

BBC

A Times of India publication

Volume 6 Issue 2
February 2016 ₹125

Knowledge

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INCORPORATING
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**SCIENCE
WORLD**

THE BIG QUESTIONS OF **ANCIENT EGYPT**

What mysteries of
Ancient Egypt have the
centuries concealed? *p38*



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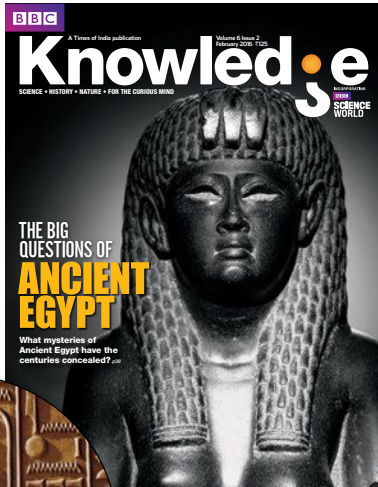


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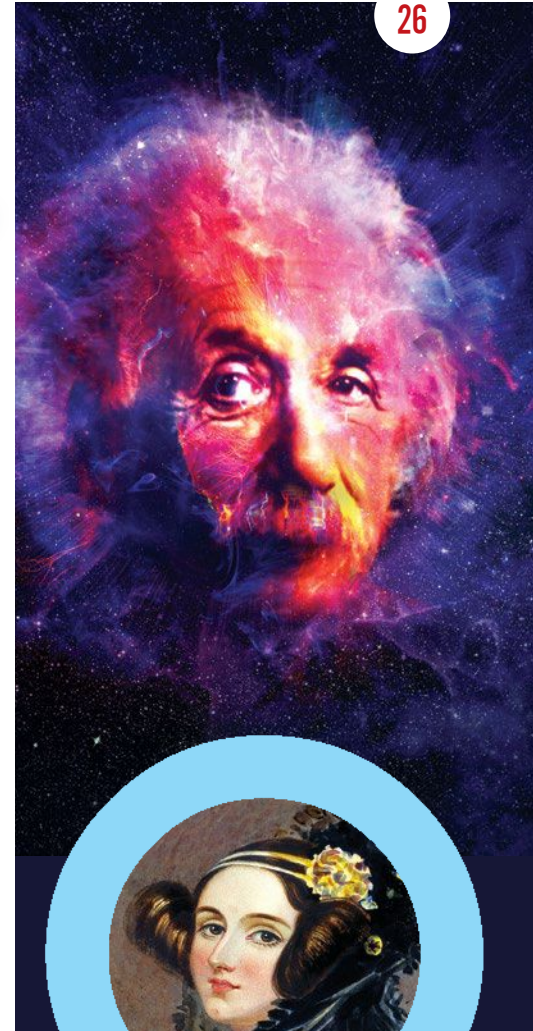
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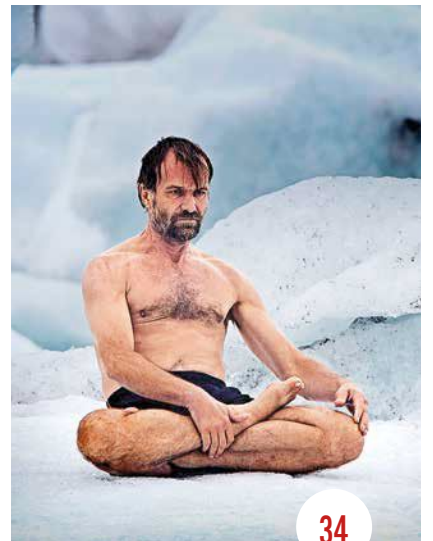
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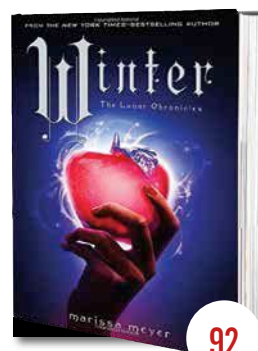
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FROM THE EDITOR



It's a new year and change is again knocking at our doors. As all years go, 2015 was eventful too. But I think some events that occurred, have made this past year a bit more significant than others to the story of our world.

Exactly a year ago in January, the Charlie Hebdo attacks in Paris rattled the western world. Terrorism, foreign policies, religion, drones, became and remain the talk of our times. In March, Iran and 6 other world powers including the United States signed a historic nuclear deal intended as a major step towards making the world safer. In August, the crisis of Syrian migrants overwhelmed Europe and emerged as one of the compelling humanitarian issue of our times; September made us more cynical about big corporations, thanks to the deceit perpetuated by Volkswagen globally with its emissions scandal. Same month, NASA confirmed there was liquid flowing water on Mars. The Paris Attacks in November made many question if this was the beginning of a third world war.

But despite the ban on diesel cars and the smog in Delhi, December ended on hope – a new, momentous climate change treaty was agreed upon by 200 nations in Paris – a big big deal since climate change and a country's responsibility towards this man-made problem has always been a point of contention.

Do you see how each and every one of these events will affect our lives? Change is indeed in the air and 2016 will bring more of it. So let's embrace it – let's know more, innovate more and do more, read, learn & discuss more, and explore more.

Have a great year.

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EXPERTS THIS ISSUE



Marcus Chown is a science journalist, writer and broadcaster who has written several books as well, including *Quantum Theory Cannot Hurt You*. In this issue, he revisits Einstein's Theory of Relativity to see how it holds up, a 100 years after its formulation. **See page 26**



Joann Fletcher is leading Egyptologist and Honorary Visiting Professor in the Department of Archaeology at the University of York. She has written many books and appeared on television and radio numerous times. In this issue, she answers some of the most pressing unanswered questions about Egypt's ancient past. **See page 38**



Christian Jarrett is a critically acclaimed author and holds a PhD in Cognitive Neuroscience. In this issue, he deconstructs the various clues to your personality and health that can be read off your face. **See page 60**



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We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine. We regret that we cannot always reply personally to letters.



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HERE'S HOW TO GET IN TOUCH

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www.knowledgemagazine.in



Printed and published by Joji Varghese for and on behalf of Worldwide Media Pvt. Ltd., The Times of India Building, 4th floor, Dr. D. N. Road, Mumbai 400001 and printed at Rajhans Enterprises, No. 134, 4th Main Road, Industrial Town, Rajajinagar, Bangalore 560044, India. Editor- Preeti Singh. The publisher makes every effort to ensure that the magazine's contents are correct. However, we accept no responsibility for any errors or omissions. Unsolicited material, including photographs and transparencies, is submitted entirely at the owner's risk and the publisher accepts no responsibility for its loss or damage. All material published in BBC Knowledge is protected by copyright and unauthorized reproduction in part or full is prohibited. BBC Knowledge is published by Worldwide Media Pvt. Ltd. under licence from Immediate Media Company Bristol Limited. Copyright © Immediate Media Company Bristol Limited. All rights reserved. Reproduction in whole or part prohibited without permission. The BBC logo is a trade mark of the British Broadcasting Corporation and is used under licence. © British Broadcasting Corporation 1996
CIN: U22120MH2003PTC142239

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EXPERT PANEL

Susan Blackmore (SB)

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

Alastair Gunn

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

Robert Matthews

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

Gareth Mitchell

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

Luis Villazon

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

ASK THE EXPERTS?

Email our panel at bbcknowledge@wmm.co.in
We're sorry, but we cannot reply to questions individually.

KNOW SPOT

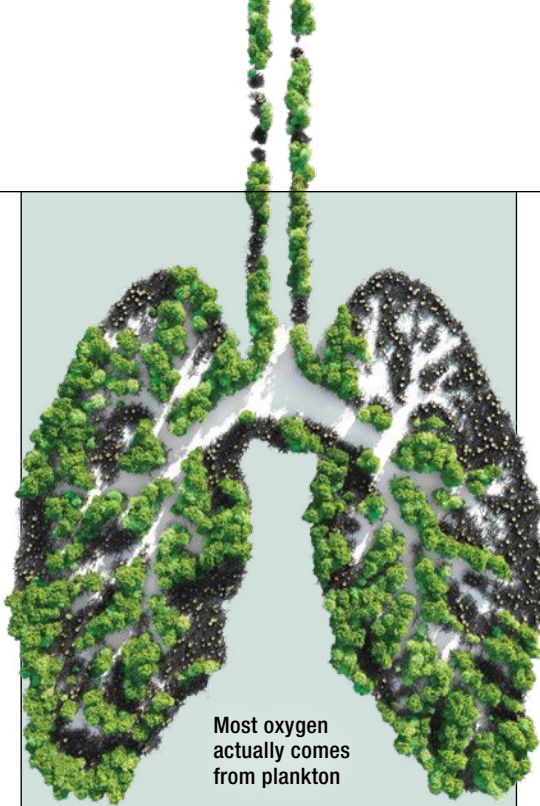


The device used to measure your foot at a shoe store is called a "Brannock Device."

How do waterfalls freeze?

Water turns to ice when its molecules move slowly enough to form rigid bonds. Normally, the molecules in the waterfall move under the influence of both the flow and thermal agitation. But if it gets cold enough, the heat effect becomes so low that not even the waterfall's motion can stop ice forming, gradually at first but then ever more rapidly. RM





Most oxygen actually comes from plankton

How does Earth maintain a constant level of oxygen?

It doesn't! The oxygen level of the planet has varied quite dramatically in the last 500 million years. It was 35 per cent during the Carboniferous period, around 300 million years ago; as the climate cooled and land plants died off, oxygen fell to as low as 12 per cent by the beginning of the Triassic. Back then, the air at sea level would have felt thinner than at the top of the Alps today.

Burning fossil fuels has reduced oxygen levels very slightly – about 0.057 per cent over the last 30 years. Deforestation only has a small effect because when rainforest is cut down, other plants are usually grown in its place. But it's marine plankton, rather than trees, that produces about 70 per cent of atmospheric oxygen. Global warming will have a significant impact on plankton, which is a much more serious threat to oxygen levels. LV

VITAL STATS

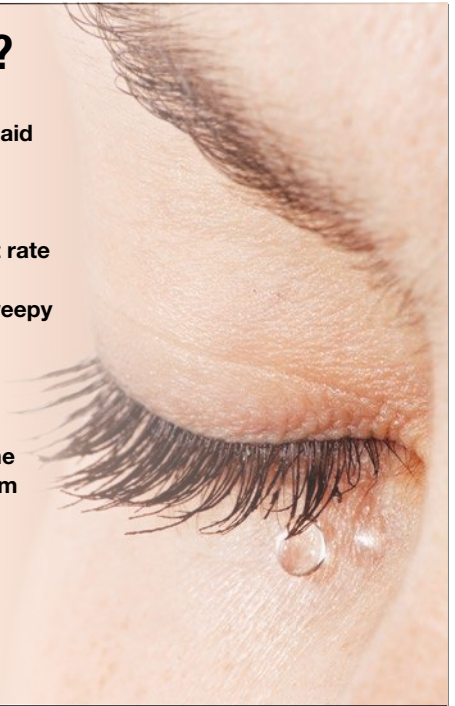
48 million

Is the age in years of a 12.5cm-long fossilised foetus being studied in Germany. The specimen is thought to be an early horse-like species

Is crying good for you?

Many people would say yes. Crying is said to be cathartic, relieve stress and even remove toxins from the body, and most therapists claim it's beneficial. There is evidence that blood pressure and heart rate fall after crying, while some allergic reactions are reduced after watching weepy films, and sufferers from rheumatoid arthritis who cry have less pain than those who don't.

Yet the experimental evidence is mixed. Benefits are more likely when the reason for crying is a resolvable problem and the person crying is comfortable expressing their emotions and not otherwise depressed. One function of crying may be to show our distress, which can help build relationships, and this may be why crying helps. SB



Could we exist on Earth under a red giant star?

About five billion years from now, the Sun's usual source of nuclear energy will be depleted. It will begin to expand and cool significantly, becoming a 'red giant'. Its outer layers will be thrown off into space. As the Sun loses mass, its gravitational pull will weaken and the planets' orbits will widen. We know that Mercury and Venus will not be able to outrun the expanding Sun, and will be engulfed and incinerated.

Earth may just outrun the swelling red giant but its proximity, and the resulting rise in temperature, will probably destroy all life on Earth, and possibly the planet itself. However, there's no reason that life could not survive on another planet (or moon) sufficiently far out from the Sun, as long as it lies within the Sun's expanded 'habitable zone'. Life could also survive on suitably hospitable planets around other red giants. AG

The future's so bright, we're all going to die horribly in a stellar inferno



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Can a yacht ever travel faster than the wind?

This seems like defiance of the laws of physics, but it just needs the right shape and size of sail to trap enough of the air-mass blowing in the wind. The resulting transfer of momentum can propel yachts to impressive speeds, especially if friction is minimised – some sleek catamarans can achieve 80km/h using 35km/h winds. RM



Perhaps if they all blow really hard, that will help too?

On average, how many of our muscles do we use regularly?

Just about all of them! But our least-used muscles are probably the lumbar multifidus muscles in the lower back. Studies have shown that prolonged slumping in front of the TV can inactivate these muscles. This can lead to back pain, and once inactivated they can take months to recover. LV



We're not convinced that a 5kg barbell gave him those biceps

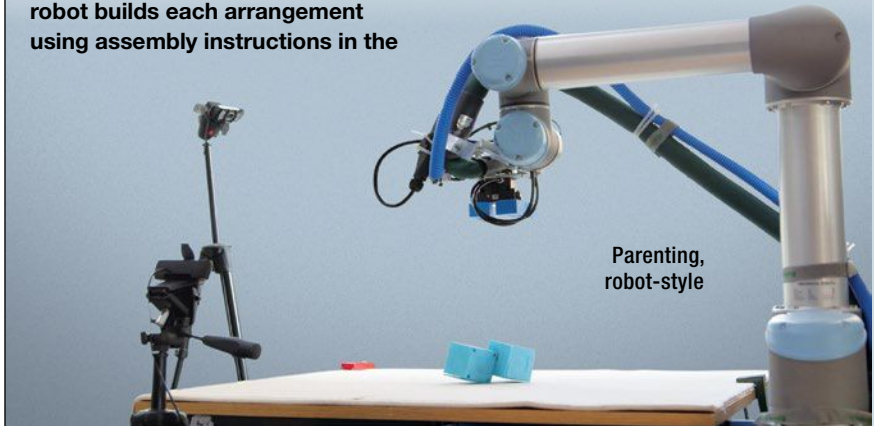
Could robots be programmed to evolve?

Yes. In research that was published in August this year, teams in Cambridge and Zurich built robots that evolve through successive generations.

The 'mother' is a robotic arm that builds 'baby' robots out of small cubes. Each cube has a mechanism where one side can waggle. When you place it on a surface, it clumsily drags itself around. The mother glues these moveable cubes together in various arrangements. Some combinations move further and faster than others. The mother robot builds each arrangement using assembly instructions in the

form of a 'genome' that is passed between successive generations of robots.

The mother is programmed to insert random mutations into each generation. Some offspring move around better than their forerunners, but others do worse. The mother rejects deficient generations but uses the genetic blueprints of successful ones to build subsequent offspring. In the lab, after only 10 generations, the robots performed twice as well as those at the start of the process. GM



Parenting, robot-style

Why do bees die after stinging you?

Honey bee stings have a barbed ratchet mechanism that pulls the stinger into the initial wound. This didn't evolve as a suicide mechanism – honey bees can pull their stings out after stinging other insects. It's meant to drive the stinger in as deep as possible; it just happens that mammal skin is too fibrous to release the sting, so the abdomen is torn open when the bee tries to escape afterwards. Honey bees are the only species to suffer this fate, but the cost to the hive of losing some workers is worth it for an improved ability to repel honey thieves. LV

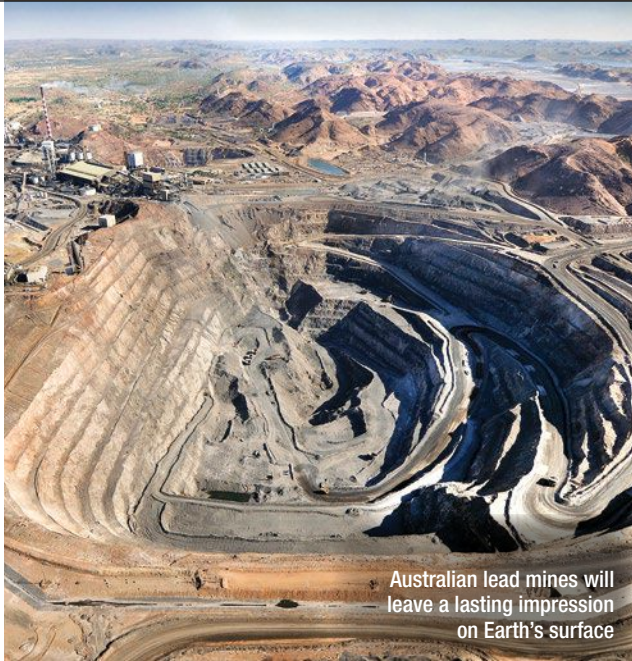
This pollinating insect has passed on. He is no more. He has ceased to be



VITAL STATS

0.235 mm

Is the size of the world's tiniest free-living (non parasitic) insect – a featherwing beetle



Australian lead mines will leave a lasting impression on Earth's surface

If humans became extinct, how long would it take for all traces of us to vanish?

Stonehenge is at least 4,000 years old and still visible today, and monuments buried nearby could be even older. Most modern buildings aren't that robust, but some traces would likely remain for at least 10,000 years, even if it was just the magnetic trace of the steel bars inside concrete blocks. When Hong Kong Airport was constructed in the 1990s, the island of Chek Lap Kok was flattened and extended, and the straight edge of its northern coastline will be a clue to our civilisation for tens of thousands of years. Our atmosphere also has high levels of

plutonium-239 due to nuclear weapons testing during the Cold War. This isotope only occurs in nature in incredibly small amounts, and will be detectable as a pollutant for at least 250,000 years.

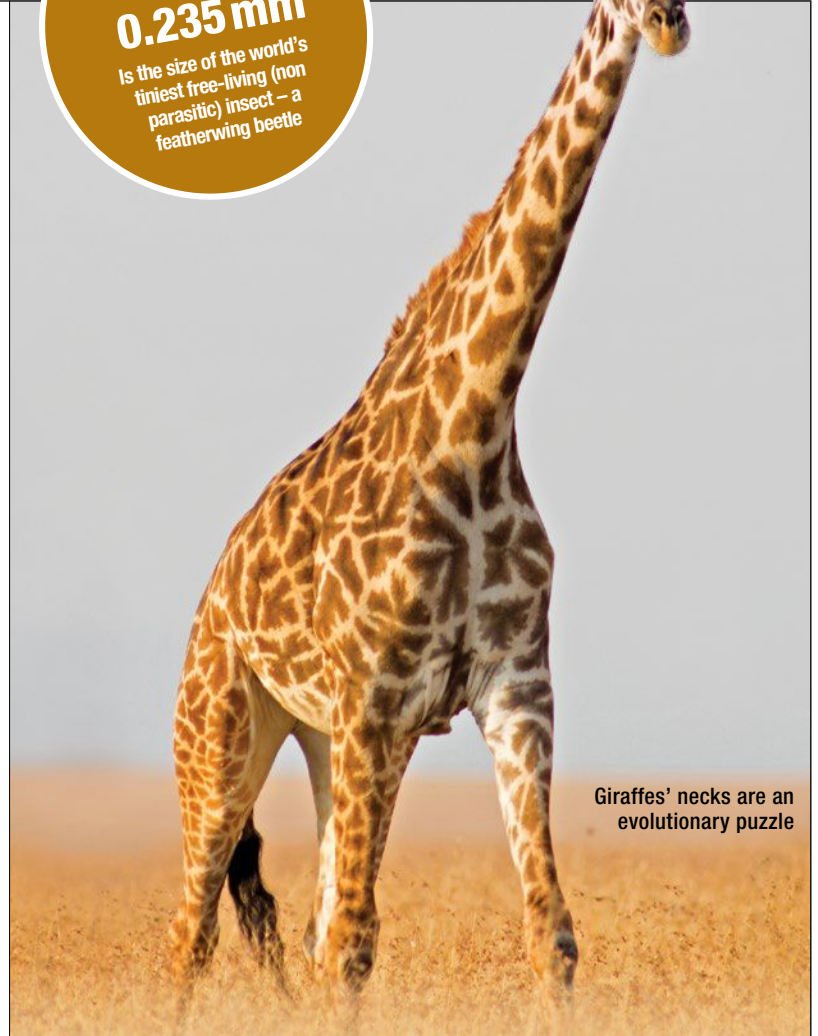
But the most enduring signs of civilisation will probably be deep mines in hard rock, such as South African gold mines and Australian lead mines. Here, visiting aliens would be able to see signs of our civilisation for millions of years, as the tunnels fill up with sediment washed down by rainwater to create massive industrial 'fossils'. LV

Aren't epigenetic effects evidence for Lamarckism?

Not really. Epigenetics is when genes alter their activity in response to external factors such as diet, exercise and chemical exposure. The sequence of letters in the DNA doesn't change, but the DNA molecule acquires other chemical changes that can be passed on to your offspring. These inherited traits last for two or three generations.

Lamarckism says the giraffe got its long neck because

parents stretched their own necks slightly during their lifetimes and passed that increase on to their children, and so on. That's quite different from the Darwinian view that each generation has a certain amount of natural variation, and that giraffes with longer necks have more offspring. Epigenetics is an important influence on evolution, but it doesn't drive long-term species change. LV



Giraffes' necks are an evolutionary puzzle



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TOP TEN COUNTRIES WITH MOST FACEBOOK USERS



1. UNITED STATES

Number of users: 152 million
Population: 319 million



2. INDIA

Number of users: 109 million
Population: 1.3 billion



3. BRAZIL

Number of users: 71 million
Population: 200 million



4. INDONESIA

Number of users: 60 million
Population: 250 million



5. MEXICO

Number of users: 44 million
Population: 122 million



6. PHILIPPINES

Number of users: 34 million
Population: 98 million



7. TURKEY

Number of users: 32 million
Population: 75 million



8. UNITED KINGDOM

Number of users: 30 million
Population: 64 million



9. JAPAN

Number of users: 27 million
Population: 127 million



10. FRANCE

Number of users: 23 million
Population: 66 million

ISTOCK, PRESS ASSOCIATION IMAGES

Why do people cheat?

Because they want to win the easy way. As competitive animals, we human beings constantly seek out opportunities to gain money, food and sex, or simply to look good. Doing all this the hard way requires expenditure of time, effort and energy, so cheating can obviously be very tempting.

Evolutionary game theory has helped to explain how altruism can exist alongside cheating. Generally, cheats do well when they are rare, but less well when they are many and have fewer non-cheaters they can exploit. So groups tend towards an equilibrium, with few enough cheats that it's not worth the cost of stopping them. Sadly, this basic biological principle means we are unlikely ever to be completely free of cheats. SB



What dictates where branches grow on a tree?

As the trunk grows upwards, buds are produced on either side. These buds are initially dormant because the growing tip at the top, called the 'apical meristem', produces the hormone auxin, which inhibits their development. Once the apical meristem has grown

far enough away, the concentration of auxin near the bud drops and it can begin growing sideways. This sideways shoot also lays down its own buds, which are in turn kept dormant until the shoot's own growing tip has advanced enough. LV





HOW IT WORKS

THE DRINKABLE BOOK

EVERY YEAR, OVER 3.4 million people die from problems associated with water, hygiene and sanitation. It's a huge problem, because the vast majority of individuals who live in areas with dirty water don't even realise that it's unsafe to drink.

To try to solve the issue, Dr Theresa Dankovich created a special type of bacteria-destroying filter paper for her PhD at McGill University. She's now based at Carnegie Mellon and has teamed up with scientists from

her current institution and the University of Virginia to create The Drinkable Book.

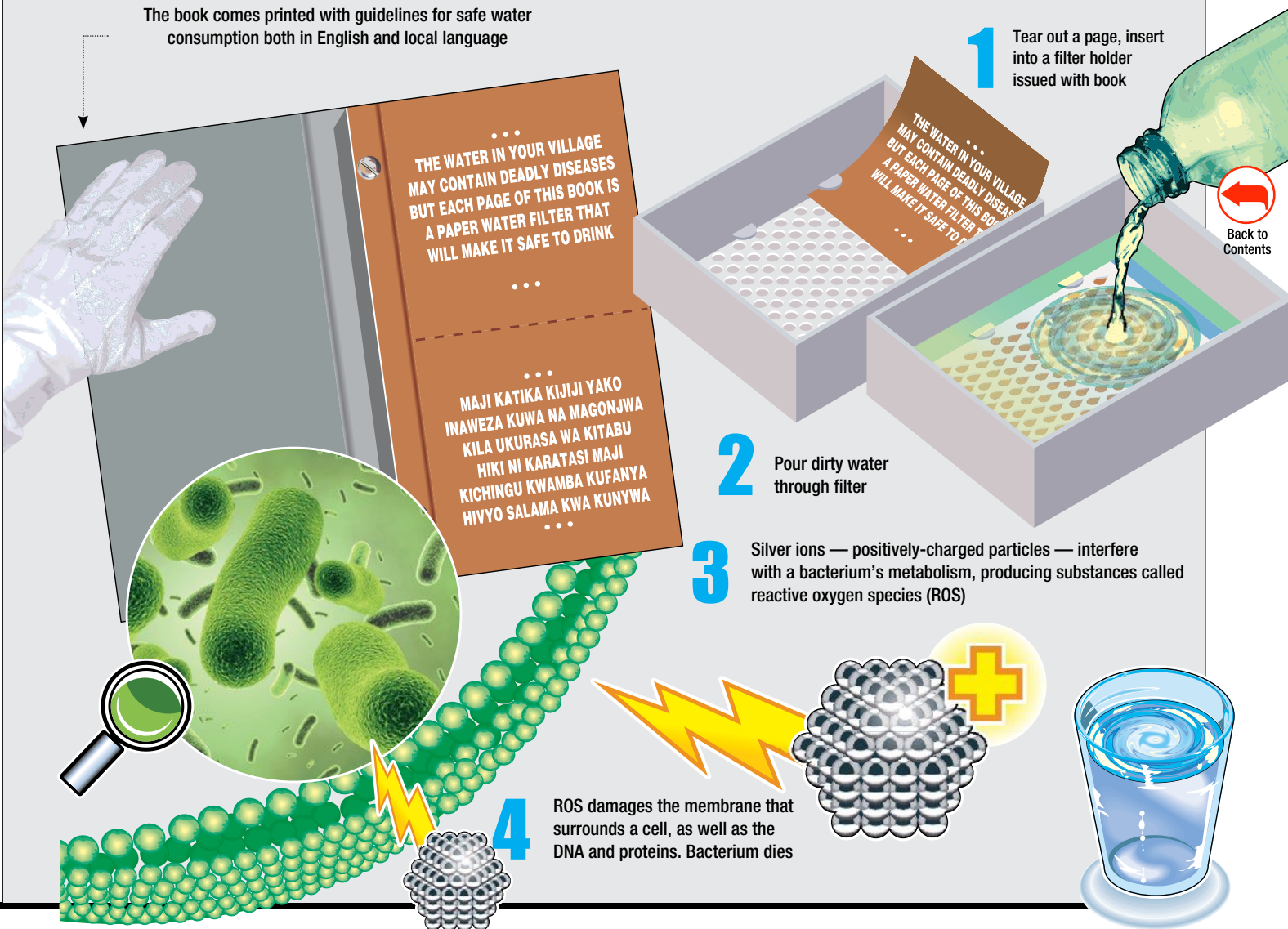
Once water has been passed through a page of the book, it comes out on the other side with a 99.9 per cent reduction in bacteria, which makes it comparable to tap water in the USA.

It works because each page is coated with silver nanoparticles, which are capable of destroying bacterial diseases such as *E. coli*, typhoid and cholera. Each filter can offer 30

days of clean water – up to 100 litres – and each book can last for up to four years.

The text printed on each page of the book helps educate people about water safety, by explaining the importance of keeping rubbish and human waste away from the water supply. So far, the filters have been trialled successfully in the developing world. However, at present, the papers are not capable of destroying other organisms, such as protozoa and viruses.

The book comes printed with guidelines for safe water consumption both in English and local language





Why do little girls like pink?

Probably because of social pressure. In Britain and the USA, older girls like pink more than boys do, but they could already have been influenced by expectations. So studies have tested one- to two-year-olds by using the

'preferential looking task', which measures what the children like to look at the most. The studies found that preferences for toys differ by sex, with boys looking longer at cars and girls at dolls, but preferences for colour do

not. So perhaps it's not surprising to learn that back in 1918 the trade publication Earnshaw's Infants' Department wrote that babies' clothes should be pink for a boy and blue for a girl. SB



What makes people afraid of the dark?

Loss of vision. Sight is our strongest sense and some of our natural predators, such as the big cats, had better night vision than our ancestors did. Our ancestors also had to watch out for enemy raids; even today, we may justifiably fear being burgled.

But our greatest fears come from our own minds. Many children, and some adults, are terrified of the monster under the bed. This is called the 'sense of presence' and is often associated with sleep paralysis, when you wake up unable to move. These monsters are due to unusual activity in areas of the brain. Then there are all those ideas that we don't like to face – our shame, guilt, anger, anxiety or whatever it may be. These seem far worse in the dark because our brains are deprived of the visual input that keeps them busy and suppresses those unwanted thoughts. SB

Torches are an effective under-bed monster deterrent

Can computers make mistakes?

Computers don't make mistakes, as such, but they can make errors. When your laptop crashes, it has gone into an error condition where it fails to run the computer code effectively. If anything, the 'mistake' is that of the human who produced ineffective code or faulty hardware. Or it's a simple case of the user asking the machine to perform a task that's outside its normal operational envelope. GM



GETTY X2, ISTOCK X4

Why does time go so fast when you're asleep?

Does it? Generally this is not true, and most people are good at judging how many hours they've slept. Some can even tell themselves to wake up at a specific time and do so. Time perception can be distorted, though, and experiments show that estimates are generally good, but people tend to overestimate time passed during the early hours of sleep and underestimate during the later hours. Time estimations during dreaming are much more variable and some people claim to have dreamt a whole lifetime in one dream. However, the best experiments to test this come from those very rare people who can induce lucid dreams (knowing they are dreaming) at will, and then signal to experimenters to indicate what they are doing in the dream. When asked to count to 100 while

dreaming or while awake, the times taken match closely. And when asked to estimate how long a dream event took, those estimates are accurate. So if time does go fast when you are asleep, you are unusual! SB



Why do we have moles on our skin?

During the first 12 weeks of pregnancy, the developing foetus is making melanocytes – the skin cells that produce ordinary skin colour. These aren't always evenly spread out: random areas will acquire a cluster and during your life, these clusters can grow into a mole.

Moles are quite different from freckles. Almost everyone has from 30 to 60 moles on their body, but freckles only occur in people with certain genes – particularly the one responsible for red hair. Freckles also need sunlight to trigger them, while moles appear spontaneously. LV

Why is it colder at the top of a mountain, if you're closer to the Sun?

As the Sun is around 150 million kilometres away, even being on top of Everest only brings you 9km closer – far too small a difference to make you feel any warmer. The distance effect is totally overwhelmed by that of having less atmosphere around you as you climb. This leads to a steady fall in atmospheric pressure, and – as the air isn't so compressed – a fall in

temperature as well. The rate of decline is surprisingly fast: around 1°C for every 100m, and continues all the way up to the so-called tropopause around 12km above the Earth.

At these altitudes, barely 10 per cent of the atmosphere remains, and the air pressure is so low that the temperature falls to a lethally cold -55°C. The threat is not academic, either: at any given

time, hundreds of thousands of people are being transported at these altitudes aboard aircraft. Passengers and crew are kept warm using hot air taken from the compressor stages of the engines before it's mixed with fuel. This, combined with insulation in the walls and heat generated by the passengers themselves, ensures the cabin can be kept at room temperature. RM

The Sun won't warm you up if atmospheric pressure is low

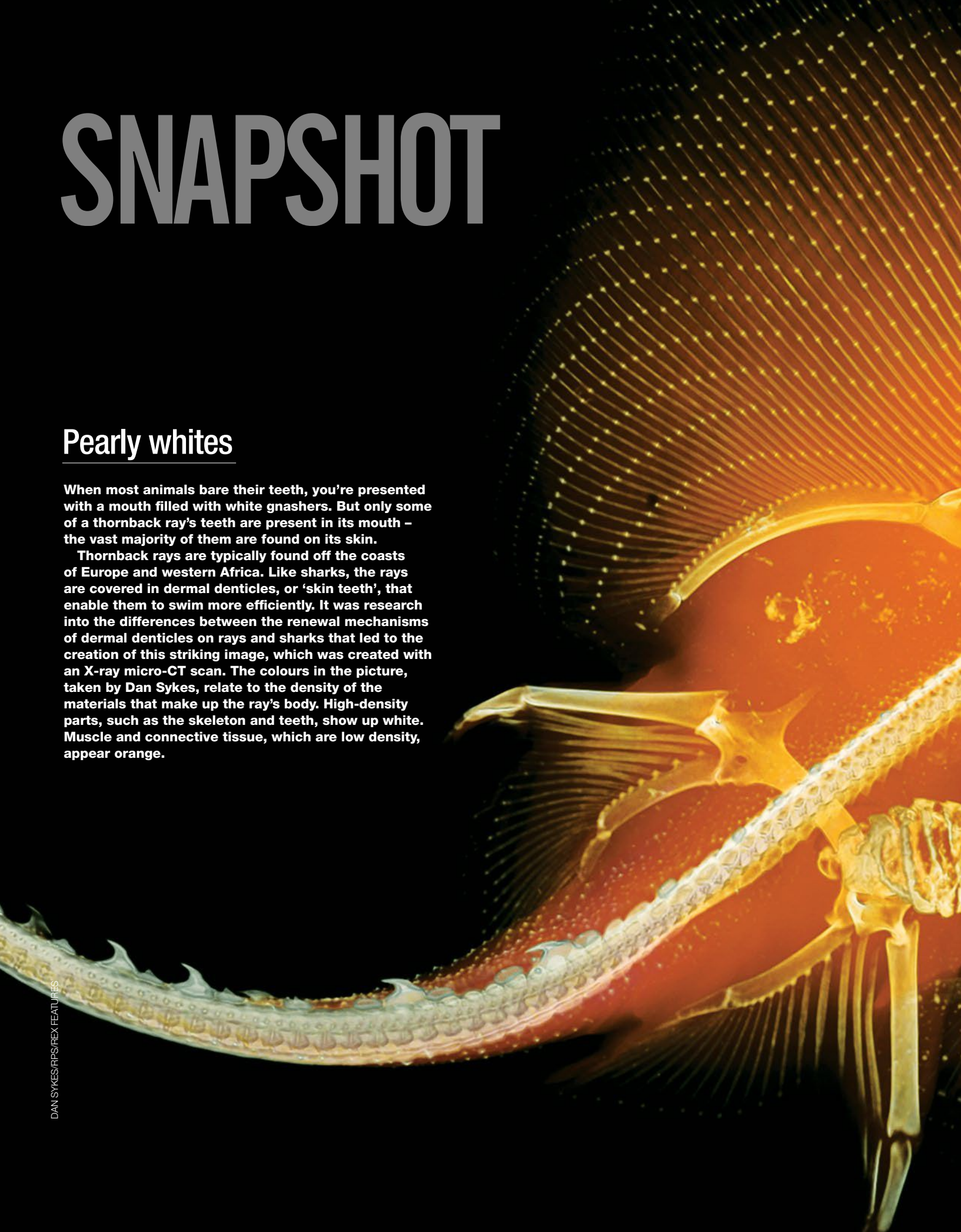


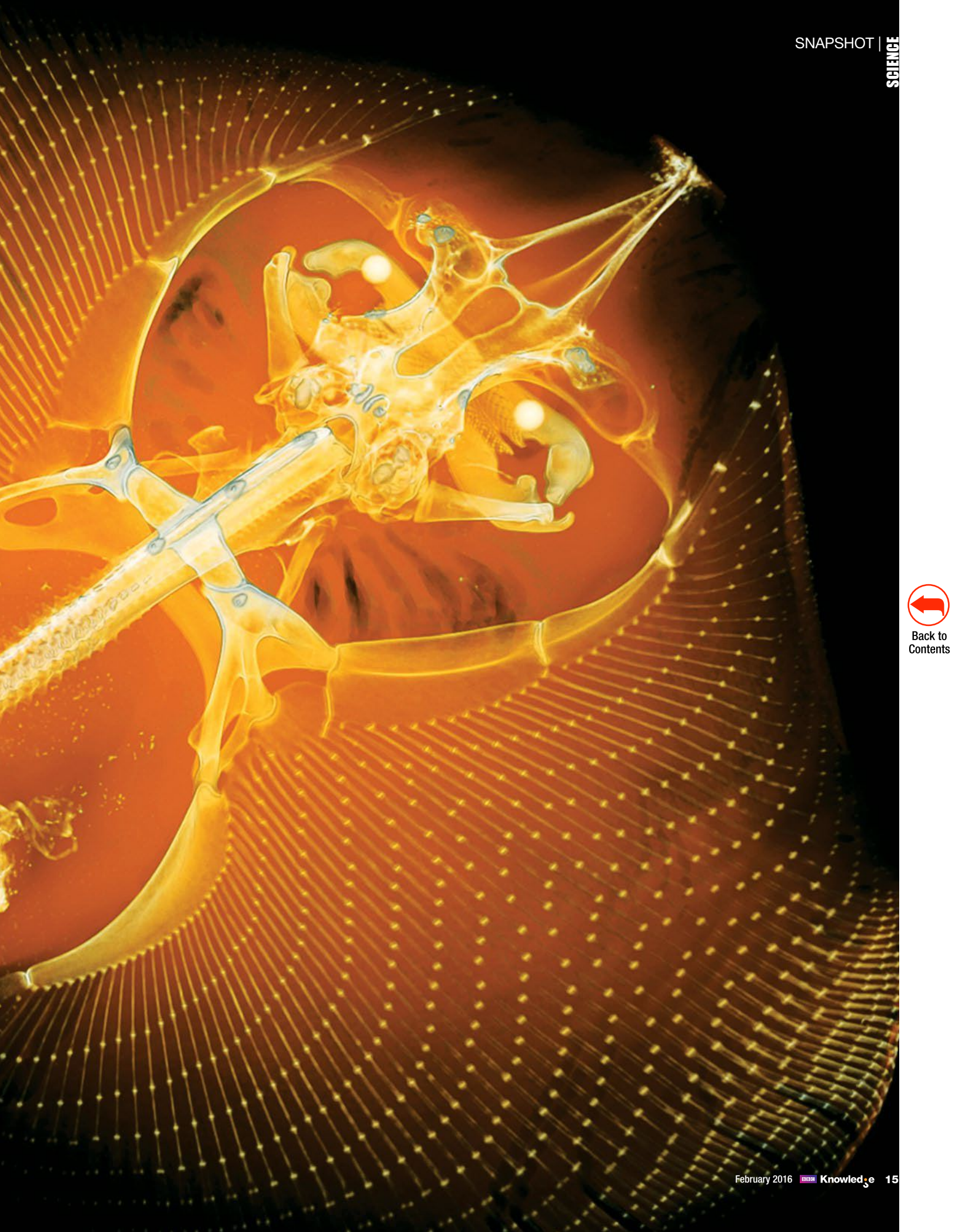
SNAPSHOT

Pearly whites

When most animals bare their teeth, you're presented with a mouth filled with white gnashers. But only some of a thornback ray's teeth are present in its mouth – the vast majority of them are found on its skin.

Thornback rays are typically found off the coasts of Europe and western Africa. Like sharks, the rays are covered in dermal denticles, or 'skin teeth', that enable them to swim more efficiently. It was research into the differences between the renewal mechanisms of dermal denticles on rays and sharks that led to the creation of this striking image, which was created with an X-ray micro-CT scan. The colours in the picture, taken by Dan Sykes, relate to the density of the materials that make up the ray's body. High-density parts, such as the skeleton and teeth, show up white. Muscle and connective tissue, which are low density, appear orange.





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Sandy sweeties

There are catacombs hidden under Paris that contain the skeletons of the deceased. While these tombs seem a world away from a tropical coastline, the two locations are more similar than you might think. On the beach, the fine, white sand between your toes is made up of the remains of tiny invertebrates. But when viewed through a microscope, the beauty of the sand is brought to life. What looks like colourful pick-and-mix sweets are actually 'spicules'. These defensive calcium-based structures protect the soft bodies of marine organisms such as Gorgonian corals, sponges and sea cucumbers. This image was taken by award-winning wildlife photographer David Maitland.



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Breathtaking branches

Nope, this isn't the root structure for some fearsome plant. This mass of black tendrils is part of a silk moth caterpillar's respiratory system, which differs dramatically from that of a mammal.

Rather than lungs, insects rely on a tracheal tree, which is a network of tubes that conveys oxygen around their bodies. Air is drawn in through spiracles – openings in an insect's exoskeleton – where it enters the tracheal tree. The branches extend throughout the insect's body, allowing the air to reach all its organs, tissues and cells. Hoops made of chitin – the same material that forms an insect's hard exoskeleton – keep the tubes open so air can flow freely.

David Maitland created this image by using differential light microscopy to magnify the tracheal tree that he found on an Edwardian microscope slide.



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DISCOVERIES

MOST EARTH-LIKE PLANETS ARE YET TO BE BORN

According to data from the Hubble Space Telescope and Kepler, Earth may be one of the earliest habitable planets in existence



The Universe may continue to pump out planets for billions of years



The Earth may be one of the earliest habitable planets ever to form, researchers from the Space Telescope Science Institute have found. Scientists surveying data collected by NASA's Hubble Space Telescope and the planet-hunting Kepler space observatory have found that when our Solar System came into being 4.6 billion years ago, only 8 per cent of the

habitable Earth-like planets that will ever form existed.

The overwhelming majority – a whopping 92 per cent – of the planets are still yet to be born and will not appear until long after our Sun burns itself out in around six billion years' time.

"Our main motivation was understanding the Earth's place in the context of the rest of the Universe,"

said study author Dr Peter Behroozi. "Compared to all the planets that will ever form in the Universe, the Earth is actually quite early."

For a planet to be considered habitable, it has to orbit its parent star at a distance that could allow liquid water to exist on the surface – not so close that it boils away, and not so far away that it freezes. Based on data from

GOOD MONTH/ BAD MONTH

IT'S BEEN GOOD FOR:

WEIGHTLIFTERS

Pumping iron twice a week may help keep your brain young. A team at the University of British Columbia has found that those who worked out with weights had less age-related brain shrinkage than their peers.

THE FOLLICLY CHALLENGED

If you hanker after the days when you had a head of luscious hair, you may be in luck. A Columbia University team has found that rapid hair growth can be triggered in mice by giving them drugs that inhibit certain enzymes within their hair follicles.



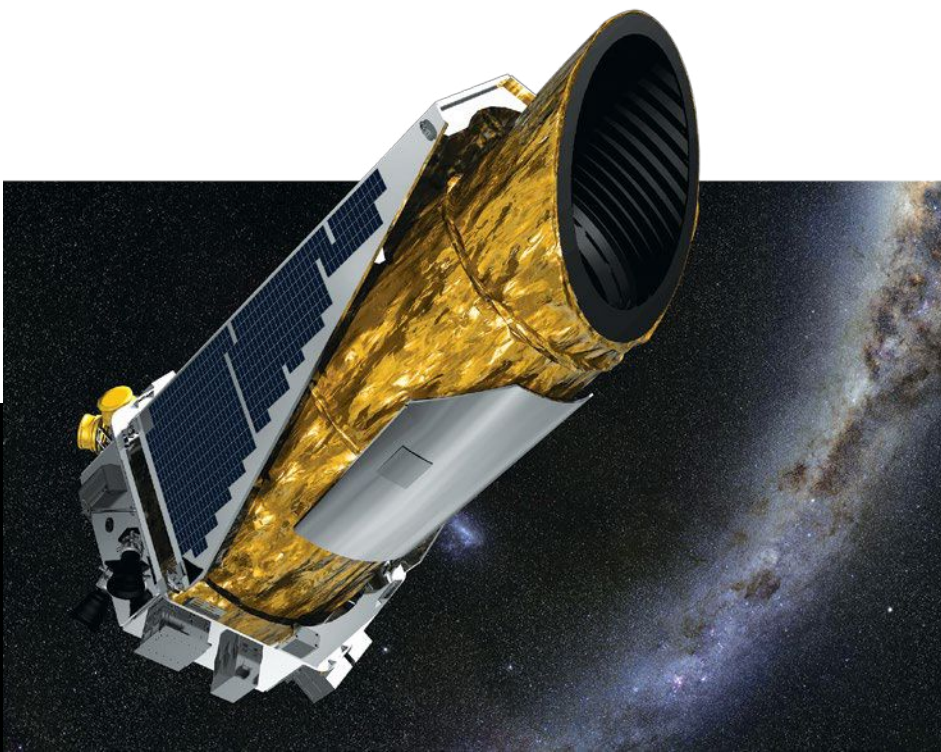
IT'S BEEN BAD FOR:

DOTING FATHERS

Any father is likely to beam with joy upon hearing their baby blurt out 'dada' for the first time. But their pride is misplaced, a study from the University of Missouri has found. The babies aren't calling for their fathers but are instead listening to the sound of their own voice.

MEAT LOVERS

Next time you are reaching for that bacon butty or sausage bap you might want to think twice. A report released by the World Health Organization claims that eating just 50g of processed meat a day, less than one average sausage, can increase the chance of developing colorectal cancer by 18 per cent. However, the overall risk of developing cancer due to the consumption of processed meat still remains small, they said.



Kepler's planet survey, the researchers predict there are currently around one billion Earth-sized planets in the Milky Way and 100 trillion in the observable Universe.

Data from the Hubble Space Telescope shows that 10 billion years ago the Universe was making stars at a much faster rate than it is now. However, only a small proportion of hydrogen and helium gas, the elements needed to form a star, was used.

Although the formation rate is much slower today, the sheer volume of leftover gas means that the Universe will continue to pump out stars and planets for hundreds of billions of years.

"There is enough remaining material after the Big Bang to produce even more planets in the future, in the Milky Way and beyond," added co-investigator Dr Molly Peeples.

The Universe's last star is not

expected to burn out for another 100 trillion years, providing enough time for countless numbers of Earth-like planets to form in habitable zones. This is perhaps bad news for those hoping to come into contact with alien life forms, but it does offer us one advantage: we are able to use powerful telescopes such as the Hubble Space Telescope to peer deep into the Universe allowing us to track its birth all the way back to the Big Bang.

We're lucky to live at this point in the Universe's history. Observational evidence for the Big Bang and cosmic evolution – encoded in light and other electromagnetic radiation – will be all but erased in a trillion years due to the runaway expansion of the Universe. This will make it incredibly difficult for far-future civilisations to figure out how the Universe began and evolved.

TIMELINE A history of exoplanet research

1992

Astronomers Aleksander Wolszczan and Dale Frail track down PSR1257+12b, which is the first planet ever discovered outside the Solar System.

1999

David Charbonneau (right) and Greg Henry independently observe HD209458 b, the first transiting exoplanet. It is the first exoplanet known to have an atmosphere.



2001

Astronomers from Geneva University find HD28185 b, the first exoplanet found to be in the so-called habitable zone around a star where liquid water can exist.

2009

NASA's Kepler mission launches to survey a region of the Milky Way with the goal of discovering Earth-like planets orbiting other stars.

1 MINUTE EXPERT

Meson $f_0(1710)$



What's that? A new first-person shooter, perhaps?

Way off. It's an exotic particle proposed as a candidate for the elusive 'glueball' by scientists at Vienna University of Technology.



So what's a glueball?

It's a particle made up entirely of gluons – elementary particles that help to bind quarks together to form protons and neutrons. Its existence was first proposed by physicists Murray Gell-Mann and Harald Fritzsch in 1972.



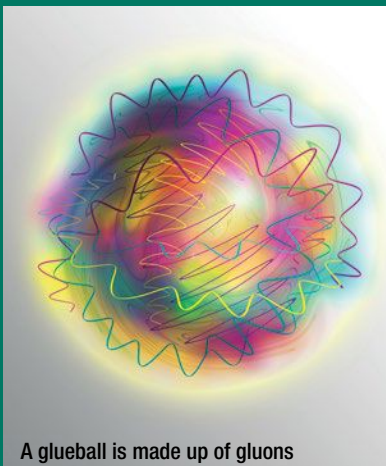
Okay. What makes them so elusive?

Glueballs are so unstable that they can only be detected indirectly by searching for evidence of their decay patterns. This means that researchers must look for the signature particle trails they leave behind as they break down. The team has proposed a mechanism for this decay process.



So now they have found them, we can break out the champagne, right?

Not just yet. While there is strong evidence that the team have got their sums right, the theory is going to be tested further in experiments carried out by the TOTEM and LHCb detectors at CERN's Large Hadron Collider in the coming months.



A glueball is made up of gluons



One day, could drugs offer all the benefits of pounding the pavements?

MEDICINE

Could we create 'exercise in a bottle'?

We all know that working out is good for us but sometimes the sofa and a bag of crisps are just too inviting.

A team at the University of Sydney has found that drugs could potentially be created that mimic the effects of exercise. "Exercise is the most powerful therapy for many human diseases, including Type 2 diabetes, cardiovascular disease and neurological disorders," explained research leader Prof David James. "However, for many people, exercise isn't a viable treatment option. This means it's essential we find ways of developing drugs that mimic the benefits of exercise."

The researchers analysed muscle biopsies

from four untrained, healthy males following 10 minutes of high intensity exercise. They found that activity triggered more than 1,000 molecular changes within the muscle.

Most traditional drugs target individual molecules, but the exercise blueprint shows that for any drug to mimic exercise it will need to target multiple molecules at the same time.

"We believe this is the key to unlocking the riddle of drug treatments to mimic exercise," James said. "Our data clearly show the complexity of the response: it is not one thing, but rather the drug will have to target multiple things. Our research has provided the roadmap to figure this out."

NEUROSCIENCE

Dream on... and off... and on...

Sweet dreams could be a mere flip of a switch away. A team at UC Berkeley has devised a method of sending mice into REM sleep in seconds.

The scientists inserted an 'optogenetic switch' into group of nerve cells in the medulla, a part of the brain that regulates functions such as breathing, heart rate and blood pressure. They then shone lasers at targeted areas of the brain to activate and deactivate it.

REM (rapid eye movement) sleep is the dream state characterised by activation of the cortex, an area of the brain connected to memory, thought and consciousness, and paralysis of the skeletal muscles.

"People used to think that this region of the medulla was only involved in the paralysis of skeletal muscles during REM sleep," said lead author Yang Dan. "What we showed is that these neurones triggered

all aspects of REM sleep, including muscle paralysis and the typical cortical activation that makes the brain look more awake than in non-REM sleep."

The discovery will help researchers understand the complex process of sleep and dreaming in the brain, and could lead to new therapies, the researchers said.

"Many psychiatric disorders, especially mood disorders, are correlated with changes in REM sleep, and some widely used drugs affect REM sleep, so it seems to be a sensitive indicator of mental and emotional health," said researcher Franz Weber.

All tuckered out from experiments



MONKEYING AROUND WITH NASA'S LATEST BOT

WITH DAVID SHUKMAN

Stepping into the robotics lab at NASA's Jet Propulsion Laboratory in California takes you into a world of extraordinary inventiveness. Facing us, between workbenches crammed with laptops, soldering irons and spools of cable, was a bundle of technology the size of a small dustbin: a highly versatile machine called the RoboSimian.

Named for the agility and adaptability of a monkey, this robot is meant to serve as an emissary on missions too dangerous for people – entering anything from the wreckage of a gas plant to the smouldering aftermath of a radioactive accident to the unknown terrain of an alien world.

To manoeuvre over debris, its four legs descend to provide a crawling motion. To roll across a smooth surface, the robot morphs into a shape that uses wheels. And to drive a car, it extends its limbs into a standing posture so it can slip behind the wheel of the vehicle.

Watching it go through these transformations is a little unnerving. The movements are extremely slow but the twists, turns and elevations are executed so smoothly that the machine gives an impression of effortless self-confidence.

The engineers running it keep stressing that although the robot is unusually robust and versatile, its two on-board computers give it pretty limited processing power – it's



certainly a long way, they say, from anything that could think or act remotely like a human being.

In fact, the lab is a good place to come for some balance in the furore over whether robots equipped with artificial intelligence will inevitably overtake and then destroy us.

Such are the difficulties of creating synthetic intelligence that might be comparable to human brainpower, and motors that are small but powerful and

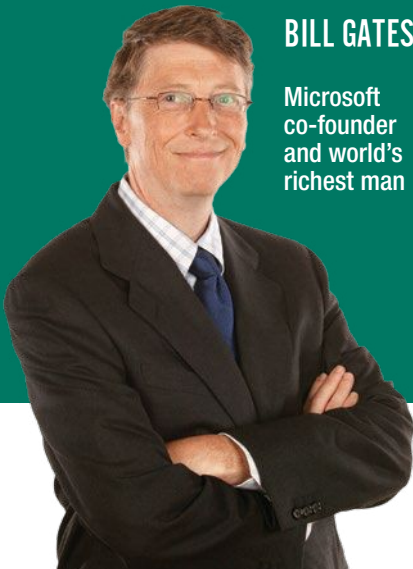
batteries that last more than a few hours, that the threat of a robot army seems too distant to take seriously.

But whenever we filmed the RoboSimian being put through its paces, we found ourselves keeping a sharp eye on it. And one of the NASA team was always on hand with a kill-switch. Just in case, they said. As I left, I wondered what safety measures a future film crew would need if they were close to a robot that was far smarter than RoboSimian.

WHO'S IN THE NEWS?

BILL GATES

Microsoft co-founder and world's richest man



What did he say?

Gates is urging governments around the world to pool money into research in renewable energy technologies on the same scale as the Manhattan Project or the Apollo Moon missions.

How much money is he talking about?

Tens of billions of dollars.

Hang on. Why doesn't he put his money where his mouth is?

Actually, he has. So far he reckons he has invested about £650m into companies researching green

technologies and intends to double this over the next five years. He has also said that private investors could stand to make a killing if they back the right companies.

So what kind of projects is he picking?

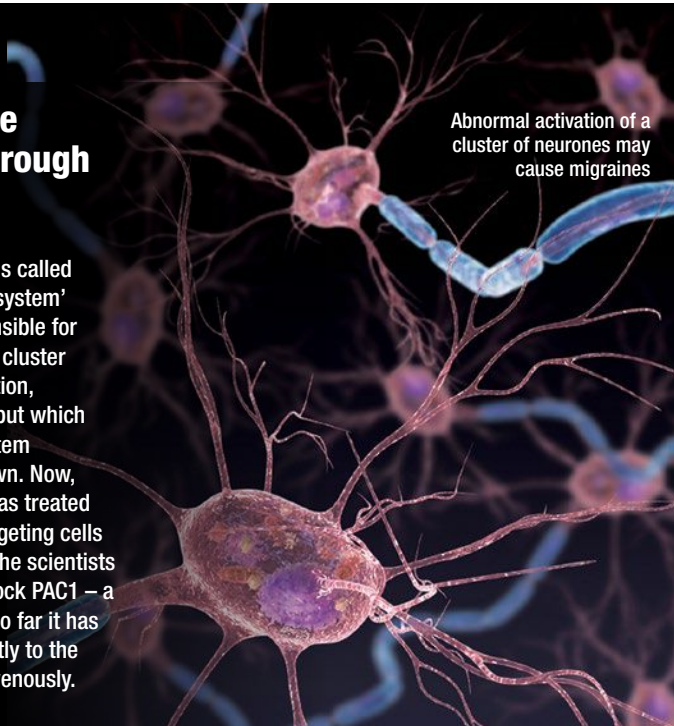
He seems particularly interested in solar chemical power, which uses a process similar to photosynthesis to make hydrogen fuel from water and sunlight. He's also keen on high-altitude wind power, which uses kite-like structures to tap the energy of jet streams.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 Migraine breakthrough

Abnormal activation of a cluster of brain cells called the 'trigeminovascular system' is believed to be responsible for causing migraines. The cluster relays sensory information, including pain signals, but which part of the nervous system triggered it was unknown. Now, an international team has treated migraines in rats by targeting cells deep inside the brain. The scientists used a compound to block PAC1 – a receptor protein – but so far it has only been applied directly to the brain, rather than intravenously.

Abnormal activation of a cluster of neurones may cause migraines



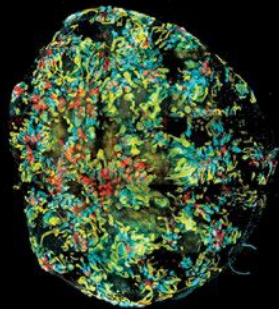
8 HIV detector

A fast, cheap way of diagnosing infectious and autoimmune diseases such as HIV and rheumatoid arthritis has been developed at the University of Montreal. A 'machine' made of DNA can recognise a specific antibody – binding to it and creating a signal by generating light – within five minutes.



The DNA machine binding to antibody

7 Lab-grown kidney cells



Lab-grown kidneys suitable for transplants are some way off. But scientists at Murdoch Children's Research Institute have grown a kidney-like structure from stem cells. It could be used for testing drugs, researching diseases and supplying kidney cells for medical treatments.

9 Self-destructing circuit

James Bond's gadget supplier Q would be proud of this: an electrical circuit that disappears after one day, leaving no trace of its original purpose. Georgia Institute of Technology designed it by depositing carbon atoms on graphene – the 'miracle material' that's also a form of carbon. The atoms initially form a circuit but gradually move out of position. The speed of this change depends on the temperature and specially designed structures on the surface. In addition to espionage there are medical applications: different patterns of atoms could trigger the release of drugs into a patient's bloodstream.



Andrei Fedorov created the Bond-like circuit

6 Anti-frost surface

Frost plays havoc with travel plans, covering your car windows and delaying flights. But now a surface has been created by engineers at Kansas State University that prevents frost forming at temperatures down to -6°C. It's 'biphilic', repelling water in some areas and attracting it in others, which delays the freezing of the droplets.

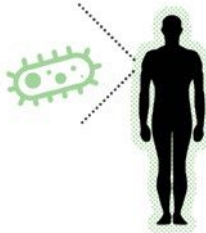


Droplets forming on a biphilic surface at -4°C

C BICKEL/SCIENCE TRANSLATIONAL MEDICINE; ROB FELT; VIPUTHESHWAR SITARAMAN; FLORIDA ATLANTIC UNIVERSITY; TRILITE; RUVID; AMY BETZ/KANSAS STATE UNIVERSITY; MINORU TAKASATO; MARCO TRIPODI

5 Microbe 'fingerprints'

Crimes could be identified from microbes in the air. We all have bacteria living on us, but the combination varies. University of Oregon scientists told 11 people apart simply by sampling the air around them.



Your bacterial 'aura' is unique

4 Robotic finger

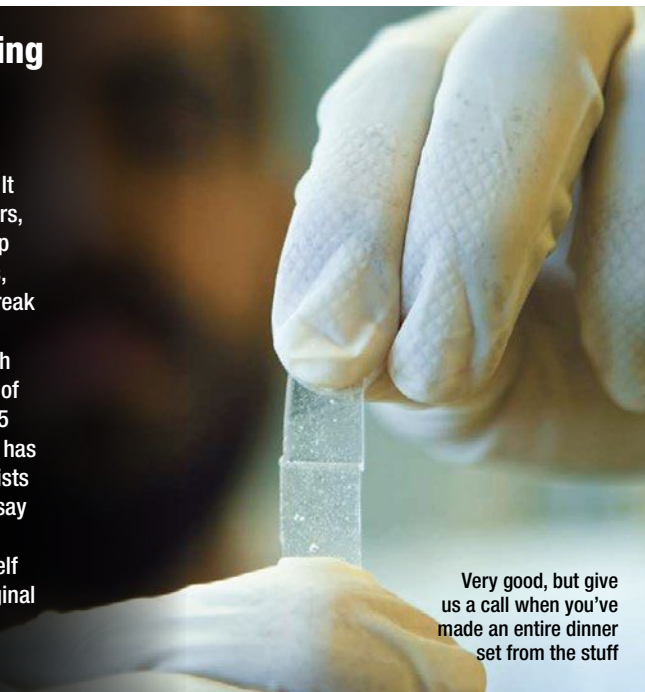
A 3D-printed robotic finger that looks and feels like a human appendage could be the future of prosthetics. It is made of shape memory alloy (SMA) that flexes and extends when it's heated and cooled by an electric current.



This finger could revolutionise prosthetics

2 Self-repairing material

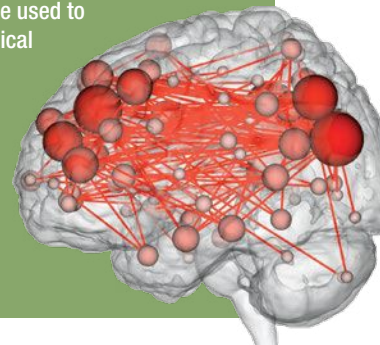
Imagine how useful a self-repairing material would be. It could be used in parts for cars, planes and spacecraft to help prevent catastrophic failures, and medical implants that break inside a human body could simply heal themselves. Such a material, which is capable of rejoining itself in less than 15 seconds if cut with scissors, has now been developed. Scientists at the University of Alicante say that the flexible, transparent resin is even able to heal itself underwater, retaining its original shape in the process.



Very good, but give us a call when you've made an entire dinner set from the stuff

1 Personalised education

Everyone's brain cells – neurones – form a unique pattern of connections, according to research by Yale scientists. They identified 126 individuals from brain scans taken as they performed a variety of tasks, producing a 'fingerprint' called a connectivity profile. The profiles could be used to predict how logical you are, how good at solving problems, and could even be used to tailor educational courses.



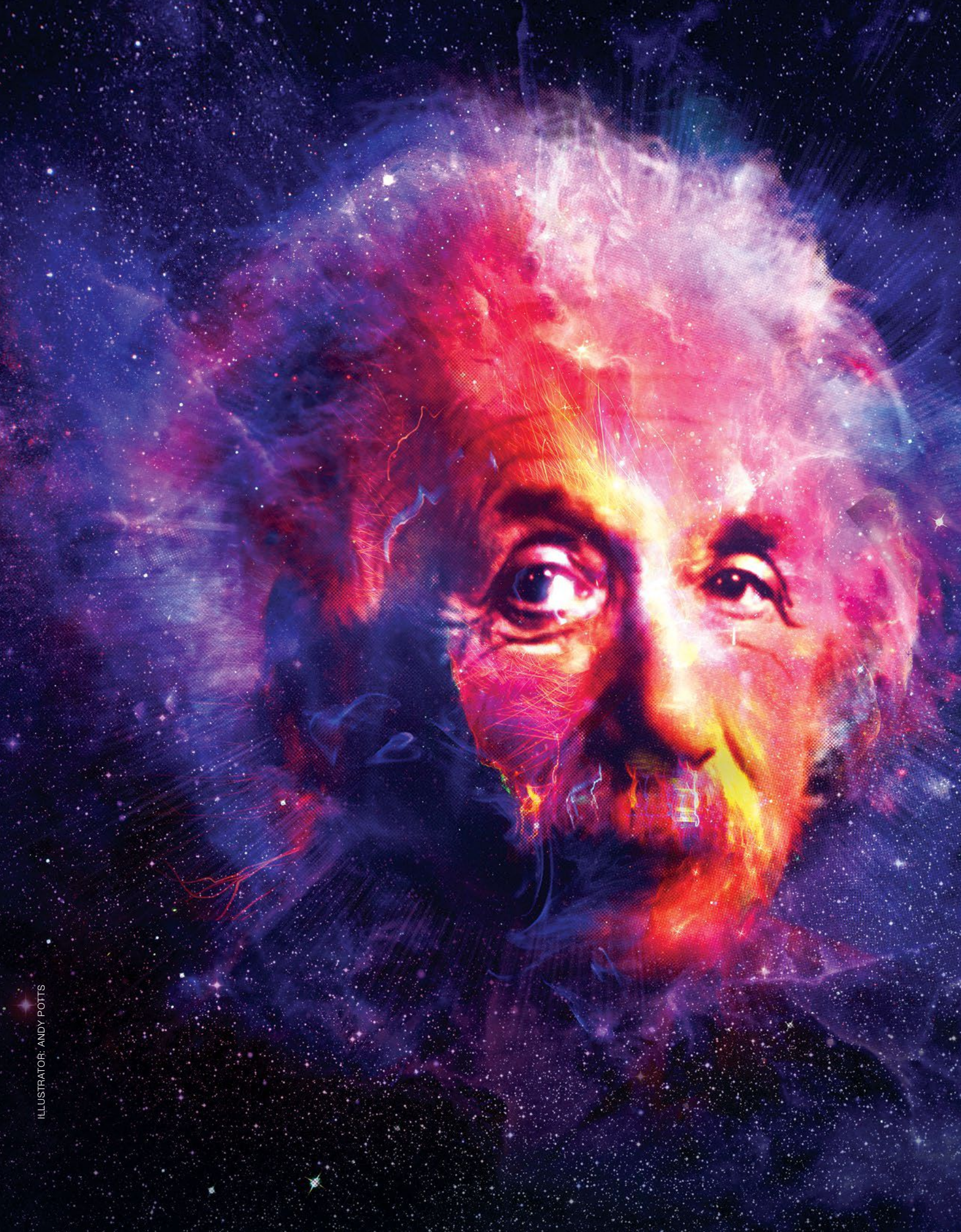
3 Three-dimensional billboard

3D is back again. At Vienna University of Technology, researchers have perfected a 3D display requiring no glasses. Its pixels, dubbed 'Triixels', combine red, green and blue lasers and moveable micro mirrors. The image changes as the mirrors sweep from left to right across your field of view,

creating a 3D picture by giving each eye a different perspective. The system is capable of playing 3D movies or serving up eye-catching adverts on gigantic billboards. Its makers say the technology is ready for commercial partners to take it forward.



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ILLUSTRATOR: ANDY POTTS

RELATIVITY ON TRIAL

One hundred years ago, Albert Einstein wrote a groundbreaking theory that transformed physics forever. But are there any chinks in its armour?

Marcus Chown delves deeper

At the height of WWI, in November 1915, German physicist Albert Einstein published a revolutionary theory of gravity. Not only did General Relativity show that Isaac Newton, arguably the greatest scientist to have ever lived, was wrong, it predicted black holes and that the Universe had been born in a Big Bang. It even showed, at least in principle, how to build a time machine.

The key thing Einstein recognised is that, in any small region of space, gravity and acceleration are the same thing. He came to this conclusion after considering Galileo's 17th-century observation

that all bodies, irrespective of their mass, fall at the same rate under gravity, hitting the ground at the same time if dropped from the same height. How could this be?

Einstein imagined a spacecraft far away from the Earth, which is accelerated at 1g. If an astronaut inside lets go of a feather and hammer from an identical height, the floor accelerates up towards them at 1g and both objects hit the floor at the same time. If the windows are blacked out and the astronaut doesn't know they are in space, they might conclude they are experiencing gravity on Earth. ▶

WHAT IS GENERAL RELATIVITY?

The General Theory of Relativity describes how mass and energy cause the fabric of space-time to warp, giving rise to what we perceive as gravity. This theory built on Albert Einstein's earlier Special Theory of Relativity. Both theories are based on the idea that the laws of physics act in the same way everywhere and that the speed of light is constant. From this starting point, Einstein deduced that as everything is moving relative to everything else, different viewers see the same event differently. This is where the theory gets its name.



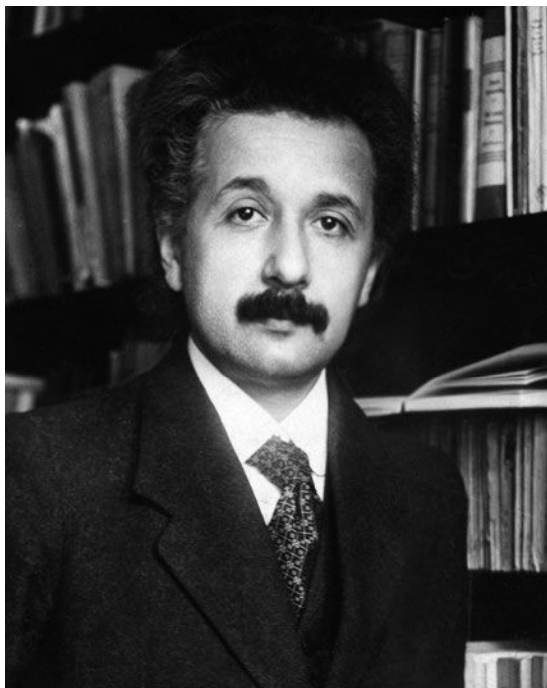
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Einstein deduced that we feel gravity because we are accelerating. We do not realise it – and this is the incredible part – because matter warps the four-dimensional space-time it sits in. There is a valley we cannot see in the space-time around Earth. Our ‘natural’ motion is to take the shortest path, or the path of least resistance, through space-time – that is, to fall to the bottom of the valley. The Earth’s surface obstructs us, pushing back. This is how we experience gravity.

In a nutshell, this is General Relativity. As theoretical physicist John Archibald Wheeler said: “Matter tells space how to curve. And curved space tells matter how to move.” The theory has passed every test in the past century, predicting and explaining phenomena beyond the scope of Newton’s theory. But it is known to break down in the ‘singularity’ at the heart of a black hole and in the Big Bang. So physicists are searching for a flaw that points the way to a deeper, more fundamental concept that will fill in the gaps of Einstein’s theory. One key prediction that has yet to be confirmed is the existence of gravitational waves...

Catching waves

Gravitational waves are ripples in the fabric of space-time, which spread outwards from an accelerated mass like ripples on a pond. The problem is that space-time is about a billion billion billion times stiffer than steel. This means it takes a lot to vibrate it and create gravitational waves. Only



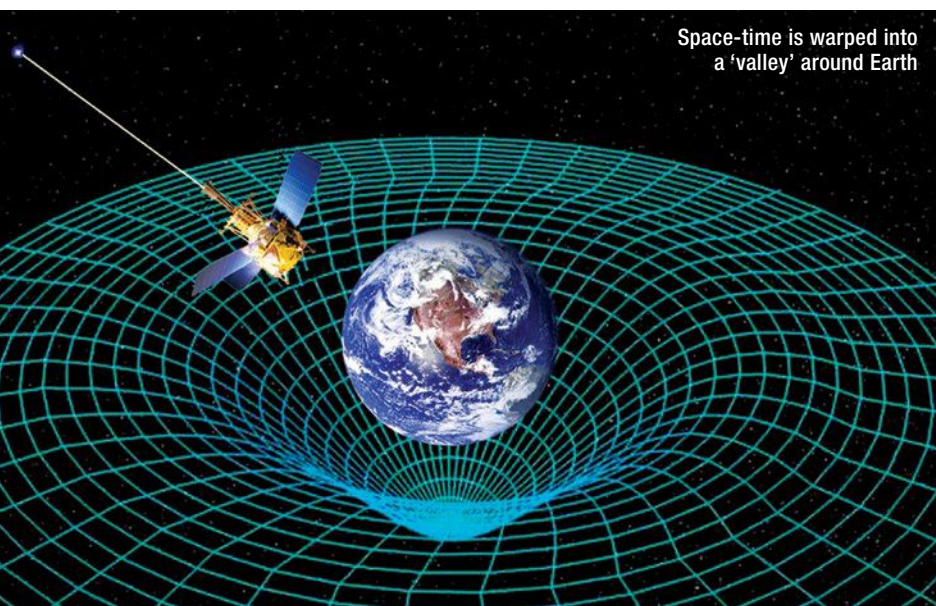
Left: Albert Einstein published his General Theory of Relativity in 1915 – the same year this image was taken.

The LISA Pathfinder mission will test the concept of a space-based gravitational wave detector



the most violent astrophysical events such as the birth or merger of black holes or the collision of super-dense stars are capable of causing vibration.

On 3 December 2015, the European Space Agency (ESA) launched LISA Pathfinder, on a mission to test the concept of a space-based gravitational wave detector. The idea of LISA, which stands for Laser Interferometer Space Antenna, is to put a giant equilateral triangle in space, probably in 2034. The triangle will consist of three satellites, somewhere between one million and five million kilometres apart, bouncing laser light back and forth using mirrors. Think of the sides of the triangle as giant rulers. A passing gravitational wave is expected to alternately stretch space in one direction and squeeze it in a perpendicular direction, so the trick will be to look for subtle changes in the length of the rulers. “We expect to be able to detect change as small as the width of an atom over millions of kilometres,” says LISA Pathfinder Project Scientist Paul McNamara.



Space-time is warped into a 'valley' around Earth

Gravitational wave experiments have been built on Earth, but background vibrations of the ground mimic real sources, making them blind to the lowest frequency of gravitational waves. Such waves should be detectable by LISA. In addition, there should be a 'background' of tens of millions of events caused by white dwarf-white dwarf binaries in the Milky Way. 'Binaries' are systems consisting of two stars, orbiting a common centre of mass. "There is also a chance that a space-borne detector will be able to directly measure primordial gravitational waves produced in the first split-second of the Big Bang," says McNamara.

"Electromagnetic waves allow us to 'see' the Universe, whereas gravitational waves will allow us to 'hear' it," says McNamara. "Imagine going to ►

The South Pole Telescope is part of a global array called the Event Horizon Telescope that aims to study the black hole at the Milky Way's centre



an orchestra recital and only being able to watch the musicians without hearing any sound... now turn on the sound... this is what it will be like when we start to observe the Universe with gravitational waves." Prepare yourself for the cosmic symphony.

Going deeper

The fact that General Relativity breaks down in the 'singularity' of the Big Bang and a black hole, where the density of matter skyrockets to infinity, is not very helpful in trying to find a deeper, more fundamental theory. The hope is that General Relativity might reveal a chink in its armour in less extreme circumstances. This is the idea behind an Earth-orbiting experiment called Satellite Test of the Equivalence Principle, or STEP, which is seeking NASA funding. "If it gets the go ahead, it could fly in six years," says Paul Worden, one of the originators of STEP in 1971.

The 'Equivalence Principle' is the fancy name for gravity being indistinguishable from acceleration so that all masses fall at the same rate. Since the

"Electromagnetic waves allow us to 'see' the Universe, whereas gravitational waves will allow us to 'hear' it"

principle is the foundation of General Relativity, it is a key place to look for an anomaly. Galileo is supposed to have dropped different masses from the Leaning Tower of Pisa, and Apollo 15's Commander David Scott repeated the experiment – with a hammer and a feather – on the Moon in 1971. STEP will suspend four pairs of 'test masses' made of at least three different materials, such as beryllium, niobium and platinum-iridium, and see whether they move relative to each other.

The masses will be inside a tank of liquid helium to insulate them from external temperature fluctuations and surrounded by a superconducting shell to shield them from electromagnetic interference. Microthrusters will counteract the atmospheric drag on the satellite, so the freefall of the test masses will be nearly perfect.

The key to the experiment is that a satellite in Earth orbit is always falling away from its desired straight-line path but never gets any closer to the Earth because the Earth's surface perpetually curves away from it. In other words, it is falling forever. This will enable small differences in the rate at

5 WAYS YOU CAN SEE EINSTEIN'S THEORY IN REAL LIFE

MASS

The 'Higgs field' accounts for only about 1 per cent of your mass. 99 per cent is due to a relativistic effect. Specifically, the quarks that compose you are moving so fast they gain mass. Without Einstein, you would weigh only about 1kg!



SUNLIGHT

According to Einstein, mass is a form of energy and so can be converted into other forms of energy. This is what is happening in the Sun's core, where nuclear reactions convert about 0.7 per cent of the mass of hydrogen nuclei into heat and, ultimately, sunlight.

GOLD

An atom absorbs and re-emits light when an electron moves between orbits. The light's energy (colour) depends on the energy difference between the orbits. Gold ought to appear silver, but its innermost electrons move so fast that they gain mass. This changes the light its atoms reflect, making it appear gold.



THE UNIVERSE

The distant Universe seen through telescopes is not actually there: it's an illusion. The reason is that matter creates valleys in space-time which light from distant objects must negotiate on its way to Earth. The Universe is therefore distorted as if seen through frosted glass.

SLUGGISH SATELLITES

If you have a smartphone or a sat-nav, it calculates your location relative to a constellation of Global Positioning satellites. When these swing in close to Earth, they experience stronger gravity and their on-board clocks slow. This effect must be compensated for to calculate your location.



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GENERAL RELATIVITY'S SUCCESSES

THIS ISN'T THE FIRST TIME EINSTEIN'S FAMOUS THEORY HAS BEEN PUT TO THE TEST



MERCURY MYSTERY

According to Einstein, the gravity near the Sun is stronger than Newton would have predicted. This causes the elliptical orbit of Mercury to gradually change its orientation. It 'precesses', which means the planet traces out a rosette-like pattern around the Sun. Before Einstein, this was such a puzzle that it led to the suggestion of a planet – Vulcan – tugging on Mercury.



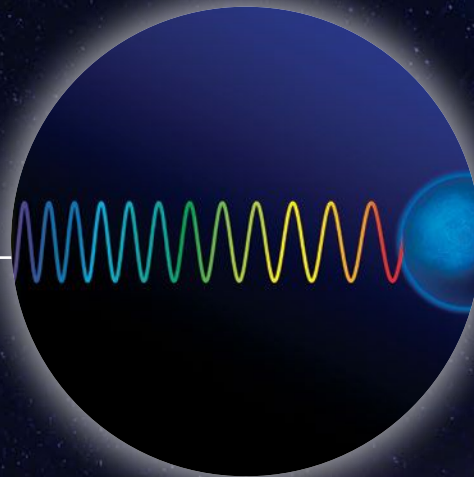
TIRED LIGHT

As light climbs out of the valley in space-time around a massive object like a star, it loses energy. This is equivalent to a reduction in its frequency and is known as a gravitational red shift. It has been observed in the light of dense, white dwarf stars. In 1959, it was even observed in light climbing up a 22.6m tower on Earth by physicists Robert Pound and Glen Rebka at Harvard University.



RIPPLING GRAVITY

Although gravitational waves have yet to be detected directly, they have been detected indirectly. In 1974, Russell Hulse and Joseph Taylor discovered two super-dense neutron stars orbiting each other. By observing the 'binary pulsar', or PSR B1913+16, they determined that the stars are spiralling together and losing orbital energy. This lost energy is exactly the amount Einstein's theory predicts they should be radiating into space as gravitational waves.



BENT LIGHT

Einstein calculated that the gravity of the Sun would bend the trajectory of light from distant stars by twice the amount Newton would have predicted. The only way to observe stars close to the Sun is during a total eclipse when the bright solar disc is blotted out by the Moon. During the total eclipse of 29 May 1919, the English astronomer Arthur Eddington confirmed that the positions of stars were shifted, exactly as Einstein had predicted.



Above: The Apollo 8 image of Earth taken from the Moon is pretty iconic – but a photo of a black hole event horizon could be even more impressive.

which different masses fall to be magnified.

The Equivalence Principle is known to hold to one part in a trillion, but STEP will better that by another factor of a million. All attempts to unify General Relativity with quantum theory involve new forces, which may affect different materials in different ways. “A violation is basically the discovery of a new force of nature, or something really weird,” says Worden. “If there’s no violation, at least to experimental accuracy, we can rule out a lot of theories of gravity but not Einstein’s.”

The ‘hole’ story

But General Relativity might be put to its toughest test within only a year or two. So far, the theory has been checked only in situations where gravity is relatively weak. Nobody has tested it where gravity is strong – close to a black hole. That could all change when the Event Horizon Telescope (EHT) images the black hole at the centre of our Milky Way, probably in 2017.

The EHT is an array of cooperating radio telescopes scattered around the globe. The radio signals recorded at each site are flown together and combined on a computer at Haystack, Massachusetts to simulate a giant dish the size of the Earth. The bigger the dish and the shorter the observing wavelength – EHT is using 1.3mm – the more it can zoom in on details in the sky.

The trouble with black holes is they are very difficult to see. Stellar-mass ones are too small and

“An image would be a turning point in our understanding of black holes and gravity”

the supermassive black holes in the cores of other galaxies, with up to 30 billion times the mass of the Sun, are too far away. Only one black hole is within reach – the one 26,000 light-years away at the centre of the Milky Way. Sagittarius A*, as it is called, will be magnified in size by its own intense gravity. “It will appear as big as a grapefruit on the Moon viewed from Earth,” says EHT scientist Shep Doeleman of the Massachusetts Institute of Technology and leader of the EHT team.

The key thing is to observe the black hole’s event horizon – the point of no-return for in-falling matter and light – and see whether it behaves as predicted by Einstein or even whether it exists. Stephen Hawking suggested it might not. This will test Einstein’s theory in the realm of strong gravity, where it has never been tested before. “An image would allow us to test General Relativity at the black hole boundary but, just as importantly, it would make the case for the existence of black holes as solid as it is ever likely to be,” says Doeleman. “An image would symbolise a turning point in our understanding of black holes and gravity.”

Doeleman is being modest. It is possible that the first image of a black hole event horizon will be an iconic image to rival the Apollo 8 image of the Earth rising above the Moon.

In the world of science, 100 years is an awfully long time. Countless theories have been proposed since Einstein published his famous paper, with many of them turning out to be nonstarters or dead ends. After a century of extraordinary success, it still remains to be seen how far the General Theory of Relativity can be stretched before reaching its breaking point. Could its time be finally up? After all, even Einstein viewed the theory as being incomplete. If STEP, LISA or the EHT are able to find even the tiniest hole in its venerable armour, scientists could be on the brink of formulating a new theory of gravity, or maybe even making the first tentative steps towards the elusive ‘theory of everything’. ☀

Marcus Chown is a science writer and author of *What A Wonderful World: Life, The Universe And Everything In A Nutshell*.



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MEET THE REAL-LIFE SUPERHUMANS

These people have tapped into the biology of their bodies to unleash the true power of our species. Katherine Nightingale explores what scientists are learning from them



'Iceman' Wim Hof increases his body temperature using meditation

COLD RESISTANCE

HIMALAYAN MONKS

Up in the climes of the Himalayas, there are tales of monks who use breathing and meditation to raise their body temperatures to the extent that they can dry wet sheets wrapped around their bodies, casting off steam into the freezing air.

Researchers from the US and Singapore have investigated these claims by measuring the monks' core (armpit) and peripheral (finger) temperatures. During the measuring, they asked them to use the breathing techniques either with or without the meditation. The researchers found that while the breathing could raise body temperature, adding the meditation increased it to that seen in a typical fever.

'Iceman' Wim Hof, pictured left, has used similar techniques to the monks to achieve the world record for longest ice bath (one hour, 52 minutes and 42 seconds) and has even run a marathon in the Arctic Circle wearing just a pair of shorts.

So what might be the benefit of being able to boost your own body temperature? Adaptation to cold environments is an obvious one, but higher body temperatures are also linked to better cognitive performance and improved immunity.



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UNDERWATER VISION

MOKEN NOMADS

A Moken tribesperson swims with a turtle; they are eaten, but also revered

Our eyes are adapted to a life on land, which means we can only see blurry shapes when we swim underwater without goggles. But children in a tribe of sea nomads – the Moken – who reportedly learn to swim before they can walk, can see well enough to collect shells, sea cucumbers and clams from the seabed.

There are around 2,000 to 3,000 Moken living in the Andaman Sea, off the coasts of Myanmar and Thailand. Researchers at Lund University in Sweden estimate that Moken children have more than twice the underwater visual clarity of European children, even though their sight on land is the same. They focus underwater by constricting their pupils and changing the shape of the eye's lens. The researchers found that European children can be trained to see just as well as the Moken.

It's difficult to tell whether Moken children learn this better vision from a young age or whether evolution has played a role, so we might all be able to see a little better beneath the waves if we put our minds to it.

EXTREME RUNNING

TARAHUMARA TRIBE

Barefoot running has recently become a trend. But the Tarahumara, who live in northwest Mexico, have been doing something similar for generations, even inspiring books on the topic. They have wowed the world with their ability to run up to 320km (200 miles) in two days, wearing traditional sandals.

Their word for men, Rarámuri, means something along the lines of ‘those who run fast’. No-one really knows why they have seemingly superhuman athletic prowess. It could be because they have traditionally lived far apart from each other, so running between settlements became necessary for communication.

Their diet, which is predominantly made up of beans, corn and vegetables, probably also plays a role. They drink home-brewed beer, and also a mixture of water, lime, chia seeds and sugar. This concoction is jammed with omega-3, fibre, protein and antioxidants. In general, Tarahumara people have low cholesterol levels, and low rates of heart disease and diabetes. But as the rocky canyon paths are replaced by roads, fast food is starting to creep in, and rates of obesity and high blood pressure are growing.



Runners will complete ultra-marathon distances into their 60s

“THE SENSATION FROM ONE STING IS SAID TO BE AS BAD AS BEING HIT BY A BULLET”

The ants are sedated before being woven into the gloves



PAIN TOLERANCE

SATERÉ-MAWÉ TRIBE

What’s more painful than the most painful insect sting known to man? Being stung by lots of those insects at once... for 10 minutes. That’s what adolescent boys of the Sateré-Mawé tribe in the Brazilian Amazon do up to 20 times before they are considered to be men.

The ritual involves threading 100s of unconscious bullet ants (*Paraponera clavata*) – stings pointing inwards – into ‘gloves’ made of palm leaves. As the ants wake up, the boy inserts his hands, receiving hundreds of stings in which the ants inject a venom called poneratoxin into his skin. Poneratoxin blocks communication between the nerve cells, causing paralysis and immense pain throughout the body that lasts for up to 24 hours. The bullet ants are so-called because the sensation from one sting is said to be as bad as being hit by a bullet.

But there is a fine line between paralysis and pain, and studies in rats have suggested that poneratoxin could be used as a painkiller. It’s also being investigated as an insecticide, so the Sateré-Mawé may have alerted the world to a useful chemical.



FREEDIVING

BAJAU NOMADS

A man strides across the ocean floor, harpoon in hand, looking for prey. In one breath, he has swum to a depth of 20m to hunt. He is a member of the Bajau, a group of sea nomads who live off the coasts of eastern Indonesian, the Philippines and eastern Malaysia.

When you're harvesting your food and livelihood from the seabed, you want to spend as much time as possible each day beneath the waves. Bajau divers spend around five hours a day submerged, diving to average depths of around 8m – but up to 30m – for minutes at a time, with only short periods between dives. They make various physiological adaptations, including the 'diving response' which slows the heart, and diverts blood to the heart, brain and working muscles, eking out the oxygen from the pre-dive breath. The spleen also contracts, forcing extra oxygen-carrying red blood cells into the bloodstream.

The Bajau aren't the only ones who show this ability. Other groups, such as the Japanese Ama, dive to greater depths, and the sport of freediving sees competitors reach depths of up to 100m. Maybe there's a diving ability in all of us just waiting to come out. 🍷

Bajau rupture their eardrums to make diving easier

Katherine Nightingale is a freelance science writer with an MSc in molecular and cellular biology.



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THE BIG QUESTIONS OF ANCIENT EGYPT

From pyramids to mummies and Cleopatra to Tutankhamun, Egyptologist **Joann Fletcher** reveals the latest discoveries and controversies surrounding the ancient civilisation

1 What is the earliest evidence of 'art' in Egypt?

The oldest graphic activity ever recorded in Egypt – indeed, in the whole of north Africa – was carved into the sandstone cliffs of Qurta around 25 miles south of Edfu, between Luxor and Aswan. Recently scientifically dated at 19,000 years old by Dr Dirk Huyge, director of the Belgian Mission who has studied the site since 2005, the gallery comprises at least 185 individual images, almost three-quarters of which depict the now-extinct, powerfully built wild cattle known as aurochs, the ancestors of domestic cows.

Some of these huge creatures – almost 2 metres long – have 'cut' marks scratched around the head and neck area. Huyge believes that these 'cuts' have some kind of symbolical meaning, possibly as an attempt to ensure a successful outcome for hunting expeditions. The Qurta scenes also feature hippos, gazelle, birds, fish and strange hybrid beings, along with several stylised female figures representing the earliest Egyptian attempts at self-portraits.

Huyge has dubbed the rich repertoire of scenes a veritable "Lascaux along the Nile", observing that these lifelike and vivid images are "uncannily close" in style to European cave art such as that seen at Lascaux in France, which also features aurochs and other large animals. He adds that "perhaps direct influence or cultural exchange over such a long distance is not as improbable as it seems... The Mediterranean Sea at the time of the last Ice Age was at least 100

metres lower than it is now: could it be that Palaeolithic people established an intercontinental exchange of iconographic and symbolic concepts?"

The pictures carved into the sandstone cliffs at Qurta are dominated by depictions of aurochs – now-extinct wild cattle – dating back 19,000 years



FRMAH/ALAMY



The famous gold death mask of Tutankhamun was discovered in tomb KV62 by Howard Carter and his team – but was it originally made for Nefertiti?

2 Who was the real Tutankhamun?

Though undeniably Egypt's most famous pharaoh, little is known about Tutankhamun. When born, probably around 1346 BC at the city of Amarna, some 180 miles south of modern Cairo, he was named Tutankhaten – 'Living Image of [sun god] Aten'. His father was the so-called heretic pharaoh Akhenaten, while his mother may have been Kiya, one of Akhenaten's minor wives, or possibly even Akhenaten's chief wife and co-ruler Nefertiti.

Tutankhaten took the throne at his father's death in c1336 BC, changing his name to the more familiar Tutankhamun when the Aten cult was terminated and worship of the state god Amun reinstated.

He ruled until his death in c1327 BC, the cause of which remains a focus of debate. Studies of Tutankhamun's tomb and its contents also continue to reveal all manner of unexpected details. Not least is the possibility that at least 80 per cent of his grave goods were originally made for other members of his family, from the famous gold throne to at least one of his three golden coffins. Even the gold death mask "had originally been a Nefertiti piece", claims Egyptologist Nicholas Reeves.



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Intricately carved hieroglyphs at the 'White Chapel' of Senusret I at Karnak (c1950 BC). Did hieroglyphs evolve from early tax records?

3 Why did hieroglyphs develop?

The deceptively simple-looking picture writing evolved over several millennia into a sophisticated system using thousands of signs. First described as hieroglyphs ('sacred carvings') by the Greeks, they were largely used to create the ritual texts covering the walls of temples and tombs, while a form of hieroglyphic shorthand known as 'hieratic' was used by the literate elite. These were mainly the scribes and officials who administered the country for the king, even before Egypt emerged as the world's first nation state in c3100 BC.

German archaeologists excavating the tombs of Egypt's earliest rulers at Abydos in the late

1980s discovered some 150 small labels of bone, ivory and wood carved with simple pictograms – 'proto-hieroglyphs' – describing everything from bolts of linen to jars of oil, together with their quantity and place of origin.

The labels, once attached to grave goods, have been dated to c3250 BC and are the earliest evidence for the way officials raised and recorded taxes in kind. They are among the most important documents in history, as the pictograms form a phonetically readable script that some claim was the earliest writing in the world – apparently predating that of the Sumerians of Mesopotamia.

4 When were dead bodies first mummified?

Mummification is so synonymous with ancient Egypt that most people assume it has been completely understood for some time. Yet recent research is rewriting much of what was previously known – from the most effective techniques used during the 14th century BC 'New Kingdom' to the preservatives that were used to obtain the most lifelike results.

The origins of embalming are now known to be much earlier than the Pyramid Age (from c2600 BC). Well before that time, linen was used to wrap bodies at sites such as Mostagedda (north of Luxor), some of it coated in a toffee-like substance. But only in 2014 was this substance finally identified, by archaeological chemist Dr Stephen Buckley of the University of York, as a blend of oils, fats and antibacterial pine resin. He discovered that "some of the ingredients were brought from the north-east Mediterranean. For example, the pine resin must have come from what is now south-eastern Turkey."

But such long-distance trade links were not the only big surprise. Carbon dating carried out on the Mostagedda linen by researchers at the University of Oxford revealed that the wrappings and mixtures both date to c4300 BC – some 1,700 years earlier than mummification was previously believed to have first been used in Egypt.

5 How many pyramids are there?

It is estimated that 138 pyramids survive in Egypt, varying widely in layout, size, location and purpose. The first was built in c2650 BC for King Djoser. His bench-shaped 'mastaba' tomb was embellished to form a six-tiered, 60 metre-high step pyramid (shown below). Snefru (c2613–c2589 BC), the greatest of all Egypt's pyramid builders, moved 9 million tonnes of stone to build three successive pyramids as he refined his plans, and his son Khufu created the Great Pyramid of Giza. This was the standard royal tomb till superseded in c1750 BC by rock-cut tombs such as those in Luxor's Valley of the Kings. Some smaller pyramids are believed to have served as territorial markers or tax-collecting points; these were built throughout the Nile Valley as far south as Aswan in around 2600 BC.



6 How old was the oldest known 'Egyptian'?

The remains of the earliest human yet found in Egypt were discovered by Belgian archaeologists in 1994 during their excavation of a Stone Age quarry at Taramsa Hill near Dendera, about 40 miles north of Luxor. They unexpectedly uncovered the shallow pit grave of a young child. Its body was carefully buried in a seated position, oriented east toward the rising sun, with its head resting back on a sand bed to face skyward. The child, who lived during the late Pleistocene, approximately 60,000–55,000 years ago, was aged between

8 and 10 when it died, though the remains were so fragile and fragmentary that it was impossible to determine whether they were male or female.

Not only is this the oldest known burial from north Africa, but it also provides a vital missing link in the human story. As the anthropologists who examined the child's remains explained: "The location of this find is significant, because it's on a possible dispersion route of modern humans from Africa into Asia and Europe between 50,000 and 100,000 years ago."

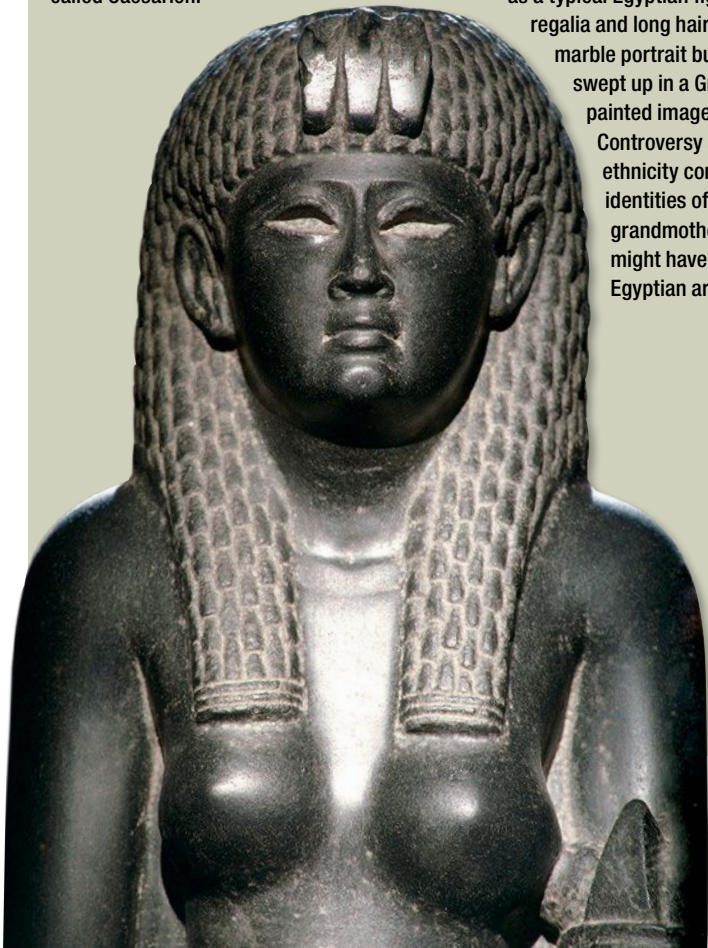
7 Was Cleopatra an Egyptian?

Cleopatra VII 'the Great' was the last pharaoh of the Ptolemaic dynasty (305–30 BC). The Macedonian King Alexander the Great had taken Egypt in 332 BC during his conquest of the Persian empire; on his death, Ptolemy I – one of Alexander's generals and rumoured half-brother – took control. His descendants – 15 male pharaohs, all called Ptolemy – shared the throne with female co-rulers. Cleopatra VII ruled first with her father, then her brothers and finally her son (by Julius Caesar) Ptolemy XV, called Caesarion.

Though the Ptolemies initially spoke Greek and clung to Greek culture, they gradually became influenced by Egypt's ancient traditions. In 181 BC Ptolemy V was mummified rather than cremated, and Ptolemy VIII married one of his daughters into the Egyptian nobility.

Cleopatra VII was born in Egypt, as were most of her predecessors, but was the first to learn the Egyptian language and gain the support of her subjects against the growing power of Rome. Images within Egypt's temples show her as a typical Egyptian figure with traditional regalia and long hair. However, classical-style marble portrait busts show her wavy locks swept up in a Greek-style bun. One painted image even suggests red hair. Controversy about Cleopatra's ethnicity continues to rage; the identities of her mother and grandmother are unknown – they might have been members of the Egyptian aristocracy.

Some Egyptologists believe that this basalt statue, now in St Petersburg's Hermitage Museum, depicts Cleopatra. The Ptolemaic dynasty was Macedonian in origin, but Cleopatra's mother and grandmother may have been Egyptian



8 Are any discoveries still to be made?

This is perhaps the question most often asked of Egyptologists – and the answer is a resounding yes!

Some of the most exciting discoveries are being made in museums. Last year museum staff in Wigan, combining their collections in new storage facilities, rediscovered antiquities covering the entire span of Egypt's ancient history, from c3500 BC to the early centuries AD, the highlight being a gilded face from an 18th-dynasty coffin. Also last year, a re-examination of ancient linen wrappings from Mostagedda stored in Bolton Museum pushed back the origins of mummification by 1,700 years (see opposite). Even the British Museum still produces surprises. In 2012, computed tomography (CT) scans revealed that the naturally mummified body of a man – known to generations of schoolchildren as 'Ginger', thanks to his faded red hair – had literally been stabbed in the back around 3500 BC.

In Egypt itself, of course, new finds are announced almost every week. Even the Valley of the Kings has not yet been completely explored. Nor, it seems, has its most famous tomb. In 2014, high-resolution scans of the walls of Tutankhamun's burial chamber revealed the outlines of two intact sealed doorways. Some experts believe these may lead to additional unexplored chambers. So, much like the iconic golden death mask, even the tomb of Tutankhamun still conceals secrets. 🗨️



A member of staff at the British Museum next to a scan of Gebelein Man, also known as 'Ginger'



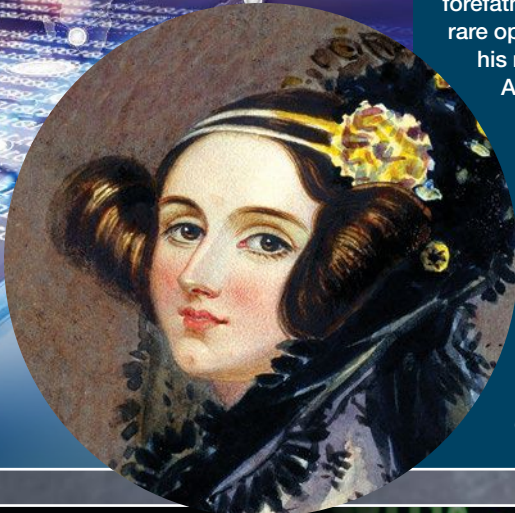
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Joann Fletcher is honorary visiting professor at the University of York.

WOMEN SCIENTISTS

YOU OUGHT TO KNOW

Pioneers in their respective fields but overlooked by history, meet the women who dedicated their lives to science and made groundbreaking advances. **Moshita Prajapati** revisits their achievements



ADA LOVELACE

First computer programmer

Countess Lovelace is considered to be a pioneer in the field of computing. Her correspondence with Charles Babbage, the forefather of the modern computer gave her a rare opportunity to transcribe and read up on his now famous lecture regarding his Analytical Engine, the first general-purpose computer at the University of Turin, Italy. Her appended notes on the transcription during the nine-month period in 1842-1843 are now considered as the first computer programme. Her notes said that the machine is suited for "developing [sic] and tabulating any function whatever. . . the engine [is] the material expression of any indefinite function of any degree of generality and complexity."

GRACE HOPPER

Programmed the first compiler

In 1950s, women led the charge when it came to computer programming, and American computer scientist Hopper had the opportunity to work on the first computer Harvard Mark 1 at Harvard University. She realised that computers needed to be user-friendly and she started working on a programme that would convert source code written in one computer language into another usually less complex language, say English. This was the early version of the first compiler created. While compilers are the norm today in computer programming, in the 1950s, they were a radical departure from what the computers were expected to do then – for performing computations/arithmetic.



AKG-IMAGES, SCIENCE PHOTO LIBRARY X3, MARY EVANS PICTURE LIBRARY X2,



NETTIE STEVENS

The science of gender

Stevens was an American geneticist who discovered that sex of a species is determined by a particular combination of chromosomes. In 1905, while at Bryn Mawr College, she successfully stated from her experiments on the yellow mealworm that the combination of an X and Y chromosome was and is responsible for the determination of the sex of an individual. XX for female and XY for male.

LISE MEITNER

Discovery of nuclear fission

In 1935, Otto Hahn, a German chemist and Lise Meitner, an Austrian physicist, started working on the transuranium elements at the now Free University of Berlin. These unstable elements decay radioactively into other elements and Hahn noticed an anomaly; the neutron-bombarded uranium had resulted in isotopes of barium. Meitner along with her cousin Otto Firsch came up with an explanation for that that is now known as nuclear fission; where the nucleus of an atom splits into smaller parts releasing insurmountable energy. This process would eventually be applied in creating atomic bombs and nuclear power plants.



CECILIA PAYNE

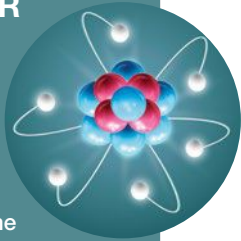
The composition of stars



What are stars made of? Cecilia Payne-Gaposchkin, British-American astronomer and astrophysicist, answered it in 1925 whilst at Harvard University. She was accurately able to prove that the composition of stars depends on their temperature and the ionization of the atoms in the elements. She calculated the relative amounts of 18 elements in space and the results showed similar compositions in all. Stars are almost entirely composed of the two lightest elements in the Universe, hydrogen and helium. Her findings have helped astrophysicists understand the Universe better.

MARIA GOEPPERT-MAYER

Nuclear shell model of atomic nuclei



To determine the origin of elements at the Argonne National Laboratory, Mayer, an American theoretical physicist, developed an explanation of how neutrons and protons in atomic nuclei are structured. Called the nuclear shell model, she summarised that elements with 2,8,20, 28, 50,82, or 126 protons were more stable than their counterparts. She concluded that the presence of protons in the structure determines its energy level. Her research provided theoretical bases for developments in laser physics, laser isotope separation, and molecular orbital calculation.

JANE GOODALL, DIANA FOSSEY, AND BIRUTE GALDIKAS

The Primates



Diana Fossey

Birute Galdikas

Coined 'The Trimates' by their mentor, anthropologist Louis Leakey, each of these women captivated the audience with their pioneering observation, research, and understanding of our primate cousins. **Jane Goodall** began observing the chimpanzees of Tanzania in 1960 and amongst her many discoveries, she noted that they fashion and use tools; a skill thought to be uniquely human at that time. **Diana Fossey's** research on mountain gorillas in Congo and Rwanda stretched over 18 years beginning from 1967 onwards. Her observations dispelled violent notions about gorillas; they are essentially pacifist and almost exclusively vegetarians. They show emotional depth and have characteristic noses and exhibit a strong family bond. And **Birute Galdikas** pioneered work on the oft ignored orangutans. Her research (1971) showed the animal as a solitary intelligent ape, with high learning abilities who uses complex tools and build intricate nests for sleeping.

Moshita Prajapati is a senior features writer for BBC Knowledge Magazine India.



Jane Goodall



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THE LAST FRONTIER

The SeaOrbiter when launched will allow man to boldly go into the deepest part of ocean, where no man has gone before. **Moshita Prajapati** finds out more

Exploring the seven seas

An astounding 95 per cent of the ocean is unexplored, unseen and unknown to humans. And 99 per cent of the ocean floor is uncharted, unfamiliar and undiscovered. But that is soon about to change. The SeaOrbiter, when operational, will become the first floating sea lab where researchers can live and explore parts of the seas and oceans unknown to man.

The \$43 million SeaOrbiter project is the result of a 30-year research and design process. Created by sea architect Jacques Rougerie and guided by experts like Jean-Michel Cousteau and former NASA chief Daniel Goldin, the vessel will hold a crew of up to 22 people when it launches. Described as a self-sufficient slow-drift vessel, this international oceanic station will conduct scientific

research as well as educational projects designed to benefit humanity.

Inspired by the scientific and pop cultural legacies of naval explorer Jacques-Yves Cousteau, oceanographer Jacques Piccard and sci-fi author Jules Verne, the vessel will be a 24/7 laboratory where the crew can live underwater for months to study and observe marine life and its phenomena and collect samples.

Operational

The French Government, several companies and a crowd-sourcing campaign have provided the initial funding. So far, the craft is still being built, albeit piece-by-piece. The Eye of the SeaOrbiter, the first constructed piece of this craft was completed in May of 2015. The 18m centerpiece will be integrated into the upper portion of the

craft where the vessel's communication systems and lookout post is, and will allow researchers to share their research, pictures and video via a live feed.

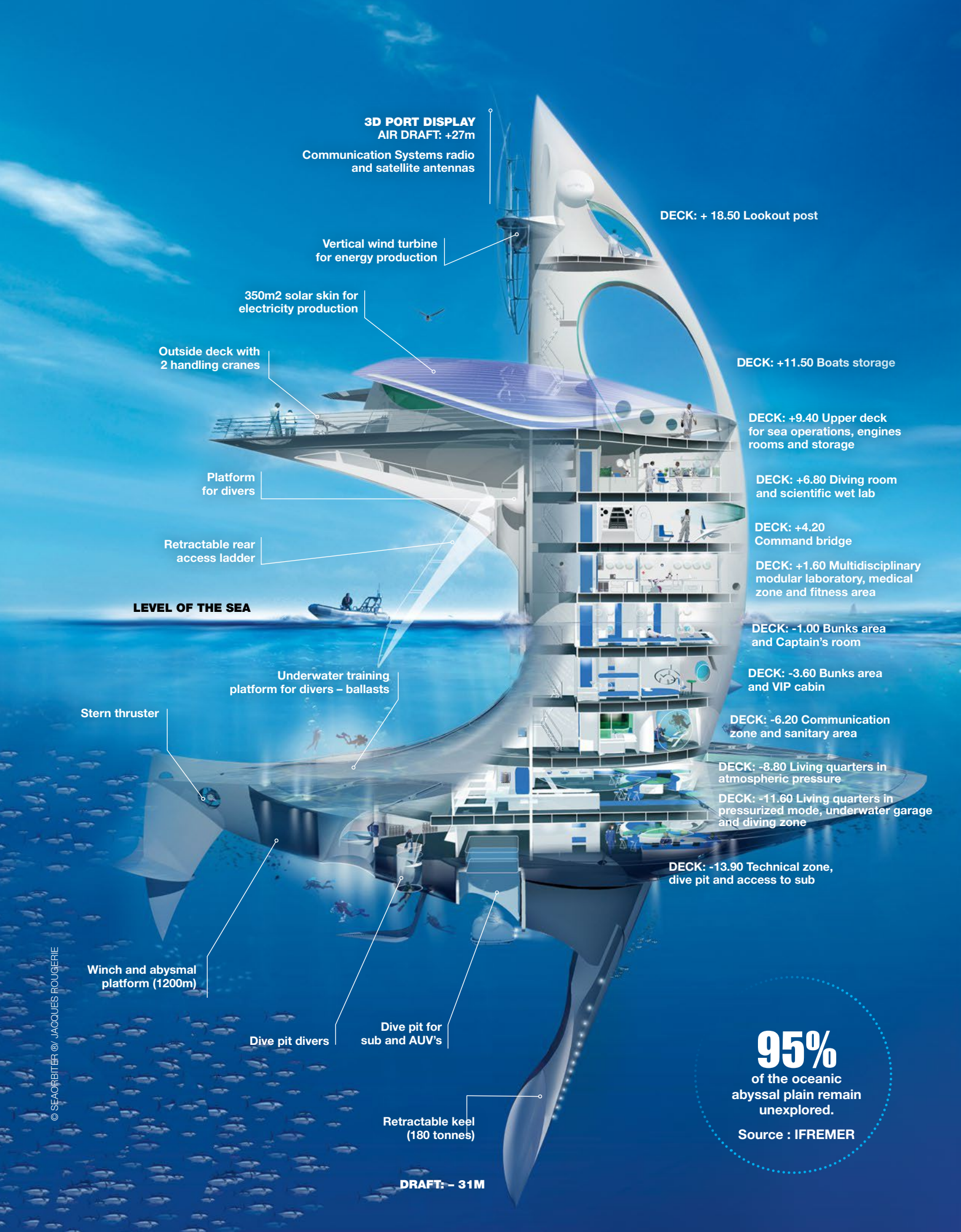
If all goes well, construction will finish by the end of 2015, and the first underwater expedition will begin in spring 2016.

The Vessel

You cannot miss the SeaOrbiter when it finally hits the waves. The momentous structure measures a total of 190ft (58m), of which, 89ft (27m) will be visible above water level. Since it is taller than it is long, there is a chance that it might topple over while navigating through choppy water or stormy weather. But its design ensures that is stable than standard ships. The large saucer section and the keel below it are denser than water. They won't sink



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3D PORT DISPLAY
AIR DRAFT: +27m

Communication Systems radio
and satellite antennas

DECK: + 18.50 Lookout post

Vertical wind turbine
for energy production

350m² solar skin for
electricity production

DECK: +11.50 Boats storage

Outside deck with
2 handling cranes

DECK: +9.40 Upper deck
for sea operations, engines
rooms and storage

Platform
for divers

DECK: +6.80 Diving room
and scientific wet lab

Retractable rear
access ladder

DECK: +4.20
Command bridge

LEVEL OF THE SEA

DECK: +1.60 Multidisciplinary
modular laboratory, medical
zone and fitness area

Underwater training
platform for divers – ballasts

DECK: -1.00 Bunks area
and Captain's room

DECK: -3.60 Bunks area
and VIP cabin

Stern thruster

DECK: -6.20 Communication
zone and sanitary area

DECK: -8.80 Living quarters in
atmospheric pressure

DECK: -11.60 Living quarters in
pressurized mode, underwater garage
and diving zone

DECK: -13.90 Technical zone,
dive pit and access to sub

Winch and abysmal
platform (1200m)

Dive pit divers

Dive pit for
sub and AUV's

95%
of the oceanic
abyssal plain remain
unexplored.

Source : IFREMER

Retractable keel
(180 tonnes)

DRAFT: - 31M

71%

of the Earth's surface are formed by the oceans, oceans representing 97% of the global planet's water volume.

Source : IFREMER

85%

of the marine biodiversity are still unknown.

Source : IFREMER


37%

of the global CO2 emissions are absorbed by the ocean

IPCC (International Panel on Climate Change)

because everything above the saucer will be extremely light and buoyant. Most of the mass of the ship will be permanently underwater; its force in opposition to the floating force will make the vessel nearly impossible to tip, even in the most severe storm.

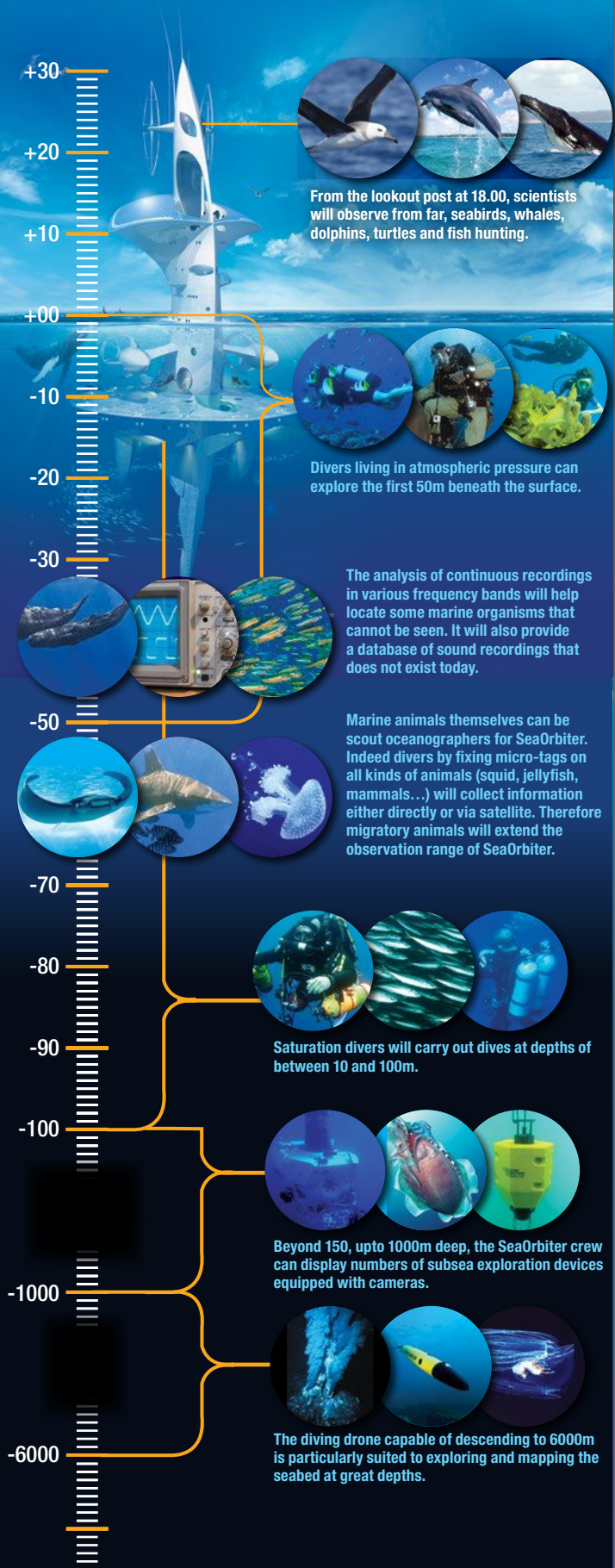
Crafted out of sealium, a recyclable aluminum specially designed for marine environments and used in aeronautics industry. It will generate all the electricity necessary to operate itself by harvesting wind, wave, and solar power.

One of the most attractive features of the SeaOrbiter is the pressurized module where aquanauts can live and work. Since the module is pressurized, the aquanauts can move freely between the module and the sea without the typical need for decompression time periods between surface and deep-sea research missions. This feature is timesaving for researchers and can also be used to help train astronauts for living in space. The area is also used for simulating space experiments. As a safety precaution, the SeaOrbiter is equipped with portable inflatable chambers as well as a fixed hyperbaric chamber. 

Moshita Prajapati is a senior features writer for *BBC Knowledge Magazine* India.



Exploration levels of the SeaOrbiter



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Sawfly caterpillars behave in unison. Here, alarmed at a predator, they rear up their hind ends to create more movement and the impression of greater size. Leaf chewings, edge-nibbles, cuts or even bare stalks are good signs of invertebrate activity

PORTFOLIO

Miracles *at your feet*

These magical images reveal a world of invertebrates that are incredibly accessible but all too often ignored. It's time to get down on your hands and knees to discover these astonishingly diverse creatures for yourself, says entomologist **Richard Jones**

PHOTOS BY LEON BAAS

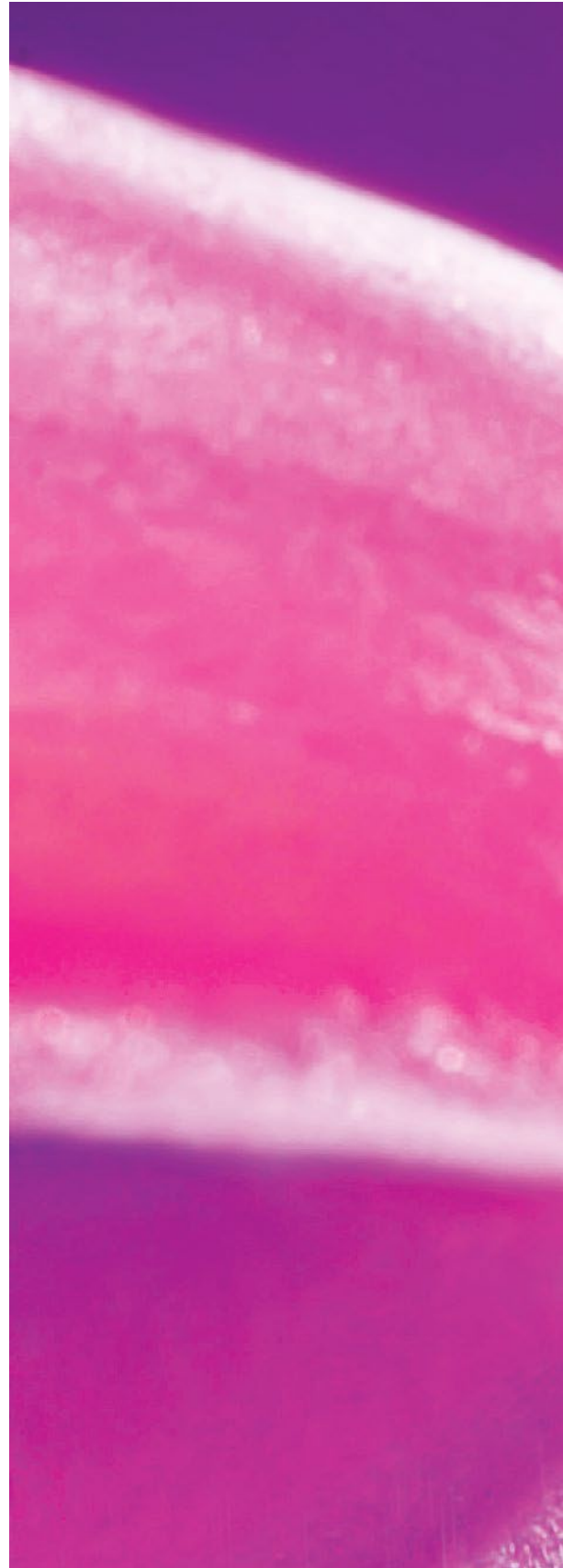


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A grassbug's long legs allow it to run very fast, but a lot of insects spend their time being still. Movement attracts attention from predators, and long grass is a good place to look for these bugs



The loud power-tool sound of this great green bush-cricket doesn't mean it's easy to find. But it's active day and night, feeding on flies, caterpillars and larvae. Get down low on your hands and knees and look for its silhouette



This yellow meadow ant is trying to find its way to dry ground. Though they nest in soil, ants stream up stems and leaves in search of nectar, sap oozing from leaf cuts or aphids. A successful discovery results in a long line of ants sharing the prize





Ruddy darter at sunrise: Hanging from a seed head, this dragonfly will roost all night and take to the wing when warmed by the next day's sun. The cool temperature makes early morning and late evening the best times to get close to many usually skittish insects. Check tree trunks catching the slanting rays of the low sun, or flowers, leaves and stems slightly sheltered and out of any wind

Green-veined white butterfly: At the micro scale colour is not just about brightness, it is about contrast, tone and disruption of any obvious body outline. Only by getting close will you be able to see past the shading and concealing mottles that allow insects to remain so secretive.



Most invertebrates have poor eyesight, but the giant eyes of this jumping spider can accurately size up prey, before it makes a leap many times its own body length. When bug-watching, move slowly, and do not allow your shadow to fall on the beast.



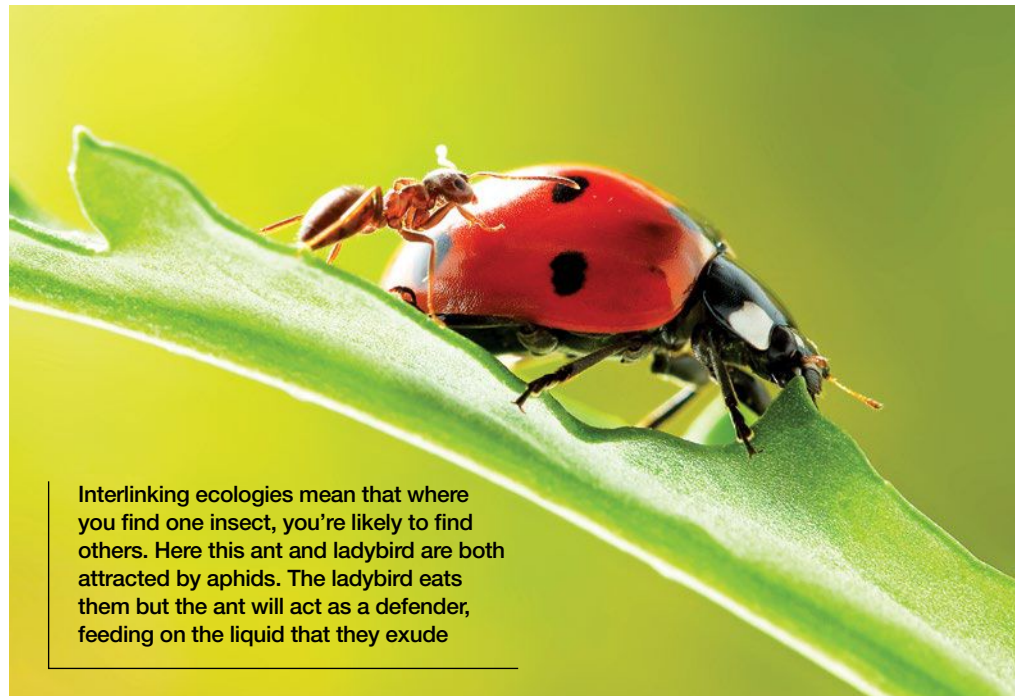
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The fanged pitcher plant
N. bicalcarata is found in lowland
peat forests in northern Borneo.
Some animals have evolved to use
its pitchers as a home and hiding
place, such as this small land crab





This water scorpion has caught a pondskater in its deadly raptorial front legs. It's easier to get close to watch insects when they are occupied sunbathing, mating or eating. Their behaviour is often more startling than their appearance



Interlinking ecologies mean that where you find one insect, you're likely to find others. Here this ant and ladybird are both attracted by aphids. The ladybird eats them but the ant will act as a defender, feeding on the liquid that they exude



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Richard Jones is an internationally acclaimed entomologist, a fellowship of the Royal Entomological Society and recently wrote a book, *House Guests, House Pests*.

The six ages of CHINA



Michael Wood explores the China's six great eras to reveal what has made its civilisation so utterly distinctive, and so fascinating, for so long

1 The rise of the Middle Land A Qin strongman unites China's warring states (c3000–221 BC)

The Chinese call their country Zhongguo, the Middle Land. Originally that meant the Yellow river plain, and our journey begins at a Henan temple fair with a million people celebrating Nu Wa, the prehistoric mother goddess who made the Chinese people out of the yellow mud. "We are all brothers and sisters," one pilgrim told us, echoing DNA discoveries that claim that over a third of all Han Chinese males share just three ancestors only 5,000 years ago (if so, they really are the world's biggest tribe!)

We also visited the great archaeological discoveries at Erlitou and Anyang, capital of the first great dynasty, the Shang (c1575–1046 BC) with whom many of the great themes of Chinese culture emerge – along with the script still used today.

In 1046 BC, the Shang fell to the Zhou, who laid down the idea of the Mandate of Heaven, a conception of moral rulership codified by Confucius in the sixth century


BC. But China was still divided into many small states – it could have ended up like Europe but for the ruthless Qin emperor Qin Shi Huang, who in 221 BC created China's first centralised bureaucratic state by force. That tension between the humanistic and the autocratic is one of the burdens of China's history.

So our big themes emerge: writing and ritual as sources of power; the Mandate of Heaven; and the importance of family and reverence for ancestors, seen in a moving scene with the Ching family of Wuxi on Tomb Sweeping Day, a festival in which millions offer prayers to their forebears. "Our family goes back a thousand years," said one old man, "and huge changes have happened to us. Now everybody is asking: what are our roots?"

Today everyone in China is asking the same question.



Above An owl-shaped wine vessel from the late Shang period, c1200 BC
Top: Michael Wood talks to a potter in Kashgar, China's westernmost city



“The Tang welcomed foreigners, and their ideas and religions, including Christianity”

2 The Tang **When China opened** **its arms to the world** (AD 618-907)

Ask Chinese people their favourite period and most will say the Tang: an age of political, cultural and commercial greatness, when China went out to the world along the Silk Roads. It also welcomed foreigners, and their ideas and religions – including Christianity. (Just imagine a Daoist mission being received in Dark Age Winchester!)

To really open up to another civilisation requires humility, curiosity and breadth of spirit, and the Chinese had that confidence in the Tang. Another great theme is a new reflective spirit in literature. This was the time of China’s best-loved poets, as we saw in a school near Luoyang when effervescent kids took us through a poem by the eighth-century writer Du Fu about the tragedies of his time.

The Buddhist monk Xuanzang travels with a tiger along the Silk Road in an image from the ninth century



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3 The Song Renaissance

A golden age of restaurants, football, printing and the Chinese Leonardo (960–1279)

If I could go back to one time and place it would be the world depicted on the great Kaifeng Qingming Scroll from the 1120s. Don't think of Chinese history as immemorial stability. The opposite is true: it is cycles of destruction and creation. After the fall of the Tang, China fragmented into 16 dynasties in five decades before the glories of the Song.

Song Kaifeng was perhaps the greatest city in the world before the 19th century. It's not on the main tourist routes but it's been one of my favourite places since I first went in the 80s. In the alleys are Daoist and Buddhist temples, Christian churches, and women-only mosques; not to mention the last Chinese Jewish community. It had the world's first great restaurant culture. They even had football, with clubs, rulebooks, fans – and music.

Long before the Renaissance in the west they had printing, paper money, coke smelting, gunpowder, the magnetic compass, water-driven spinning machines, the endless chain drive mechanism, and the famous astronomical clock built by Su Sung, the Chinese Leonardo.

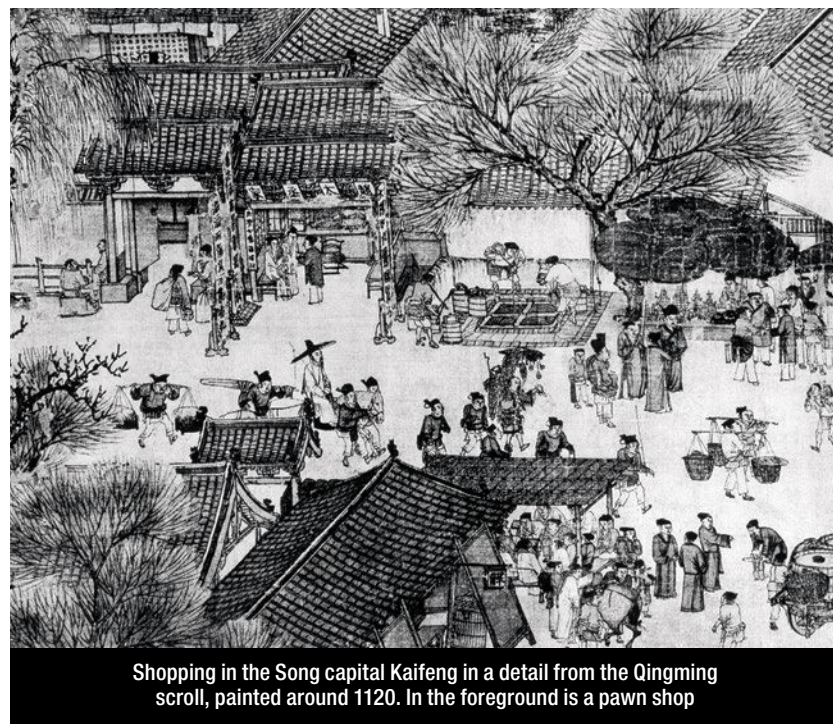
That's what makes the Song so exciting, from their debates about good governance to their ideas about the good life, and from their arts to their staggering advances in science.

So why didn't China become the first modern civilisation, before the west? Foreign invasion played a big part. The fall of Kaifeng to northern barbarians in 1127 was a huge blow. Then the Mongols overthrew the Southern Song in the 1270s, at around the time when Marco Polo described the wonders of Hangzhou. The experience of defeat would haunt them.



Animals adorn a Ming dynasty jar from Jingdezhen in Jiangxi Province

“Long before the Renaissance in the west, the Song had printing, paper money, coke smelting and gunpowder”



Shopping in the Song capital Kaifeng in a detail from the Qingming scroll, painted around 1120. In the foreground is a pawn shop

4 The Ming

The dynasty that gave us the Forbidden City and Great Wall (1368–1644)

The Forbidden City, the Great Wall, fabulous ceramics: the Ming is how we see historic China. The Ming came out of the shock of Mongol occupation and the civil wars of the 1350s. The founder, Zhu Yuanzhang, was born a peasant, lived as a penniless beggar and wandering monk, but became one of China's greatest rulers.

It's a tale of three cities: first Zhu's splendid capital, Nanjing; then Beijing, the new capital of the usurper Yongle who built the Forbidden City. Yongle wanted to show China to the world and sent the admiral Zheng He to east Africa and the Persian Gulf in giant ships (we filmed the construction of a spectacular full-sized replica in Nanjing).

The third city is Suzhou, the Chinese counterpart to Renaissance Florence, where a rising urban middle class demanded fashion, gardens, theatre and novels. To coin a phrase, if you were tired of Suzhou you were tired of life! But in 1644 the declining and over centralised Ming state fell to the Manchus, China's last dynasty.

5 The Great Qing

From world's greatest empire to "crazy old man of war" (1644–1911)

The Qing dynasty is often seen as a time of decline, but in many ways the 18th century was a brilliant epoch. After the horrors of their conquest, the Manchus restored order, setting out to be more Chinese than the Chinese. Three great emperors reigned between 1661 and 1820; and the first, Kangxi, was one of the greatest in Chinese history. The Qing took control of Xinjiang, Mongolia and Tibet, doubling the size of the empire.

China then was still the greatest and most populous empire on Earth, and by far the biggest market. New wave Qing historians talk now of a diversified economy, and even aspects of what we might call civil society: guilds, cultural clubs, banks, charities, newspapers, even 'public opinion' – all features of Enlightenment states in Europe. It was a time of great cultural projects.

Far from the capital,

the city of Yangzhou was a centre of printing, painting, novels and theatre; there Kangxi sponsored the printing of the Complete Tang poems (over 48,000 of them!) And then there's the 'novel of the millennium', *The Dream of the Red Chamber*, an 18th-century family saga – magical realism long before Marquez or Rushdie. One autumn day in a bar by Beijing's North Lake a young electro musician with henna'd hair spoke of China's best-loved book with a smile: "It's really about the eternal verities: love – and freedom!"

Into this world in 1793 came the British. Ambassador MaCartney summed up his hosts with breezy self-assurance and a nautical metaphor: "The Chinese empire," he said was "a crazy old man of war... which may drift for a while yet, but can never be rebuilt on the same bottom."

China was about to be overtaken.



A portrait of Kangxi, "one of the greatest emperors in Chinese history". He was the second Qing ruler of China, from 1661 to 1722



Communist leader Mao Zedong waves to a rally celebrating China's Cultural Revolution, Beijing, 1966

6 Modern China

Jaw-dropping cruelty and success (1911–2015)

In the mid-19th century, China was shaken by a cataclysmic war, the Taiping Rebellion, in which 20 million died. The story began in the villages of Thistle Mountain in Guangxi where it all began. The Qing won, but at a price. The imperial system was now in crisis. New ideas flooded in, from naval technology and railways to democracy, feminism and socialism.

Terminally rocked by the Boxer rising (partly motivated by opposition to foreign interference), the empire fell in 1911 and China became a republic. It was on the winning side in the First World War, but the gross injustice of Versailles sparked new upheavals. Was the way forward western or Chinese? A reformed Confucianism, liberal democracy, or Marxist-Leninism?

That the communists won out was really an accident of history: it was the Japanese invasion that turned them into a liberation movement. But the stark truth is that all the 20th century's Marxist-Leninist states were tyrannies, and Mao's regime was no exception.

Recently historians have exposed the disasters of Maoism, especially the Great Famine in which tens of millions died, the largest man-made catastrophe in Chinese history. Yet the party held on to power, and though moves to political reform were put on hold after 1989, its economic achievements since have been jaw-dropping.

Modern China faces great challenges – not just economic, but social and political: the rule of law; the representation of the people; the safety of the food chain; the despoiled environment. But the Chinese have been through many ups and downs, and possess incredibly rich resources in culture and civilisation going back millennia. And as always, in the end, the Mandate of Heaven is theirs to bestow. ■

Michael Wood is professor of public history at the University of Manchester. He has recorded over 100 documentary films on history.



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10

THINGS YOUR FACE SAYS ABOUT YOU

The eyes may be the window to your soul but your face, features and complexion give away all sorts of information about you. **Christian Jarrett** investigates

1 HOW MUCH CHOLESTEROL YOU HAVE

“Mirror, mirror on the wall, who’s the fittest of them all?” Asking this very question might become a commonplace occurrence following the announcement this summer that a mirror is in development that will assess the health of anyone who looks into it.

The Wise Mirror is being developed by researchers from seven European countries, coordinated by the National Research Council of Italy. The device uses five compact cameras and a 3D scanner to measure facial skin tone, the amount of fat on the face and facial expressions. It also analyses breath. Based on this data, the mirror estimates factors such as cholesterol levels, glucose levels, anaemia, weight gain and stress. If you’re looking a little run-down, the idea is the mirror will provide you with tailored health advice to get fit again.

Right now, the mirror is still only at a prototype stage. For a more immediate estimate of your longevity, find some old photos of yourself and see if you’re smiling. A recent analysis of baseball photos in a 1952 register found that of the players who’d since died, those pictured with a genuine smile had lived to age 80, on average, compared to an average age of 73 among the non-smilers.



Baseball players who smiled on their photos lived longer than those who didn’t

2 HOW TRUSTWORTHY YOU ARE

We routinely make assumptions about each other’s traits based on facial appearance. Sometimes these inferences are made quickly, suggesting that we can gather significant clues in a split second.

Generally, faces that are babyish (think less pointy, with a high forehead) are rated as more trustworthy. Other face-based character assumptions appear at first to be tied to specific facial features, but the reality is more complicated. For example, there’s evidence that men with brown eyes are perceived to be more dominant than men with blue eyes. But when a blue-eyed man dons brown contact lenses, this does nothing to increase how dominant he appears to strangers. This suggests there’s something else about brown-eyed

men that creates an impression of dominance.

There’s some recent evidence that we can overcome the personality signals given off by our static facial structure, simply by pulling the right facial expressions. Psychologists call this ‘social camouflaging’ and it was demonstrated in a study published last year by researchers at the University of Glasgow. An animated face morphed to look optimally untrustworthy based on its basic structure was rendered trustworthy by programming it to pull a facial expression that involved raising the lips and cheeks. “Social camouflage of dominance and trustworthiness is probably commonplace in everyday interactions,” the researchers explain.



“MEN WITH BROWN EYES ARE PERCEIVED TO BE MORE DOMINANT THAN MEN WITH BLUE EYES”



Brown-eyed men are viewed as more dominant than their blue-eyed friends

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WHAT MOOD YOU'RE IN

3

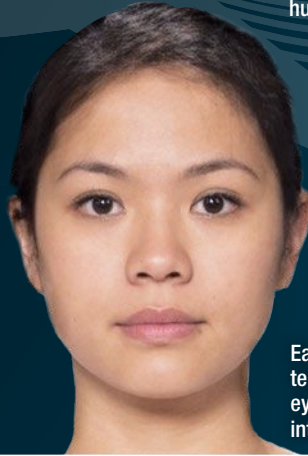
Since Charles Darwin first compared the emotional displays of humans and animals, it's been argued by many experts that humans exhibit six basic emotions via six core facial expressions: happiness, surprise, fear, disgust, anger and sadness. No-one disputes that facial movements convey what we're feeling, but there is some debate over the

cultural universality of the emotional expressions.

At the recent Royal Society Face Facts exhibition, researchers from the University of Glasgow presented their evidence that the interpretation of emotional facial expressions is not, in fact, universal. They used a unique 3D computer system to create digital avatars that could independently manipulate all 42 muscles in the face. The researchers then presented participants from a Western or an East Asian background with these avatars showing random combinations of facial muscle movements, and the participants had to say when they recognised one of the six basic emotions. There were differences in how

the Westerners and East Asians responded – for example, the East Asians were a lot less consistent in how they categorised some emotions (especially surprise, fear, disgust and anger), and saw movements of the eyes as more important for interpreting emotional intensity.

Quoting Darwin, the researchers say: "Although some basic facial expressions such as fear and disgust originally served as an adaptive function when humans 'existed in a much lower and animal-like condition', facial expression signals have since evolved and diversified to serve the primary role of emotion communication during social interaction."



East Asian people tend to rely more on eye movements when interpreting expressions



"NO-ONE DISPUTES THAT FACIAL MOVEMENTS CONVEY WHAT WE'RE FEELING, BUT THERE IS SOME DEBATE OVER THE CULTURAL UNIVERSALITY OF THE EMOTIONAL EXPRESSIONS"

4

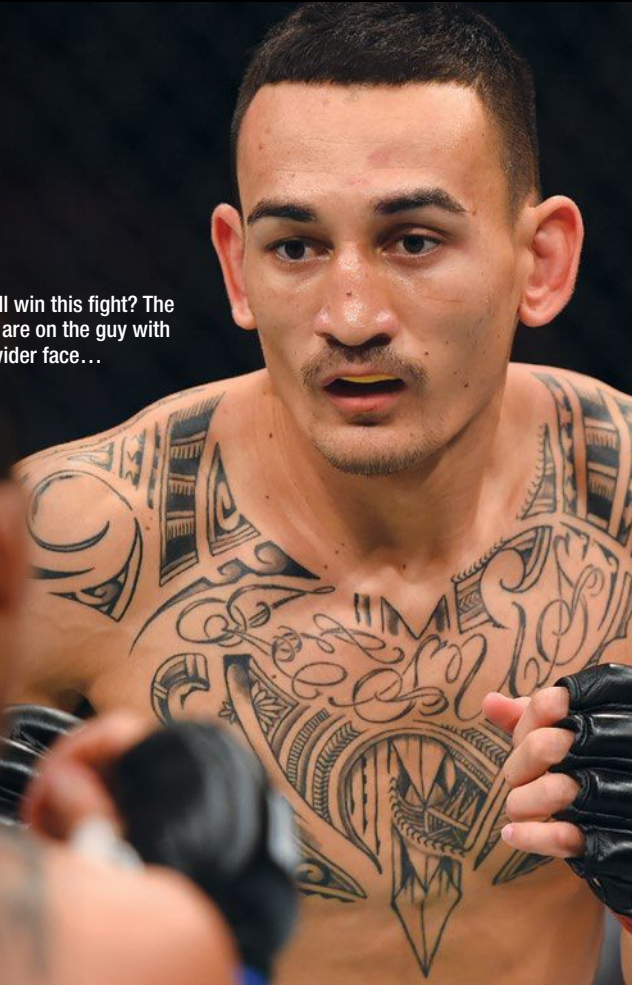
HOW WELL YOU FIGHT

The shape of your face is related to your fighting prowess – if you're a man. Psychologists made this discovery in 2014 after analysing photographs of over 200 mixed martial

artists in the Ultimate Fighting Championship (UFC). Male fighters with faces that were wider relative to their length tended to win more fights, and the association held even after factoring out the influence of body size. The result chimes with past research linking facial width with aggression. What's more, it seems we intuitively know that this facial characteristic is a marker of pugilistic prowess. When the researchers manipulated fighters' photos to make their faces appear wider, this led observers to rate the fighters as more deadly.

Another temporary facial cue to fighting ability is a smile. Across the animal kingdom, it's common for a smile to be used as a signal of submission. Consistent with this, a 2013 study of UFC fighters published in the journal *Emotion* found that those who smiled at a pre-match face-off were more likely to lose the ensuing confrontation. "Smiles appear to play a unique role in physical confrontations, as a sign of a person's reduced physical dominance," the researchers say.

Who'll win this fight? The odds are on the guy with the wider face...



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If you concentrate on someone's mouth movements, you'll have more success in deciphering their emotional state



WHAT YOU'RE REACTING TO

5

Do you think you could tell what had just happened to someone from a short, silent video of their facial reaction? Specifically, could you tell whether they'd been told a joke, heard a sad story, received a compliment or been made to wait for five minutes?

This is exactly the challenge that University of Nottingham psychologists gave their participants for a study published in 2012, which they say was a more realistic test of the way we interpret each other's facial expressions than simply naming the emotion on display. The participants averaged around 60 per cent accuracy – not great, but if they'd just guessed each time, their accuracy would only have been 25 per cent. Accuracy was especially high (90 per cent on average) for recognising when someone had been made to wait.

In general, participants who were more accurate tended to focus more on the mouth region. The researchers say: "From observing just a few seconds of a person's reaction, it appears we can gauge what kind of event might have happened to that individual with considerable success."

WHETHER YOU'RE ARTY OR SCIENTIFIC

6

Many of us have a side of our face that we prefer, and that we turn to face the camera for photos. However, an analysis of thousands of university academics' homepage photos suggests there's more to this than vanity. Engineers, mathematicians and chemists more often posed with their right cheek forward, while arts scholars and psychologists more often posed with their left cheek showing. There was also a gender difference, with female academics more likely to display a greater amount of their left cheek.

The research, led by Owen Churches at the University of South Australia (incidentally, his web photo shows more right cheek) says that the findings were consistent with past work suggesting that more emotionally expressive people tend to pose with the left cheek on display, and that naive observers assume right-cheek posers are more scientific.

"Academics be warned," the research concluded. "We present ourselves to our students and colleagues in our profile pictures, and the way we do so may reveal more about ourselves than we think."

WHAT LIFESTYLE YOU LEAD

7

Some people certainly seem to have more 'lived-in' faces than others. This year, researchers at the Chinese Academy of Sciences elaborated on this principle, reporting that they'd used computer imagery to generate 3D models of over 300 people's faces (aged 17 to 77), and that they'd used these models to look for correlations between specific facial features and age. For example, older people tended to have wider noses and more sloping eyes. Some people had faces that were 'young' for their age based on these markers, with any two people of the same chronological age differing by around six 'face years' on average.

Facial age correlated more strongly with objective markers of health, such as cholesterol levels, than with chronological age – showing that a person's lifestyle is indeed written in their face.

"THERE WAS A GENDER DIFFERENCE, WITH FEMALE ACADEMICS MORE LIKELY TO DISPLAY A GREATER AMOUNT OF THEIR LEFT CHEEK"





In the picture on the left the boy is suffering ongoing pain, on the right he is suffering transient pain – the difference in his facial expression is clearly visible

8 HOW MUCH PAIN YOU'RE IN

It's often difficult for people to articulate their pain, especially children. Thankfully, researchers at the University of California recently announced that they've created a computer algorithm that decodes videos of children's changing facial expressions to determine how much pain they're in. The algorithm was tested on children aged five to 18 who were recovering from appendix surgery, and its estimates of their pain correlated well with their self-reports – better, in fact, than the estimates made by nurses.

An advantage of this technique is that it could provide a continuous measure of a patient's pain. Scheduled assessments, by contrast, can miss those times when a patient is suffering the most. Moreover, the computer program is not biased by a patient's age, gender or ethnicity, and could be used for children who are too young to communicate how much pain they're in.



affiliation, their perceptions were then used to create 'perfect' Labour and Conservative MPs (pictured on the left and right respectively)

9 YOUR SEXUALITY

Your face gives away a lot – but not your political leaning. Researchers tested this in 2011 when they asked 19 subjects to look at the faces of 90 unfamiliar backbench male British MPs and to say whether they were from the Labour or the Conservative party (using a rating scale to show how confident they were in their guesses). The results showed the participants were unable to judge the MPs' affiliations from their faces. MPs with beards or glasses were excluded in case these were used as cues.

Sexual orientation is another matter. Research from 2008 by Tufts University found that a 50 millisecond glimpse of 90 men's faces was enough for undergrad students to judge their sexuality (homosexual or heterosexual) with an accuracy of 57 per cent, which is superior to chance. "The rapid and accurate perception of male sexual orientation may be another symptom of a fast and efficient cognitive mechanism for perceiving the characteristics of others," the researchers say.

10 WHAT YOU EAT

If someone has an orange glow, it's tempting to assume they've been spending too much time on a sunbed. In fact, a person's diet – specifically the consumption of carotenoid-rich fruit and veg such as carrots – can also affect their skin in a similar way, making it appear more yellow. In 2014, psychologists from the University of Leeds and the University of St Andrews showed that faces made more yellow through diet were rated more attractive by observers than the same faces with an equivalent suntan. It's thought that skin turned yellow through diet is attractive because it's a sign the person is in good health. 🟡



Christian Jarrett is a psychologist and the author of *Great Myths Of The Brain*.



Honeypot ants hold onto the ceiling of their cave with their legs as their sister workers tend to them. The workers bring food from above ground and use their small mouths and mandibles to clean the distended bodies of the honeypots



Sweet & low

When food is scarce honeypot ants turn to the living larders in their underground colony. Entomologist **Rob Dunn** provides an insight into the world of the insects that use their bodies to stockpile sugar

PHOTOS BY ERIC TOURNERET



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There are about 30 species of honeypot ant in the world, named for a very specific behaviour. Some of the colony's worker ants prepare for hard times by storing food in their sisters. The workers feed these special sisters, known as repletes, until their abdomens swell. The feeding continues until they're so swollen that all they can do is hang from the ceiling of their nest in diaphanous, golden rows. Then, when the hard times arrive and everything above ground is dry and inedible, the worker ants come back to the repletes and beg for food. Drop by drop, the honeypots regurgitate the sugar they've been storing.

The practice has evolved repeatedly in regions where food is predictably scarce for part of the year. The other thing that occurs repeatedly in these regions is that humans discover these sugar-loaded ants and eat them. They're delicious, a ball of sugar with a subtle texture imbued by six tiny legs. In the desert of the south-west USA honeypot ants are eaten by Native Americans. But it's in Australia that honeypot ants, and specifically the red honey ant *Melophorus bagoti* photographed here, are most valued. The insects were discovered there in the time before corn syrup and sugar cane, and became a treat worth some work.

The technique involves finding a nest among the roots of mulga trees and tracking a returning ant to the entrance. Once you have, use a stick to figure out the direction of the nest's first tunnels, then start digging, probing with your stick each time you reach a new turn. Dig down the central tunnel until you come to a large chamber where, hanging from the ceiling, you'll see the honeypots. Pop a few in your mouth. Savour the texture and the exotic sensation of the wiggling legs before you bite down and let the sugar pour through your mouth.



THE LOCATION

MacDONNELL RANGES, AUSTRALIA

The honeypots dwell about a metre underground in hidden nests throughout the driest parts of the country. These particular ants have been photographed in the MacDonnell Ranges, a series of mountains 644km-long, to the west of Alice Springs, in the heart of one of the regions of Australia that is most sacred to Aboriginal people.



An Aboriginal woman and her daughter dig up a honeypot colony, which can be located by the discoloration of the soil due to formic acid. A century ago the ants were one of the few sweet foods available in the outback. Now less nutritious corn syrup and cheap sweets dominate diets





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Far left: All insects have external skeletons. But in honey pot ants the skin between the segments of the exoskeleton is stretched so taut with the volume of the honey that it becomes transparent – a body through which the entire world appears to be delicious and gilded.

Left: When children run after ice-cream vans they recreate the ancient experience of the hunt for subtler sweets in the form of ant bottoms, bee combs or berries, a joy composed of equal parts of sweetness and the pleasure of discovering something rare.



Above: The honeypots wait for the hard times when food is scarce, and all that can sustain the colony until the return of the rains is the sweet and necessary sugar that they've dutifully stored.

Right: Honeyspot ants are just one of the many biological treasures hidden in the thorny scrub of the outback where riches abound for those who take the time to look for them. The ants build their nests under mulga trees *Acacia aneura* on whose twigs lives a psyllid insect that produces a honeydew in exchange for protection from the ants.





The behaviour of these small-brained insects often seems to embody characteristics we wish were more apparent in ourselves, such as a selflessness on behalf of the community and the ability to plan ahead in order to replace scarcity with plenty. Of course when times are really hard ants have also been known to eat their offspring – but then no society is perfect





Above: When sweets were very rare – the first explorers to land in Australia described it as a place without berries or fruits – this handful of honeyspot ants would have been priceless.

Left: Honeyspot ants remain part of Aboriginal culture as a symbol of both the treasures of the desert and the rich knowledge of that biodiversity held by Aboriginal people long before European colonists ever reached Australia's shores. 🟡

Rob Dunn is Professor of Applied Ecology at North Carolina State University, who studies insects, fungi and microbial organisms.

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Babies learn the rules of ring-tailed lemur society by watching adults and, when older, by playing with other young in their crèches

Photos by Suzi Eszterhas

Ring-tailed lemur society is ruled by a language of smells, displays and violence, and is teaching us about primate evolution, says **Mike Unwin**.



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SCRATCH & SNIFF

(Or, how to speak lemur)

It's a hot day in Berenty Reserve, south-east Madagascar, and there's a rumpus among the ring-tailed lemurs. Yips and squeals resound through the understorey as these spring-heeled primates bound around the roots of a tamarind tree. One young male advances with quivering tail arched forward over his head, only to be confronted by a rival doing exactly the same. In the shadows, a female performs a backwards handstand against a sapling.

To the enchanted groups of tourists watching these habituated lemurs, it looks like some kind of madcap primate circus. But, as their guides explain, the action is replete with meaning, and to catch the gist you need only learn the lingo. This means not only translating the lemurs' various yips, squeals, purrs, yells and wails, but also interpreting their sign language of posture, leap and grimace, and – even trickier to our untutored noses – their extensive repertoire of smells.

That's right: ring-tailed lemurs say it with stink, using scent to convey strategic messages about territoriality, social rank and sexual availability. Olfactory communication is far more developed in lemurs than among monkeys and apes, and especially so in this species, which produces a pungent secretion from an array of scent glands. There are some on the inner forearms (antebrachial glands), some on the shoulders (brachial) and yet more in the ano-genital region (perianal).

Those two tail-waving individuals were indulging in a 'stink fight' (see box, p55). The handstanding female, meanwhile, was marking the group's territory by smearing tree bark with scent from her vulva. A further glance around the group might also have revealed a male using special horny spurs on his wrists to gouge scent into the bark of saplings.

A most unusual lemur

"Madagascar's trademark" was how the celebrated primatologist Alison Jolly once described the ring-tailed lemur.



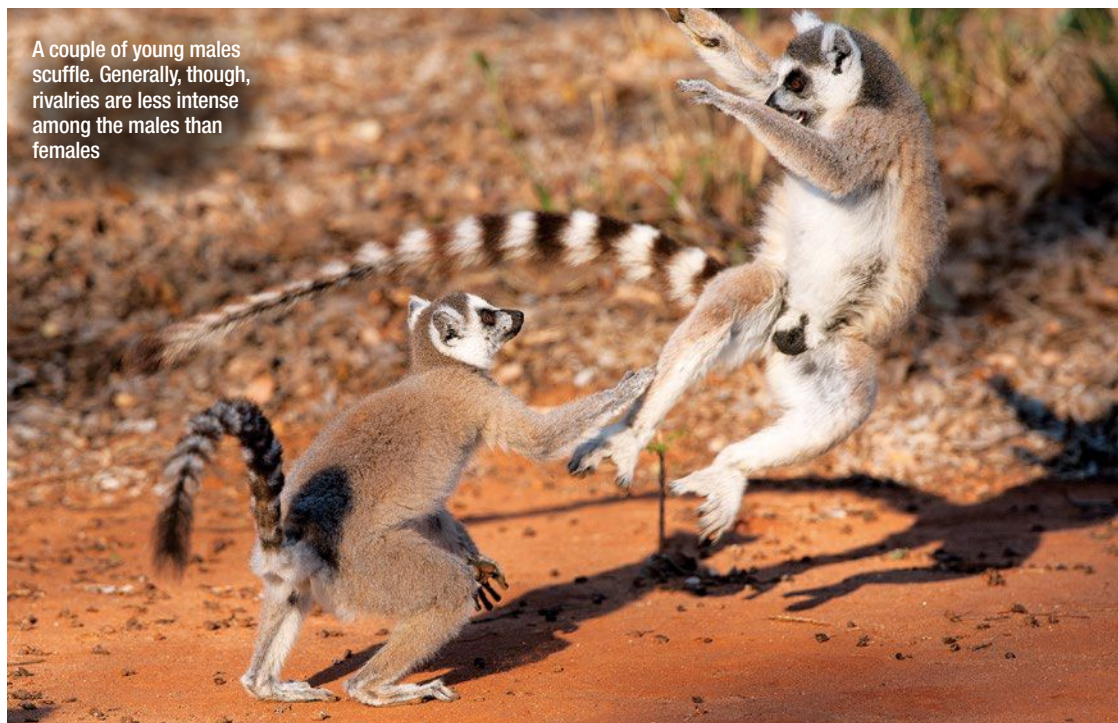
This baby is just two weeks old. All of the adult females carry the group's infants, often swapping them. Young are weaned at three months and independent at six months

Indeed, to people around the world it is emblematic of the island, and today that raccoon-like bandit mask and long black-and-white tail make the perfect symbol for the Madagascar National Parks Association.

Nonetheless, the ring-tailed is far from your typical lemur. For a start, it is much the most terrestrial of its kind – spending some 33 per cent of its time on the ground – and the most sociable, forming mixed-sex groups of generally 6–24 animals. It is also the most active by day, which makes it relatively easy to observe – and, crucially, to study. Jolly, who died this February, began

researching the ring-tailed lemurs of Berenty Reserve in 1963, continuing the study for four decades.

Central to her research were communication strategies. She discovered, for example, that ring-tailed lemurs use at least 28 vocalisations, ranging from soft contact calls, such as moans and meows, to howls audible from up to 1km away that advertise a group's presence to other groups in the area. Other sounds include contented purrs during grooming, chirps given when on the move, yips uttered by subordinates in the presence of superiors, and chutters given by a dominant



A couple of young males scuffle. Generally, though, rivalries are less intense among the males than females



Ring-taileds spend more time on the ground than other lemurs. Groups on the move hold tails aloft like flags to signal ownership of their territory

individual upbraiding an inferior.

Taken in tandem with body language and scent-marking, this range of expression allows ring-tailed lemurs a complexity of social interaction that was once held to be the preserve of 'higher' anthropoid primates – that is, monkeys and apes. Indeed, studies of anti-predator warning strategies among ring-tailed lemurs have revealed that they employ a specific vocabulary to distinguish between threats. Thus shrieks warn of a passing Madagascar buzzard or another bird of prey, while yaps are used when mobbing a predatory mammal, such as the mongoose-like fosa.

Learning the language of ring-tailed lemurs helped Jolly and her colleagues to unlock the secrets of their social life. It turned out that, in contrast with monkeys and apes, the lemurs live in a matriarchal society. While both males and females have separate dominance hierarchies within their sex, all females enjoy dominance over all males – a status that they readily assert by cuffing, lunging, biting and other displays of force.

Females stick together in their natal

groups, with one high-ranking alpha female providing the central point for the group. Being the dominant sex, they maintain the group's territory – a fairly loose home range that overlaps with that of other groups. They will also take the lead in confrontations, driving off intruders with stares and other ritualised expressions of hostility. These interactions seldom lead to violence. Within their own troop, however, female dominance battles can turn ugly, resulting in serious injury or even expulsion.

Dominance hierarchies among males are short-lived, and settled through stink fights and other ritualised displays. Competition is most intense during the breeding season, when it may erupt into 'jump fights' – rivals leaping into the air and slashing at each other with their canines. High-ranking males inhabit the centre of a group, where they associate more with females than with other males. Lower-ranking individuals hang around at the periphery and often switch groups in the hope of more success.

The breeding season is a frenetic three-week window from mid-April ▶

STINK FIGHTS

During the breeding season, male ring-tailed lemurs engage in stink fights to compete for females and resolve conflicts without resorting to violence. They anoint their tails with pungent perfume by rubbing the fur against the scent glands on the insides of their wrists and shoulders. Then they arch their smelly tails over their backs and wave them, to waft the fragrance towards their rival, hoping to deter him by sheer force of body odour. A stink fight breaks out when two males face off and start to pull their tails through these two glands. It lasts anywhere between 10 minutes and an hour, ending when one lemur backs down and flees.

Anointing the tail to prepare for a stink fight



RING-TAILS USE AT LEAST 28 VOCALISATIONS, FROM MOANS AND MEOWS TO HOWLS AUDIBLE 1KM AWAY



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Feeding on the leaves of *ocotillo*, a succulent plant typical of the spiny forests in south-west Madagascar

to mid-May, during which each female comes into oestrus for just four to six hours at a time. The group goes into social overdrive, males battling over mating rights and females copulating with multiple partners. The young – usually a single infant, or occasionally twins – are born in September. Females mature sexually at about three years; males leave the group when mature, and move between groups every three to five years for the rest of their life.

Jolly's studies have had implications far beyond her lemur subjects. "It seems likely that the rudiments of primate society preceded the growth of primate intelligence, made it possible, and determined its nature," she argued in a groundbreaking 1966 paper. At the heart of her thinking was the Social Intelligence Hypothesis: the idea that social intelligence – the collection of mechanisms such as politics, family relationships, quarrels, collaboration and reciprocity that we see as integral to our own species – was the driving force behind the development of the large human brain.

Before Jolly's work, it was thought that evidence of early social intelligence could be observed in large-brained

monkeys and apes, but that the smaller brains of lemurs made them irrelevant. It was her revelations about ring-tailed lemur society that first implied clues might lurk lower down the primate evolutionary tree. "Jolly was suggesting that primate social life provided the evolutionary context of primate intelligence," says Christoph Schwitzer of Bristol Zoological Society and the IUCN Primate Specialist Group. "Her work has helped us to unlock some of the mysteries of primate evolution."

More recent work with captive ring-tailed lemurs – for instance, at the Duke Lemur Center in North Carolina – has revealed cognitive skills never observed in the wild. These include the ability to organise sequences, understand basic arithmetical operations and use simple tools. The discovery of such capacities in more primitive primates suggests that they may have existed at an even earlier stage of primate evolution, though the skills did not emerge until much further down the evolutionary line, unlocked by the development of social intelligence.

Survival of a national icon

Who knows how much more there is to learn? Only last November, studies

of ring-tailed lemurs living on the arid Mahafaly Plateau in south-west Madagascar revealed that these naturally forest-dwelling primates had adapted to living in limestone caves, where they find sleep sites safe from predation, refuges from extreme temperatures and a ready source of drinking water.

To study ring-tailed lemurs further, of course, there need to be subjects left to study. But with Madagascar's natural

Lemurs of both sexes (this is a female) do handstands to rub their anogenital scent glands against saplings.





LEMUR LIFE

Lemurs communicate and socialise using a host of both physical and behavioural adaptations

environment now under severe threat, this cannot be taken for granted. A 2014 update to the IUCN's Red List categorises 90 species of lemur (91 per cent of the known total) as at risk of extinction. Though the ring-tailed is one of the more plentiful species, recent drastic population declines have led the IUCN to 'uplist' it two categories from Near Threatened to Endangered – a rare event, says Schwitzer.

Habitat loss and degradation are the key threat. The island has lost 90 per cent of its original forest cover since the arrival of humans 2,000 years ago – and the process continues. Yet all is not lost. The IUCN is working on a new action plan. "With sufficient long-term funding and functioning institutions," says Schwitzer, "I am hopeful that we can secure the future of this wonderful lemur."

Meanwhile, according to Madagascar expert Derek Schuurman, ecotourism has a vital part to play. "The ring-tailed is the lemur that everyone wants to see," he points out, explaining how revenue ploughed back into the community provides an incentive for protection. Schuurman cites the success of the spectacular Anjaha Community Reserve,

RING-TAILS HAVE A COMPLEXITY OF INTERACTION ONCE HELD TO BE THE PRESERVE OF ANTHROPOID PRIMATES – MONKEYS AND APES

where villagers guide tourists through a small but pristine pocket of forest in search of ring-tails.

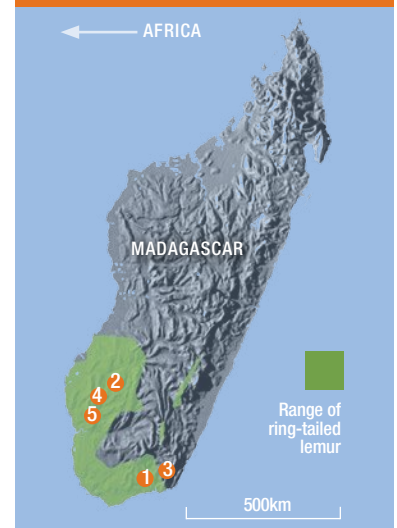
It's true that with an estimated 2,000 ring-tailed lemurs in zoos and collections worldwide, the species is not about to disappear. But on its island home it may have to adapt to survive. "Finding out how ring-tailed lemurs cope with deforestation and forest fragmentation will inevitably become a research focus," predicts Schwitzer.

It seems unthinkable that we might lose the ring-tailed lemur in the wild. It is, after all, the flagship for a nation. And as long as pungent stink fights and territorial battle cries enrich the air of the reserves it calls home, who knows what else this beguiling primate might teach us? 🍌

HOW TO SEE RING-TAILED LEMURS

Ring-tailed lemurs are confined to a handful of reserves and protected areas within nine separate forest blocks in south and south-west Madagascar. They are most easily observed in the dry, open forest at Berenty Reserve (1), where the population density is high and lemurs are extremely tame, though you'll be sharing the experience with other tourists. Ring-tails may also be seen in the amazing-looking spiny forest at Anjampolo, north of Berenty, and at Isalo National Park (2), among impressive sandstone rock formations.

Other sites include Andohahela National Park (3), Zombitse-Vohibasia National Park (4) and Anjaha Community Reserve (5). Look for groups sunning themselves in the early morning in open areas or on bare rock, adopting the distinctive 'lotus' or yoga position (see p76). Family groups are attracted to seasonal food sources – for example, in open forests in October and November they gather to eat the fruit and new leaves of the kily tree *Tamarindus indica*.



Mike Unwin is a naturalist and wildlife author. His most recent book is the *Bradt Travel Guide to Swaziland*.



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HOW DO WE KNOW?

THE EARTH'S CLIMATE IS CHANGING

BY KATE RAVILIOUS

Global temperatures have risen and fallen repeatedly during our planet's long history, so should the recent rises be any cause for alarm? And are we really to blame for them?

Once upon a time, palm trees flourished in the Arctic and crocodiles basked on Alaskan beaches. There was no ice at either of the poles, and Earth's average temperature was nearly 23°C (today's average is around 14.6°C). This was our planet 56 million years ago, a time known as the 'Paleocene-Eocene thermal maximum'. For Earth, global warming is nothing new.

Today, the Earth is warming once more. Since 1880, the average global temperature has risen by 0.8°C, and in recent times warming has really escalated, with 10 of the warmest years occurring since 2003, and 2014 being the warmest year on record. As our planet has become hotter, our oceans have soaked up the heat, making surface waters around 1°C warmer than they were 140 years ago. When water warms it expands: the sea level has risen 17cm over the last century. Already low-lying Pacific islands, such as the Polynesian island of Tuvalu, are struggling with frequent floods.

Meanwhile on land, glaciers and ice sheets are melting all over the world. Satellite measurements reveal that around 400 billion tonnes of glacier ice has

gone since 1994. In Tanzania the snowy summit of Mt Kilimanjaro is shrinking, and estimates suggest the glacier may disappear completely by 2030. One gruesome side effect is the number of dead bodies emerging from under the ice – from victims of mountaineering accidents in decades past, to recent plane-crash victims and, in South America, Inca children who were sacrificed 500 years ago.

Sea ice is also disappearing, with satellite observations showing that the area covered by Arctic sea ice is now shrinking by more

than 10 per cent per decade. In recent years, ships other than icebreakers have been able to glide through the fabled 'Northwest passage' with ease.

What's going on?

These measurements confirm that our planet is warming, but what's pushing temperatures up? During Earth's last major warming phase – the Paleocene-Eocene thermal maximum – carbon dioxide (CO₂) was the culprit. The splitting of the Pangaea supercontinent triggered that warming: as the land tore apart, volcanoes sprung up in the cracks, frequently erupting and belching out carbon dioxide.

Carbon dioxide is a greenhouse gas, as is water vapour, methane, nitrous oxide and ozone. These gases trap heat in the atmosphere and keep Earth warmer than it would be otherwise by absorbing heat coming from the Earth's surface. On some planets, like Venus, the greenhouse effect is massive. There the dense, carbon dioxide-rich atmosphere elevates surface temperatures up to a blistering 460°C. In contrast, planets without greenhouse gases, like Mercury, have no way of preventing heat escaping at night so they experience huge swings in temperature: ►



People on a flooded street in Tuvalu, where rising sea levels are already causing problems



< IN A NUTSHELL

Earth's climate is determined by the interaction of a bewildering number of different processes. But as our ability to measure and analyse the climate has improved, it's become increasingly clear that man-made carbon emissions are driving rising temperatures.



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Mercury goes from 400°C in the day to -170°C at night. Without greenhouse gases, Earth's average surface temperature would be below freezing but with vast variation between day and night.

The greenhouse effect has helped to keep Earth habitable, but the geological record reveals that even small changes in the proportions of greenhouse gases can have a big effect on climate. During the build-up to the Paleocene-Eocene thermal maximum, volcanoes are thought to have pumped around five billion

tonnes of CO₂ into the atmosphere, resulting in a warming of around 6°C over a period of 20,000 years, with seemingly no ill consequences. So why is everyone fretting about the recent 0.8°C rise in average global temperature?

The answer is the speed of change. In the years leading up to the Paleocene-Eocene thermal maximum, the planet warmed by around 0.025°C every century. Today Earth's thermostat is being cranked up by around 1°C

every century – that's 40 times faster. Meanwhile, measurements show that during the 21st century the burning of fossil fuels released around 35 billion tonnes of carbon dioxide into the atmosphere every year. Volcanoes, by contrast, release just 0.2 billion tonnes per year.

The link between burning fossil fuels and altering Earth's climate was predicted over a century ago. In 1896, Swedish scientist Svante Arrhenius realised that the Industrial

THE KEY EXPERIMENT

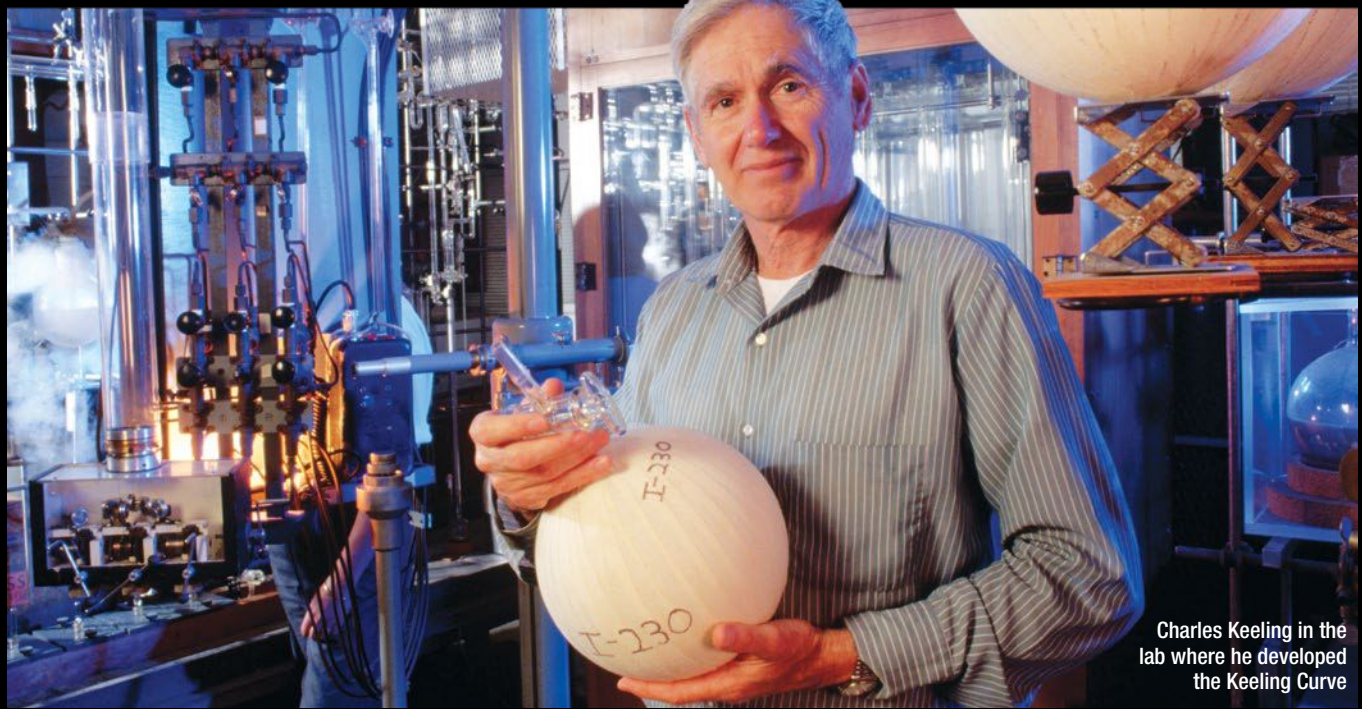
Nearly 60 years ago, US scientist Charles Keeling began monitoring atmospheric carbon levels in Hawaii, providing the foundation for our understanding of the problem today

In 1958, American chemist and oceanographer Charles Keeling began measuring atmospheric carbon dioxide concentrations at the remote Mauna Loa Observatory in Hawaii. He chose this location because it was far from the influence of smoky chimneys. By taking measurements high on the mountain, in the ocean breeze, he could ensure he was sampling average concentrations over a wide area. Initial measurements revealed a

strong seasonal cycle, with levels dipping every summer as plants absorbed carbon dioxide. But by 1961, his results showed that atmospheric CO₂ levels were rising steadily.

At first, his findings failed to attract much attention and he struggled to find funding. Luckily, he scraped together enough money to keep the experiment going. Today there are approximately 100 locations around the globe measuring atmospheric

carbon dioxide, but Keeling's long-running experiment provides the most convincing proof that human activities are increasing carbon dioxide levels. The Keeling Curve shows that average carbon dioxide concentration was 315 parts per million by volume (ppmv) in 1958, and that it peaked at 401ppmv in spring 2014 – higher than at any other point in the past 800,000 years.



Charles Keeling in the lab where he developed the Keeling Curve

Revolution was altering the chemistry of Earth's atmosphere and calculated how future emissions of carbon dioxide might alter the surface temperature on Earth. Arrhenius showed that burning coal would significantly increase the levels of carbon dioxide in the atmosphere, and estimated that a doubling of carbon dioxide would cause the temperature to rise by around 4°C – not far off the predictions made by modern climate models. Unlike today's scientists, though, Arrhenius concluded that the resultant warming would be a good thing, preventing the world from entering a new ice age and helping crops to grow to feed the rapidly increasing population.

Competing influences

Predicting global warming was fairly straightforward, but actually measuring it hasn't been quite as easy. That's because Earth's climate is influenced by many factors, including cloud, snow and ice cover, volcanic activity, ocean temperature, cosmic ray flux, distance from the Sun and sunspot cycles. Constant changes in all of these factors keep Earth's climate yo-yoing up and down.

For example, after Mount Pinatubo in the Philippines erupted in 1991, the dimming caused by the ash cloud resulted in global temperatures dropping by 0.4°C the following year. Meanwhile, the periodic warming in the western Pacific Ocean known as El Niño created havoc in 1997, bringing droughts to some parts of the world and extreme rainfall to others. Teasing out the impact of rising carbon dioxide from natural highs and lows of climate has proved to be a herculean task – but separate studies of global temperatures and CO₂ suggest there is a relationship between them.

Back in 1938 a British engineer and amateur climatologist called Guy Callendar gathered temperature measurements from 147 weather stations scattered around the globe, to try and work out whether the world was indeed warming. Although he had no data from the Arctic, Antarctic or over the oceans, he showed that the planet had warmed by around 0.3°C over the previous 500 years.

Callendar's calculations reignited the debate over whether CO₂ emissions could change Earth's climate. But his evidence failed to convince people, partly because global warming ground to a halt around 1940 and temperatures plateaued until the mid-1970s. Furthermore, most people believed the oceans would mop up most

CAST OF CHARACTERS

Five innovative scientists who helped us understand how Earth's climate works



JOSEPH FOURIER

The 'greenhouse effect', as it's now known, was discovered in 1824 by French physicist, Joseph Fourier. He calculated that the Earth should be colder than it actually was if it was only warmed by solar radiation.

SVANTE ARRHENIUS

In 1896 this Swedish scientist realised that the burning of coal would increase carbon dioxide and enhance the Earth's greenhouse effect. He estimated that a doubling of carbon dioxide would lead to a temperature rise of around 4°C – not far off the predictions made by modern climate models.



ROGER REVELLE (pictured) and HANS SUESS

Together, these US scientists overturned previous assumptions and showed that the oceans would not be able to absorb all of the additional carbon dioxide that burning fossil fuels was adding to Earth's atmosphere.

JAMES LOVELOCK

An independent British scientist who developed Gaia theory in the 1960s. This is the idea that Earth is a living system, and that life on Earth interacts with its surroundings to keep the planet habitable. Crucially, the theory has led to the prediction of 'tipping points' in Earth's climate.



JAMES HANSEN

Outspoken US scientist and climate activist who produced the first climate model prediction in 1988. In the same year, Hansen gave a testimony before the US Congress saying that it was "99 per cent certain that the warming trend was not a natural variation but was caused by a build-up of CO₂ and other artificial gases in the atmosphere."



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TIMELINE

A brief history of climate change and carbon emissions, from the steam engine to Al Gore



British ironmonger Thomas Newcomen invents a steam engine for pumping water out of tin and coal mines. This is the first step on the road to the Industrial Revolution.

1712

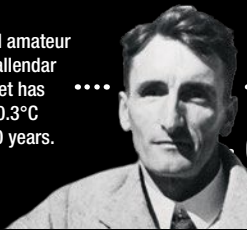
1886

German engineer Karl Benz is granted a patent for his first automobile. By 1888 his 'Motorwagens' are on sale to the public; the motoring era has begun.

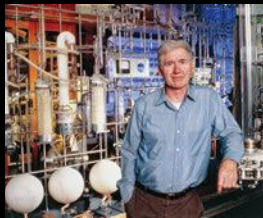


British engineer and amateur climatologist Guy Callendar shows that the planet has warmed by around 0.3°C over the previous 50 years.

1938



1961



American scientist Charles Keeling shows that levels of carbon dioxide in Earth's atmosphere are rising steadily.

2007

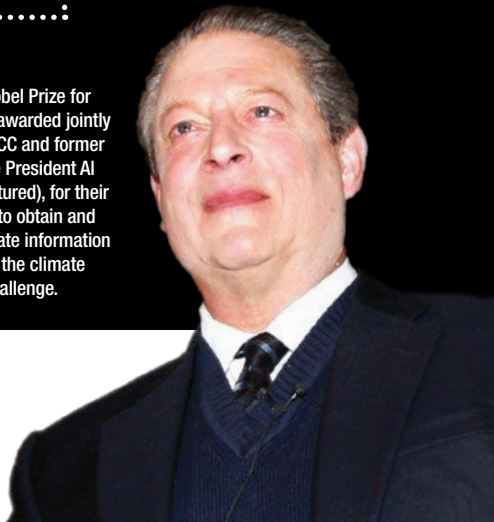
The IPCC's 4th Assessment Report states: "It is extremely likely (over 95 per cent) that human activities have exerted a substantial net warming influence on climate since 1750."



27th Session of the Intergovernmental on Climate Change

2007

The Nobel Prize for Peace is awarded jointly to the IPCC and former US Vice President Al Gore (pictured), for their efforts to obtain and disseminate information about the climate challenge.



of our excess carbon emissions.

This relaxed attitude to carbon emissions began to change in 1957, after US scientists Roger Revelle and Hans Suess managed to track the lifetime of carbon molecules in the ocean using radiocarbon dating. They showed that most carbon dioxide absorbed by the ocean evaporated back into the atmosphere after a few years.

Soon after, another US scientist, Charles Keeling, began measuring atmospheric CO₂ concentrations at the remote Mauna Loa Observatory in Hawaii in 1958. His initial measurements revealed a strong seasonal cycle, with carbon dioxide levels dipping every summer as plants absorbed the gas. But by 1961 he was also able to show that carbon dioxide levels were steadily rising.

Today, Keeling's long-running experiment provides the most convincing proof that human activities are increasing carbon dioxide levels. The Keeling Curve shows that in 1958, the average carbon dioxide concentration was 315 parts per million by volume (ppmv), and that it peaked at 401ppmv in spring 2014. Meanwhile, measurements of gas trapped in air bubbles in polar ice cores show that the average concentration of CO₂ during the last 10,000 years has been between 275 and 285ppmv, and it's only since the 19th century that levels began to rise sharply. This rise in atmospheric carbon dioxide is also reflected in the oceans, where the dissolving of carbon dioxide has increased acidity of surface waters by around a third since the start of the Industrial Revolution.

Unnatural change

But rising carbon dioxide alone didn't prove that the climate is changing, or that man was responsible – stronger evidence was required. By the mid-1970s global temperature began to rise again, after a 35-year hiatus. It's now believed that temperatures were suppressed during this period by the particles and soot released by burning fossil fuels, which reflected more solar radiation back into space.

During the 1980s there was still much scepticism that global warming was real, but there were some strong dissenting voices. In 1988 US climatologist James Hansen produced the first climate model prediction and, in the same year, gave a testimony before the United States Congress saying that it was "99 per cent

NEED TO KNOW

A handy glossary of terms for understanding climate change

1 GREENHOUSE GAS

A gas that traps heat in the atmosphere and keeps Earth warmer than it would otherwise be, by absorbing heat coming from the Earth's surface. Examples include methane, ozone and carbon dioxide.

.....

2 SUPERCONTINENT

A vast landmass made up of most of Earth's continental blocks. Supercontinents have formed at least seven times in Earth's history, the most recent being the supercontinent of Pangaea, which started to break up around 180 million years ago.

.....

3 RADIOCARBON DATING

A means of calculating the age of anything containing carbon by assessing the amount of radioactive decay, developed in the late 1940s.

.....

4 TIPPING POINT

An abrupt change in global climate from one stable state to another. Some tipping points are thought to be irreversible, comparable to tipping over a glass of wine: standing the glass back up won't return the wine back to the glass.

certain that the warming trend was not a natural variation but was caused by a build-up of carbon dioxide and other artificial gases in the atmosphere." Some politicians, including British Prime Minister Margaret Thatcher (who had a degree in chemistry), were convinced by the threat. In a speech to the United Nations in 1989, Thatcher said: "We are seeing a vast increase in the amount of carbon dioxide reaching the atmosphere. The result is that change in future is likely to be more fundamental and more widespread than anything we have known hitherto." At the same time, she called for a global treaty on climate change.

But many didn't trust these predictions, and insisted that the changes in climate could just be part



British economist Sir Nicholas Stern, speaking at a press conference on his report 'The Economics of Climate Change' in 2006. The report highlighted the importance of dealing with climate change sooner rather than later

of natural variability. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was formed to monitor and assess the evidence that the climate was changing. It took until 2007 for the IPCC to gather enough evidence to state conclusively that it was exceedingly unlikely – less than a 5 per cent chance – that natural variations were causing the changes we were seeing. In other words, after running thousands of climate simulations of the last century, scientists had found that today's climate only emerges naturally in five out of every hundred runs. In their 2007 Fourth Assessment Report, the IPCC stated: "It is extremely likely (over 95 per cent) that human activities have exerted a substantial net warming influence on climate since 1750."

Although not 100 per cent proven, the links between human activity and global warming are now compelling enough for economists to sit up and take notice. In 2006 British government economist Nicholas Stern published a review which concluded that, if left unchecked, the cost of climate change will be equivalent to losing at least 5 per cent of global gross domestic product each year. By contrast, his calculations suggest that curbing climate change would cost around 1 per cent of global gross domestic product. Not everyone agrees with Stern's figures, but most accept that climate change will be cheaper to tackle now rather than later.

Today, the major concern is how much climate change we're committed to. In the 1960s James Lovelock, a British scientist, developed Gaia theory – the idea that Earth is a living system, and that life on it interacts with its surroundings to keep the planet habitable. Gaia theory was greeted with scepticism initially, but it has gained credibility and today a number of scientists are worried about what happens when the Earth is pushed too far. Gaia theory suggests that climate change doesn't always happen smoothly and sudden leaps should be expected. We refer to these abrupt changes as 'tipping points'. For example, there is concern that if the Arctic is warmed enough it could lead to methane bubbling out of previously frozen soil. The consequences of such a huge pulse of greenhouse gas would likely occur very fast and perhaps lead to irreversible climate change.

Earth has seen extremes in climate before, from when ice stretched all the way to the equator, to when palm trees flourished in the Arctic. But never has its climate been pushed as fast as it is today. In 1957, Roger Revelle wrote: "Human beings are now carrying out a large scale geophysical experiment." Today the experiment continues, but we still have little idea of the outcome. ■

Kate Ravilious is a science writer with a degree in molecular biology.



PUZZLE PIT



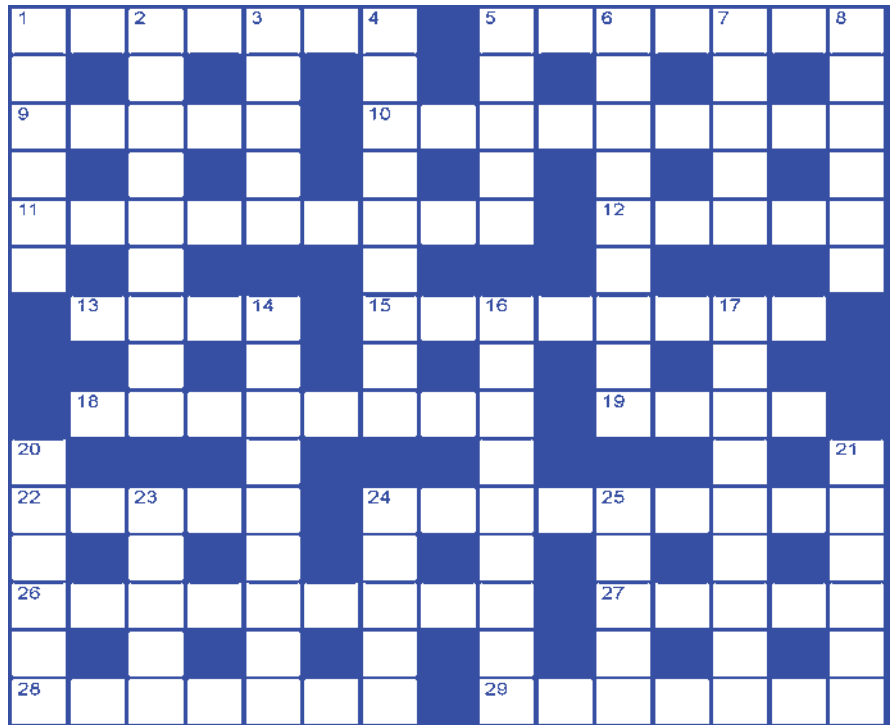
CROSSWORD NO. 30

ACROSS

- 1 Read aloud (7)
- 5 Accuses by legal process (7)
- 9 Housie or lotto? (5)
- 10 A puzzle like this one (9)
- 11 Without a will (9)
- 12 Do it to show pain? (5)
- 13 Bide one's time? (4)
- 15 Teach (8)
- 18 Hint; aspersion (8)
- 19 By ___ of : by force or means of? (4)
- 22 Muscular spasm (5)
- 24 Edifying; inspiring (9)
- 26 Banish; exclude by general consent (9)
- 27 Dormant, motionless or passive (5)
- 28 In an unambiguous and clear-cut manner? (7)
- 29 Singers Frank and Nancy (7)

DOWN

- 1 Common burrowing animal (6)
- 2 Curb, check or confine (9)
- 3 Blows a horn (5)
- 4 Spoken words for typing (9)
- 5 Perfume ingredient - "i.e. nor" changed? (5)
- 6 Terry Pratchett's fictional universe (9)
- 7 Circus entertainer (5)
- 8 Quick and unexpected (6)
- 14 Play your _____ : use that valuable piece of information to outwit one's opponents? (5,4)
- 16 Shrug one's ___ : refuse to take responsibility? (9)
- 17 One of the five land divisions of earth (9)
- 20 Shoal of fish, whales, etc. (6)
- 21 Queen of Crime ___ Christie (6)
- 23 Garret (5)
- 24 Wholeness (5)
- 25 Pretend or sham (5)



YOUR DETAILS

NAME: _____

AGE: _____

ADDRESS: _____

PINCODE: _____

TEL: _____ MOBILE: _____

SCHOOL/INSTITUTION/OCCUPATION: _____

EMAIL: _____



How to enter for the crossword: Post your entries to BBC Knowledge Editorial, Crossword No.30 Worldwide Media, The Times of India Bldg, 4th floor, Dr Dadabhai Navroji Road, Mumbai 400001 or email bbcknowledge@www.co.in by **10 February 2016**. Entrants must supply their name, address and phone number.

How it's done: The puzzle will be familiar to crossword enthusiasts already, although the British style may be unusual as crossword grids vary in appearance from

country to country. Novices should note that the idea is to fill the white squares with letters to make words determined by the sometimes cryptic clues to the right. The numbers after each clue tell you how many letters are in the answer. All spellings are UK. **Good luck!**

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

WINNERS FOR CROSSWORD NO. 29

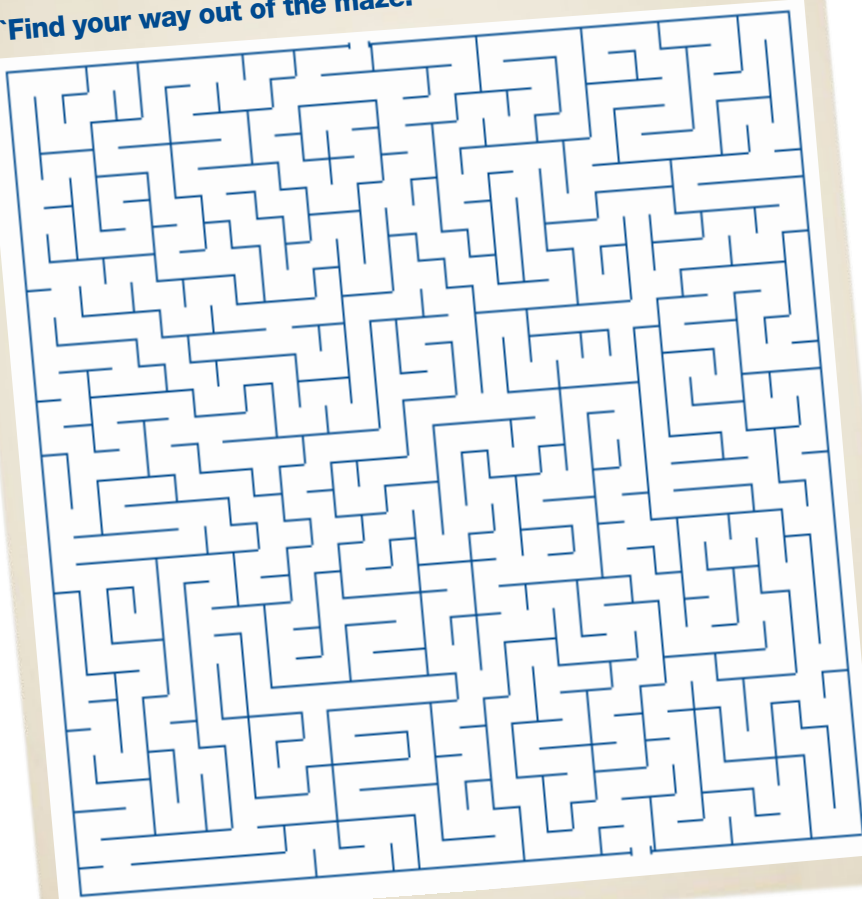
Cashmere Lashkari, New Delhi
 •
 Manu Nicholas Jacob, Bengaluru

SOLUTION OF CROSSWORD NO. 29





Find your way out of the maze.



Q1 PICTURE SEARCH

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

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Q3 SCRAMBLE

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

HMSAS

*		*			
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FSWIT

		*		*	
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CCELNH

					*
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AIKKUB

		*			
--	--	---	--	--	--

First we make our ____, then our ____ make us.
— Charles C. Noble (6,...,6) (same word twice)



Q2 HEAD AND TAIL

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

Descend	Go	<input type="text"/>
Depressed	<input type="text"/>	<input type="text"/>
Common alloy	<input type="text"/>	<input type="text"/>
Period of history	<input type="text"/>	<input type="text"/>
Condition of sorts	<input type="text"/>	<input type="text"/>
Mathematical value	<input type="text"/>	<input type="text"/>
Signal	<input type="text"/>	out

MINDGAMES

Test your knowledge with our Big Quiz set by James Lloyd

- 1** What creature recently set a new record as the world's fastest land animal?
- a) An Australian tiger beetle
 - b) A Southern Californian mite
 - c) A Northwest African cheetah

- 2** Scientists in China have come up with a strategy for winning which game?
- a) Twister
 - b) Scrabble
 - c) Rock-paper-scissors

- 3** Which of these isn't the title of a study recently published by students at the University of Leicester?
- a) How many lies could Pinocchio tell before it became lethal?
 - b) Does Winnie the Pooh have a B12 deficiency?
 - c) Was Snow White's apple genetically modified?

- 4** This bizarre creature has been named as one of the top 10 new species of 2014. What is it?
- a) A skeleton shrimp
 - b) A saltwater squidworm
 - c) A clawed seadragon



What an attractive little fella

- 5** What disease is the unfortunate lady suffering from in this 19th Century medical illustration?
- a) Typhus
 - b) Tuberculosis
 - c) Cholera



- 6** What's special about a giant poster recently unveiled at the University of Sheffield?
- a) It gives off a floral scent when it rains
 - b) It absorbs pollution
 - c) It converts vibrations from passing cars into electricity

- 7** Scientists have found that the health benefits of the Mediterranean diet could be down to a chemical reaction between what?
- a) Olive oil and leafy vegetables
 - b) Feta cheese and leafy vegetables
 - c) Olive oil and feta cheese

- 8** Complete the recent headline: 'Grave find may be Western Europe's earliest false _____'
- a) Eye
 - b) Tooth
 - c) Leg

- 9** Researchers have discovered Africa's longest-known terrestrial migration. Which animal makes the 500km (310-mile) journey?
- a) Wildebeest
 - b) Zebra
 - c) Gazelles

- 10** Space hopefuls in China have spent three months in an artificial biosphere eating what?
- a) Mealworms
 - b) Locusts
 - c) Spiders

- 11** Complete the headline: 'Cat people are _____ than dog people, new study shows'

- a) Smarter
- b) Louder
- c) Smellier

- 12** Conservationists have called on FIFA to help protect which animal, the inspiration for this year's World Cup mascot?
- a) Brazilian snake-necked turtle
 - b) Brazilian three-banded armadillo
 - c) Brazilian heart-tongued frog

- 13** Divers recently discovered the skeleton of a teenage girl in an underwater Mexican cave. Approximately how long ago did she live?
- a) 2,000 years
 - b) 7,000 years
 - c) 12,000 years



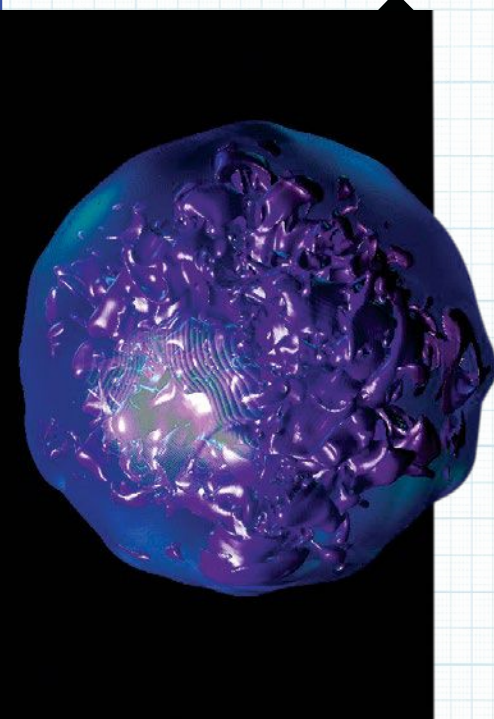
The owner of this skull probably didn't envisage this

- 14** A bizarre quacking sound heard in the Southern Ocean for 50 years has been revealed as what?
- The underwater callings of Antarctic minke whales
 - The sound of ice calving from glaciers
 - Sonar chirps from nearby submarines

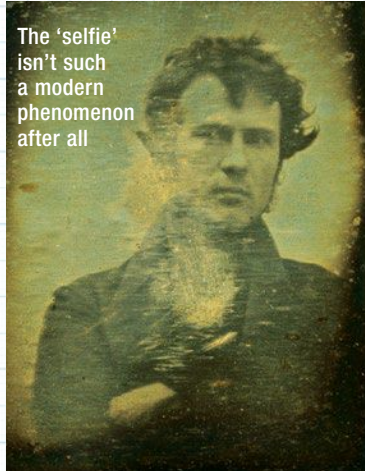
- 15** Scientists in the UK and Ireland have made graphene using which common household appliance?
- Kitchen blender
 - Vacuum cleaner
 - Electric iron

- 16** Between 2000 and 2013, the Comprehensive Nuclear-Test-Ban Treaty Organization detected how many explosions on Earth caused by asteroid impacts?
- 6
 - 16
 - 26

- 17** This image shows a computer simulation of what cosmic event?
- A supernova
 - The Big Bang
 - A gamma-ray burst



- 18** In what year was this photograph – the first ever ‘selfie’ – taken?
- 1779
 - 1839
 - 1899



The ‘selfie’ isn’t such a modern phenomenon after all

- 19** Complete the recent headline: “Men’s beard fashions guided by _____”
- Sunlight
 - Hormones
 - Evolution

- 20** What’s the name of the social Q&A app launched earlier this year by Twitter co-founder Biz Stone?
- Jelly
 - Cream
 - Custard

- 21** Scientists have discovered what could be the birth of a new moon around which planet?
- Mars
 - Saturn
 - Mercury

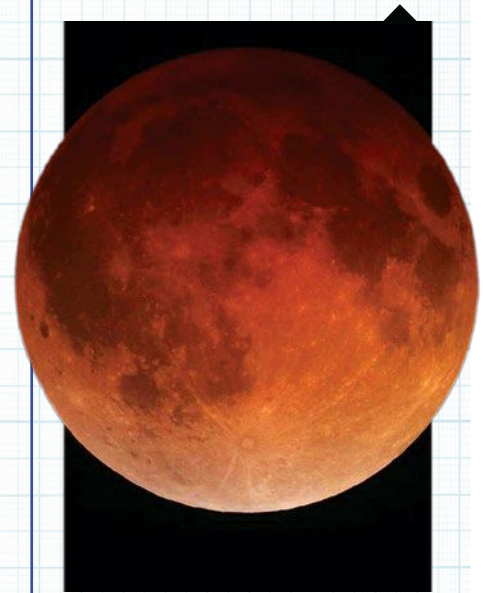
- 22** Scientists have found that blood inside an elaborately decorated gourd probably didn’t belong to which beheaded person?
- Marie Antoinette
 - Louis XVI
 - Charles I

- 23** What’s unusual about the cave-dwelling insect *Neotrogla*?
- The males eat their own faeces
 - The females have penis-like sex organs
 - The juveniles are bigger than the adults

- 24** Complete the recent headline: “_____ have structurally different brains”
- Monkeys
 - Lawyers
 - Artists

- 25** Which of these items wasn’t contained in a recent cargo shipment to the International Space Station?
- Clean underwear
 - Microbes from a T. rex fossil
 - A set of robotic legs

- 26** What caused this red Moon, photographed in California in April?
- Outgassing from the Moon’s craters
 - Air pollution
 - A total lunar eclipse



This sight is called a ‘blood Moon’ – but what causes it?

SOLUTIONS:

01 Picture Search: Carlton, Chart, Crane, Crayon, Dosa, Fan, Garlic, Hawk, Headphone, Jack, Jar, Koala, Pirate, Quarter, Spider, Volin.

02 Scramble: Smash/shams, swity, clenck, kabuki

Answer: First we make our **habits**, then our **habits** make us. — Charles C. Noble

03 Head & Tail: Go-Down-Cast-Iron-Age-Limit-Point-Out.

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

GADGETS

FOR EVERY BUDGET

Under ₹50,000

HP PAVILION 15

If you're serious about your gaming hobby, but don't want to pay through your nose to assemble a gaming PC, then the HP Pavilion 15 is the perfect laptop for you. The modest price belies a laptop that can deliver a solid gaming performance. The laptop packs in an NVIDIA GeForce GTX graphics card that makes short work of even high-end games. User immersion is taken care of with a vivid 1080p display resolution and high-end audio enabled by the B&O Play speakers.

Price: ₹ 45,490 | www8.hp.com



Under ₹25,000

ONEPLUS 2

The OnePlus 2 offers features more commonly associated with higher priced phones, like the iPhone and the Samsung Galaxy series. At a competitive price the OnePlus 2 offers a superior performance, powered by a Qualcomm Snapdragon Processor as well as 4GB of RAM, making multitasking incredibly efficient. Also, now you can pick up the OnePlus 2 without an invite just as easily.

Price: ₹ 24,999 | www.oneplus.net



MOTO 360

Motorola's biggest winner in the wearable segment returns in a new avatar with the 2nd generation Moto 360. The updated version of the popular smartwatch retains the popular round face and customisable strap options that made the original so popular. Also, the ability to access and use Android apps, an inbuilt fitness tracker, Wi-Fi connectivity and seamless music streaming make this a gadget that could render your phone obsolete

Price: ₹ 19,999 | www.motorola.in



Under ₹15,000

ASUS ZENFONE 2

For those who would rather not spend too much on a smartphone, the ASUS ZenFone 2 looks to be the brightest offering of the lot. Besides boasting technical specs for a much higher priced phone (4GB RAM, 13MP camera, Android Lollipop), the ZenFone 2 is also highly customisable, with a range of skins as well as accessory products to add to the consumer's experience.

Price: ₹ 14,999 | www.asus.com



RAZER DEATHSTALKER

If you want to add a splash of colour to your gaming experience, the Deathstalker Chroma edition is the keyboard for you. Apart from the mesmerising rainbow spectrum backlit keys, this keyboard also lets you assign custom functions to up to ten keys, an invaluable addition to any gaming keyboard. Add a customisable lighting option to the mix, and you've got yourself a winner.

Price: ₹ 6,595 | www.razerzone.com



Under ₹3,000

HESH 2

Skull Candy's Hesh 2 headphones offer great quality while remaining economically priced. When it comes to performance, the sound quality of the Hesh 2 holds its own thanks to its oversized cans that can handle a high volume output. With the large range of customisable options, as well as a detachable cable for convenience, the Hesh 2 is a convenient solution for those who desire quality audio without breaking the bank.

Price: ₹ 2799 | www.skullcandy.com

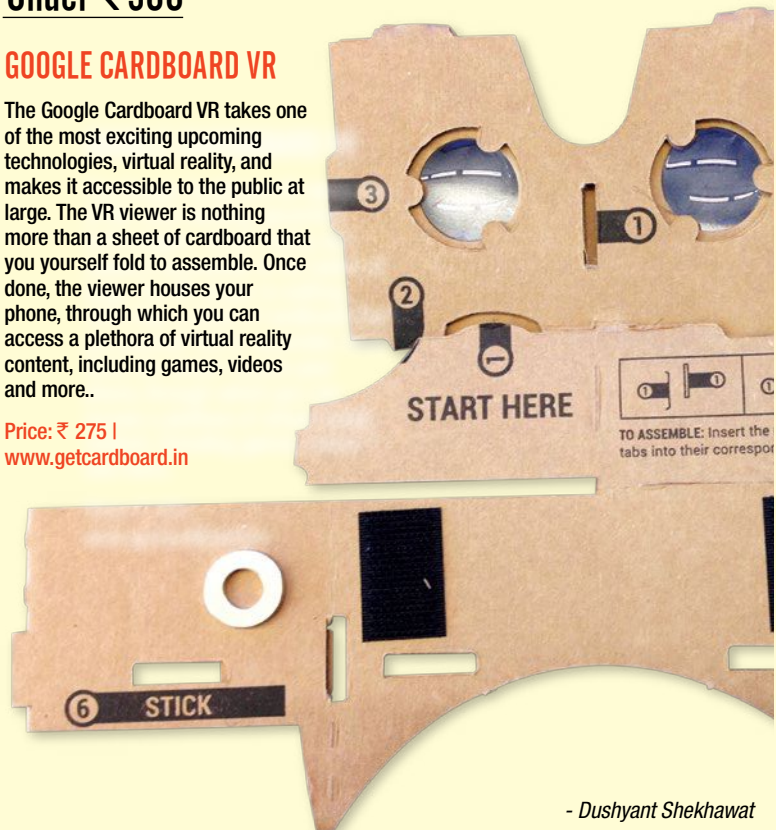


Under ₹500

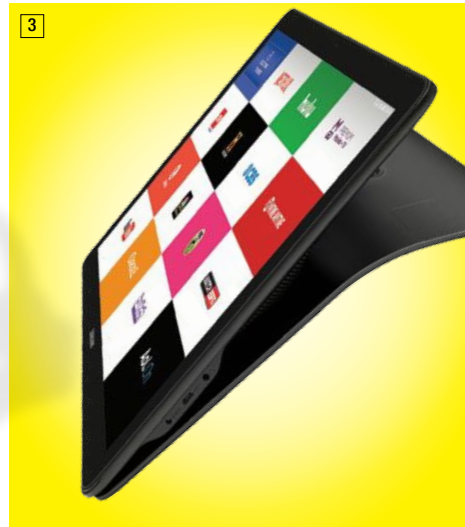
GOOGLE CARDBOARD VR

The Google Cardboard VR takes one of the most exciting upcoming technologies, virtual reality, and makes it accessible to the public at large. The VR viewer is nothing more than a sheet of cardboard that you yourself fold to assemble. Once done, the viewer houses your phone, through which you can access a plethora of virtual reality content, including games, videos and more..

Price: ₹ 275 | www.getcardboard.in



- Dushyant Shekhawat



APPLIANCES OF SCIENCE

1 BACK ON BLACKBERRY

No need to check the date... we really *are* shouting about a new BlackBerry in 2015! The PRIV is the embattled mobile-maker's first phone to run on Android, and its name reflects the emphasis placed on security. With an 18MP camera, 5.4-inch screen, 4K video camera and up to 2TB of storage, the full range of Android apps plus BlackBerry's slide-out keyboard, could a BlackBerry once more become 'the mobile for business'?

BlackBerry PRIV
blackberry.com

2 CAN YOU SEE MY AURA?

At time of writing, this latest virtual reality headset had smashed its Kickstarter target with three weeks to go, and the first units will ship in February. Unlike Google Cardboard or Samsung Gear, it's a self-contained unit and doesn't require you to strap your smartphone to your face; unlike Oculus Rift or HTC Vive, it's also completely wireless. It runs on Android, and comes complete with a Bluetooth controller.

AuraVisor
auravisor.com

3 ROOM FOR A VIEW?

As smartphones get larger displays, some have been predicting the death of the tablet. In response, Samsung's gone for the nuclear option, serving up this 18.4-inch, Full HD Android tablet with an octacore 1.6GHz chip, Wi-Fi and 32GB of storage. The specs are a tad underwhelming, but if we had a choice of watching *The Force Awakens* on a Note 3 or this, we know which we'd choose!

Samsung Galaxy View
samsung.com

4 SMUT-FREE SURFBOX

Torch is a router built with families in mind. As well as all the built-in porn-busting filters you'd expect – which are user-customisable – it can be easily set up via a smartphone app (iOS only for now) to impose 'time-outs' and 'bedtime', limiting the time young 'uns spend online, as well as providing parents with a complete browsing history that can't be erased or circumvented by 'private browsing'.

Torch router
mytorch.com

5 BOOKSHELF BLUETOOTH

Bluetooth speakers come in many shapes and sizes these days, but one form factor that's surprisingly rare in Bluetoothland is the traditional 'bookshelf' speaker. That's the gap in the market that Thonet & Vander hopes to plug with its Hoch BT airshifter, which boast a one-inch silk tweeter and 5.25-inch Aramid fibre woofer, and pump out 35W per channel. Don't expect lashings of bass, though.

Thonet & Vander Hoch BT
thonet-vander.com

6 FUTURE FELINE

Designed to combat loneliness in the elderly, Companion Pet Cat is the first in a new line of robot pets from Hasbro. Equipped with motion and light sensors, realistic fur and, ahem, VibraPurr technology, it responds to being petted by purring, but will go to sleep if left alone for more than a few minutes. Whether it'll also wake you up at 5am by jumping on your face is still TBC.

Companion Pet Cat
joyforall.com

EDU TALK

Seema Sapru, Principal of The Heritage School, Kolkata, talks to Moshita Prajapati on how cultivating independent thinking is an imperative for good education

We don't want students to be mechanical in their learning, we want students to be able to think



What is the school motto and how is it inculcated into everyday learning?

The school motto is *atma deep bhava*, which means 'be your own light'. It may sound clichéd that we want our students to be happy but truly we make a concerted effort to make their learning enjoyable. We encourage students to think independently, ask questions, be curious about the world and think logically. Students are encouraged to participate in various extra-curricular activities both within and outside of school; this makes them confident and helps them accept their shortcomings.

How does your approach to education promote all-round development of students?

Students below class 5 do not appear for exams. In all grades up to 8, students are encouraged to read and participate in open discussions to encourage their curiosity for learning. From class 9 onwards, we start

prepping our students with the exams that they will have to take in the future. Out of 230 students who sat for the ISC examination, everyone did extremely well. Furthermore, our students aren't just studying all the time. They participate in debates, quizzes, sports competitions and many more activities. Mohit Podar and Sayantan Bhattacharya won the Frank Anthony Memorial Debate competition, one of the most prestigious debating events in the country. We have also won the Bournvita quiz contest in the city and actively participate in theatre, dance and sporting events.

Is there a need to revamp the education/method of learning in the country?

As teachers will tell you, listening and speaking before learning to read and write are essential parts of a five-to six-year-old student's progress. Unfortunately in India, all parents are keen that their

child's school exercise book is filled up. We don't want students to be mechanical in their learning, we want them to be able to think and for that a paradigm shift in teaching/learning is required. Thanks to the ready availability of information through the Internet, computer and books, the study material is available everywhere. It becomes the responsibility of the teacher to make it interesting and ensure that there is meaningful learning in class. In fact, when a teacher is teaching, the class becomes a stage and one has to act, dance, crack jokes at times to break the monotony and also hold the attention of the students.

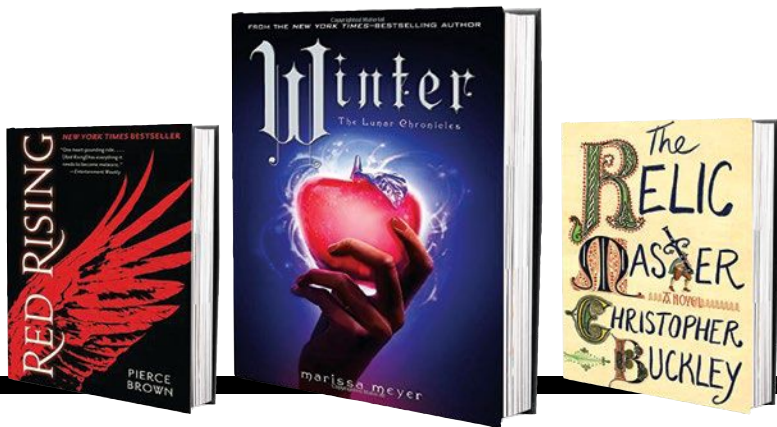
What according to you is good education?

According to me, education means continuing to learn. Mutual learning among students, teachers and parents through collaborative family-school relationship is my idea of good education.

INSIDE THE PAGES

ON THE SHELF

BOOKS TO READ



THE RID RISING TRILOGY BY PIERCE BROWN

Set in the dystopian future, 700 years have passed since man has colonised most of the planets in the Milkyway Galaxy. But Mars is still uncolonised and Darrow, a Red is working beneath the planet's unforgiving surface to extract precious minerals that might make the planet habitable. Or so it seems. During his work, he discovers a group of people termed Gold, who have been living on Mars. Betrayed by the privilege classes, Darrow infiltrates the Gold class with an intention to take down the oppressors from behind. How does the battle end? Find out when the last book in the trilogy releases this year.

LUNAR CHRONICLES BY MARISSA MEYER

Fantasy fiction meets fairy tale magic in this enchanting book

series. The author gives a modern spin to the stories of Cinderella, Little Red Riding Hood, Rapunzel, and Snow White. Set in the futuristic world where humans, cyborgs and android co-exist. Cinder, Scarlet, Fairest, and Winter come together and join forces to save the magical kingdom.

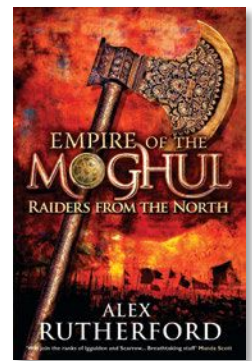
THE RELIC MASTER BY CHRISTOPHER BUCKLEY

Dismas is a sixteenth century relic hunter who procures religious relics for wealthy and influential individual. When the greed of one of his clients, Albrecht of Mainz, increases for more rarer relics, Dismas conspires with his artist friend Durer to create the Shroud of Chambery, the burial cloth of Jesus Christ. What follows is a hilarious tale of comic adventure, historical details and witty repartee, make this book a delightful read.

Question of the Month

A book I would get my parents to read.

My parents are both history buffs. On all our holidays together, we visit the palaces and monuments in the cities we go to. Because of this, I would recommend the book *Raiders*



from the North by Alex Rutherford. It is the first book in the Empire of the Moghul series, and tells us how Babur came to India to found the Mughal dynasty. The book is written in a very exciting manner and is also full of historical details, which I think my parents will be interested to learn about.

- Vignesh Rajan, Bangalore

Reader review

The Girl in the Spider's Web

By David Lagercrantz

Lisbeth Salander is back! This fourth book in the Millenium series is the first after the death of the original author Stieg Larsson. The book has new characters, twists and a complex plot, but the writing style is quite similar to the original. Lisbeth is still the most intelligent and interesting character in the book, and I am looking forward to the next in the series..

- Dikshita Rupani, Mumbai

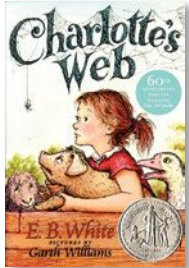


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Top 5 – Venture into the world where the plot unfurls through the eyes of animals

CHARLOTTE'S WEB

BY E B WHITE

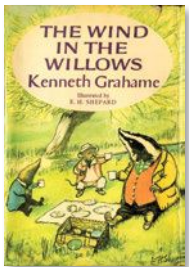


This is a heart-wrenching story of an unlikely friendship between a piglet named Wilbur and Charlotte at a farm. Snubbed by the other farm animals, Charlotte befriends the emotionally wrought Wilbur. When Wilbur overhears the farmer's plan of

slaughtering him, he breaks down. Charlotte decides to save her friend by weaving messages praising Wilbur in the barn in the hopes that it persuades the farmer to spare Wilbur's life. Does she succeed?

THE WIND IN THE WILLOWS

KENNETH GRAHAME

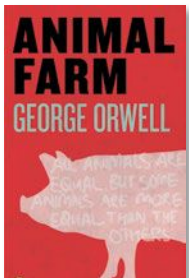


Set in the Thames Valley, *The Wind In The Willows* is a celebrated tale of animal cunning and human camaraderie. Four anthropomorphised animals; Mole, Ratty, Badger and Toad, friends who share an eccentric archetypal friendship and unwillingly participate in misadventures in

gypsy caravans, stolen sports cars and in the woods near their houses. Spread across the seasons, the story delights and brings alive the imagination of the author and captures the hearts of its readers.

ANIMAL FARM

GEORGE ORVILLE



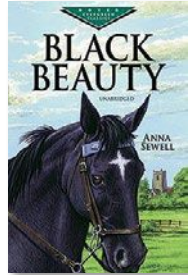
An allegorical and dystopian novel, it satirizes and addresses the socialist and communist philosophy of Stalin in the Soviet Union. Set in Manor Farm in England, the farm animals tired of their servitude towards the humans, revolt and establish their own

society with a chosen leader and seven animal commandants to create a society where "all animals are equal". But in a twist of fate, the animals are betrayed in their servitude towards their animal leader Napoleon, who now acts like a human and consorts with them. With no way to distinguish between the pigs and humans, the animals resign themselves to

abridged animal commandant, "All animals are equal, but some animals are more equal than others".

BLACK BEAUTY

ANNA SEWELL

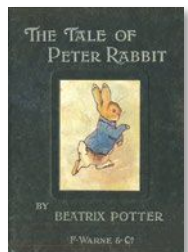


Narrated in first person, this autobiographical story follows the long and varied life of the horse named Black Beauty. First he talks about his carefree days as a young foal with his mum on the farm he was born on, to his pride and joy in being employed to pull the elegant horse

carriage of a gentleman. His life then takes a turn as a cruel hansom cab driver in London whips and painfully overworks him to earn his daily wage. He does get his happy ending, a life of peaceful retirement in the farm where he was first born.

TALES OF PETER RABBIT

BY BEATRIX POTTER



"Now my dears," said old Mrs. Rabbit one morning, "You may go into the fields or down the lane, but don't go into Mr. McGregor's garden: your Father had an accident there; he was put in a pie by Mrs. McGregor." Now, Peter, her youngest of five, doesn't heed to her

warning and does visit Mr McGregor's garden, where he is caught in a jam and spotted by the farmer himself! The adventurous tales of Peter Rabbit are delightful, full of sass and of course fights with siblings, where the goody ones earn bread, milk and blackberries for supper and the naughty one is fed medicine and sent to bed early.

DID HE SAY THAT!?
"The road to hell is paved with adverbs"

- Stephen King

Top 10 books of 2015



Go Set a Watchman
By Harper Lee
HarperCollins Publishers



Grey: Fifty Shades of Grey as Told By Christian
By E L James
Knopf Doubleday Publishing Group



Secret Garden: An Inky Treasure Hunt and Colouring Book
By Johanna Basford
Laurence King Publishing



THE GIRL ON THE TRAIN
By Paula Hawkins
Penguin Publishing Group



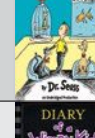
All The Light We Cannot See
By Anthony Doerr
Scribner



Enchanted Forest: An Inky Quest 7 Colouring Book
By Johanna Basford
Laurence King Publishing



Harry Potter and the Sorcerer's Stone: The Illustrated Edition
By J K Rowling
Scholastic Inc.



What Pet Should I Get
By Dr Seuss
Random House Children's Books



Old School (Diary of A Wimpy Kid Series #10)
By Jeff Kinney
Amulet Books

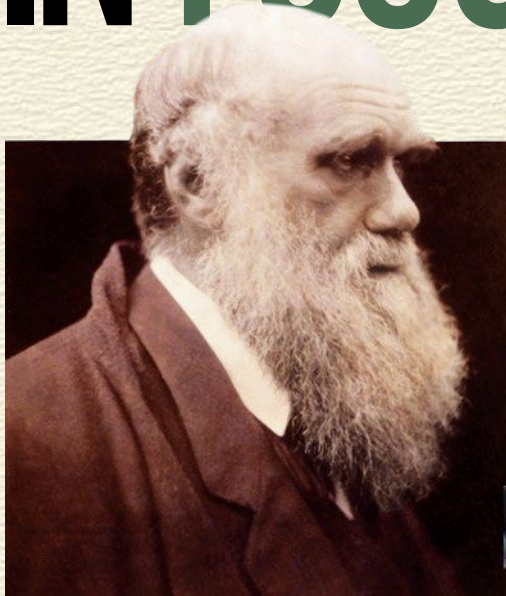


The Life – Changing Magic of Tidying Up: The Japanese Art of Decluttering and Organizing
By Marie Kondo
Potter/TenSpeed/Harmony

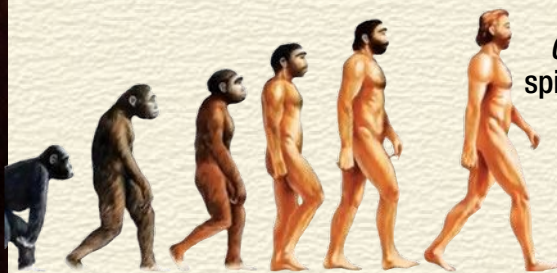
- List by barnesandnoble.com

- Compiled by Moshita Prajapati

IN FOCUS



“I am not apt to follow blindly the lead of other men”



- In *The Life & Letters of Charles Darwin*, we see the spirit of independent thinking that led Charles Darwin to formulate his theory of evolution, challenging the orthodox notion of divine creation

LEGACY

Charles Darwin (12 February 1809 – 19 April 1882), an English naturalist and geologist, was the first person to propose the theory of natural selection. Challenging the notion of divine creation, he said that species evolved into their present forms through a process of adaptation to changing environments. His work laid the foundation for the study of evolutionary biology, and contributed to the retreat of religious dogma from scientific discourse.

Darwin arrived at his conclusions after an epic, five-year long circumnavigation of the globe while serving as the on-board naturalist of the *HMS Beagle*. The notes on the flora and fauna he encountered during the voyage became the basis of his theory of evolution.

Along with fellow naturalist Alfred Russel

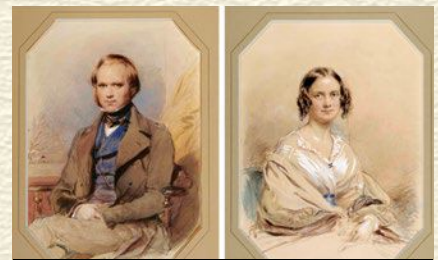
Wallace, he jointly published a paper in 1858 which outlined the principles governing the field of evolutionary biology. In the following year, Darwin published *On the Origin of Species (OOTS)*, a seminal work that presented his revolutionary theories with compelling evidence.

Initially, Darwin's discoveries were met with scepticism. However, he continued to publish material supporting his finds, including *The Descent of Man* and *The Expression of Emotion in Man and Animals*, both which are regarded with the same reverence as *OOTS* today.

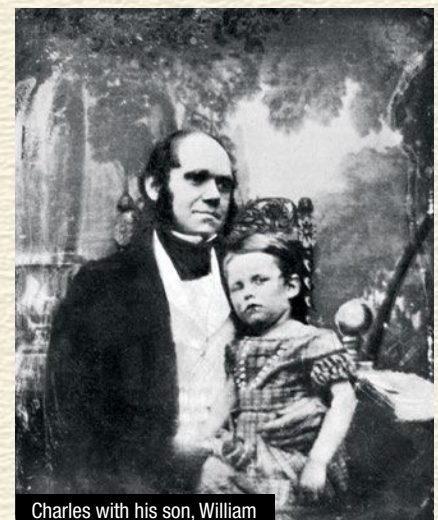
By the time of his death, nearly three decades after he had upended science's long-standing deferent status to religion, Darwin was well respected throughout the globe as a leading expert in his field.

DID YOU KNOW

- Unorthodox thinking ran in the family – Charles' grandfather Erasmus Darwin wrote *Zoonomia*, a scientific work published in 1794, that outlined principles very similar to Darwin's natural selection theory.
- In modern times, The Darwin Awards are a humorous project that commemorates individuals who die in the most outlandish manner, protecting our gene pool from their stupidity by sacrificing their lives.
- After his death, Darwin's peers petitioned that he be accorded the honour of burial in Westminster Abbey. His final resting place is close to Isaac Newton and John Herschel.
- Darwin's father never thought he would amount to much. He once wrote to Charles in a letter, "You care for nothing but shooting, dogs and rat-catching, and you will be a disgrace to yourself and all your family."
- The Bank of England felicitates Darwin's contribution to science by printing his face on the ten pound note.



Charles and Emma Darwin on their wedding day



Charles with his son, William

- Dushyant Shekhawat



#KnowledgeTurns5

All Things 5 was the flavour of the month on BBC Knowledge's social media channels. We took to Facebook, Twitter and Instagram to discover the significance of the number five.

On Twitter, the #KnowledgeTurns5 contest was a daylong quiz that saw 1800 people participate online. Meanwhile, on Facebook and Instagram, content that contained interesting trivia linked to the number five was put out weekly, reaching around 57,600 people. That's a huge number of friends to have on just your fifth birthday!



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Knowledge



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