.

However they do come at a cost, making the overall size of the Reader noticeably longer than its contemporaries. The icon-based user interface is easy to use, as is Sony's Reader Store, with many titles on offer for just 20p. But this is let down by the search feature, which can be frustratingly random in what it turns up. The Reader also comes with a stylus that allows you to jot down notes and make annotations. This by itself is only so useful, but Sony has provided support for Evernote, a popular cross-platform app that enables notes to be synced wirelessly with other devices. The fact that there is nowhere on the device to store the stylus seems like a remarkable oversight, or possibly a cynical ploy to make you buy a case, but this is slightly made up for by the fact that the device seems to be just that little bit more powerful in terms of processing power and how fast the pages turn.

FOCUS RATING ■■■□□

E-INK: THE NEXT GENERATION

This Christmas, eReaders have been rebooted with the new front light technology included in the Kobo and the Kindle. But what will be the next big advance in eReader technology?



TECHNOLOGY: Colour-based Triton
WHEN? 2013
E-ink displays work by suspending black and white charged particles in fluid-filled cells and using electric fields to control which appear at the front. With Triton, it's the same except that each cell has either a red, green or blue filter. This works, but results in a threefold reduction in the resolution.



TECHNOLOGY: Mirasol displays
WHEN? 2013
Currently used on the Japanese reader Kyobo in Asia only, this is a whole new approach to low-power screens. Each pixel consists of a red, blue and green sub-pixel of tinted glass, with a reflective sheet underneath. To create different colours the distance between the two is altered, making each pixel darker or lighter.

PHOTO: STUDIO4PHOTO.CO.UK



ARCHOS 70D

Archos.com, £59.99

Turn on an Archos 70d eReader and, after looking at the E-ink displays of the other devices, it's hard not to feel like Dorothy stepping into the Land of Oz. Even when just reading text the screen effuses colour, and your eyes willingly lap it up. But there the thrill ends. The Archos 70d is positioned as an affordable eReader with added multimedia features, and sadly it works as neither. Some may be willing to forego a long battery life in favour of a colour screen and video playback, but the Archos interface makes the device almost unusable. Instead of a touchscreen you're left to try to navigate the device with a set of counterintuitive buttons on the side of the device. One, for example, looks and feels like a trackball, but turns out to be just a very small button that's hard to press without actually deselecting what you want. Even if the buttons worked, the interface is clunky.

As an eReader there is no wireless connectivity or bookstore support – you have to download files to your computer and drag them to the device – and as a media player the screen quality is poor and the controls difficult to work.

FOCUS RATING ■□□□□



AMAZON KINDLE PAPERWHITE

Amazon.co.uk, £109

The first thing you notice about the Paperwhite is its lack of buttons. This is no bad thing, though: with just a single power button on the case, all other features are simply controlled through an intuitive touchscreen interface. Turned on, the Paperwhite tech – a fibre optic cable laid into the glass itself – creates a much more evenly lit surface than the Kobo, making for a better reading experience. Books, papers and magazines are quick and easy to find and buy through Amazon's well-designed, browser-like store. Once you've downloaded your books, they're presented in a grid with the cover artwork on display, and there are plenty of snazzy features, including 'X-ray' which will let you search for themes and characters within a book, and 'Time to read' which estimates how long it'll take you to read a title.

The Paperwhite does have its flaws, though. The cross-platform app that lets you download Kindle content to your smartphones and tablets is niggly to set up and doesn't always work as you'd expect. The build doesn't feel quite as sturdy as the Kobo and the Paperwhite just isn't as nice to hold in your hand.

FOCUS RATING ■■■■□



TECHNOLOGY: Dual-screen readers
WHEN? 2014
Amazon has patented a screen that would allow for a hybrid between its LCD-based Kindle Fire tablet and its eReaders. For reading, the E-ink screen is easy on the eyes and battery; then for video or web surfing, you could flip over to the LCD.



TECHNOLOGY: Xerox Fuji E-ink
WHEN? 2014
Xerox Fuji has found a way to do away with colour filters altogether, by including three different coloured particles inside the same fluid-filled cells. It does this by giving each yellow, magenta or cyan particle type a different charge threshold, so it will respond to a specific intensity of electric field.



TECHNOLOGY: Electrowetting
WHEN? 2015
This system is the brainchild of Dutch company Liquavista, now owned by Samsung. It uses electrical fields to control the movement and shape of microscopic droplets of oil. The coloured pixels beneath can then be obscured or revealed at speeds that would allow for video.

Dell recommends Windows.

intel inside
CORE i3
Ultrabook
Inspired by Intel

This is the story of a boy, a girl and 30 million billion stars.

Billy and Charlotte were inspired by the same great love: stargazing
So what better gift for her than a few billion stars?

With a snap of his camera and a download on his Inspiron 14z laptop
Billy captured the entire cosmos and sent it to her.

Now Charlotte could stargaze whenever she wanted.





Give them the gift of inspiration.
With Intel® Core™ i3 processor and powerful graphics, the thin, fast Inspiron 14z Ultrabook™, inspired by Intel, helps them always reach for the stars. Find the perfect gift at **dell.co.uk/inspiron**

DELL
The power to do more

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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

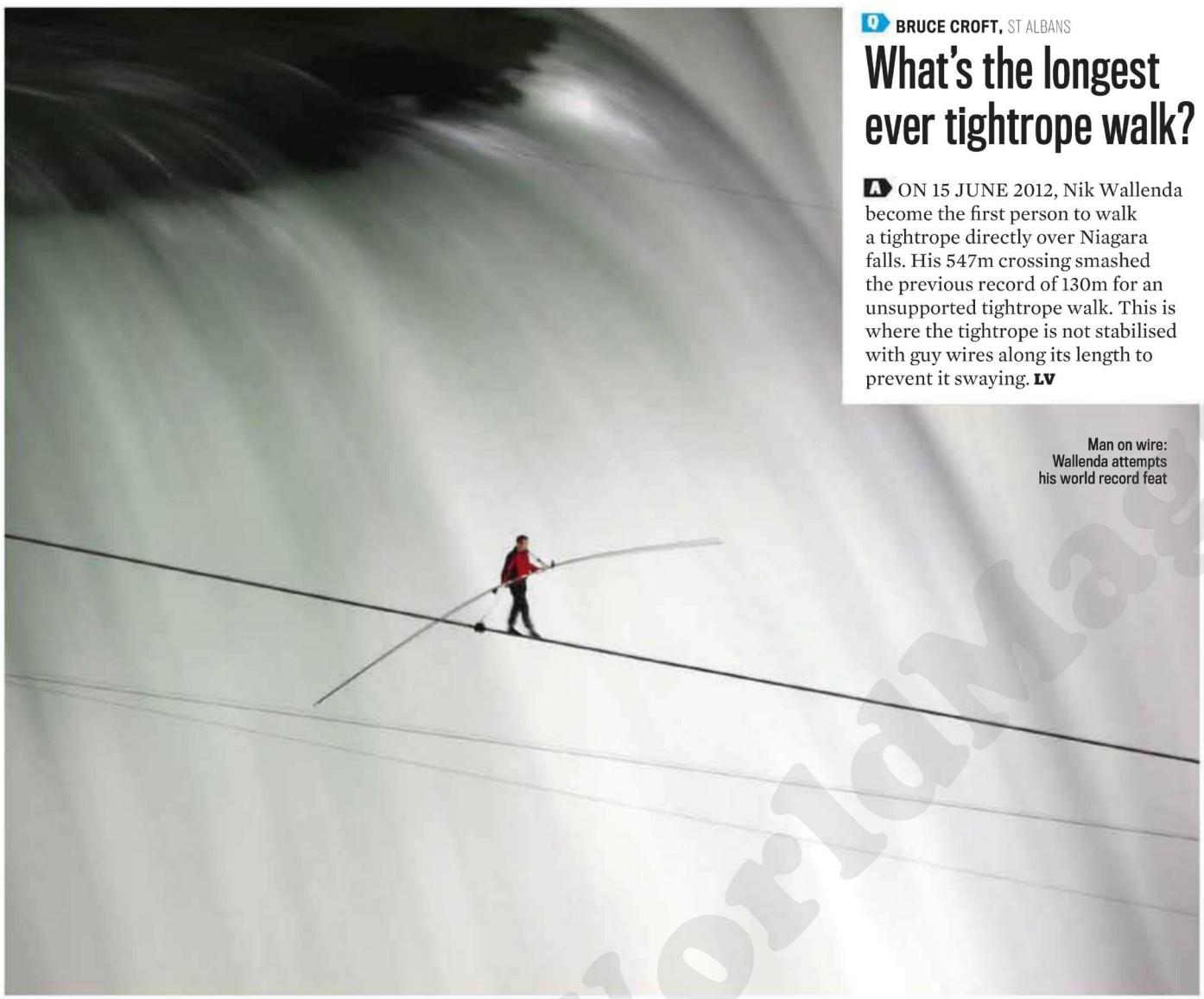


GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



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 BRUCE CROFT, ST ALBANS

What's the longest ever tightrope walk?

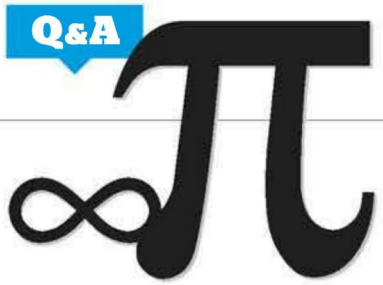
A ON 15 JUNE 2012, Nik Wallenda become the first person to walk a tightrope directly over Niagara falls. His 547m crossing smashed the previous record of 130m for an unsupported tightrope walk. This is where the tightrope is not stabilised with guy wires along its length to prevent it swaying. **LV**

Man on wire: Wallenda attempts his world record feat

PHOTO: PRESS ASSOCIATION

Worldmags

Q&A



MAX PARIS, OXFORD

How do we know that Pi is infinite?

MANY PEOPLE KNOW that the value of Pi is roughly 22 divided by 7, which is around 99.96 per cent accurate – plenty good enough for most practical purposes. But in 1768, the Swiss mathematician Johann Lambert revealed the remarkable fact that it's impossible to use any such fractions to pin down the precise value of Pi, as it just goes on forever.

To prove it, he showed that Pi is not a 'rational' number – that is one the exact value of which is given by the ratio of two whole numbers. Rational numbers can be turned into decimal numbers that either stop after a few places (like 1/8 = 0.125) or just keep repeating after a certain number of places (such as 4/7 = 0.571428571... and so on). By showing that Pi is not a rational number, Lambert revealed that its decimal value neither stops nor cycles – but just carries on to infinity. **RM**

In Numbers

560 million

page edits have been made to Wikipedia since its launch in January 2001

DEREK BUCKLEY, AUSTRALIA

What happens when a volcano erupts underwater?

THREE QUARTERS OF the magma that erupts from the Earth's crust does so under the sea. If a volcano erupts close to the shore, in shallow water, it can fire rock and lava with enough force to break the surface and form a new island. Most undersea volcanoes lie in deep water though, and behave quite differently. Below 2,200m, the pressure is so great that water can't boil and behaves as a supercritical fluid, something with the properties of both a gas and a liquid. The volcano spews clouds of black minerals in almost complete silence and the lava emerges as a series of lumpy pillows, rather than an even flow. The lava cools much more rapidly underwater and doesn't have time to form a crystal structure, becoming volcanic glass instead.

Since the lava doesn't flow far, volcanic mountains rise very steeply and eventually reach the surface. Hawaii is an island chain formed in this way. **LV**



Deep water volcanic activity can have beautiful results, such as the island chain of Hawaii

STEVE VARMAN, FELTHAM

What makes something transparent?

WHETHER A SUBSTANCE is transparent depends on how light interacts with its atoms. If they're of the right frequency, an atom's electrons can absorb photons of light, making the matter opaque. However, the atoms of transparent matter enable photons to pass through. **RM**

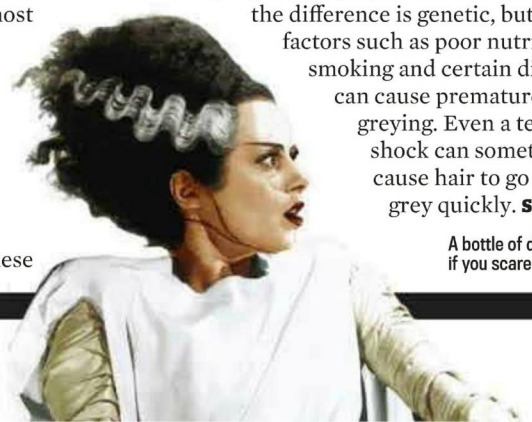


Water enables light to be transmitted through it

ANGELA SMITH, SOUTHAMPTON

What causes hair to turn grey?

GOING GREY IS the result of reduced amounts of melanin in the hair, a pigment found in almost all organisms, not just in humans. It is the same compound that tans your skin in response to sunlight. In one form, eumelanin, it results in brown or black hair, while pheomelanin is responsible for red hair and freckles. These are produced in special cells called melanocytes that are found within the hair follicles in the skin. As people get older, their melanocytes become less active and produce less and less melanin, until they finally die and are not replaced. Hairs then grow without any colouring and are transparent. The age at which people turn grey varies widely. Most of the difference is genetic, but other factors such as poor nutrition, smoking and certain diseases can cause premature greying. Even a terrible shock can sometimes cause hair to go grey quickly. **SB**



A bottle of dye can help if you scare easily

PHOTO: THINKSTOCK X2, SCIENCE PHOTO LIBRARY, NASA, REX

WINNER! Stuart wins a copy of *International Space Station – Owner's Workshop Manual* (Haynes, £21.99)



QUESTION OF THE MONTH

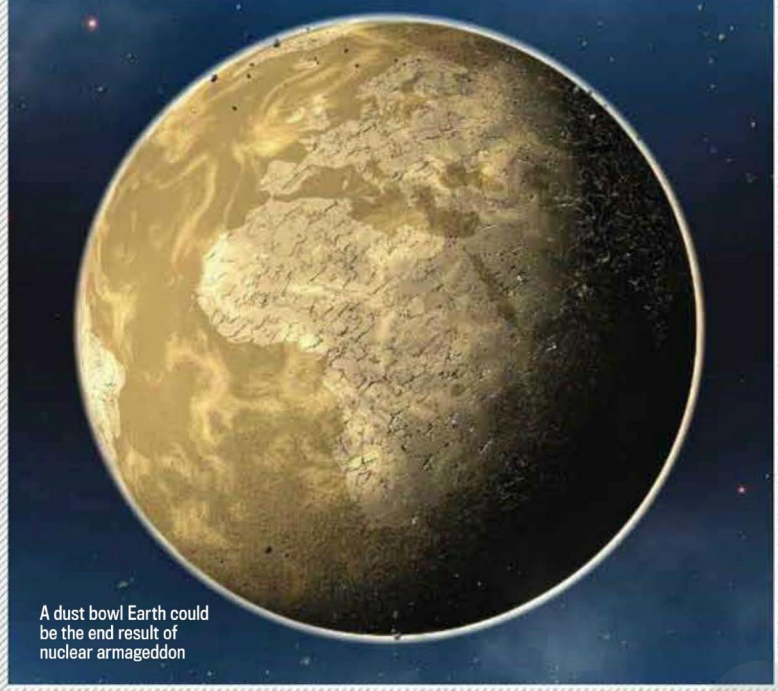
STUART BYE, FAREHAM

What would happen if all the nuclear bombs were detonated?

ALTHOUGH EXACT figures are secret, the Federation of American Scientists estimates there are around 19,000 nuclear warheads, 95 per cent of which are Russian and American – the UK has around 200.

Their explosive power varies enormously: the strategic thermonuclear weapons of the superpowers pack a punch measured to be equivalent to several million tonnes of TNT (1 million tonnes of TNT is a megatonne), while warheads tested by India and Pakistan are around 100 times less powerful.

But assuming every warhead had a megatonne rating, the energy released by their simultaneous detonation wouldn't destroy the Earth. It would, however, make a crater around 10km across and 2km deep. The huge volume of debris injected into the atmosphere would have far more widespread effects. This 'aerosol' of particles would reduce the amount of heat reaching the surface from the Sun, producing a so-called nuclear winter with huge environmental impact. The nuclear explosion would also unleash a pulse of electromagnetic energy that would wreck everything from national power grids to microchips around the world. **RM**



A dust bowl Earth could be the end result of nuclear armageddon



It really is a starry night with a septillion stars out there

JOHN HARLEY, CUMBRIA

Why aren't there more stars?

ASTRONOMERS ESTIMATE there may be 1 septillion (10^{24}) stars in the observable Universe. As huge as that number is, our understanding of how clouds of gas and dust collapse to form stars says there should be 10 times as many. However, recently researchers in the US found a weak magnetic field in a distant cloud disrupting star formation, which could explain the discrepancy. **AG**

NICKY STAFFORD-WATSON, SOUTHAMPTON

How do monitor privacy screens work?

SCREENS THAT SHIELD the view of a monitor from passers-by are made of alternate layers of a transparent and light-absorbing polymer. The light-absorbing layer has tiny acrylic resin structures called microlouvers. These microscopic venetian blinds only let light pass within a narrow angle. **GM**

PETER WALTON, LANCASHIRE

How does my mobile 'know' I'm abroad?

WHEN YOU GET off the plane your phone connects with the host network. The visited provider notes that you are not registered with it and connects to your home provider through the phone's International Mobile Subscriber Identity number. Once the networks are talking to each other, the foreign provider finds out whether your contract allows roaming. **GM**

TOP TEN
HIGHEST MOUNTAINS



1. Everest (Nepal)
8,848m (29,029ft)
First climbed on 29 May 1953 by Edmund Hillary and Tenzing Norgay.



2. K2 (Pakistan)
8,611m (28,251ft)
It was first climbed in 31 July 1954 by an Italian team.



3. Kangchenjunga (India/Nepal border)
8,586m (28,169ft)
First climbed 25 May 1955 by a British team.



4. Lhotse (Nepal)
8,516m (27,940ft)
A Swiss team were first to scale the mountain on 18 May 1956.



5. Makalu (Nepal/ Tibet border)
8,481m (27,825ft)
A French team were first up on 15 May 1955.



6. Cho Oyu (China/Nepal border)
8,201m (26,906ft)
First climbed 19 October 1954 by an Austrian team.



7. Dhaulagiri (Nepal)
8,167m (26,795ft)
Conquered on 13 May 1960 by a Swiss/Austrian team.



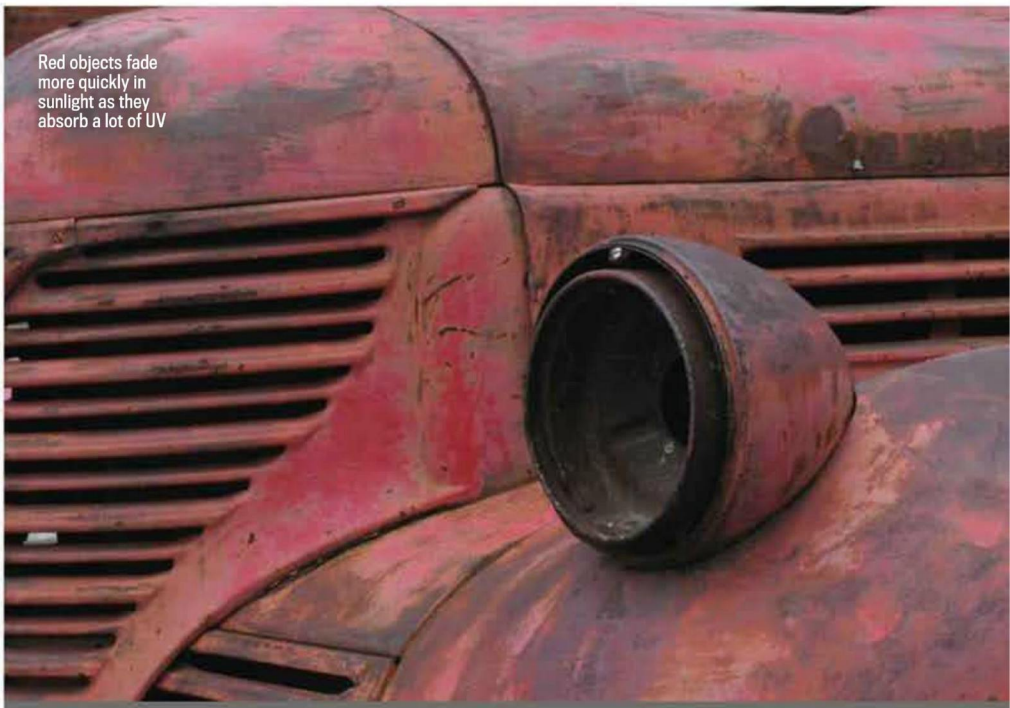
8. Manaslu (Nepal)
8,156m (26,759ft)
First climbed on 9 May 1956 by a Japanese team.



9. Nanga Parbat (Pakistan)
8,126m (26,660ft)
A German/Austrian team were first on 3 July 1953.



10. Annapurna (Nepal)
8,091m (26,545ft)
Its peak was first reached 3 June 1950 by the French.



Red objects fade more quickly in sunlight as they absorb a lot of UV

Q **EMILY RAY,** SUFFOLK

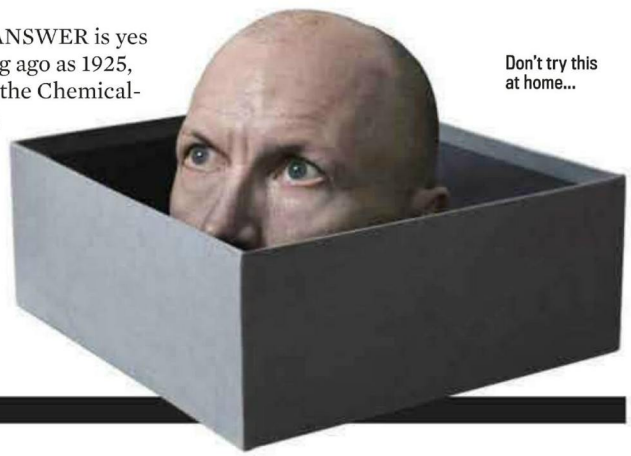
Why does light make things fade?

A SUNLIGHT IS A mixture of different wavelengths of light. The shorter the wavelength, the more energy the photons carry. Wavelengths shorter than about 400nm (the ultra violet range) have enough energy to break the chemical bonds in some compounds. Pigments from natural dyes tend to be quite large molecules with lots of fairly weak bonds. Red pigments fade more readily because they only reflect the lower energy red wavelengths and absorb everything else, increasing the chance of molecular damage. Glass absorbs a lot of the ultra violet, but objects left on a window ledge will still fade over time. **LV**

Q **JACKIE MCLEAN,** GLASGOW

Could a brain be kept alive independently of a body?

A GRUESOMELY, THE ANSWER is yes – at least for a while. As long ago as 1925, Dr Sergei Briukhonenko of the Chemical-Pharmaceutical Institute in Moscow showed that the severed heads of animals could be kept alive for several hours if connected up to a crude version of what became the life-saving heart-lung machine. **RM**



Don't try this at home...

PHOTO: THINKSTOCK, SUPERSTOCK, SCIENCE PHOTO LIBRARY X3, GETTY



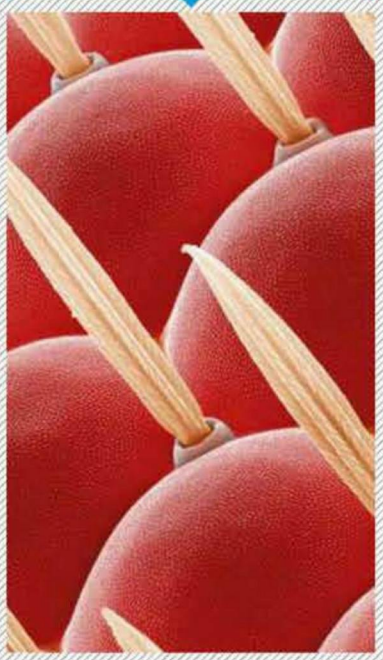
Q **WILL ROBINSON,** MANCHESTER

Why do some voices carry further than others?

A THIS IS BECAUSE they include frequencies of around 3,000Hz (or beats per second), when most human speech is between 80 and 250 hertz. Speech sounds are made by the vibration of two small flaps called vocal folds inside our voice boxes, which interrupt the flow of air from the lungs, producing puffs of air at different frequencies. Additional movements create harmonics at multiples of these basic frequencies. The vibrating air then travels through the throat and mouth up the vocal tract, which amplifies the sound, much as an organ pipe does.

Vocal tracts that are restricted just above the vocal folds tend to amplify higher frequencies. So people with booming voices have vocal folds that produce high frequencies and vocal tracts that amplify them. Some people naturally have voices that carry, but others train themselves to create what is called the 'speakers' formant' to carry their voice further. **SB**

WHAT IS THIS?

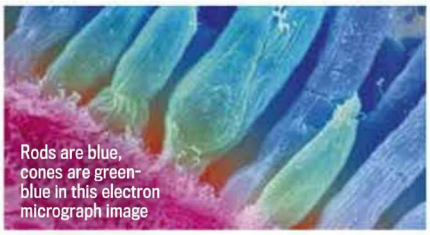


KNOW THE ANSWER?
Go to **sciencefocus.com/qanda/what** and submit your answer now!

LAST MONTH'S ANSWER:
Well done to Kumar Gaurav, who correctly guessed a frozen coniferous tree.

Q **RYAN CAIRNS,** NORTHERN IRELAND

What resolution does the human eye have?



Rods are blue, cones are green-blue in this electron micrograph image

A THERE ARE AROUND 6 million cone cells on each retina and 90–126 million rods. Each receptor cell contributes a single point of information to the image; roughly like a pixel on a screen. So for a single snapshot, your eye's cone cells capture about 6 megapixels of colour information, while the rods manage 100 megapixels in black and white. Most of the cones are clustered around a central point called the fovea and the eye constantly roves to assemble a composite image. Dr Roger Clark of the US Geological Survey has calculated that the eye captures the equivalent of 576 megapixels. **LV**

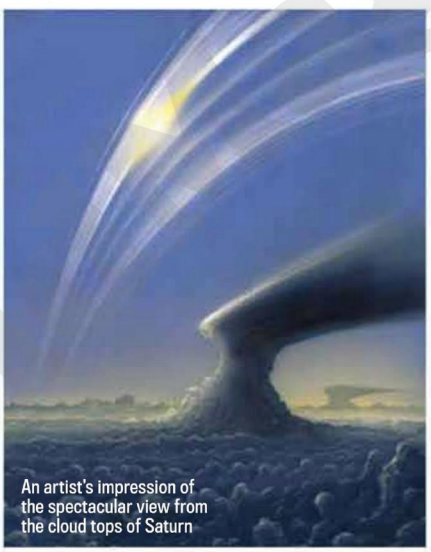
Did you know?
Tsutomu Yamaguchi survived two nuclear bombs. He escaped Hiroshima with burns and was injured the next day in Nagasaki.

Q **HARRIET DOIG,** DUBLIN

If it were possible to stand on the surface of Saturn, how would the rings appear?

A IT ISN'T POSSIBLE to stand on Saturn because the planet is a gas giant and has no solid surface. The 'surface' is actually the tops of dense hydrogen clouds. Assuming you could hover above these clouds, bracing yourself against the ferocious winds, the sky would not look that alien. In the planet's northern hemisphere, the sky would appear blue, very similar to Earth's sky, probably with a yellowish band towards the horizon. Oddly though, while Saturn's northern hemisphere has blue skies, its southern hemisphere does not. Here the skies are cloudier and appear yellow.

You would certainly be able to see Saturn's rings. However, they are so thin that if you were on Saturn's equator, they would be almost invisible. From anywhere else they would appear as a spectacular milky arc spanning the entire sky. The further from the equator you travel, the thicker the arc would appear. **AG**



An artist's impression of the spectacular view from the cloud tops of Saturn

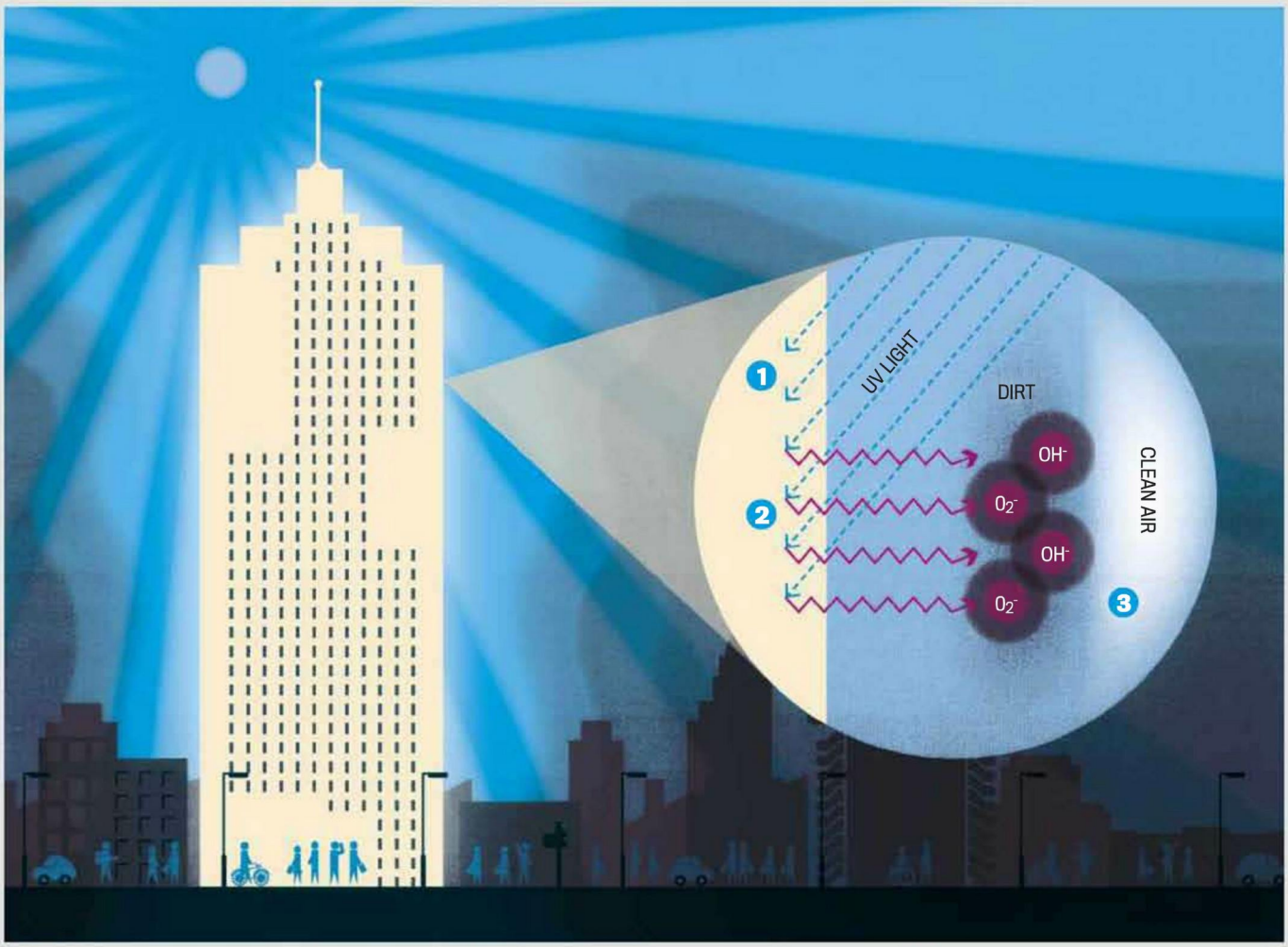
HOW IT WORKS

POLLUTION-EATING PAINT

WITH CITIES LIKE Beijing and Mumbai swamped in pollution, health issues are on the rise. According to the Beijing Health Bureau, lung cancer rates in the Chinese capital were up by 60 per cent over the last decade, despite no increase in people smoking. So a smog-eating chemical paint sounds like the environmental jackpot. Several companies are marketing a coating of titanium dioxide (TiO_2). Sprayed onto buildings, it could help save lives by eliminating smog.

TiO_2 works using a process called photocatalysis, meaning that sunlight shining on the surface kick-starts chemical reactions. When ultraviolet light hits a particle of the paint, it energises the material. The excited state of the electrons leads to a reaction with water and oxygen molecules in the air. Free radical products (particles with unpaired electrons) and negatively charged ions including hydroxyl and superoxide then attack smog-causing chemicals. These organic molecules and nitrogen oxides are broken down in the reaction. The manufacturer EcoClean claims that 930m^2 of its coating has the same air-cleaning capability of 80 trees.

As well as the ability to destroy organic molecules, TiO_2 coatings also wash away the resulting debris. Water forms a thin, even layer over the surface and cuts underneath dirt, allowing it to run off easily. However, applying TiO_2 directly over certain paints results in chalky streaks as it reacts with the material underneath. But by combining the TiO_2 with other minerals and dissolving them in water, sprays can be produced that will turn existing buildings into air purification stations. One day, the tower blocks of busy cities might just save the lives of the people who live there.

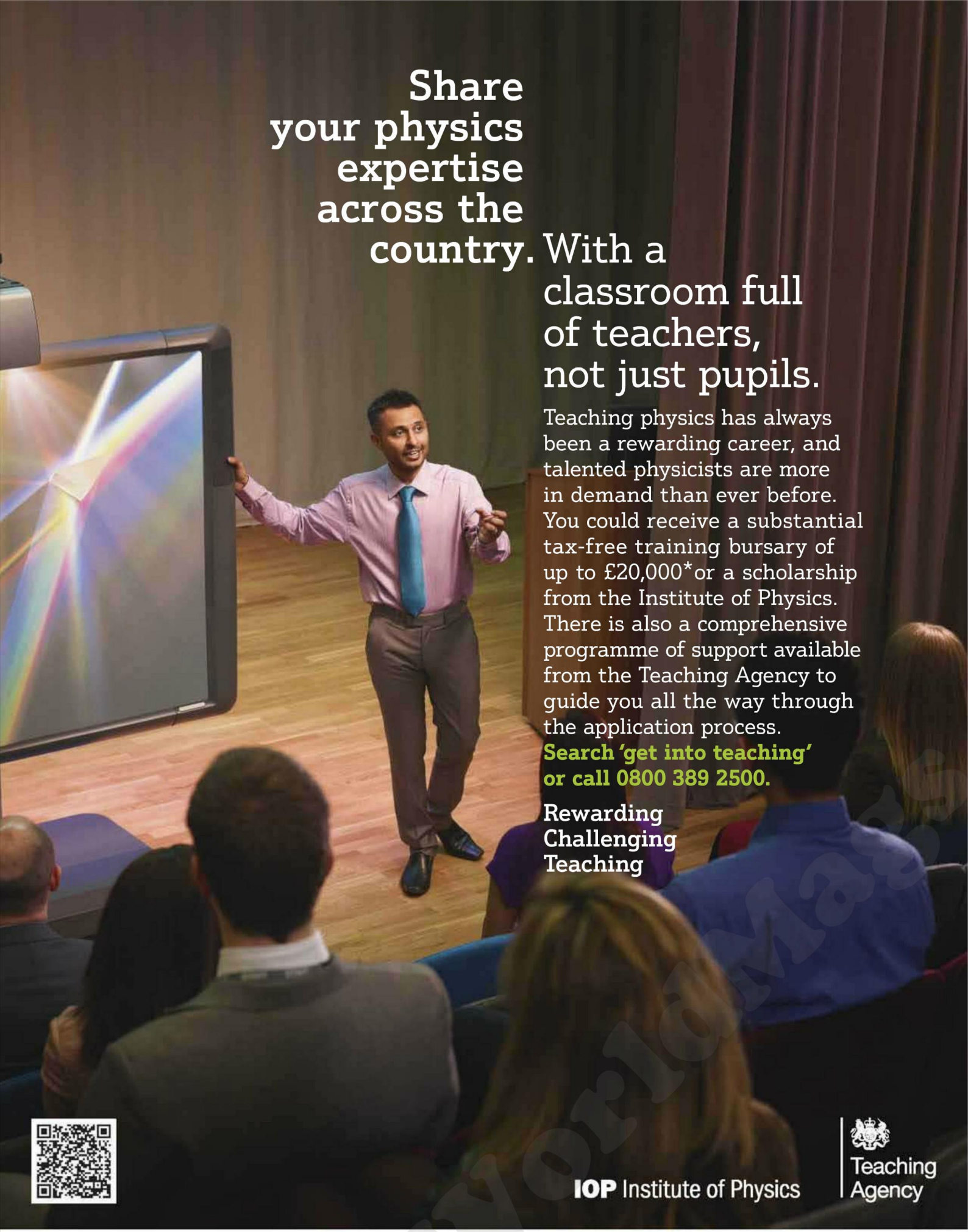


1 UV light from the Sun hits the surface of the titanium dioxide.

2 The energised surface releases the free radicals OH^- and O_2^- from the water and air.

3 The free radicals cut through dirt, leaving the air clean.

ILLUSTRATOR: ANDREW BAKER



*Conditions apply. See education.gov.uk/teachconditions for full details.

GORDON JUDGE, HORSHAM

How do we know how many neurones the human brain has?



86 billion of these enable you to read *Focus*

A THE ONLY way to measure the number of neurones is to count them in a specimen of brain tissue, under a microscope. Since counting every single one would be impractical, measurements are based on extrapolations from small samples of different parts of the brain. The figure commonly given is that we have 100 billion neurones and a trillion glial cells (which provide support to the neurones). But a 2009 study found that the number of each type of cell varies a lot from one region of the brain to another. We actually have about 86 billion neurones and a similar number of glial cells. **LV**

KELVIN YU, MILTON KEYNES

Can fish catch colds?

A NO. THE COMMON cold is caused by any of the nearly 100 different forms of rhinovirus, which all thrive at temperatures between 30 and 35°C. This means that they could not survive in fish because they are cold blooded; they don't maintain a constant body temperature and live in waters cooler than this. There are plenty of viral infections that affect fish, but none could cause anything like the common cold because fish do not have lungs or breathe air and so cannot sneeze, cough or go to bed with an aspirin. **SB**



Tissues wouldn't be very effective underwater

Did you know?

The loudest land animal is the male howler monkey (*Alouatta*) of Central and South America. Its call can travel 4.8km (3 miles).

AARON HACON, NORWICH

Could a human ever be as big as a dinosaur?



We'd have to re-engineer our skeleton to such an extent that becoming as big as a T-rex wouldn't be practical

A WEIGHT INCREASES WITH the cube of height. A 6m T-rex is 3.33 times the height of a 1.8m human, so scaling a 70kg human up increases the weight by 3.33 cubed, which is about 37 times as much, or 2.6 tonnes. But the cross-sectional area of the leg bones only increases with the square of height. So the pressure on each one would be more than three times greater (pressure is weight divided by area and 3.33 cubed divided by 3.33 squared is 3.33). This would fracture your legs if you did anything more energetic than a very careful walk.

Even if we re-engineered a human with legs as thick as an elephant there is still the problem of balance. The bipedal dinosaurs all had huge tails to counterbalance their body weight. Without that, giant humans simply wouldn't be able to bend over without breaking their back. Long before you evolved all the different adaptations that would allow a human to function at this size, you would have created an entirely new species, which couldn't really be called human anymore.

The evolutionary tendency for animal lineages to grow larger over time (called Cope's rule) occurs because animals compete with their own species for food, and being larger helps defend against predators. We don't have predators and we compete with each other using money, not size, so there's not much incentive to evolve or engineer ourselves to be huge. **LV**

LIZ WRIGHT, GLASGOW

What is the wettest place in Europe?



Iceland's Mýrdalsjökull glacier is the wettest place in Europe

A CRKVICE IN MONTENEGRO is the wettest *inhabited* place in Europe. Its subtropical location means it gets plenty of humid air, and when this is forced up the slope of the Orijen mountain, it cools and forms rain clouds. Average rainfall is 4,600mm, but that is beaten by Iceland's Mýrdalsjökull glacier, which receives more than 10,000mm of rain per year. **LV**

PHOTO: CORBIS X2, GETTY, THINKSTOCK

THE NIGHT SKY: WHAT CAN I SEE IN DECEMBER?

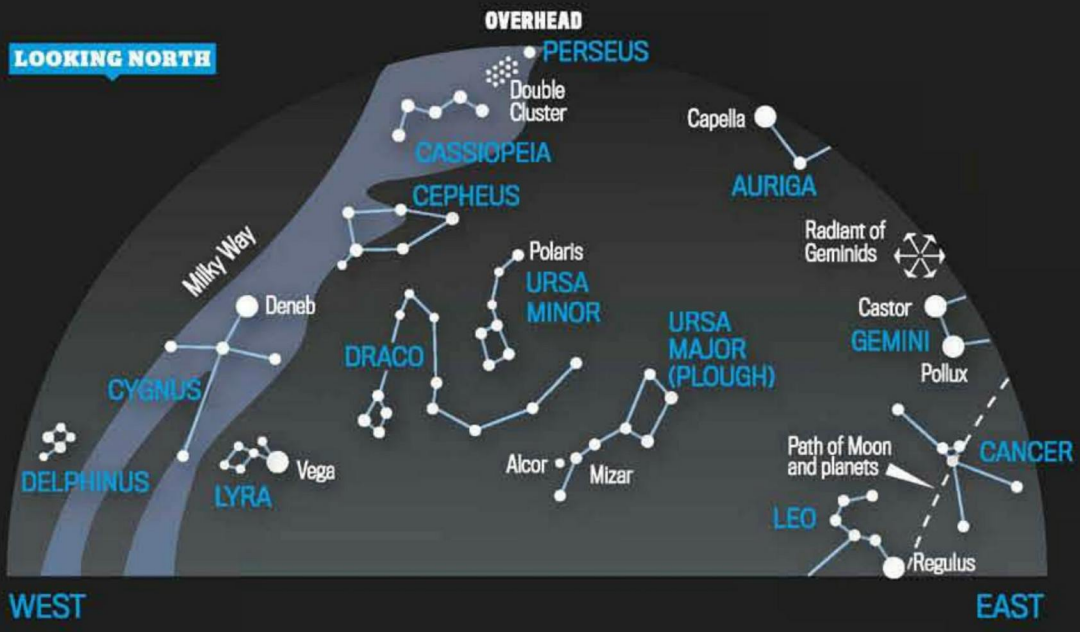
BBC ONE Don't miss *The Sky at Night* on BBC One every month www.bbc.co.uk/skyatnight

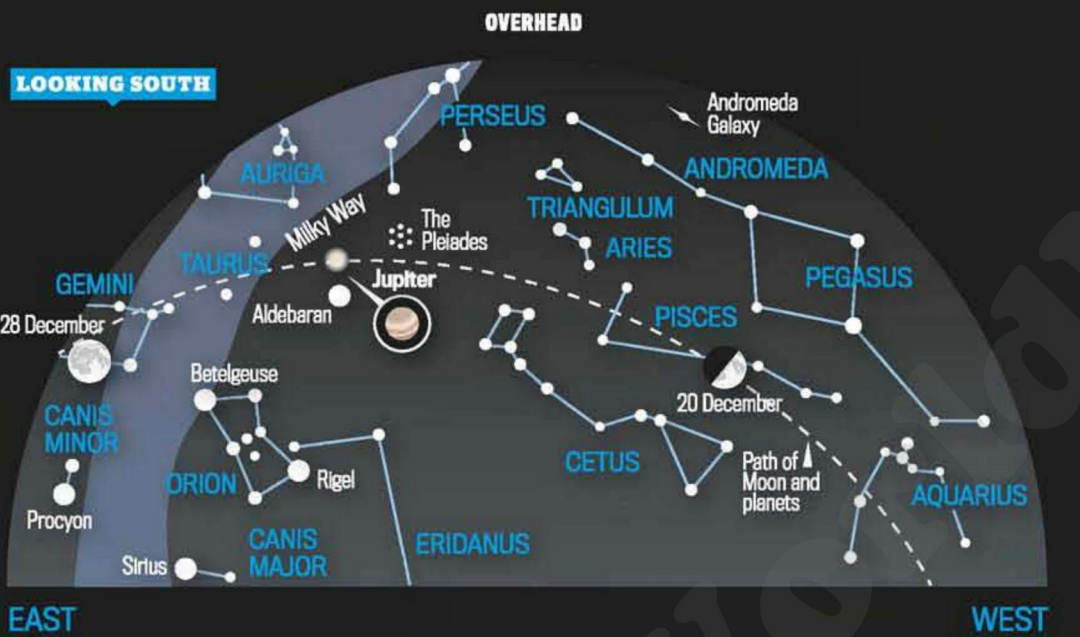
Astronomy with Heather Couper and Nigel Henbest





The rather barren constellations of autumn are slipping away to the west as winter arrives. Now, the dazzling stars of the cold nights are taking their place: Orion's Belt and Sirius are starting to make their presence felt, as well as the glorious star cluster of the Pleiades. Meanwhile, the brilliant star Capella is climbing higher each night to rule over the heavens. And we have two highlights this month – a 'Christmas Star' in the form of the planet Jupiter, and a great display of shooting stars mid-December.





LOOKING NORTH

All month, late evening
Look almost overhead to spot the 'Double Cluster' in Perseus. These two groups of young, blue-white stars are visible to the unaided eye, but look fantastic through binoculars. Each cluster contains about 300 stars.

All month, all night
Check out the last but one star in the 'tail' of the Great Bear (Ursa Major). Yes – it's double! The jury has been out for some years as to whether Mizar (the brighter star) and Alcor are true companions, but now it seems that they're both members of a six-star system.

13/14 December, midnight
Time for the Geminids, the best meteor shower of the year. The shooting stars, fragments of the asteroid Phaethon, should be bright. Expect more than a meteor per minute in a dark location.

LOOKING SOUTH

3 December, but visible all month, all night
Jupiter is at its closest to Earth tonight (600 million km away). But because it's made of gas and it's so huge, it reflects a lot of sunlight and appears dazzling in December's skies.

11 December, around 6.30am
If you're up just before dawn, look out for a beautiful spectacle in the morning sky. Venus pairs up with the crescent Moon, while Saturn shines high up on the right, and Mercury lies to the lower left.

Find out more

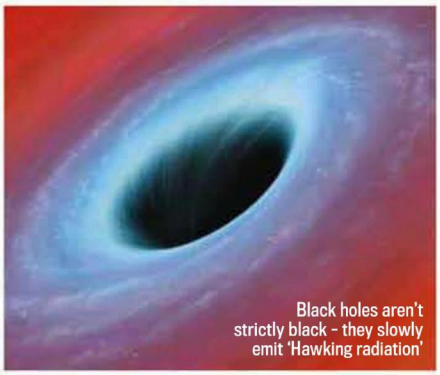


Stargazing 2013
Discover astronomy with Heather Couper and Nigel Henbest (Philip's, £6.99)

Q **FERGAL O'BRIEN**, IRELAND

Do black holes die?

A YES, BLACK HOLES die, but in a very slow fashion. They die because they aren't entirely black – they glow faintly, although not in visible light. This glow is known as Hawking radiation after Stephen Hawking who first postulated its existence. According to quantum physics, 'empty' space is actually teeming with virtual particles that flash in and out of existence, often as particle/anti-particle pairs. Normally these particle pairs quickly annihilate each other. But near a black hole's 'event horizon' it is possible for one particle to disappear inside the black hole and be lost forever, while the other one escapes as Hawking radiation.



Black holes aren't strictly black - they slowly emit 'Hawking radiation'

This process gradually reduces the mass and the energy of the black hole. So black holes that aren't actively sucking in new material will slowly shrink and ultimately vanish. However, for most black holes this slow death would take many billions of times the age of the Universe! **AG**



California's giant sequoias are the biggest species of tree. Record specimens have measured 17m in diameter

Q **ANDREW POLLARD,** BRISTOL

Why are the tallest trees on Earth not even taller?

A THE REASON TREES have a trunk at all is to raise the leaves above other vegetation to maximise the amount of light they receive. Once a sapling is taller than the shrubs and ground vegetation, it will continue to grow because it is competing with other, older trees in its vicinity.

However, the bigger the tree, the more likely it is to blow down or be struck by lightning, which tends to weed out the bigger specimens. To grow taller, a tree also needs to grow thicker, so growth slows down over time. The tallest trees are over 2,500 years old, which is a long time to keep dodging disease and disaster. **LV**

Did you know?

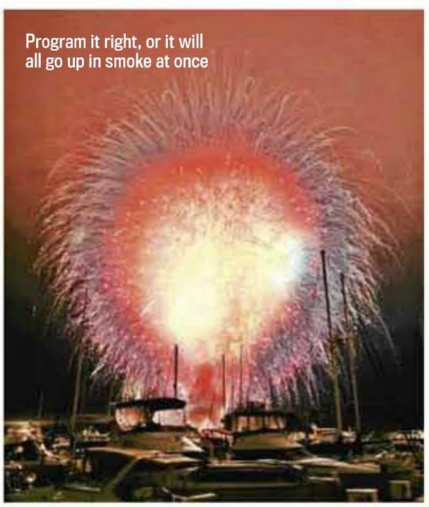
The largest land vehicle is the 14,196-tonne RB293 bucket wheel excavator. At 220m long, it moves earth in a German coal mine.

Q **JOHN MITCHELL**, GLASGOW

How do computerised firework displays work?

A IN A COMPUTERISED firework display, the pyrotechnics are detonated by electric matches, or e-matches. The e-match head contains a zirconium compound that ignites readily when heated, the heat coming from a coil of wire encasing the head. The e-matches are triggered remotely from controllers called electronic firing panels, which have banks of switches assigned either to individual pyrotechnics or batches to be fired simultaneously. The more advanced panels run automatically from computer code. This is often programmed using specialist pyrotechnic software and then downloaded to the panel before the display.

Using software to launch a display is open to error, however, as seen at the San Diego 2012 Fourth of July celebrations when a glitch triggered all the fireworks at once. **GM**

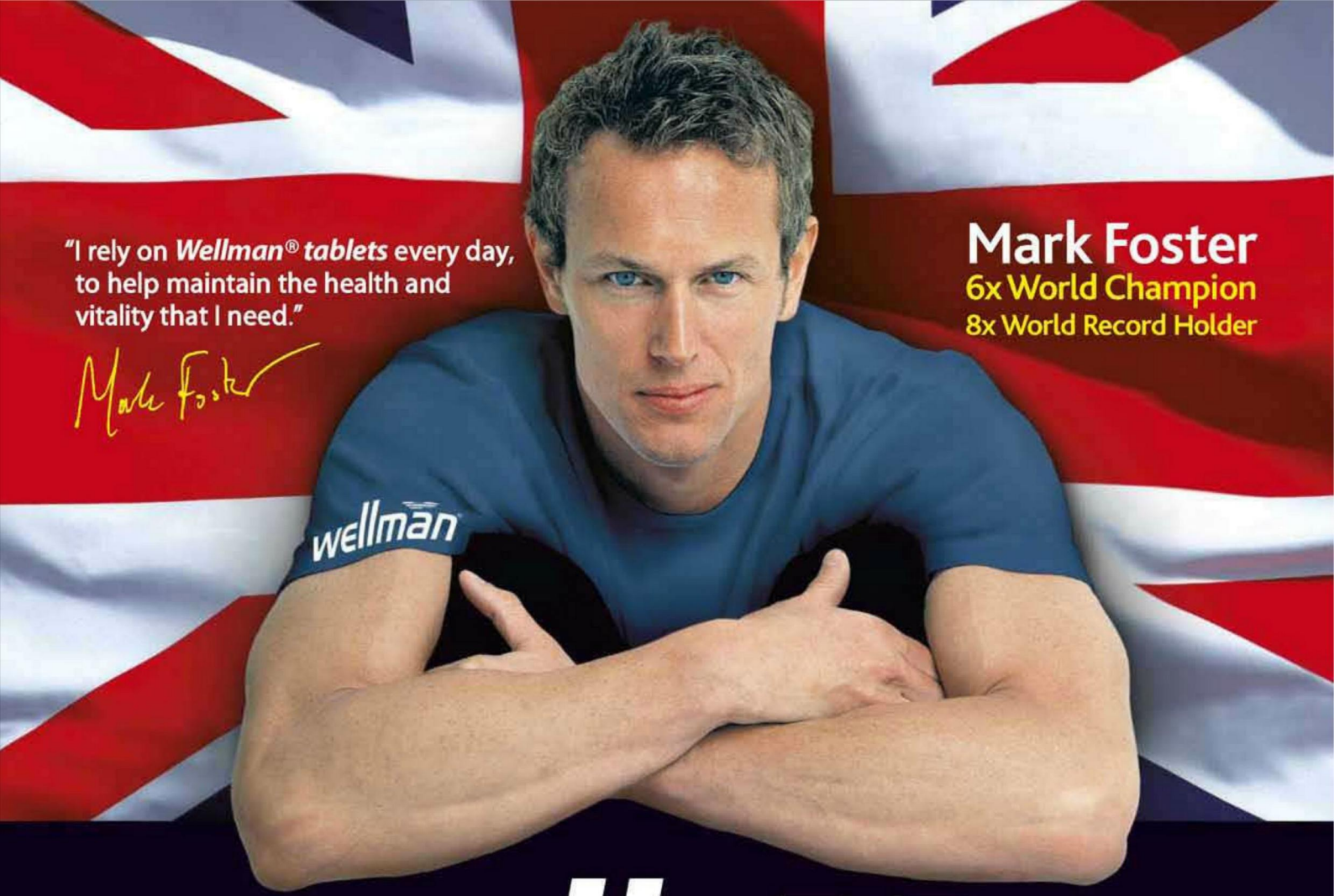


Program it right, or it will all go up in smoke at once

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/qanda**

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Vitamin supplements may benefit those with nutritionally inadequate diets. † Professor Beckett is not cited in the capacity of a health professional, but as a product inventor and former Chairman of Vitabiotics.

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Prof. A. H. Beckett† OBE, PhD, DSc (1920-2010) Professor Emeritus, University of London

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HOW DO WE KNOW?

THE AGE OF THE EARTH

BY DR CHERRY LEWIS

It's taken three centuries for scientists to pin down the age of our home planet, a complex task with a cast of characters as diverse as its many experiments

Today we know that the Earth is 4.54 billion years old, plus or minus one per cent. It's a number that has changed little since it was first determined 56 years ago, back in 1956 – only the error has got smaller. But how can we be so certain that it is accurate and why did it take so long to find it? To answer those questions we must turn the clock back three centuries.

Archbishop James Ussher was just one of many scholars in the 17th Century attempting to establish the exact day on which God had created the Earth. They based their analyses on many texts, including the *Bible*, and estimates ranged from 3,616 to 6,984BC. Starting with Adam, Ussher developed a chronology for all the significant people in the Bible. He then added up their ages to determine that heaven and Earth were created on 23 October 4,004BC, which was a Saturday. This date would have remained as unknown as all the others had it not been for an enterprising bookseller called Thomas Guy. Recognising a demand for cheap, mass-produced *Bibles*, in 1675 Guy began printing a version that included Ussher's chronology in the margins.

SPHERES OF TIME

As knowledge about geology gradually accumulated, geologists began to realise that a few thousand years was just not long enough. In particular, a French Count, George-Louis Leclerc de Buffon, believed that the Earth and the planets had all originated simultaneously from a plume of intensely hot material torn from the Sun. The Count tried to determine when this had happened by replicating the cooling process experimentally.

Over a period of 11 years, Buffon conducted extensive experiments with spheres of iron and rock of varying sizes, timing how long they took to cool and then scaling up his experimental results to the size of the Earth. He published his results in 1775, giving the age of the Earth as 74,832 years since its formation to its current temperature. Privately, however, Buffon considered the Earth to be much older – possibly as much as 10 million years (Ma).

Over the following century, evidence for the aeons of time needed for geological processes began to emerge from studying the rates at which they could be seen to be operating, and by the middle of the 19th Century two of these 'hour-glass' methods prevailed. The first attempted to estimate both the total thickness of rocks in the world and the rate at which sediments were deposited, which gave the time taken to deposit all the rocks. But because deposition rates are different in different places, ages calculated using these rates produced a broad range – from 3 to 2,400 Ma.

The second hour-glass method attempted to measure the rate at which salt accumulated in the sea. Rivers hold dissolved salts in solution, derived from decomposition of the rocks over which they pass. Assuming that the sea had originally been pure water, they thought it should be possible to measure the time it had taken to accumulate present levels of salt.

PHOTO: SCIENCE PHOTO LIBRARY



> IN A NUTSHELL

From the first investigations involving cooling spheres of iron over 200 years ago, to exact measurements of isotopes in meteorites, the quest to fathom the age of the Earth has been a difficult path for generations of scientists. With a cast of characters as diverse as its many types of experiment, find out about geology's finest hour.

But this method was fraught with difficulties and also led to a wide range of ages.

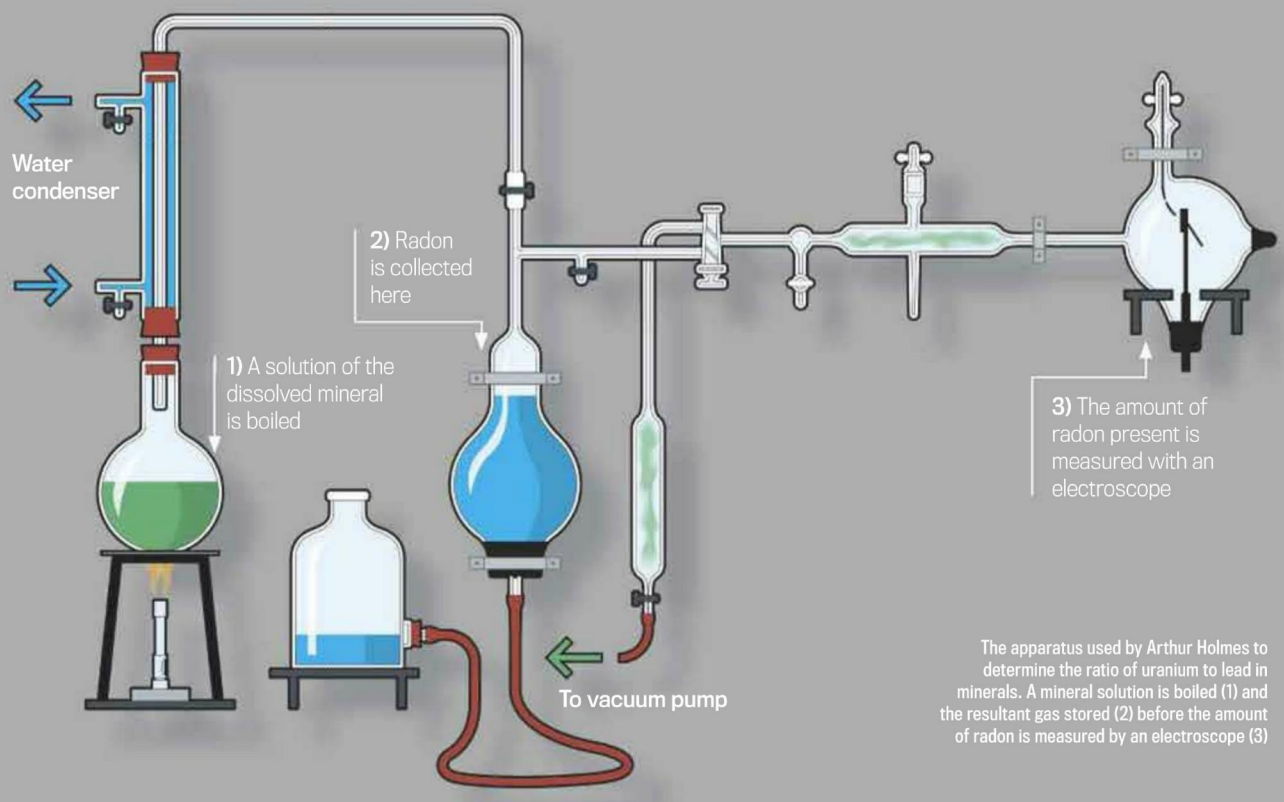
Then in 1862, Lord Kelvin, a renowned physicist, opened his address at a meeting of the Edinburgh Royal Society with a blistering attack on geologists and their methods for determining the age of the Earth. Like Buffon, Kelvin argued that the Earth had originally been molten and considered it 'obvious' that if the temperature at which rocks melted and the rate at which they had cooled down was known, then it should be possible to calculate the time at which the Earth's crust had consolidated. Given these unknowns, Kelvin initially allowed very wide limits, between 20 and 400 Ma, but a few years later, following some accurate measurements on the melting temperature of rocks that turned out to be much lower than anticipated, Kelvin revised his estimate downwards to between 20 and 40 Ma. There was uproar from the geologists.

The decade that straddled the turn of the 20th Century must have been thrilling. The excitement over the discovery of X-rays in 1895 and the realisation in 1896 that uranium emitted similar 'mysterious rays' (termed 'radioactivity' by Marie Curie), triggered an explosion of activity in labs around the world.

In 1897, JJ Thomson discovered the electron and in 1902 Ernest Rutherford and Frederick Soddy revealed radioactive decay. They astounded the world with their announcement that in the process of radioactive decay, one element changed into another: uranium decayed to radium, which in turn decayed to the gas radon.

THE KEY EXPERIMENT

By measuring the ratio of uranium to lead in rocks, Arthur Holmes found a reliable dating method and paved the way for the age of the Earth to be determined



The apparatus used by Arthur Holmes to determine the ratio of uranium to lead in minerals. A mineral solution is boiled (1) and the resultant gas stored (2) before the amount of radon is measured by an electroscope (3)

In 1910, Arthur Holmes set out to determine the uranium/lead (U/Pb) ratio of 17 different minerals in a rock, in order to both date the rock and prove that lead was the stable decay product of uranium.

He spent days separating the minerals from the rock, the resulting powder being 'fused with borax in a platinum crucible, and the resultant glass dissolved in dilute hydrochloric acid. After boiling and standing for several days in a corked flask [1], [radon] was boiled out, collected in a gas-holder [2], and ultimately transferred to an electroscope [3],' which measured the amount of radon.

The known rate at which uranium decayed to radon gave the amount of uranium present. While waiting for the radon to accumulate, the lead was measured using delicate chemical techniques. In order to verify results, analysis of each mineral was repeated up to five times.

At one point Holmes discarded all the data and started again because radon leaked into the room, contaminating his results. He calculated the average U/Pb ratio from these minerals to be 0.045 and the rock to be 370 million years old.

Furthermore, the U/Pb ratio increased consistently with age, demonstrating the reliability of the uranium–lead dating method. This technique was eventually used to date the age of the Earth.

PHOTO: SCIENCE AND SOCIETY, SCIENCE PHOTO LIBRARY X2, AIP EMILIO SEGRE X2 ILLUSTRATOR: RICHARDPALMERGRAPHICS.COM

Shortly afterwards, Soddy demonstrated that not only radon was produced, but helium as well, and that radon was also unstable and went on to decay to other elements. Then a couple of months later, just before Pierre and Marie Curie were awarded their Nobel Prize in 1903, Pierre detected that as electrons were explosively emitted from the atom in the process of radioactive decay, energy was given out in the form of heat. This meant that while Kelvin might be right in believing the Earth to be cooling from a molten state, what he had not known was that at the same time, radioactive elements within the Earth were generating enough heat to prolong that cooling for as long as geologists might need it.

ROCK OF AGES

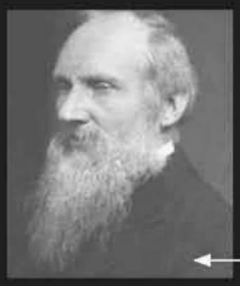
Having identified that helium was a by-product of uranium decay, it was but a short step for Rutherford to realise that if the rate of helium production could be established, by measuring the amount of uranium and helium in a rock, a relatively simple calculation would show how long it had taken for the helium to accumulate, and the age of the rock could be established. A year later, Rutherford became the first person ever to date a rock by radioactive decay – obtaining an age of 40 Ma.

Unfortunately, there was a flaw in his method and it was Robert Strutt, a physics lecturer at the Royal College of Science in London, who recognised it: because helium is a gas, it can escape from the rock. This meant that only some of the helium from radioactive decay was being measured, and the age obtained was only a minimum age. A better method was needed and Strutt encouraged one of his students, 20-year-old Arthur Holmes, to find it.

In 1907, Bertram Boltwood, an American chemist, analysed rocks containing uranium. He noticed that along with helium, large amounts of lead were present. He postulated that lead might be the end product in the decay chain from uranium. If Boltwood was right, Holmes realised, then it should be possible to obtain an age by measuring the amount of lead in the rock, rather than the helium. He decided to try and in the winter of 1910 analysed the uranium and lead content of 17 minerals (see 'Key experiment' on p106).

CAST OF CHARACTERS

The scientists whose efforts forged a bright future for geology



William Thomson, Lord Kelvin (1824–1907)
Mathematician and physicist at the University of Glasgow. He regarded his work on the age of the Earth as his most important contribution to science.

Frederick Soddy (1877–1956)
English chemist whose discoveries of radioactive decay (with Ernest Rutherford at McGill University) and isotopes at the University of Glasgow revolutionised the science of radioactivity.





Alfred Nier (1911–1994)
American physicist at Harvard University who pioneered the development of mass spectrometry. He discovered ^{204}Pb and provided Arthur Holmes with data to calculate Earth's age.

Arthur Holmes (1890–1965)
English physicist and geologist who developed the uranium-lead dating technique. Holmes worked at Durham University building the geological time scale.





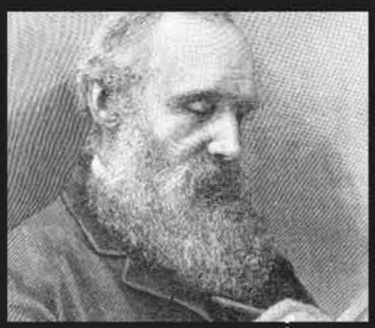
Claire Patterson (1922–1995)
American geochemist who finally dated the age of the Earth at the California Institute of Technology, by isolating microgram quantities of lead from meteorites. He later changed his first name to Clair.

TIMELINE

Three hundred years of investigating the properties of elements has shown us how old Earth is



1775 — **Count Buffon** calculates the age of the Earth to be 74,832 years by heating spheres of iron and timing how long they took to cool, then scaling up his results to the size of the Earth.



1862 — **Lord Kelvin** determines that the Earth was a molten globe between 20 and 400 million years ago, but by 1899 had revised the time downwards to between 20 and 40 million years ago.



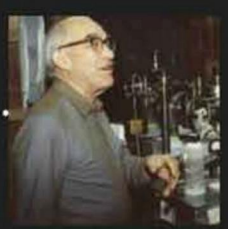
1902 — **Ernest Rutherford** (pictured, left) and **Frederick Soddy** discover radioactive decay; two years later Rutherford dates the first rock determined by radioactive decay. It is found to be 40 million years old.



1911 — **Arthur Holmes** develops the uranium-lead dating technique and calculates the Earth must be at least 1,640 million years old. Two years later, Soddy discovers isotopes which greatly improve the accuracy of dating.

1946

1956 — **Claire Patterson** analyses the lead content of five meteorites and a sample from Earth, which defines the age of the Earth, Moon and meteorites to be 4,550 ± 70 Ma.



Following **Alfred Nier's** discovery of a 2,480 million-year-old rock, Holmes uses Nier's data to develop a model for calculating the Earth's age, which he determines to be 3,015 million years old.

The results enabled Holmes to conclude that lead was indeed the final decay product of uranium and that a reliable technique had been found for dating rocks – it has been used ever since. The oldest date in his dataset was 1,640 Ma, showing that the Earth must be at least that age, but his results horrified the majority of geologists who adhered to Kelvin's timeframe.

Progress was slow and the discovery of isotopes by Frederick Soddy in 1913 complicated things considerably. At that time, the only way to distinguish one isotope from another was by measuring its atomic weight and there were few labs in the world that could do this. Furthermore, Holmes argued, some lead had probably been around since the Earth first formed – called primordial lead – but if he could not identify which isotope of lead was the result of the decay from uranium and which isotope was that of primordial lead, his dates would be inaccurate.

TRIAL AND ERROR

In 1924, Holmes was appointed Professor of Geology at Durham University, where he continued working on refining the geological time scale and attempting to date the age of the Earth. During this time he also tried to find new dating techniques. Although each new method initially looked promising, after much time, trial and error they were all unsuitable.

Then in 1938, the young American physicist Alfred Nier, working with a new mass spectrometer at Harvard University, tried to identify all the known isotopes of lead (chemical symbol Pb). As expected, he quickly saw the three known isotopes – ^{206}Pb, ^{207}Pb and ^{208}Pb – but at the end of the spectrum a tiny blip was seen. The minute spectrum of primordial lead was finally visible and identified as ^{204}Pb. The missing piece in the uranium-lead jigsaw had at last been found.

Although a physicist, Nier was fascinated with measuring geological time and just before World War II, he performed a series of very precise age determinations on 25 different rocks of varying geological ages. One of these, a pegmatite from Manitoba, gave an age of 2,480 Ma. Intrigued by Nier's results, Holmes wrote to him in May 1945 after Nier returned from working on the Manhattan

PHOTO: SCIENCE PHOTO LIBRARY, SCIENCE AND SOCIETY, PHOTOSHOT, UNIVERSITY OF EDINBURGH, CHEMICAL HERITAGE FOUNDATION, CORBIS

NEED TO KNOW

Five key terms to help you understand the ageing process

1 Isochron
If all the rock samples on an isotope ratio diagram fall in a line (isochron), then they all formed at the same time. The slope of the line gives the age of the rocks.

2 Isotope
Chemically identical atoms of any element that contain different numbers of neutrons in the nucleus. The neutrons and protons added together give the isotope number. The unstable isotope ^{238}U decays to the stable isotope ^{206}Pb.

3 Mass spectrometer
An instrument that measures the molecular mass of a sample. They also determine the concentrations of elements, so the Mars rovers used them to analyse Martian soil and ice.

4 Pegmatite
A coarse-grained, intrusive, igneous rock. It forms near the margins of a magma chamber during the final phases of crystallization. It often contains minerals that are suitable for dating purposes.

5 Radioactive decay
The spontaneous change (decay) of one element into another. The number of atoms that decay is dependent upon the number present. As the parent atom decreases, the daughter element increases in the same proportions.

Project: '...this is of the greatest interest, not only because the rocks here seem to be the oldest yet found, but also because such a figure shows that current views about the expanding Universe need revision...'. Edwin Hubble had recently determined that the Universe was only 1,800 Ma old, but Nier's data showed this must be wrong since it was impossible to have a Universe younger than the Earth. Holmes also predicted that Nier's data would offer a new model with which to determine the age of the Earth.



The hyper-saline waters of the Dead Sea show just how much salt is held in seawater; early attempts to determine the age of the Earth involved measuring how long it would have taken salt to dissolve

Having purchased an early calculating machine with which to complete the complex calculations, Holmes again wrote to Nier on 16 February 1946: 'The age [of the Earth] works out at about 3,000 Ma by various sets of solutions... the average of the best set of solutions being 3015. We can, however, afford to neglect the odd 15!' By the early 1950s, using uranium-lead isotopes for dating rocks finally looked possible. Sadly, Holmes was now unwell, and stepped aside for the next generation to continue his quest.

As the technology progressed, another American, Claire Patterson, succeeded in determining the vanishingly small amounts of lead in iron meteorites. The advantage of choosing iron meteorites was that the amount of uranium they contained was negligible, therefore any primordial lead they held could never have been contaminated by radiogenic lead. It then dawned on Patterson that if, as suggested by astronomers, the Earth had been formed at the same time as the Solar System, he could use the values for primordial lead determined from meteorites to date the age of the Earth.

Patterson spent the next three years trying to prove the relationship and in 1956, he demonstrated that the Earth, planets and meteorites had a common ancestry. He analysed the lead content of five meteorites and showed how the ratios of their isotopes created a straight line (an isochron), which defined an age of 4,550, plus or minus 70 Ma.

Furthermore, samples from the Earth (and later, the Moon) also fell on that line. This proved that the Earth and the meteorites were formed at the same time from the same solar material around 4.5 billion years ago. Exactly 300 years after Ussher died in 1656, the age of the Earth had finally been found. ■

Dr Cherry Lewis is an honorary Research Fellow in the School of Earth Sciences at the University of Bristol

Find out more

BBC Radio 4 Listen again to two episodes of *In Our Time*, with Melvyn Bragg and guests including Cherry Lewis.
The Earth's Origins (2001)
http://bbc.in/Lr4SYI
Ageing The Earth (2003)
http://bbc.in/ffu2gK

The Dating Game by Cherry Lewis (Cambridge University Press, 2000)

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TO DO LIST

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

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PICK OF THE MONTH



Lucky Dallas visits a cosmodrome in Kazakhstan, a superscraper in the Gulf and a sewer in Mexico. Well, two out of three ain't bad...

Generation Earth

WE'RE THE FIRST generation to see Earth from space. And one of the things we can see is our own handiwork, as electric lights pick out cities as bright dots. We humans are shaping the environment in ways our ancestors would not have believed possible. So for this three-part special, *Bang Goes the Theory*'s Dallas Campbell travelled the world for 18 months, finding out how engineers rise to today's biggest challenges.

Time-lapse filming and CGI capture the progress of huge projects from bare rock to finished constructions. In the first programme, Dallas visits the world's tallest building, the Burj Khalifa in Dubai, and is set to work cleaning the windows almost a kilometre above the ground. The show also looks at how far we've come in just a few lifetimes. Go back 30 years and the world's tallest building was in Chicago. How did we build cities like Dubai and Las Vegas in the inhospitable desert?

In the second programme he flies a replica of the Wright brothers' 1902 glider and then follows the history of flight over the last 110 years. At a cosmodrome in Kazakhstan, he sees the dusty past and the hopeful future of human spaceflight. Finally, he discovers the ingenuity at work in keeping billions of people fed, watered and provided with energy.

If you're jealous of the places he's gone, you might change your mind when you see him scuba dive with Julio, whose job is unblocking Mexico City's failing sewers. "Raw sewage... human and animal waste. It was hideous," says Dallas. Rather him than us.

TIMANDRA HARKNESS

Listen to an interview with Dallas on the *Focus* podcast at sciencefocus.com/podcasts

BBC ONE *Generation Earth* airs on 21 November on BBC One

DON'T MISS!



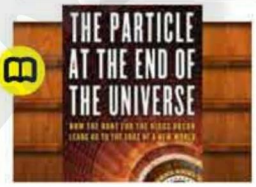
RI Christmas Lectures

Go behind the scenes at the Royal Institution, with an exclusive money-saving offer for *Focus* readers! p112



Hawken

A super-fast take on the mech-sim genre that has you strapping on a huge robotic suit to do battle in a dystopian city. p117



The Particle At The End Of The Universe

The hunt for the Higgs boson explained. p118

PHOTO: BBC

VISIT

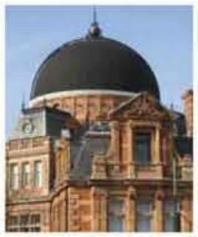
EVENTS & EXHIBITIONS

WITH JHENI OSMAN

21-28 NOV

Evening With The Stars

Royal Observatory, London; 21, 23, 24, 28 November, 5:30-6:30pm or 6:10-8:10pm; £16, £56 family, www.rmg.co.uk



The popular after-dark experience at the Royal Observatory Greenwich includes a show in London's only public planetarium and the chance to look through the gigantic 28-inch telescope at what the night sky has to offer. Plus you can spend some time on the Prime Meridian with a hot drink, an amazing view of London and astronomers on hand to answer all your questions.

26 NOVEMBER

Fuelling The Future

Tobacco Factory, Bristol, 8-10pm, free, bscia-bsba.org.uk



IF WE'RE GOING to meet our energy needs for the future, then some young, bright mind somewhere had better come up with a solution. At Bristol's Tobacco Factory theatre, some of the leading researchers from the University of Bath will be debating exactly where that solution will come from, whether it's via biofuels, carbon capture or high-altitude wind farms. If you spot them in the bar downstairs, be sure to tell them to get back to work.

27 NOVEMBER

Public Health: Time For Social Renewal

Curtis Auditorium, Newcastle University, free, www.ncl.ac.uk/events



FLU SEASON IS in full swing, so if you're not bedridden this talk is worth attending. Often we're just trying to fend off the latest lurgy rather than prepare for battle with next year's bug, let alone plan further ahead. In this talk, Hilary Graham, Professor of Health Sciences at the University of York, suggests we need to stop defending against this year's bug and start attacking future generations of flu.

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)



EDITOR'S CHOICE

Dr Peter Wothers: chemist and skilled sorcerer

11, 13, 15 DEC

Christmas Lectures: behind the scenes tour

Royal Institution, London, 11 December, 3pm; 13 December, 3pm; 15 December 3pm; £10.50 for *Focus* readers (when booking, quote promo code FOCUS); www.rigb.org

STARTED BY MICHAEL Faraday in 1825, the Christmas Lectures are broadcast every year by the BBC. This time, the University of Cambridge's Dr Peter Wothers unpicks the chemistry of the world around us.

Through live demonstrations, his three-part series called 'The Modern Alchemist' will look at air, water and earth, the three original 'elements' of the Ancient Greeks. He'll explores the cocktail of gases that make air vital for life, how water may hold the key to our energy challenges, and how the properties of materials like silicon and graphene could unlock future technologies.

Since the lectures are only open to Royal Institution members and registered schools, the only way to get up close to the chemistry are these tours of the Royal Institution that run in the afternoon prior to each talk. You'll be able to sneak into the rehearsals to find out how the lectures take shape, go behind-the-scenes in the practical workshop and, if you're lucky, see Dr Wothers unleash some explosive chemistry experiments as he prepares for the shows.

Make sure you use your *Focus* reader voucher code to get £4.50 off. See above for details.

PHOTO: THINKSTOCK X2, CAMBRIDGE UNIVERSITY, ADRIAN BURROWS, SCIENCE MUSEUM, NATURAL HISTORY MUSEUM, GETTY

30 NOVEMBER

Goo's Everywhere – In Nature And Nearer To Home

Royal Institution, London, 8-9:15pm, £10.50 for Focus readers (when booking quote promo code FOCUS), www.rigb.org



YOU'D THINK THAT goo wouldn't be an area of scientific study, but you'd be wrong. Dame Athene Donald, Professor of Experimental Physics at the University of Cambridge, explains how cells and protein stick together, what makes a good goo and how we can learn from nature to create better synthetic materials.

30 NOVEMBER

Treasures

Natural History Museum, London, Free, www.nhm.ac.uk



SO MUCH OF the Natural History Museum's collection remains behind closed doors, reserved for researchers' eyes only. But on display for the first time in this new gallery are 22 of the museum's greatest treasures. Curiosities include the *Archaeopteryx lithographica* fossil (pictured), which proved that birds are descended from small dinosaurs, and a first edition of Darwin's *On The Origin Of Species*.

7 DECEMBER

Echoes From A Black Hole

BRLSI, Queen Square, Bath, 7:30pm, £4, www.williamherschel.org.uk



IF YOU EVER have the misfortune of falling into a black hole, you'll be stretched out like a piece of spaghetti. Fortunately there are other ways to find out what happens inside these cosmic abysses. In this talk, Dr Andy Young will reveal how the inside of black holes are studied using nearby X-ray sources that illuminate matter as it's falling in. By analysing the 'echoes' from this matter, it's possible to get clues about what's going on inside these most enigmatic of cosmic objects.

11 DECEMBER

Firework displays: explosive entertainment

Science Oxford Live, St Clement's, Oxford 7:30pm, free, www.cafesci.org/oxford



FIREWORKS CONSULTANT, AUTHOR and former chemist Dr Tom Smith reveals the inner workings of the colourful explosions in this lively talk. He looks at their basic chemistry, how they are put together, and their use in displays. And, if you love pyrotechnics, there will be plenty of bangs to keep you on the edge of your seat.

SPEAKER OF THE MONTH



29 NOVEMBER

Dr Alice Roberts

Theatr Brycheiniog, Canal Wharf, Brecon, 7:45-8:45pm, £10.50, www.rgs.org

Who is she?
You'll probably recognise Alice from BBC shows like *Origins Of Us*, *Woolly Mammoth* and *Coast*. If not, she is someone who knows a lot about dead bodies. More accurately, Alice is an expert in human anatomy with a passion for palaeontology, so she's well placed to tell you about the evolution of early man.

What is she talking about?
Alice will explain how humans endured the Ice Age while many other large mammal species died out. And the answer isn't simply that we made coats out of them. In her talk 'Survivors Of The Ice Age', Alice will use the fossil records to illustrate how mankind's adaptability proved crucial to withstand such bleak conditions.

UNTIL 1 DEC

Oramics To Electronica

Science Museum, London, Free, www.sciencemuseum.org.uk

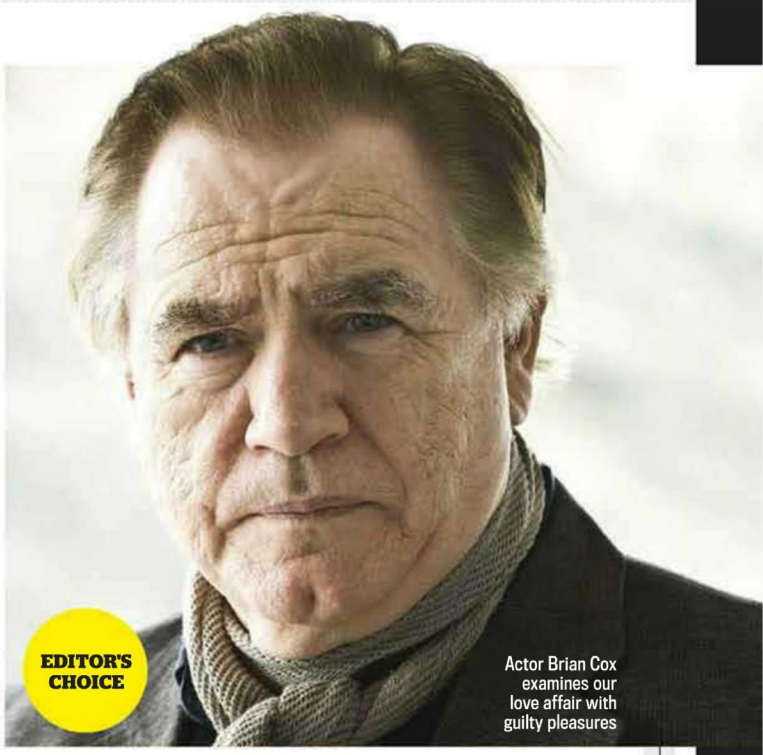


TODAY WE TAKE synthesizers, samplers and the hallowed keytar for granted, but prior to the 1950s electronic music didn't exist. Back then pioneers like Daphne Oram, the BBC radiophonic workshop and Electronic Music Studios created never-heard-before sounds for TV, film and music. This collection pieces together some of the pivotal inventions. It's a must-see for disciples of electronic music, if only to witness the Oramics machine first-hand, a room-sized early synthesizer.

WATCH

TV, DVD & BLU-RAY

WITH TIMANDRA HARKNESS



Actor Brian Cox examines our love affair with guilty pleasures

NOVEMBER

Alien Deep

National Geographic, November



THE WORLD'S OCEANS hide many mysteries, and one man has spent 50 years angling for answers. In this four-part series, oceanographer Dr Robert Ballard travels the seven seas, exploring shipwrecks, freak waves and everything in between. He's developed some nifty technology to let him examine an environment that would kill him in seconds, and hooked up with teams using robots at underwater volcanoes. Did life itself begin in the depths? Ballard thinks we must go deep before we boldly go out into space.

NOVEMBER

Brain Surgery

Channel 5, November



THE MEDICAL EQUIVALENT of rocket science, brain surgery is able to achieve remarkable results. Today's doctors not only save lives but preserve and improve the patients' ability to speak, move, think, and generally live. This series takes up residence in Liverpool's Walton Centre, the only NHS Neuroscience Trust in the UK. Expert surgeons and advanced technology tackle a range of problems from depression to road accidents, Parkinson's to brain tumours, and each episode follows a person with a different problem.

FROM 15 NOV

Richard Hammond's Journey To The Centre Of The Earth

Eden, starts 15 November, 8pm



SADLY, NOT THE *Top Gear* special to end them all, but a two-parter on what our planet's made of, and how it works. Hammond uses location filming and CGI to show us how earthquakes happen, what causes volcanoes and where diamonds come from, peeling back the layers of a virtual planet like a giant Scotch egg. Yeah, he's got satellite imagery and science and stuff, but does he drive to the centre of the Earth in a car that cost him £100? No.

TIMANDRA HARKNESS is a BBC Radio 4 presenter and stand-up comic. Her latest show is 'Humans Vs Nature: Engineering FTW'

FROM 28 NOV

Addicted To Pleasure

BBC One Scotland, starts 28 November

ALCOHOL, TOBACCO, sugar – all guilty pleasures that are frequently blamed for everything from ill health to social breakdown. But how did they come to be part of our lives? This time it's the other Brian Cox – the actor from Dundee – who explores the history, science and economics of these three substances plus opium in a four-part series.

You probably know about the sugar plantations in the Caribbean, feeding Britain's sweet tooth with slave labour. But you might be surprised to learn that indentured Scots, defeated by Cromwell, also toiled in the West Indies to supply the coffee houses of the Enlightenment with sweetness. Then domestic cake and biscuit factories fed the energy-hungry workers flooding into newly industrial cities. But today it's accused of feeding an epidemic of obesity. Cox himself, a diabetic, has an ambivalent relationship with sugar.

The history of whisky is deeply political, and the Temperance Movement goes back further than recent attempts to set minimum prices for Scottish drinkers. Tobacco, too, has been controversial before, with King James (VI of Scotland, I of England) campaigning against it in 1609.

Opium, however, was initially hailed as a medical wonder drug. Edinburgh-educated physician Dr William Jardine became one of Scotland's richest men by dealing it, laying the foundations for the city's eminence in finance, medicine and trade. Now science can tell us why its impact on the human body and brain is so instant, so powerful – and so addictive.

The series comes right up to date with current concerns about all four substances and how they're used today.

PHOTO: GETTY, DISCOVERY NETWORKS, NASA, THINKSTOCK, JONATHAN WILKENDORF, BBC, PRESS ASSOCIATION

FROM 27 NOV

Dust Up!

Quest, starts 27 November, 10pm



REMEMBER THE SCENE in Hitchcock's *North By Northwest* – Cary Grant pursued by a small aeroplane? You may be surprised to hear that such planes, and their pilots, are still in demand to dust fields with pesticides. It's risky work, too, as the planes need to fly only metres above the ground at speeds well over 100mph. Not surprising, then, that it attracts daredevils. This series follows some crop-dusting families in Canada who fit that bill.

DECEMBER

North Pole Ice Airport

FIVE, December



HOW DO YOU get to the North Pole? Flying reindeer-drawn sledge, obviously, but if you're not Santa you need Ice Station Barneo. For just one month a year, an airport built on the sea ice is open for travellers. As well as scientists studying the ice itself and the ocean beneath it, Barneo welcomes explorers and thrill-seekers onto its temporary runway. Looking to trek to the Pole, compete in the Arctic Marathon, play extreme golf or bag the ultimate wedding venue? Check in here.

9 DECEMBER

Scanning The Skies

Discovery Channel and Discovery Science, 9 December, 9pm



Discovery Channel's eye on the sky

WE'VE ALL SEEN gorgeous colour pictures of distant galaxies, nebulae and sweeps of star-sprinkled sky. But we seldom think about the technology that took them. Discovery kicks off Space Week with a documentary about the Discovery Channel Telescope, at the Lowell Observatory in Flagstaff, Arizona. The astronomers involved plan to share what they find with schools, homes and the whole internet, taking advantage of control systems that allow it to find objects in the sky faster and easier than ever before.

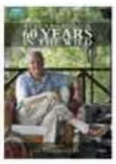
DVD & BLU-RAY



James May's Man Lab series 2

DVD, BBC, £19.99

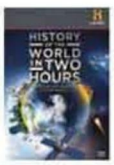
If you know someone who likes to tinker in a shed or take things to bits to find out how they work, this could be a great Christmas present. May tackles the pressing questions of our time with practical experiments. Questions like: how can I blast my pet's ashes into space?



Attenborough: 60 Years In The Wild

DVD, BBC, £20.42

After 60 years in natural history filmmaking, Sir David Attenborough has made three more films looking back on his career. Focusing on Science, Environment and Filmmaking itself, he delivers personal views, informed by his unparalleled experience of wildlife.



History Of The World In 2 Hours

DVD, History, £9.99

Want to know how the Universe began, how matter, galaxies and planets formed, humans evolved, civilisation appeared... and on, all the way up to, say, last Wednesday? A History special, this DVD rattles through the salient points with CGI loveliness and killer pub facts.

10 DECEMBER

Mars Landing 2012

Discovery Science, 10 December, 8pm



SPACE WEEK CONTINUES with a special on the Mars Science Laboratory – better known as the Curiosity rover – that landed on Mars this year. The scientists and engineers involved discuss designing and building the one-tonne, self-guided robot and how they got it safely to the surface of a distant planet. Landing it with delicate instruments in working order was an impressive feat, but just the start of the search for signs of life beyond our planet.

17 DECEMBER

10 Ways To End The World

National Geographic, 17 December, 9pm



IS THE HUMAN race about to end with a bang or a whimper? Brighten up your November with a countdown of the top 10 ways people could die out, from climate change to a meteorite strike. Two one-hour specials pull in scientists to compare us to the dinosaurs, debate how doomed we are, and argue over what form that doom could take. Part of a cheery End Of The World season that also includes *Omens of the Apocalypse* and *Evacuate Earth*.

LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

NOVEMBER

The Forum: Supermachines

BBC World Service

IBM BUILT A supercomputer, nicknamed Watson, that won the American TV gameshow *Jeopardy*. But though that was great publicity, Watson is intended for more important work. Cancer specialist Dr Larry Norton hopes to use Watson's superhuman memory for diagnosis. But how do we interact with technology that can so far excel our own capabilities?

NOVEMBER

Saving Species

BBC Radio 4, Tuesdays 11am, repeated Thursdays 9pm

BRETT WESTWOOD TAKES a weekly look at wildlife and conservation issues. Each programme is live and topical, so we can't tell you what will be covered. However, the last week in November will be devoted to reporting from Scottish Natural Heritage's Species Action Framework Conference. Wolves? Beavers? Find out here.

DECEMBER

Frontiers

BBC Radio 4, December

YOU MAY HAVE heard about – or seen – Claire Lomas, who completed the 2012 London Marathon course despite being paralysed, using a robotic exoskeleton. This programme explores the kind of brain-machine interfaces that may one day allow anyone to control external limbs or devices wirelessly, using only brain activity. Meet Miguel Nicolelis of California's Duke University, whose goal is for the first ball of the Brasil 2014 World Cup to be kicked by a paralysed person in an exoskeleton.



Lomas crosses the line at the London Marathon with the ReWalk exoskeleton

DECEMBER

The Living World

BBC Radio 4, Sundays 6.30am

AMONG THE MYRIAD of delights in this series are the humble myriapods – better known as centipedes and millipedes. Natural history is all around you and the presenters go on location with all sorts of experts to make sure you'll never look at bramble the same way, or turn your nose up at the rotting wood at your feet. Well, would you argue with somebody whose job title is 'Deadwood Entomologist'?

DECEMBER

Exchanges At The Frontiers

BBC World Service, December

EAVESDROP ON DISCUSSIONS between a philosopher and a series of prominent scientists, recorded with a live audience at London's Wellcome Collection. Anthony Grayling asks difficult questions of a different guest each week.

PHOTO: PRESS ASSOCIATION

TOUCH

SMARTPHONE & TABLET APPS

WITH CHRISTOPHER PHIN



Learnist

iPhone, iPod touch, iPad; Grockit; Free

IF YOU WANT to learn about something, you could start with a Google search and pick through the results, or you could try Learnist. You can create curated boards for any topic in a range of categories, and then add links to it to pages all around the web. You can comment on, 'like', annotate and share the pages. The Science tab has interesting topics, from the relatively simple 'Why do some planets have rings?', to the more complex, and if you can't find what you want by browsing, create your own board.



Partly Cloudy

iPhone, iPod touch; Raureif; £1.49

WEATHER FORECASTING IS a built-in feature on an iPhone, so another weather app has to be pretty special for us to recommend it. Fortunately, Partly Cloudy is.

It's not so much that the data behind it is necessarily better – though, in our experience, data from the Norwegian Meteorological Institute, is excellent – but that it makes it so easy to read a 12-hour, 24-hour or seven-day forecast at a glance. Yes, it's initially baffling, but once you know how it works, it's a must for us weather-obsessed Brits.



Earth-Now

Android 2.2 or later, iPhone, iPod touch, iPad; Jet Propulsion Laboratory; Free

THOUGH THIS APP has been available on iOS for a while, it has just made it to Android, putting up-to-date and recent historical climate data at the fingertips of millions more people. Information from NASA's satellites is presented on a 3D globe which you can rotate with your finger and unpinch to zoom in on, and you can choose whether to show colour-coded tiles for air temperature, carbon dioxide and monoxide, ozone and more. The app explains what you're looking at and you can animate recent blocks of data.

CHRISTOPHER PHIN is the editor of *TAP!* magazine

PLAY

CONSOLE & COMPUTER GAMES

WITH NEON KELLY



Far Cry 3

PC, Xbox 360, PS3; Ubisoft; £39.99

UBISOFT'S OPEN-WORLD first-person shooter returns with a tropical island setting and the over-arching theme of insanity. The plot is certainly bonkers: a young man goes on an extreme sports holiday, gets kidnapped and held for ransom. Escaping, he joins a tribe of warriors, gets a tattoo, and sets out to rescue his friends – by blowing the archipelago to pieces. It's the kind of game where you set fire to pirates while a Komodo dragon bites your leg off.



Baldur's Gate: Enhanced Edition

PC, Mac, iPad; Atari; $19.99 (£12.40)

DO YOU LIKE bearded men who carry swords? If so, you're probably familiar with *Baldur's Gate*, one of the most important RPGs of all time. The original was released in 1998 to rave reviews and is now regarded as the godfather of games where you bash goblins in the face and have conversations with people called 'Spatarruk' or 'Anteon' (but never 'Kevin'). This remake worships its source material, while adding a great helping of new quests.



When Vikings Attack!

PS3, Vita; Sony; price TBC

A LOST HORDE of Vikings has invaded the UK, and it's up to the public to stop them! The brilliant conceit here is that you control a small mob of pedestrians, squaring off against a crowd of pointy-hatted warriors. The more people in your gang, the bigger the objects you can throw at the enemy – barrels, wooden benches, or even parked cars. A direct hit will send your foes scattering like human bowling pins, a delightful touch that helps create one of the most addictive multiplayer modes of 2012.

NEON KELLY IS DEPUTY EDITOR AT VIDEOGAMER.COM

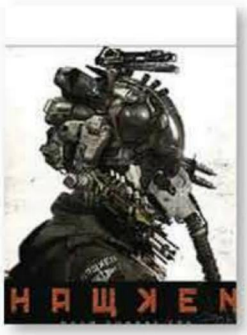


EDITOR'S CHOICE

Life in a dystopian city: if it's not the poor air quality that kills you it's the giant mechanised death robots

Hawken

PC; Meteor Entertainment; Free-to-play



DO YOU REMEMBER the '90s? We wore colour-changing T-shirts and burnt our mouths on Pop-Tarts. And when we weren't at Laser Quest, some of us pretended to stomp around in a virtual giant bi-pedal robot suit.

Despite the graphical limitations of the era, 90s mech games tended to strive for verisimilitude, for the authentic feeling that you really were in control of a massive, lethal machine. The genre was hugely popular at the time, but over the past decade it's slowly faded into stasis.

Hawken seeks to change all that. The first project of LA-based studio Adhesive Games, this is a love letter to clanking great weapons of mass destruction. There's a faster pace than the mech games of old, fuelled by modern sensibilities: this is a multiplayer-only affair, offering a quartet of competitive match types. Regardless of what you plump for, you're handed an unlimited sack of ammo at the door – though your weapons will overheat if you're too trigger-happy.

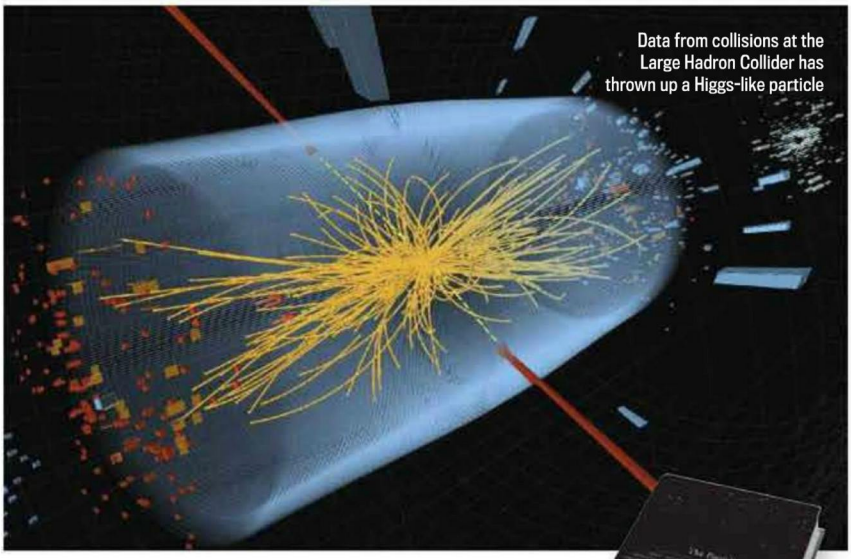
Despite the concessions to accessibility, *Hawken* achieves a sense of realism that *MechWarrior* pined for all those years ago. The metal frame of your cockpit obscures large chunks of the screen, and when you move it rumbles like a washing machine in an earthquake. Even in the lightest suits, there's a huge sense of weight as you lumber about ruined cities. You can practically *smell* the petrol.

In true retro style there's even a tie-in peripheral, the MEK-FU. This behemoth of a controller features twin joysticks and a massive bank of buttons, flip-switches and lights. But the best thing of all? *Hawken* is a free-to-play game. If you want to customise the look of your 'bot then there are various cosmetic tweaks to buy for real cash, but if you're penniless – because you just bought a joystick the size of a small child – you can play for gratis. And that's something that never happened in the '90s.

READ

THE LATEST SCIENCE BOOKS REVIEWED

P Paperback H Hardback



Data from collisions at the Large Hadron Collider has thrown up a Higgs-like particle

The Particle At The End Of The Universe

Sean Carroll

Oneworld H £14.99

THE ORIGIN OF atoms, molecules – and ultimately the seeds of everything we see around us – is an all-pervading mysterious essence, known as the Higgs field. That at least was what particle physicists suspected for decades, and they've now found the first hints that it is true. The announcement on 4 July that researchers at CERN had probably discovered the Higgs boson, the particle whose existence is a consequence of this theory, hit headlines around the world. A spate of literature on the subject followed.

In the rush to be first, there is a danger of books being filled with superficial or misleading content. How are readers to decide which, if any, are reliable? Well, you could do far worse than select Sean Carroll's effort, which stands out among the early competition – it's written by a physicist who both knows what he's writing about, and writes well.

What you get is an overview of particle physics, setting the scene for the Higgs boson, and a decent attempt to give a sense of what it is – without resorting to some of the misleading, superficial analogies that permeate so many presentations. You'll get a lot out of the book even if your knowledge of physics is limited, and there are also several pearls of wisdom for those already well-versed in the field. Carroll also looks to the future, and discusses what the implications of the discovery might be.

I'll forgive his perpetuation of the myth that Peter Higgs is 'Scottish', plus the bizarre suggestion that physicist Jeffrey Goldstone is also Scottish (and a few other wobbles) for a beautiful remark about the mass of the Higgs itself. Why is the Higgs boson massive? Because it has no reason not to be. Carroll is not being flippant – this is a serious answer, and the reasons may be found in his delightful book. For anyone excited by the particle at the end of the Universe, start here.

■■■■■

PROFESSOR FRANK CLOSE is a particle physicist at Oxford University and the author of *The Infinity Puzzle*

MEET THE AUTHOR



Sean Carroll

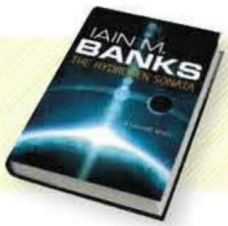
Why did you write this book?
The book is about the Large Hadron Collider, the particle accelerator, and its search for the Higgs boson. I was acting as a journalist when it came to the experimental side – in awe at what people had accomplished building the largest machine ever. Then in my role as a theoretical physicist, there are certain deep concepts that we never explain in the popular media – quantum field theory, symmetries and symmetry-breaking – so I had a lot of fun doing my best to explain that to a general audience.

What surprised you most?
You're told the project is difficult, but those words don't make an impression until you dig into *what* made it complicated. For example, one of the experiments, called CMS, was built 300ft underground in a tiny town in France called Cressy, and they needed to lower it through a tube to get it to the accelerator. First, they realised they had dug up an ancient Roman ruin from 400 AD. Then they find an underground river. So like good physicists they tackled this problem by flooding it with liquid nitrogen and freezing the river so they could lower their experiment down the tube.

Which part of the book was most challenging to write?
There's always the question: who's going to win the Nobel prize? The Higgs boson idea came from at least seven people in the 1960s – the experiments and collider are built by thousands of people. I tried to explain who contributed what. It's fascinating both as physics and as history, but tough going for the average reader.

MORE ON THE PODCAST
Listen to the full interview with Sean Carroll on the podcast at sciencefocus.com/podcasts

PHOTO: PRESS ASSOCIATION



The Hydrogen Sonata

Iain M Banks

Orbit £20

SAD TO SAY, but most SF sequences soon run out of rocket fuel. Iain M Banks's Culture series, which this year celebrates its 25th anniversary, remains a shining exception.

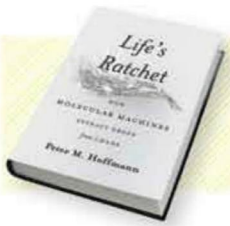
Why? Perhaps it's because the Culture books have never followed an overarching narrative. Instead, each novel has an energy born of telling a self-contained story that explores an aspect of Banks's utopian, semi-anarchistic future society. For *The Hydrogen Sonata*, this means the Culture's relationship with the Gzilt, a sister civilisation preparing to 'Sublime' – to ascend to a more complex plain of existence.

Except there's a problem, centred on the Gzilt's holy book, a problem that also appears to involve the Culture's creation 10,000 years previously. Gzilt musician Vyr Cossont is sent to find the Culture's oldest living man, the near-mythical QiRia, who may be able to shed light on long-forgotten events. From the moment the Gzilt Regimental High Command is destroyed, this doesn't prove easy.

Sharply satirical and packed with brilliant action scenes, this space opera proves British SF's big beard still plays the best tunes.

■■■■■

JONATHAN WRIGHT is a journalist and science fiction expert



Life's Ratchet

How Molecular Machines Extract Order From Chaos

Peter M Hoffmann

Basic £18.99

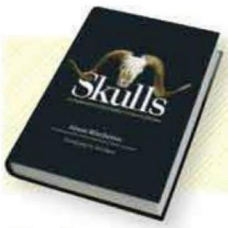
RICHARD FEYNMAN DIED in 1988, so we'll never know what the physicist would have made of laser tweezers, kinesin molecules, and other wonders of modern biology. But he certainly understood the importance of thermal motion and nanotechnology.

Indeed, as this engaging book describes, one of Feynman's famous thought experiments was a miniature ratchet driven by thermal motion. How could such a device ever perform useful work at a constant temperature? After all, that's what millions of molecular motors do inside cells every second. The answer, we're told, is free energy (the energy in a physical system that can be converted to do work)... plus evolution. By degrading a small quantity of free energy, the motor – life's ratchet – rectifies the random motions of thermal noise, thanks to its non-symmetrical molecular structure, which has been crafted by evolution. We therefore get the creation of order and living systems.

If you want to understand how life appeared spontaneously in a chaotic Universe, this book is for you.

■■■■■

PROFESSOR DENNIS BRAY is the author of *Wetware: A Computer in Every Living Cell*



Skulls

An Exploration Of Alan Dudley's Curious Collection

Simon Winchester

Black Dog & Leventhal £19.95

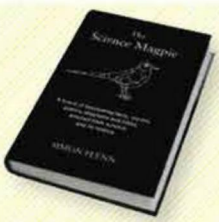
THIS IS A GORGEOUS, coffee-table book that will delight the heart of someone like me, whose career is based around the study of bones. It presents beautiful examples of skulls from across the vertebrate family tree, collected by enthusiast Alan Dudley. If you have even a passing interest you'll be engrossed too.

The order in which the groups and notes are presented would strike a zoologist as a little idiosyncratic, but then again the idea isn't to take an overtly educational approach. The skulls aren't shown to scale either – as the notes make clear – but some idea of their actual size would have made this book just that little bit more useful without compromising the presentation.

Each specimen is given some context by including a photo and notes on the living animal, its scientific name and classification. Since every one of the featured creatures is part of the Kingdom Animalia and phylum Chordata, however, repeating that information every time is a bit redundant. Nit-picking apart, I loved this book. A real treasure.

■■■■■

PROFESSOR JENNY CLACK is a palaeontologist at Cambridge University



The Science Magpie

A Miscellany Of Paradoxes, Explications, Lists, Lives And Ephemera From The Wonderful World Of Science

Simon Flynn

Icon £12.99

A TEENAGE NEWTON'S self-confessed sins; how flipping a molecule left-to-right affects its smell; poems about the lives of forgotten female astronomers... as the subtitle promises, this book is a cabinet of scientific curiosities. Judging by his selections, the author has pretty eclectic taste – there are trips through poetry and anecdote, as well as science facts.

Luckily, these deviations don't come at the expense of scientific accuracy. In fact, the author should be congratulated for not falling for the poorly substantiated – but often repeated – stories that do the rounds when scientific oddities are brought up. For example, rather than seeing the golden ratio everywhere like Dan Brown, he points out that finding such patterns is often wishful thinking, and goes on to discuss the real role that the ratio plays in plant development, for instance.

Books like this are typically read once and given away, but the diversity in *The Science Magpie* makes it worthy of at least a couple of re-reads, and it will stimulate good topics of conversation for the pub.

■■■■■

KATE OLIVER communicates engineering research at University College London

World Mags



COMPETITION TERMS AND CONDITIONS:
Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. The closing date and time are as shown on page 128. Entries received after that will not be considered. Entrants must supply their full name, address and daytime phone number. Immediate Media (publisher of *Focus*) will only ever use personal details for the purposes of administering this competition unless you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemedia.co.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown on the Crossword page. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. The name and county of residence of the winners will be published in the magazine within three months of the closing date. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.

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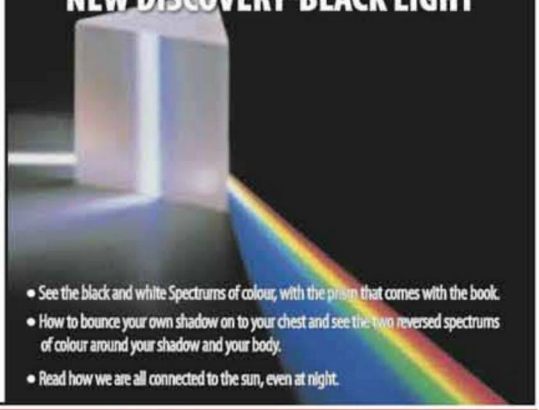
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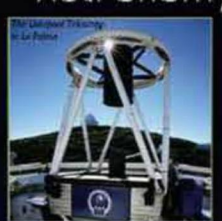
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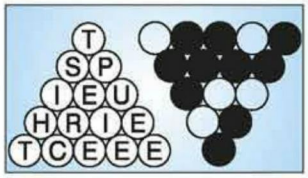
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MINDGAMES

BBC FOUR Pit your wits against these brainteasers by David J Bodycombe, question-setter for BBC Four's *Only Connect*

PRIZE PUZZLE

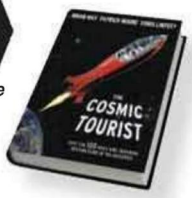
Use these two triangles in some combination to find a well-known phrase.



WIN! THE COSMIC TOURIST

The first five correct entries win a copy of *The Cosmic Tourist* by Brian May, Patrick Moore and Chris Lintott (Carlton, £25).

Post your entry, marked 'Prize Puzzle 249', to: *Focus*, PO Box 501, Leicester, LE94 0AA, to arrive by 5pm on 13 December 2012. We regret that we cannot accept email entries for this competition. See sciencefocus.com/winners for a list of previous winners and solutions.



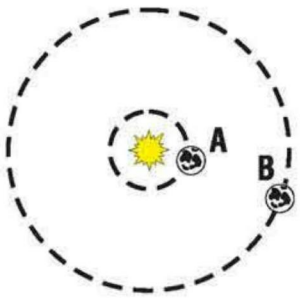
See bottom of p120 for T&Cs. Congratulations to Henry Kuttner Fukes (Middlesex), Mark Radford (Lancashire), Stephen Savage (Sheffield), Peter Haworth (Bristol) and David Thompson (Gurnsey) who solved the September Prize Puzzle to each win a copy of *Planet Dinosaur 3D*.

Q1

Ireland has 2,880 square miles of it. Portugal exports 150,000 tonnes of it a year. What is it?

Q2

Planet A is 100 miles from the Sun's centre and takes six months for one orbit. How long would planet B take if it is 300 miles further out than A? (Hint: according to Kepler, d^3/t^2 = constant.)



Q3

What is self-descriptive about this clever sequence? 1, 3, 7, 8, 10, 12, 14, 15, 20, 24, 27, 29, 30, 33, 34, 37... (Hint: spell out the numbers).

Q4

Which is the odd one out?



Q5

After a recent trip to the US, I have two dollars in loose change. After putting thirty five cents in a charity envelope, only quarters remain. How is that possible?

Q6

Which two consonants have been removed from this crossword?



Q7

Move one number so that the list is in numerical order:

3 9 17 4 6

Q8

Move the listed cards into the grid so that the best possible poker hand in each row and column matches the label shown. The cards are not necessarily in the right order (eg 5-4-6-7-3 still counts as a 7-high straight).



SOLUTIONS

4♦	4♥	2♣	8♦	8♥
A♦	Q♦	J♦	9♦	10♦
2♦	2♥	2♠	7♦	7♥
3♦	K♣	7♣	K♦	7♠
5♦	6♣	J♥	6♦	J♠

Q1) Cork (as in County Cork and tree bark).
Q2) B's distance from the Sun's centre is 400 miles, four times larger than A's. Using Kepler's Third Law as given, orbit time increases by the square root of (4x4x4) = 8 times, i.e. 4 years.
Q3) Spelling out ONE, THREE, SEVEN, EIGHT... you find that the vowels appear at the 1st, 3rd, 7th, 8th... letter.
Q4) The angle between the hands of the top-right clock is different.
Q5) I put 30 five cents (30 nickels) in the envelope, not 35 cents. Hence, 50 cents (two quarters) remain.
Q6) P and S (clues include OPPOSES, SPOUSES, OSSEOUS and SUPPOSES).
Q7) Move the 6 next to the 4 to give: 3, 9, 17, 4, 6.
Q8) See illustration, right.

QUICK QUIZ

How much do you know about dinosaurs?

Q1

During which geological period did dinosaurs first appear?

a) Triassic
b) Jurassic
c) Cretaceous

Q2

The most complete T-rex skeleton, 'Sue', can be seen in which city?

a) Chicago
b) New York City
c) Los Angeles

Q3

Which of these dinosaurs was a carnivore?

a) Triceratops
b) Velociraptor
c) Stegosaurus

Q4

Which famous palaeontologist coined the word 'Dinosauria'?

a) Barnum Brown
b) Edward Drinker Cope
c) Richard Owen

Q5

The Diplodocus belonged to which group of dinosaurs?

a) Ornithopods
b) Theropods
c) Sauropods

Q6

Which of these is not a real dinosaur name?

a) Bambiraptor
b) Spielbergsaurus
c) Irritator

Q7

Approximately how long ago did all non-avian dinosaurs become extinct?

a) 65 million years
b) 95 million years
c) 125 million years

ANSWERS:

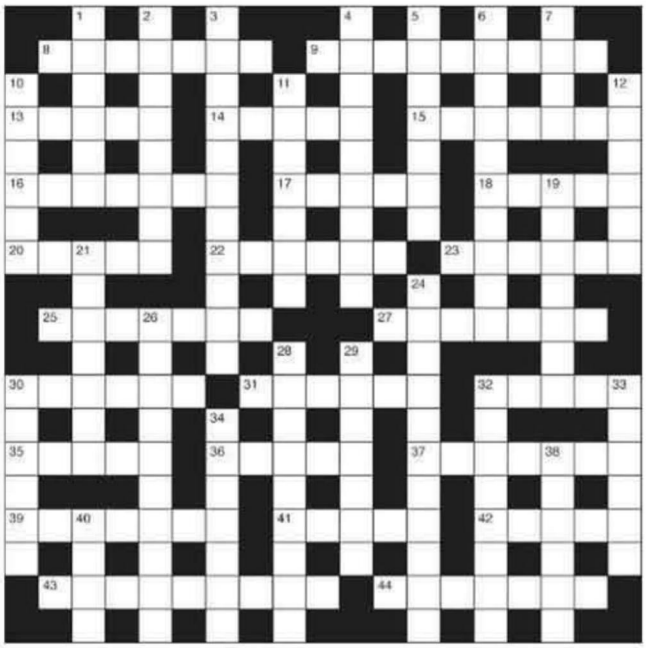
1a, 2a, 3b, 4c, 5c, 6b, 7a

YOU ARE A:

0-3 Toothless lizard
4-5 Tolerable lizard
6-7 Terrible lizard

FOCUS CROSSWORD No 145

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ACROSS

8 Nip back to get some new particle (2,5)
9 Exponent of record to harm its progress (9)
13 Right to boot out a machine (5)
14 Illuminated concerning amount (5)
15 Group that is putting glasses out (7)
16 Bird enclosure with one weapon outside (7)
17 Whole time alto was performing (5)
18 First character to help a translation (5)
20 Go on about a bee (5)
22 Source of guttural sound or that confusion (6)
23 It's vital for watching TV (6)
25 Bitter speech about sulphuric acid (7)
27 Scottish peak has frame of fern (7)
30 Girls cook Eastern fish (6)
31 A seal, say, or a bird (6)
32 Without a mathematical sign (5)
35 Alloy that's a bargain, reportedly (5)
36 One transaction is perfect (5)
37 Generator engineers performer (7)
39 Quote a composition, taking Republican line (7)
41 Simple enough for a computer to understand (5)
42 Chat about student field of activity (5)
43 Like an impossible clue, especially in water (9)
44 Rest lie about being unproductive (7)

DOWN

1 Boils away new capital (6)
2 Equipment to try out on the underground (4,4)
3 Reproduction of survey on one country (11)
4 Capacity for having some energy (9)
5 Dry fruit providing some medicine (7)
6 When bill came, it somehow included two elements (10)
7 Asian connection is heard (4)
10 Supporter of photography (6)
11 Figure it has right height (7)
12 A maths mistake produces complaint (6)
19 Sculptor in steep decline (7)
21 Bull to one side managed to turn red (7)
24 Cheery try to affect blood cell (11)
26 Decision on picture's sharpness (10)
28 See barley hop about, forming conic section (9)
29 Single movement with top of his tongue (7)
30 For packing German steak away (6)
32 Find me terribly moral about Welsh larva (8)
33 It's red, varying pace (6)
34 Having gas isn't our problem (7)
38 Utter chaos, having left reptile (6)
40 Supporter of foul nature (4)

SOLUTION TO CROSSWORD No 142

John Hodgkinson, Steve Cooper, S Barnett, GA Caldwell and Stuart Milner solved the issue 246 puzzle and each receive a copy of *It's Not Rocket Science* by Ben Miller.



WIN! *EVERYTHING YOU NEED TO KNOW ABOUT EVERYTHING YOU NEED TO KNOW ABOUT INVENTIONS*

The first five correct solutions drawn will each win a copy of *Everything You Need To Know About Everything You Need To Know About Inventions* by Michael Heatley and Colin Slater (Portico, £14.99). Entries must be received by 5pm on 13 December 2012. See below for more details.



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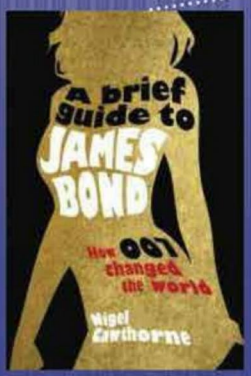
EMAIL

Post entries to *Focus*, December 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to december2012@focuscomps.co.uk by 5pm on 13 December 2012. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 120. Immediate Media, publisher of Focus, 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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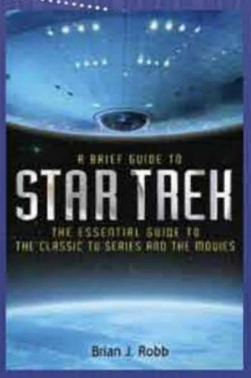
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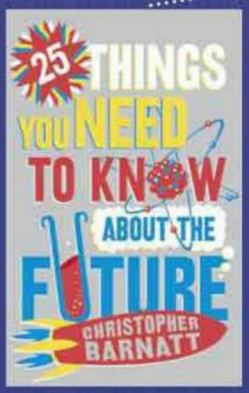


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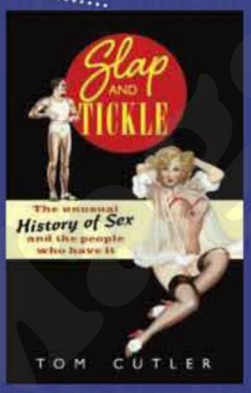
Two of the latest in the Brief Guide series from Robinson, other new titles in the series include Star Wars and J.R.R. Tolkien.



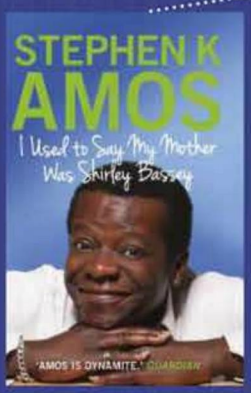
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INTO THE FUTURE

STEPHEN BAXTER

WHEN WE IMAGINE first contact with extraterrestrial intelligence (ETI), we generally picture a human meeting the alien. But our first ships to the stars are likely to be robot craft, just as with the first planetary probes. Imagine a smart probe sent to explore a star system like Alpha Centauri, four light-years away. What if the robot discovered ETI at that system – what if it made first contact, on behalf of humanity?

We've already thought about this possibility to some extent. We put messages in the form plaques and records on the Pioneers and Voyagers, the first probes to leave the Solar System, in case they were ever picked up drifting in interstellar space. But a probe sent to a specific star system, where it will presumably stay in orbit around the star or one of its planets indefinitely, is much more likely to be detected by any native ETI. They might see its drive, for instance. US scientist Robert Zubrin has calculated that a spacecraft driven by an antimatter drive (like the one that powered the Venture Star starship in the movie *Avatar*) could be visible to a Hubble Space Telescope across hundreds of light-years – let alone within a solar system.

Or, of course, the probe might detect the presence of ETI itself. An advanced robot probe could listen for radio signals, as SETI (Search for Extraterrestrial Intelligence) researchers have done for decades from Earth. It could inspect planetary surfaces from orbit for artefacts or structures. This has been proven to work on Earth's surface. As reported in *Focus* in June 2012, high-resolution visual images returned by Earth-orbiting satellites have been used to make new archaeological discoveries. Landers on the planets, meanwhile, could conceivably detect traces of even long-vanished civilisations, such as smaller-scale artefacts, from pyramids down to flint axes.



Should a probe attempt contact with an alien civilisation or keep quiet?

"What should a probe do if it did make contact? It would be light-years from Earth, and would have to wait years for news to reach scientists"

What should a probe do if it did make contact? It would be light-years from Earth and would have to wait years for news of the discovery to reach scientists, and for any instructions to return. If it detected signals, possibly an advanced enough probe could attempt some kind of translation. Even today we have software systems that can detect the level of complexity contained in a signal. This is done by looking for patterns and relationships in the data making up the signal. John Elliott of Leeds University is developing an analysis suite capable of measuring the complexity of signals ranging from whale song to (hypothetical) speech more complex than a human's.

If a probe did detect a signal, could it reply? One easy way for a probe to announce its presence would be to echo back native radio broadcasts to their senders, even if it couldn't translate those broadcasts. Scientists have looked (unsuccessfully) for similar echoed signals in our own Solar System. Of course we could load the probe up with Voyager-type plaques and discs full of information about Earth, as a gift to any contacted culture.

But is making contact the wisest course? Some people think the reason we haven't detected any signals from ETI is because there are aggressive cultures out there, and everybody else is hiding. In L Ron Hubbard's *Battlefield Earth* the voracious Psychlos use a Pioneer plaque, which had a map showing where the Sun is in the Galaxy, to find Earth and conquer us. Maybe the safest option would be for the probe to report the find back to Earth and wait for instructions: either to attempt contact of some kind, or perhaps, in the worse case, to self-destruct, to keep the existence of Earth a secret. And in the meantime, to stay very quiet... ■

STEPHEN BAXTER is a science fiction writer whose books include the *Destiny's Child* series and *The Science Of Avatar*

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