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Well, sort of...

BALL LIGHTNING

Does weather's weirdest trick even exist?

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Were they history's first sailors?

IN THE ZONE
PERTH, AUSTRALIA

THE ZONE ABOVE:
THE INDO-PACIFIC ERA IN SPACE

8 OCTOBER 2018

OPTUS STADIUM, BURSWOOD

Perth USAsia Centre in collaboration with The University of Western Australia will deliver a thought provoking conference on **Monday 8 October at Perth's stunning Optus Stadium,** discussing space exploration and the role of Australia along with their strategic partners, the Indo-Pacific region. Our capabilities in this area continue to evolve, as we build on the recent establishment of the Australian Space Agency.

The conference program will cover topics across three key themes:
security, earth observation and space environment.

SPEAKERS FROM AROUND THE GLOBE WILL UNITE FOR THE ONE-DAY EVENT, INCLUDING:

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Governor of Western Australia

PAMELA A. MELROY
Director, Space Technology and Policy at Nova Systems; former NASA Astronaut and Space Shuttle Commander

PROFESSOR L. GORDON FLAKE
CEO, Perth USAsia Centre

DR MEGAN CLARK AC
Head, Australian Space Agency

ENRICO PALERMO
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THE UNIVERSITY OF WESTERN AUSTRALIA

SCIENCE ILLUSTRATED

Issue #62 (4th October 2018)

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THE SCIENCE ILLUSTRATED CREDO We share with our readers a fascination with science, technology, nature, culture and archaeology, and believe that through education about our past, present and future, we can make the world a better place.

Cover Image: NASA/Kim Shiflett

Per Ingens Flamma Ad Astra

Yeah okay that's pretty terrible Latin, but it's meant to be a play on the old air force motto "per ardua ad astra", or "through adversity to the stars". In this case, it's through a huge flame. Meh, the Romans didn't have rockets, I did my best. Please send complaints to the email below - but only in Latin.

Anyway, the point here is that the age of the big lifters may be dawning anew. Space-X tested its Falcon Heavy this year, a test that ended with a truly spectacular synchronised dual-booster landing, and that's the *little* one in the new generation. Our feature starting on page 24 details the lineup, but of particular interest is NASA's Space Launch System (below, left).

Following the cancellation of the Constellation program and the Ares I and Ares V Mars-shot rockets, NASA had to come up with something cheaper. The SLS is derived from Space Shuttle tech but the important aspect is that it can be upgraded over time. The first mission might not break too many records, but NASA hopes this rocket will still eventually take someone to Mars.

The SLS will definitely work, no doubt about that, but it's not exactly a mould-breaking design. Combining the power of the Saturn V moon rocket with the detachable side-boosters of the Space Transport System (better known to us as the Space Shuttle), it still carries a cone-shaped crew module that only holds one more person than Apollo. That's four instead of three, for those keeping count.

Elsewhere, Space-X's ambitious Big Falcon Rocket is still in the design stage, and it's truly a quantum leap ahead of anything we've done before. Can a single company build a rocket bigger than anything NASA - or Russia, or any government - has even done?

Well, why not exactly? That's what space travel is all about; doing things that have never been done. When NASA built the Saturn V, nobody had ever constructed a rocket powerful enough to lift humans out of low Earth orbit and send them on to the Moon.

And yet all it took was thousands of people working on hundreds of different problems simultaneously and spending about 2% of the USA's GDP of the time. Easy!

Okay, I'm being sarcastic. Still, one thing about the Apollo program is how little, shall we say, supporting technology existed for the engineers of the 1960s. No personal computers, no supercomputers to run simulations, not even mobile phones to quickly call someone to check a detail or setting.

Today, our knowledge of materials and our ability to quickly prototype new parts - without even having to resort to 3D printing which is a whole other thing - means building something like the Saturn V is... not exactly easier, but certainly more manageable.

The bottom line is: we need big rockets, at least for the forseeable future, because there seems to be no other realistic alternative to getting out of Earth's gravity well.

Even if we launch small spacecraft from under aeroplanes, or build reusable single-stage-to-orbit launchers, that still only gets us a few hundred kilometres from the surface.

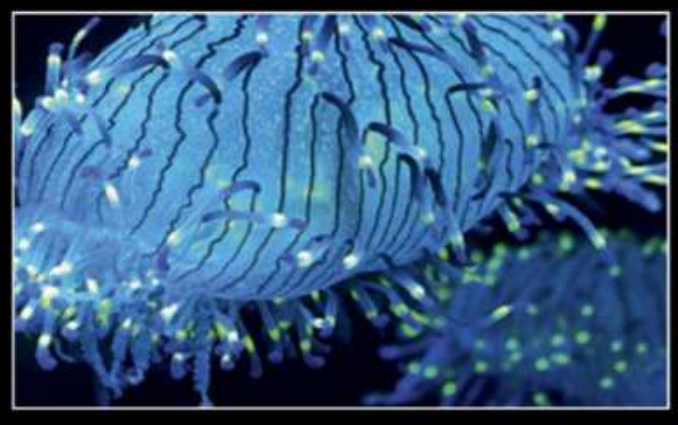
To go on to the Moon, let alone Mars, needs a big shove. And until we find the time, money and willingness to build and test more exotic tech like ion drives, a big rocket remains the best tool for the job.

Plus they look awesome when they take off. Which is a plus.

Anthony Fordham
afordham@nextmedia.com.au

THINGS WE LEARNED IN THIS ISSUE

+ There are many ways to **MAKE YOURSELF GLOW** in the Animal Kingdom, some weirder than others.
+ We might see **BIPLANES RETURN** to our skies, if we want to travel at hypersonic speeds.
+ If you've ever seen **BALL LIGHTNING** then at last science admits you weren't hallucinating!
+ The quest for **ETERNAL LIFE** is still ongoing, but would you take immortality if it was offered?
+ New medical devices literally **SMELL YOU FOR DISEASE** and could save your life.



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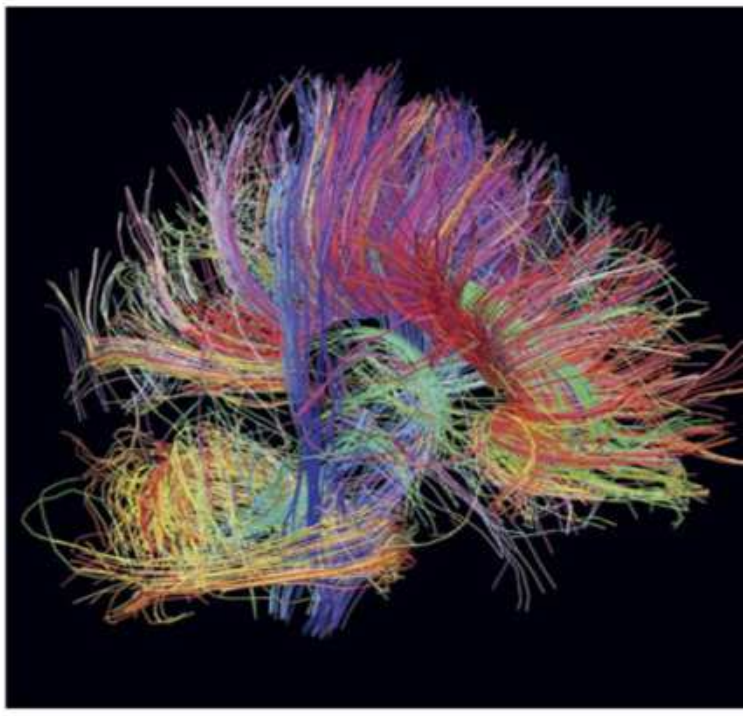


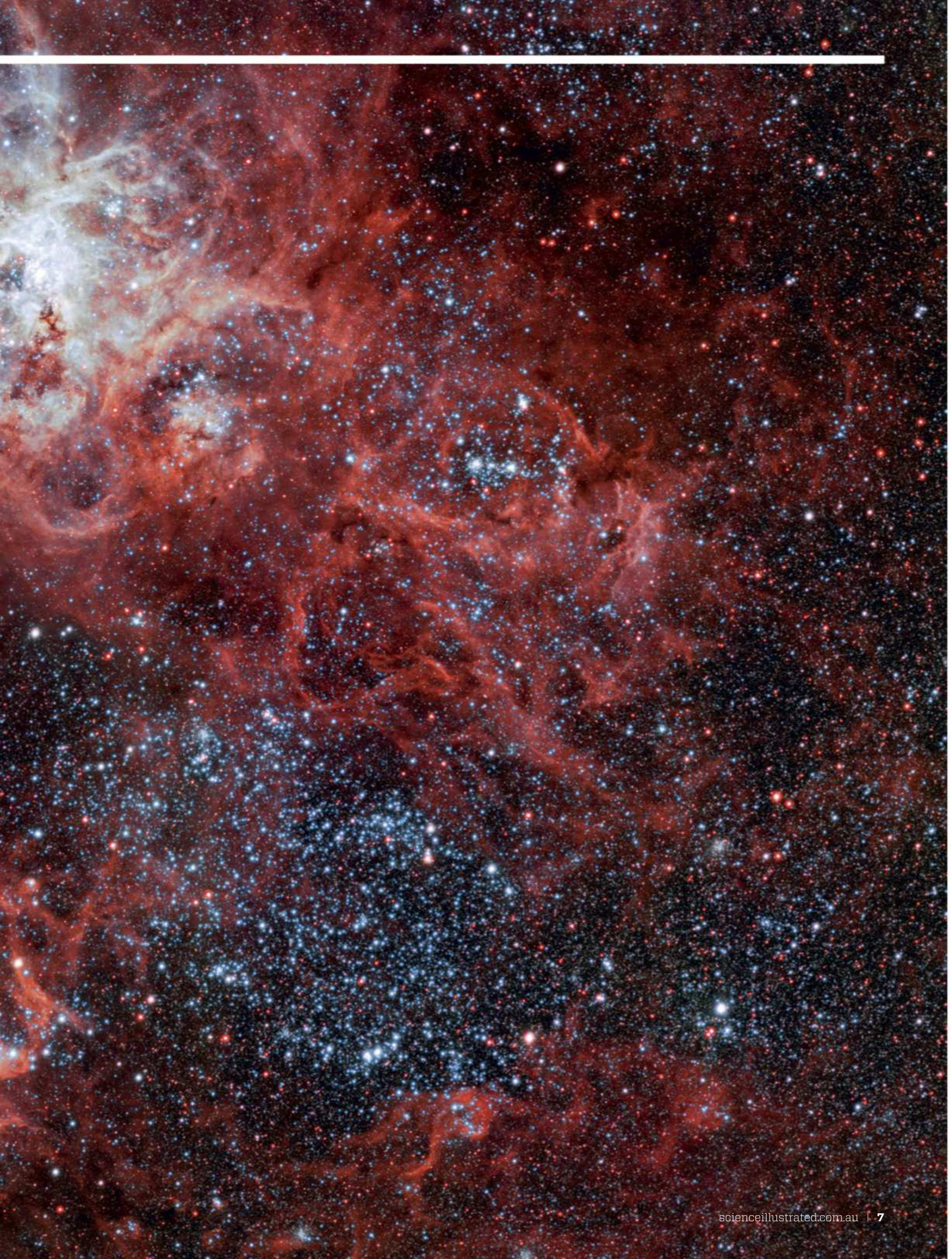
REGULARS AND OTHER FEATURES

Suns are born in the sky's brightest star factory

Thousands of new stars form in a haze of gas and dust known as the Tarantula Nebula. Thanks to the Paranal observatory in Chile, astronomers have taken the sharpest picture ever of the nebula. Tarantula is 600 light years wide and the brightest star formation region seen from Earth. High-energy radiation from the new-born stars forces hydrogen atoms in the gases to give off electrons, giving the gas a reddish glow. The light from the nebula shows the conditions required for a star to form.

Photo // European Southern Observatory

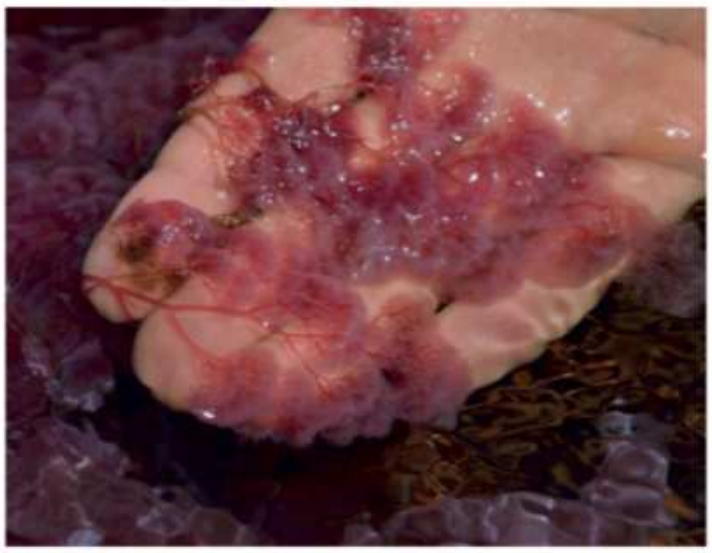
ESO



Rare plant paints river bed blood red

The Columbian Caño Cristales river is also known as the River of Five Colours. Green plants, black rocks, yellow sand, and the reflection of the sky cause the permanent hues, whereas the *Macarenia clavigeras* river plant's red colours dominate the 100-km-long river from July to December. The plant requires special conditions to bloom, such as both a dry and a wet period, and subsequently a specific water level. So, the phenomenon is only observed in Caño Cristales.

Photo // Olivier Grunewald



OLIVIER GRUNEWALD

Science Update

THE LATEST FINDINGS AND DISCOVERIES

Three gene 'flaws' made our brains grow

Seven billion brain cells mark your brain from that of a gorilla, thanks to three genes that have changed since evolution separated humans and apes.

EVOLUTION In 14 million years, the human brain has grown from about 0.5 kg in our earliest ancestors to 1.4 kg, probably thanks to three newly-identified genes.

Californian scientists spotted the genes, when they studied how many nerve cells a macaque produces in its brain. They cultivated the animals' brain tissue in the lab, particularly focusing on NOTCH genes, which influence the development of stem cells in embryos. The scientists discovered that humans have three active NOTCH genes on chromosome 1, which do not exist in macaques nor in our closest relatives, chimps and gorillas, i.e. the three genes are unique for humans. So, scientists can reconstruct our evolutionary history.

The first gene emerged as a partial copy of a gene on chromosome 1 some 14 million years ago, before humans parted from the other apes. 11 million years later, the gene was repaired, coinciding with the time when the human brain started to grow. Later, the gene was copied two more times. Other scientists have revealed that the three genes code for a protein that causes the stem cells of the brain to divide in four instead of two nerve cells. The result is that we produce many more nerve cells than other primates.

First conference for Australia's new Space Agency

SPACE RACE Australia finally got a proper space agency in July 2018, and now a conference in Western Australia will start to explore how the agency will play a role in the future.

In partnership with the University of Western Australia and the international policy think-tank Perth USAsia, the In The Zone conference will discuss Australia's role in space. The focus will especially be on our regional partners in the Indo-Pacfic and how we can work together in space.

Topics of discussion will include improving the Earth observation systems and platforms available in our region (that means satellites) as well as "preserving the space environment". This is about space junk and how Australia can play a role in cleaning up near-Earth orbit for future space missions.

After we parted from other apes, humans developed a larger brain. Homo erectus is one of our ancestors.

The brain grew by coincidence

One of our chromosomes has undergone three changes that have provided us with a larger brain than almost any other animal - especially apes.

MUTATION RESULTS IN AN EXTRA GENE

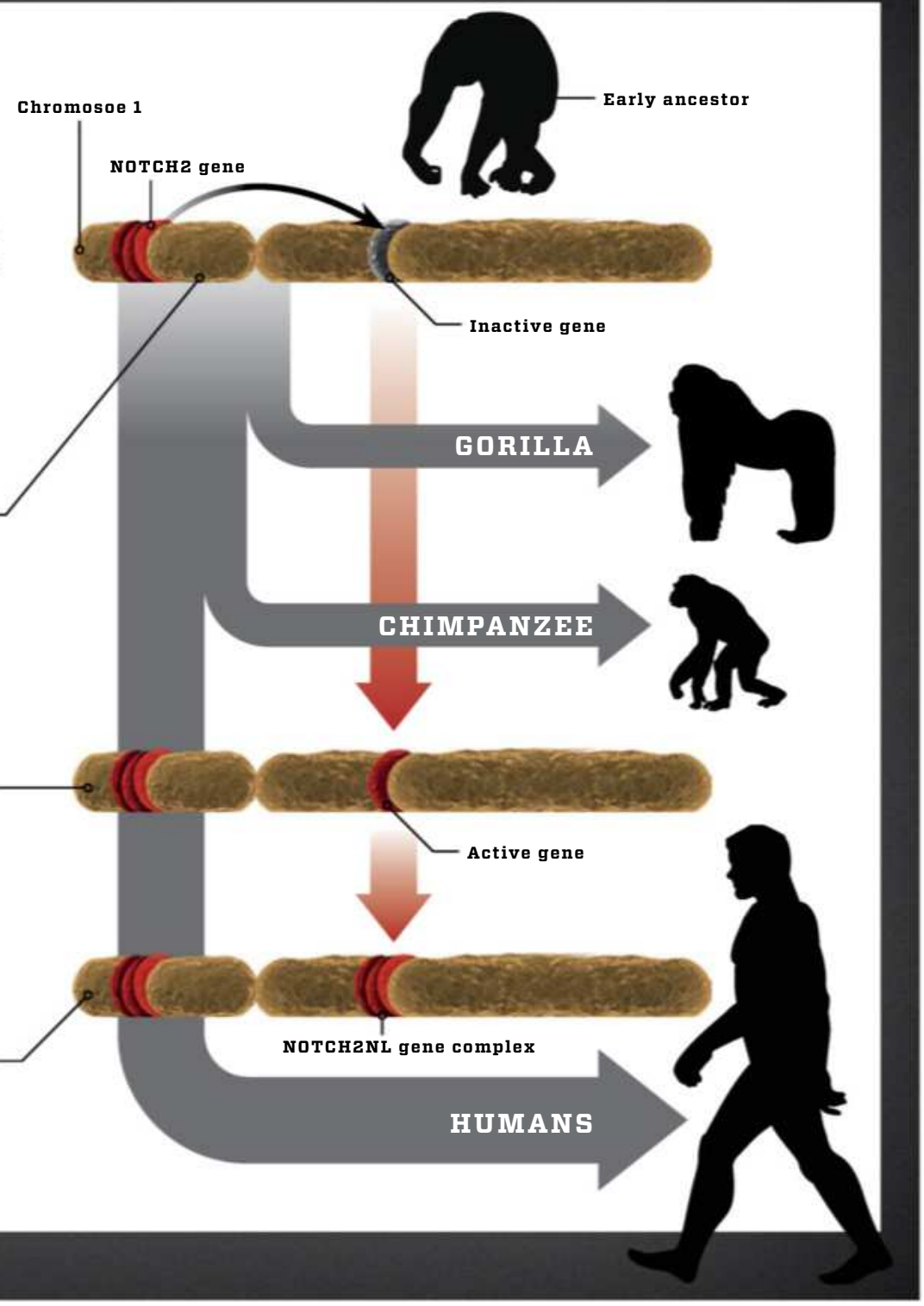
1 In the genetic material of one of our early ancestors, the NOTCH2 gene was copied to another location on chromosome 1. The copy was not complete, so it had no function.

REPAIR ACTIVATES THE GENE

2 After we parted from the other apes, the new gene was repaired and suddenly had an important function.

THE GENE HAS COPIED ITSELF UP UNTIL NOW

3 Over the past 3-4 million years, the gene has been copied, leaving three almost identical genes in the NOTCH2NL gene complex, which only exists in humans.



SHUTTERSTOCK

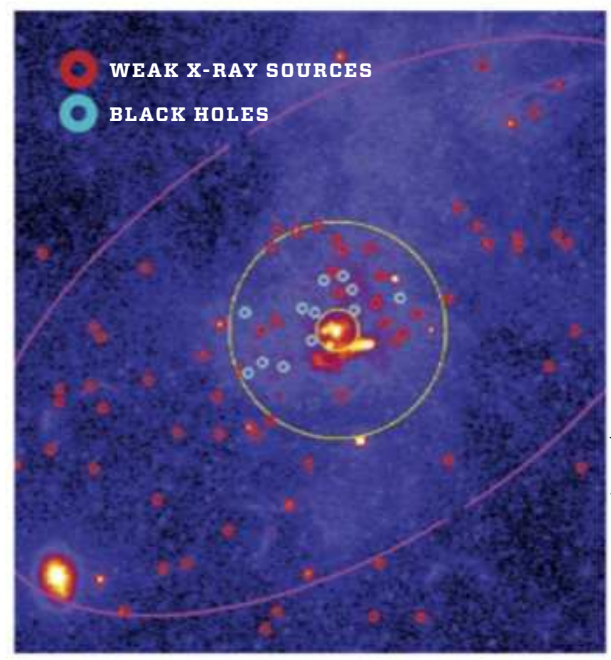
The centre of the Milky Way is full of holes

ASTRONOMY The large black hole at the centre of our galaxy is not the only one. A new study indicates that an entire swarm of small black holes are orbiting it, swallowing matter from the stars around them.

Astronomers from the Columbia University in New York, USA, have taken a closer look at more than 10 years of recordings from the Chandra space telescope. Twelve sources stand out. From those, the X-radiation is so powerful that according to theories, it can only come from the extremely hot matter orbiting a black hole. The 12 holes were produced by very large stars, which burned out and collapsed under their own weight. Only stars that weigh 25+ times more than the Sun can end up as black holes.

The newly-discovered black holes are within 3.3 light years of the centre of the Milky Way. The discovery confirms the most recent theories about the development of galaxies, according to which the Milky Way must be ripe with stars that have become black holes. Over time, many of them will move towards the centre. According to theory, there ought to be thousands orbiting close to the superheavy black hole at the centre of the Milky Way.

The huge black hole weighs millions of times more than the Sun and was probably born early in the history of the galaxy. Since then, it has grown bigger by swallowing matter. Astronomers' new discoveries are known as stellar black holes due to their origins. They are very small compared to the huge one at the centre of our galaxy.



CHARLES J. HAILEY/COLUMBIA UNIVERSITY

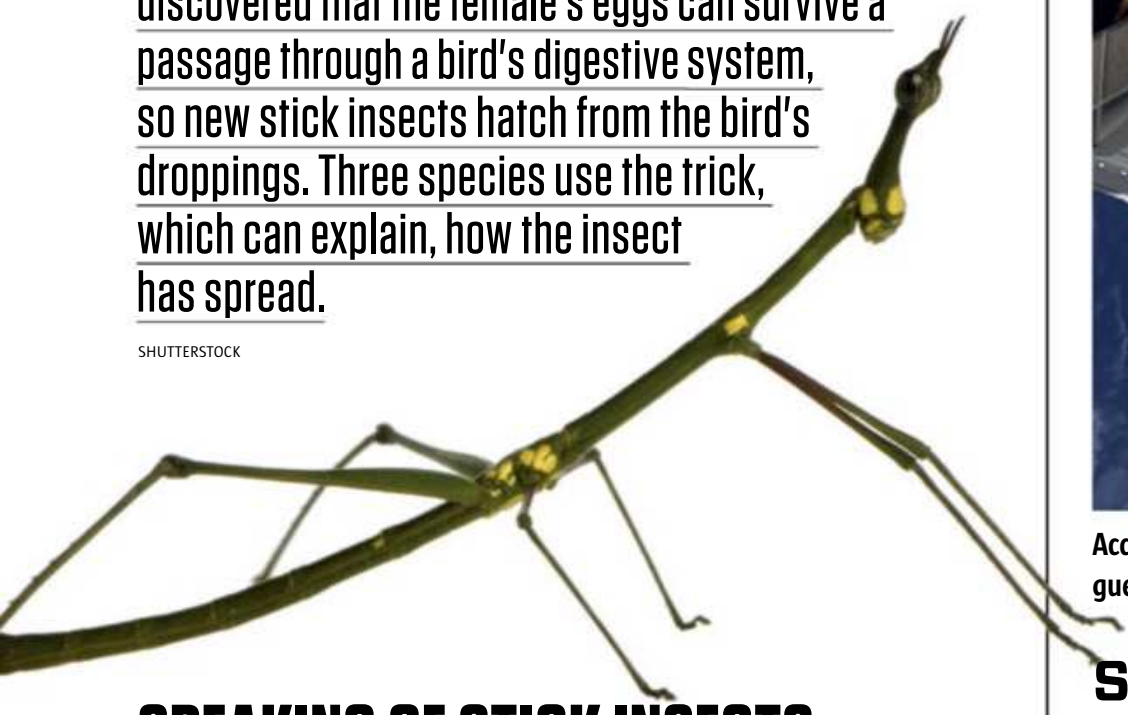
The Chandra X-ray telescope has found 12 black holes within a radius of 3.3 light years (yellow circle) from the centre of the Milky Way.

BY THE WAY

INSECT EGGS GET A LIFT

If a pregnant stick insect is consumed by a bird, it makes the most of it. Japanese scientists have discovered that the female's eggs can survive a passage through a bird's digestive system, so new stick insects hatch from the bird's droppings. Three species use the trick, which can explain, how the insect has spread.

SHUTTERSTOCK



SPEAKING OF STICK INSECTS ...

HUGE SPECIES REVIVED ON AUSTRALIAN ISLAND

In 1918, a large stick insect species went extinct on Lord Howe Island. The 15cm insect was consumed by ship's rats. Gene studies have revealed that the species still exists on another small island. The authorities aim to reintroduce the species to Lord Howe Island.

ROHAN CLEAVE/MELBOURNE ZOO

BACTERIA COULD IMPROVE ANTIBIOTICS

Diapherodes gigantea stick insects carry bacteria that are resistant to antibiotics. Scientists aim to find out if the bacteria developed their resistance in the encounter with the plants that the insect consumes. If they find how the bacteria become resistant, they might be able to prevent it.

SHUTTERSTOCK

PERFUME ATTRACTS THE PERFECT MATE

British scientists have revealed how stick insects find each other. Each species has its own individual mix of oils on its surface: a perfume that allows them to smell their way to the perfect partner, which should preferably be not too closely genetically related. This prevents genetic disease.

THE UNIVERSITY OF SHEFFIELD

ORION SPAN

According to plan, the Aurora Station space hotel will accommodate four guests and two crew members.

Space hotel to open in four years

SPACE RACE With three months of training and a fat wallet, you might soon be able to take a holiday in space. The Orion Span company expects to open its Aurora Station space hotel in four years.

According to plan, the first module of the space hotel will be launched in 2021 to orbit 322 km above Earth. That is slightly lower than the International Space Station, which orbits 408 km above Earth.

The company has not yet disclosed how the launch will be carried out. Aerospace players such as SpaceX, Orbital ATK, and Blue Origin are constantly pushing the boundaries of private aerospace activities, and companies such as Orion Span will probably need to cooperate with one of them to launch their projects. In 2022, the hotel is meant to have been completed to such an extent that it can accommodate four tourists and two guides. The guests will live in double rooms. The Aurora Station will have more windows than any other aerospace modules, so there will be plenty of opportunities to experience auroras from above.

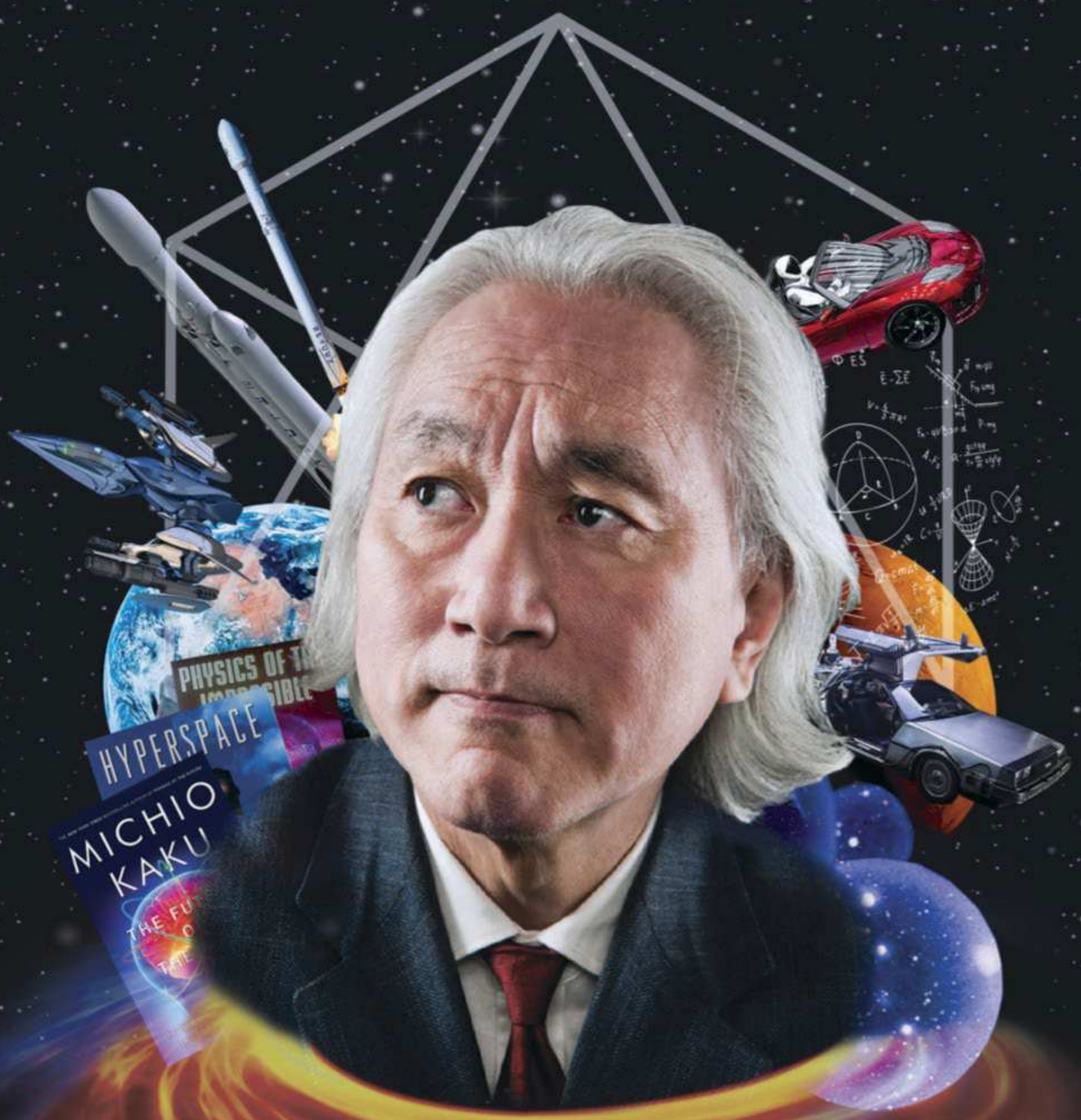
According to Orion Span, the hotel will orbit Earth in 90 minutes, so the guests will be able to watch about 16 sunrises a day. One ticket reservation costs $1000,000, and the price of 12 days in space is $12million - including the trip up and back.

28,000

km/h is the speed at which the space hotel travels. If you book a 12 day stay, you will complete more than 8 million kilometres.

MICHIO KAKU

THE FUTURE OF HUMANITY



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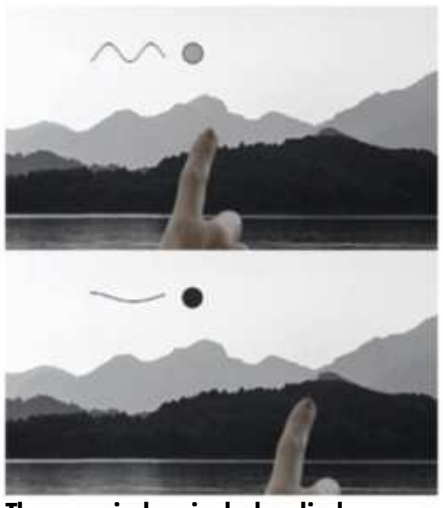
Blind people will soon feel view from car

TECHNOLOGY A new method will allow blind people to experience the landscape, as they move their finger tips across a car window. “Feel the View” was invented by Ford, and the method involves a camera on the side window operated by the passenger. The pictures are translated into grey tones, which are reproduced by diodes in the window glass. The diodes vibrate at different frequencies, allowing the blind person to scan a detailed picture with his finger tips. Light areas in the landscape vibrate at a higher frequency than dark ones. The system prototype can reproduce pictures at 255 different frequencies.

The idea is inspired by haptic technology that is to expand our sensory impressions. In mobile phones and computers, the idea is that we are able to feel that we press a button as if it were a physical button.

Ford has not yet disclosed when “Feel the View” will be available to car buyers, but according to developers, the concept opens wide perspectives outside the car industry as well. The carmaker has named the method a brand new language that blind people in schools and institutions can benefit from to visualise the surroundings.



FORD

The car window includes diodes, so light areas vibrate at a higher frequency than dark ones.

Fat people to be cured with their own fat

Scientists have found out how to convert white fat into brown – and so how to make your fat consume itself.

MEDICINE An efficient diet that does not involve neither eating less nor any training – that could be the result of a new concept developed by scientists from the NYU Winthrop Hospital in the US. The idea is to extract a small portion of white fat from the body, cut it to small pieces, and place it in a bioreactor, where it is converted into brown fat, which converts energy deposits into heat. The fat tissue is injected back into the patient, where it will burn energy, so the patient loses weight.

The scientists’ new invention is a bioreactor that subjects white fat to a chemical bath including a speial mix of growth factors and chemical compounds, which stimulate the browning process. The device takes 1-3 weeks to convert white fat into brown. This means that the fat cells change their structure and get more mitochondria, the power stations of cells. The function of the brown fat in the body is best known from babies, whose bodies it keeps warm, but adults also have a little of it. Brown fat is very active and burns large quantities of energy. Only 50-70 g is sufficient to manage 20 % of the body’s energy conversion.

The scientists have tested the method on mice and with human cells outside the body. They aim to develop a simple bioreactor for doctors and clinics.

SHUTTERSTOCK

FAT WILL MAKE YOU THINNER

In a matter of a few weeks, a lump of fat is converted into a fat burner. The secret is in the cells’ mitochondria, which convert energy.

DOCTOR EXTRACTS FAT FROM THE PATIENT

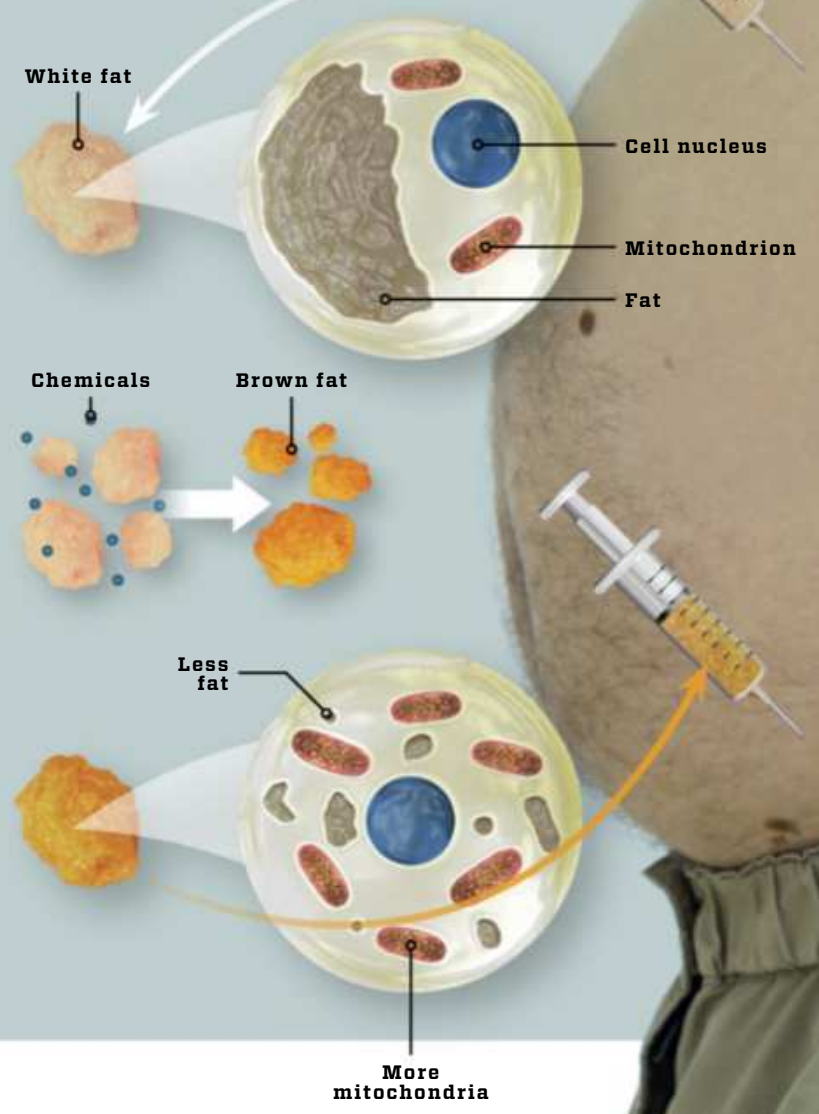
1 White fat cells include large fat deposits, but only a few mitochondria, which convert energy in a cell.

CHEMICAL BATH CONVERTS FAT

2 The fat samples are cut to small pieces, which are subjected to a cocktail of chemicals in a bioreactor, making the white cells turn into brown ones.

DOCTOR INJECTS BROWN FAT BACK INTO PATIENT

3 The cells now include much more mitochondria, so they can convert large quantities of fat into heat. The brown fat is injected back into the patient's fat deposits.



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Physicists have invented new nuclear particle

PHYSICS In cooperation with a supercomputer, Japanese scientists have spent three years calculating that an unknown type of particle might exist. If so, it exists in places of the universe, in which matter is subjected to extreme forces.

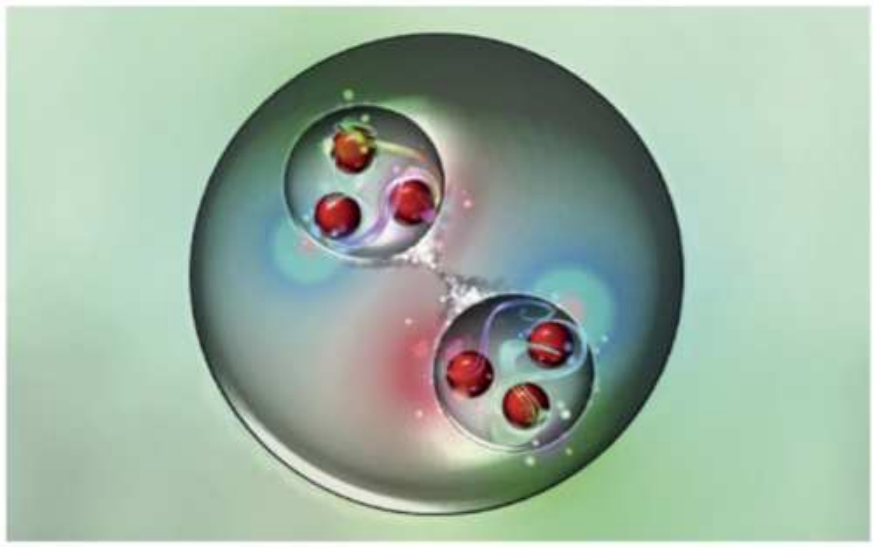
Usually, matter consists of atoms, whose nuclei include baryons, i.e. protons and neutrons. The baryons are known as elementary particles, though they consist of even tinier particles – quarks. So far, particle physicists have discovered six different types of quarks.

The Japanese scientists predict the existence of a particle that contains another type of quark known as a strange quark. They have named the particle di-Omega, and it is apparently made up of two baryons accompanied by three strange quarks each. The scientists aim to prove the existence of the particle in particle accelerators.

If the di-Omega particle turns out to be produced at extreme energy levels, it might also exist in the neutron stars that remain, when a star explodes into a supernova. According to theory, a neutron star consists of very compressed baryons from atoms that were shattered, as the stars collapsed. The matter is so compact that 1 cm^3 weighs hundreds of millions of tonnes..

QUARKS STICK TOGETHER

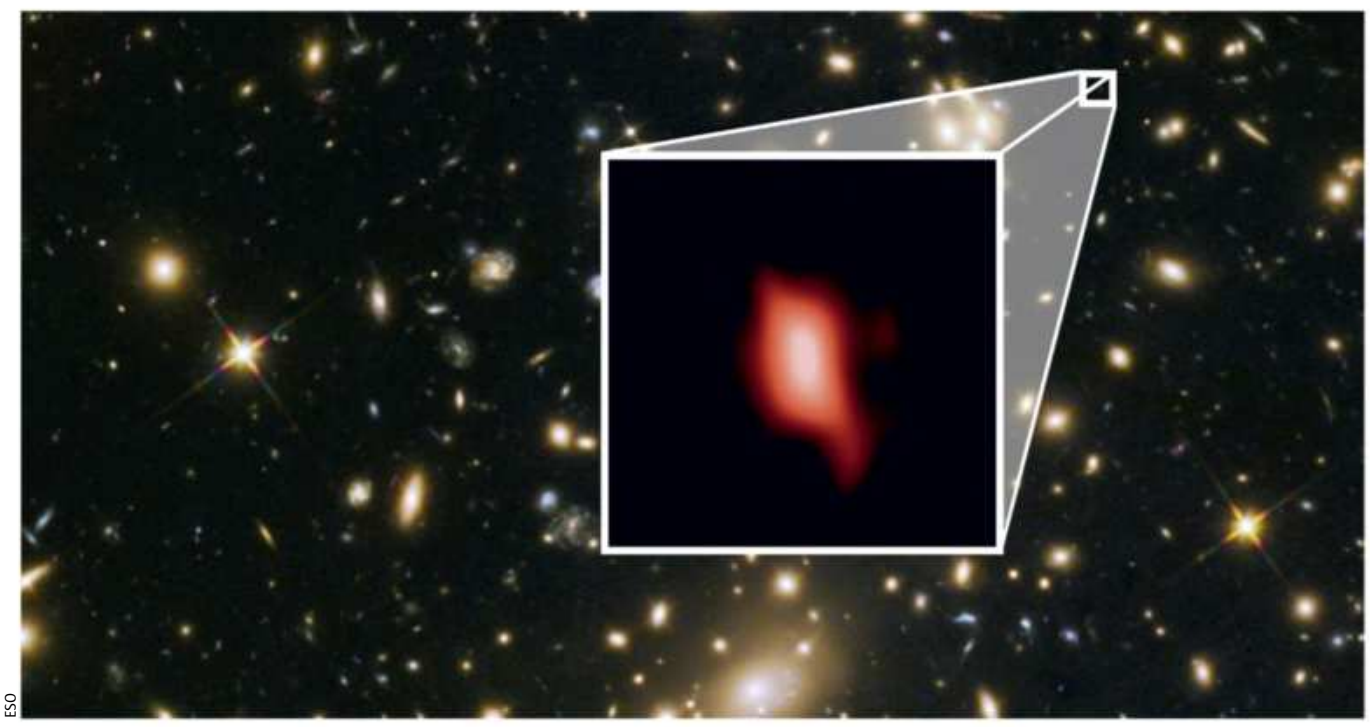
- Quarks are the tiniest building blocks of atomic nuclei.
- There are six types: up, down, top, bottom, charm, & strange.
- Quarks are usually never alone, they always combine into larger particles.



KEIKO MURANO

The new particle has been named di-Omega. It is made up of two baryons, which each consist of three strange quarks.

SHOOTING STAR



ESO

Stars were born surprisingly early

A weak glow from a remote galaxy tells a story of stars being older than we thought. The ALMA and VLT telescopes have detected the light that was emitted 13.3 billion years ago. The flash is due to oxygen released by dying stars, revealing that they probably formed already 250 million years after the Big Bang.

JUAN GAERTNER/SCIENCE PHOTO LIBRARY

Alzheimer's victims produce plaque in their brains (orange), but scientists might have a cure.

Gene shows the way to a cure against Alzheimer's

BRAIN The brains of the millions of people who are annually diagnosed with Alzheimer's are slowly withering away, but now, American gene researchers from the Massachusetts Institute of Technology in the US might have found a cure.

Studies have shown that people with the APOE4 gene variant suffer a greater risk of developing Alzheimer's than individuals with the more common APOE3 variant. So, the scientists cultivated two types of brain cells in the lab: a portion of each gene variant. After a while, the brain tissue with APOE4 was filled with plaque, which is a sign of Alzheimer's. The scientists now changed APOE4 into APOE3 by means of the CRISPR method that allowed them to replace DNA sequences in the genes of cells. The change had a drastic effect: the plaque formation did not only stop, it shrank.

So, APOE3 seems able to clean up brain tissue that has already started to wither. The scientists emphasize that the cleanup involves complex interaction between many genes, but APOE3 could be the key to a future gene therapy against hereditary Alzheimer's. The method might both cure and prevent the disease.

Will flying taxies save us from rush hour?

Airbus has carried out the first test flight of its flying taxi that is to prevent traffic jams during rush hours and stop at the top of city skyscrapers from 2020.

TECHNOLOGY In a few years, you can fly across the city to arrive very quickly at your destination. That is the promise made by Airbus and its Vahana flying taxi.

Airbus introduced the plans in 2016, and now, the company's developers have carried out the first prototype test flight. The flight lasted 53 seconds and took place at an altitude of 5 m.

So, Airbus has become a vital player in the race to market a flying taxi first. Earlier this year, a company called Kitty Hawk carried out a test flight of its Cora project, and both Boeing and Uber have projects in the pipeline.

Vahana seats one passenger, is electrically powered, and autonomous. Eight rotors lift and land the plane vertically, and during horizontal flight, the rotors tilt to produce propulsion. A computer calculates the route and makes corrections for obstacles such as birds and other air taxies, ensuring that the craft reaches its destination fast and safely. In the event of an accident, a parachute will unfold, carrying the passenger safely to the ground.

According to the developers, a breakthrough as regards batteries and lightweight materials has made the dream come true. Batteries have become lighter, stronger, and more reliable. Moreover, composites manufacturing has become cheaper. The test version of Vahana weighs 745 kg and has a wing span of 6.2 m.

AIRBUS' FLYING TAXI CONQUERS THE AIR

(1) Passengers board at the top of a high-rise. (2) The plane calculates the route and takes off. Once the craft is airborne, the rotors are tilted, and it flies forwards. (3) The craft avoids obstacles such as birds unaided.

AIRBUS INDUSTRIE

Watch the video at https://youtu.be/uy0G208rS0A

The first test flight of the Vahana flying taxi lasted less than a minute and was carried out 5 m above the ground.

FLYING TAXI BY THE NUMBERS

- **Weight:** 745 kg
- **Width:** 6.2 m
- **Length:** 5.7 m
- **Height:** 2.8 m

AIRBUS INDUSTRIE

How does a polaroid camera work?

New polaroid cameras can be adjusted according to the light and connected with phones.

Film was traditionally developed in special solutions in dark-rooms, so how are polaroid photos developed in a few seconds?

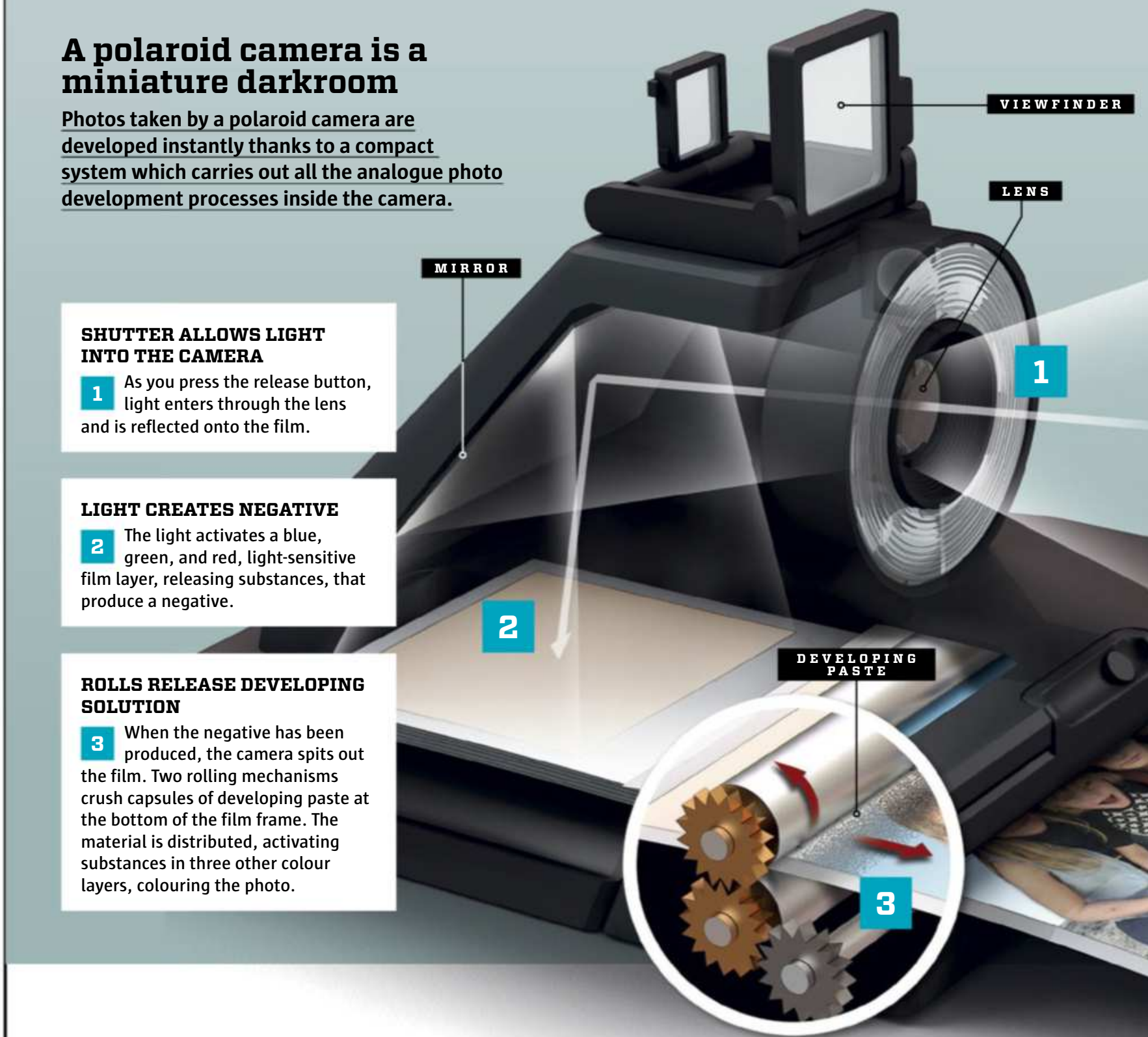
TECHNOLOGY Photos taken on film usually require film rolls, a darkroom, and light-sensitive chemicals to be developed. A polaroid camera unites all the elements of the process in its interior by including film and chemicals in the same paper.

In a film camera, the film reacts as light is admitted through the lens, producing a negative – an image, in which the light of the subject appears in its own complementary colours. Red becomes cyan, green is magenta, and blue turns yellow. In a darkroom, light is shone onto the negative, and the photo emerges on photographic printing paper. The chemicals of the photo paper are extremely sensitive to light, and so, the development must take place in complete darkness.

A polaroid camera is a fast-working darkroom, in which light is only admitted briefly after pressing the shutter release button. The light produces a negative on a piece of layered film, while the two rolls that push the paper out of the camera add chemicals, which fill out the areas of the the negative that have not already reacted. A few seconds later, the camera has produced a photo.

A polaroid camera is a miniature darkroom

Photos taken by a polaroid camera are developed instantly thanks to a compact system which carries out all the analogue photo development processes inside the camera.



SHUTTER ALLOWS LIGHT INTO THE CAMERA

1 As you press the release button, light enters through the lens and is reflected onto the film.

LIGHT CREATES NEGATIVE

2 The light activates a blue, green, and red, light-sensitive film layer, releasing substances, that produce a negative.

ROLLS RELEASE DEVELOPING SOLUTION

3 When the negative has been produced, the camera spits out the film. Two rolling mechanisms crush capsules of developing paste at the bottom of the film frame. The material is distributed, activating substances in three other colour layers, colouring the photo.

Six colour layers paint an entire picture

Polaroid film consists of three light-sensitive layers that are activated, as red, green, and blue light is admitted. The light draws a negative in the layer like a film of silver crystals. Under each layer, there is a layer of yellow, magenta, and cyan colour, which is released by developing solution, as the camera spits out the film. Where silver has been released in the layer above, no colour is admitted. Instead, the colours of the two other colour layers combine to produce the colour of the light-sensitive layers.

In a photo of a blue sky, the light-sensitive blue layer blocks out yellow colour, whereas magenta and cyan produce blue.

MIKKEL JUUL JENSEN/POLAROID ORIGINALS

TOP 5 · Which diseases are the most common?

SHUTTERSTOCK

1 Cold

2-5 times a year. Most people get colds regularly. The extremely contagious viral disease spreads via sneezing, coughing, and physical contact. A number of viruses spread the infection that makes noses snotty.

DIARRHOEA
ONCE A YEAR

2 Diarrhoea is a symptom of intestinal infection, poisoning, etc. The condition is defined as three or more loose or liquid bowel motions. Diarrhoea can be lethal.

HERPES
60-90 % OF US

3 The majority of the world population are chronically infected by the herpes virus, that causes blisters of genitals and lips. Some never have symptoms.

CARIES
50 % OF US

4 Tooth decay is due to plaque, that develops acid over time, breaking down teeth. The decay is known as caries. 1 in 2 people have at least one example.

ANAEMIA
25-50 % OF US

5 Anaemia is caused by too few oxygen-carrying red blood cells, and at least 25 % of us have it. The symptoms are often headaches, fatigue, weakness and dizziness.

Can starfish tolerate fresh water?

BIOLOGY Starfish live in salt water, and their bodies have the same salt content as ocean water. Varying salt concentration in the water can be a life-threatening challenge to a starfish. If there is less salt in the surrounding water than in the creature's body fluids, its cells might burst.

This is due to osmosis, which means that water will always balance areas with different salt contents. In salt water, there is osmotic equilibrium, as the salt concentration is the same on both sides of the starfish's cells. Equal quantities of water pass in and out of the cells. In fresh water, there is no equilibrium, as the salt concentration is higher inside the cells than in the surrounding water. So, water seeps into the cells, and they could burst. Unlike fish, starfish have no osmosis regulation, and consequently, long periods in fresh water could be fatal.

SHUTTERSTOCK

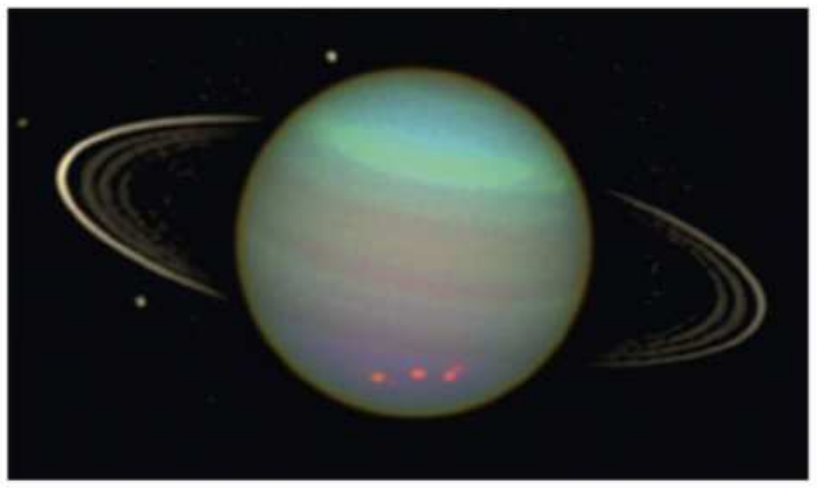
If a starfish is left in fresh water, it will die, as its cells burst.

How many rings does Uranus have?

ASTRONOMY When Galileo Galilei aimed a telescope at Saturn in 1610, he observed a number of objects around the planet that later turned out to be rings. In 1977, astronomers discovered that Uranus also has rings that probably consist of ice and dust.

In the first place, 5-6 rings were identified, but when the Voyager 2 space probe photographed the planet in 1986, the number increased to 11. In 2005, astronomers used the Hubble telescope to spot another two rings, so Uranus now has 13 known rings.

The rings are hard to oberve, as most of them are dark and only some 100 m thick. They are located 14,000-72,000 km from the planet. The other huge planets of the Solar System, Jupiter and Neptune, also have rings, which were discovered in 1979 and 1989, respectively.



NASA

Just like Saturn, Uranus is surrounded by rings which are a few km wide. The rings consist of objects with diameters of 0.2-20 m.

⊕ HOW THINGS WORK · How do the gears of a racing bike work?

Gears allow a racing cyclist to keep up a comfortable pedalling rhythm uphill and downhill. When the cyclist changes gears, the chain shifts from one gear wheel to another with a different number of teeth. If the chain links the front gear wheel with the most teeth and the smallest back gear wheel, the bike is in the highest gear.

PEDALS POWER GEAR WHEELS

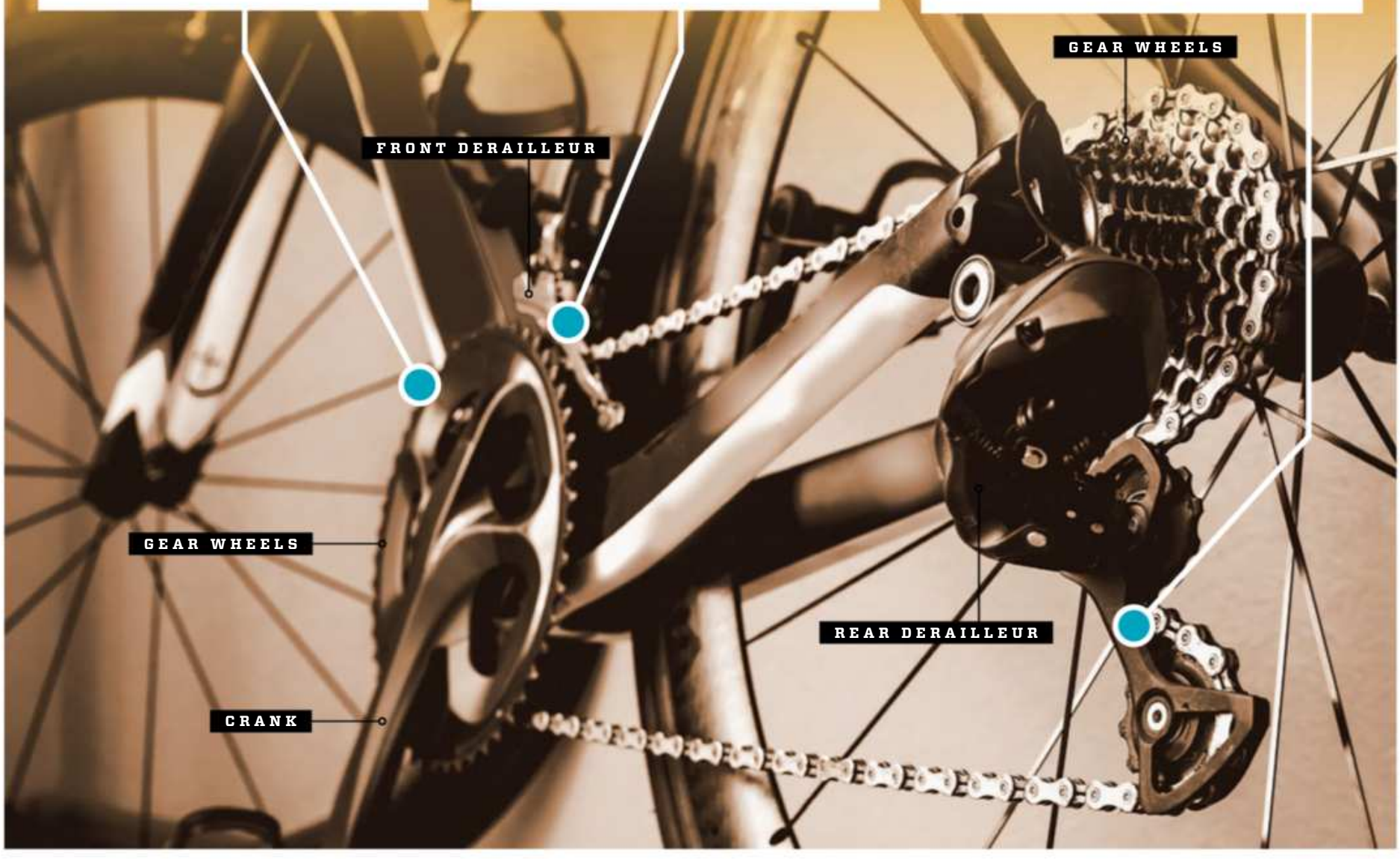
1 As a cyclist pedals, the crank rotates. It is fastened to two or three gear wheels located in layers. The outermost gear wheel has the most teeth.

THE CHAIN TRANSFERS ENERGY

2 The gear selector makes a front derailleur force the chain from one gear wheel to another. The force of the pedalling is transferred via the chain to rear wheel gear wheels.

GEAR DETERMINES REVOLUTIONS

3 The rear derailleur adjusts the chain's length and shifts it between the gear wheels of the rear wheel. The greater the teeth number difference of the front and rear wheel gear wheels, the higher the cadence.



SHUTTERSTOCK

WORLD RECORDS

Which natural material is the world's hardest?

Lonsdaleite is a very rare type of diamond that exists in meteorites and results, when the graphite of a meteor hits Earth. The heat and pressure from the collision transforms the material into diamonds which are up to 58 % harder than diamonds formed in the usual way. The hardness is probably due to a more stable atomic structure.

D. VAN RAVENSWAAY/SPL

58 %

harder than diamond

USA

WHERE: The first lonsdaleite finds are from a meteorite from the Barringer Crater in Arizona.

WHAT: Lonsdaleite results, when pressure and heat from a meteor strike converts carbon into diamond.

Snakes use scales on their stomachs to hold on to the surface.

How do snakes climb?

Snakes have neither arms nor legs, so how do they climb trees?

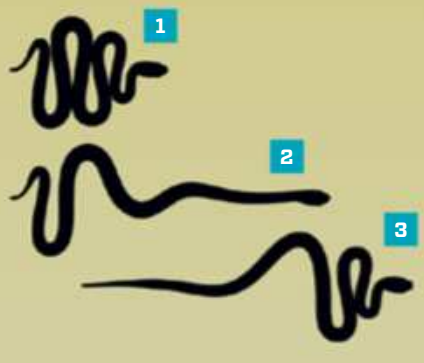
BIOLOGY On the ground, they wriggle forwards by means of oblong scales on their bellies. Known as ventral plates, the scales ensure some grip, when they climb trees. Some species such as corn snakes can control their belly scales, so the underside gets more folds, standing more firmly on any irregularities. Corn snakes can climb vertical tree trunks

As snakes move from branch to branch, they use a harmonica motion. First, the snake gets a good grip by "wrapping" the front of its body around a branch or trunk. Subsequently, it pulls up its tail, and the hind part of its body gets a grip, pushing the forepart forwards.

Snakes are very cautious, when they climb. Their grip is much harder than it needs to be – probably to make sure that they do not fall down and become an easy prey for enemies – and to avoid consuming energy for climbing up again.

Climbing snakes fold up like a harmonica

The forepart and hind part of the body take turns to get a grip in a harmonica-like motion, as snakes move from one branch to the next.



1. First, the snake folds up its body.

2. Subsequently, the snake moves the front part of its body forwards.

3. When the snake has gotten a good grip at its front end, it will move the back of its body forward.

SHUTTERSTOCK

Does fast speech indicate higher intelligence?

HUMANS There is no indication that fast speech is equivalent to a faster brain or higher IQ. Studies show that people who speak slowly communicate the same information using fewer syllables. By translating a text very accurately into different languages, scientists have calculated how many syllables different languages use to communicate the same information. Languages with little information per syllable are typically spoken with more syllables per second to compensate. The final result is the same.

According to another general theory, people who speak fast use the flow of talk to think aloud, whereas people who speak slowly do not start talking, until their message has been worded.

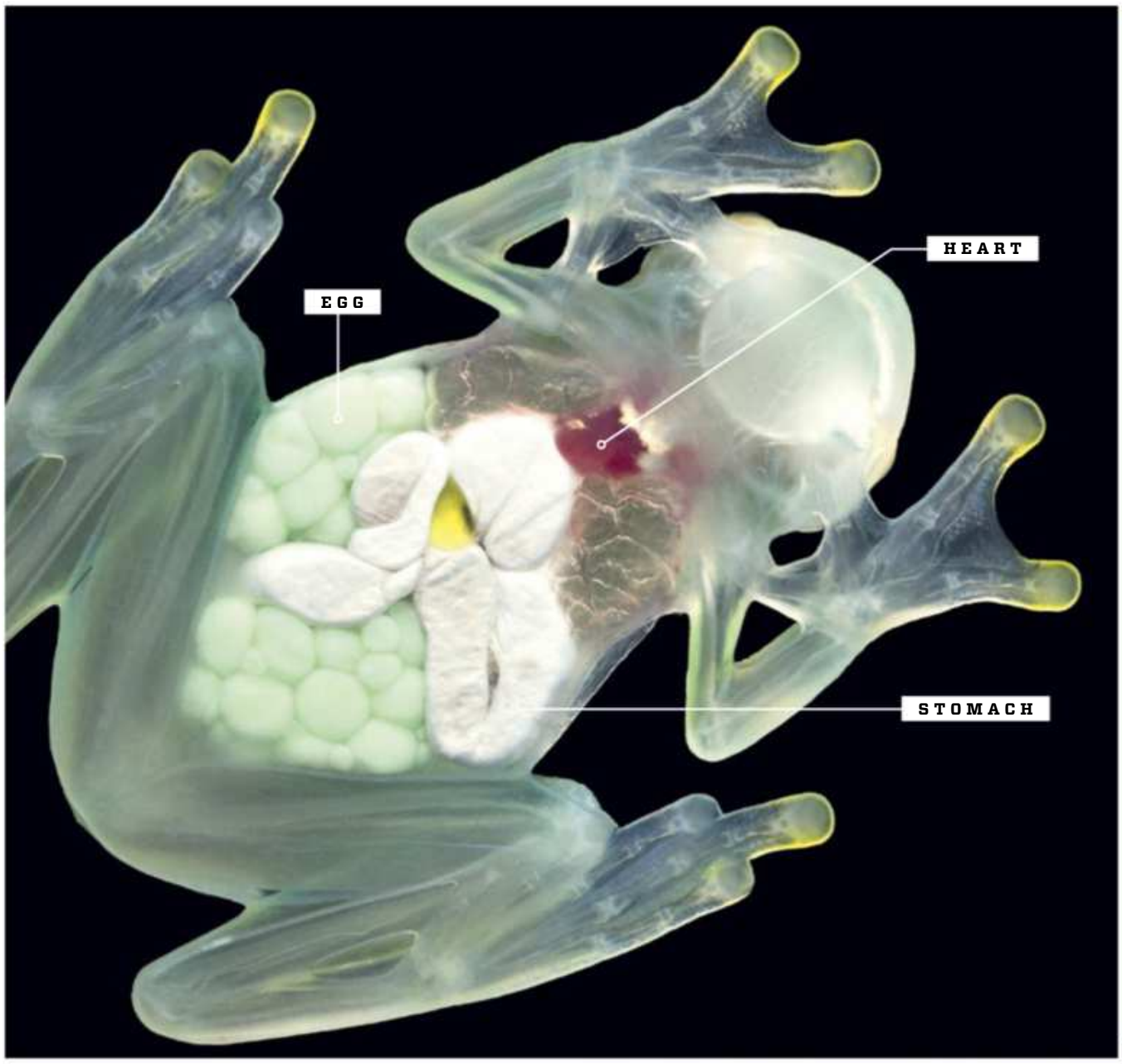
ALAN CROWHURST/GETTY IMAGES

Horse race callers and auctioneers speak very fast, but nothing seems to indicate that they are more intelligent.

MOST INFORMATION PER SYLLABLE

- **English:** 6.19 syllables/second – information/syllable: 1.08
- **Vietnamese:** 5.22 syllables/second – information/syllable: 1
- **French** 7.8 syllables/second– information/syllable: 0.99
- **Spanish:** 7.82 syllables/second – information/syllable: 0.98

THE FROG THAT NEVER NEEDS AN X-RAY



In the trees of South and Central American jungles, you will find glass frogs of 2-8 cm with transparent skin.

› Glass frogs are famous for their thin and partly transparent skin, particularly that of the belly. The skin is believed to provide camouflage, as the frog is hard to see for predators.

› Females lay 20-30 eggs which, like the internal organs, can be seen clearly through the skin. Males protect the eggs after their laying, keeping them clear of parasites.

› The frog's organs are covered by a layer of pigment cells (iridophores), which can reflect and protect them against sunlight and heat. The frogs can grow 10+ years old.

PETE OXFORD/MINDEN PICTURES/GETTY IMAGES

... binary stars can have solar systems?

A solar system in which the planets orbit two stars sounds like pure science fiction. But binary stars are said to exist. Is this true?

ASTRONOMY Not nearly all stars travel alone through space. At least half of all stars in the night sky have companions and belong to a system of two or more stars, which gravity maintains in permanent orbits around a common centre of gravity.

Within a distance of 20 light years from the Sun, you will find 16 binary stars and three triple stars. The Sun's closest neighbour, Alpha Centauri, is a system of 3 stars, consisting of the 2 stars of Alpha Centrauri A and B in close orbit around each other and the more remote and weaker Proxima Centauri.

Binary stars are formed in the same cloud of gas and dust. So, they consist of the exact same elements and are the same age. But sometimes they are born with different masses, meaning that they develop differently and do not live for the same period of time. The star with the largest mass will die first.

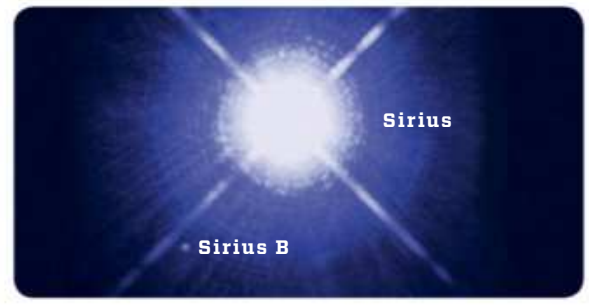
Some scientists even assume that all stars, including our own Sun, are born as binary stars. The Sun's hypothetical twin is called Nemesis, and billions of years ago, it entered a path that sent it far away from the Solar System. According to this theory, Nemesis might still exist somewhere in the Milky Way. The twin is probably a brown dwarf – i.e. a small, cold star that will never be warm enough to start a fusion process.

In the Kepler 47 star system 3,400 light years from the Sun, at least three planets are orbiting a spectroscopic binary star.

Three methods capture binary stars

Binary stars orbit the same centre of gravity, but often only one star is visible. So, astronomers use several methods to identify the couples.

1 **Astrometric binary stars:** Some binary star systems are spotted due to irregularities of the motions of the brightest star. One example is Sirius and Sirius B in the Canis Major constellation.



2 **Eclipsing binary stars:** In other cases, the orbits of two stars block out each other's light. One example is Algol A in the Perseus constellation, whose brightness is clearly reduced by two thirds every third day.

3 **Spectroscopic binary stars:** Two very close stars must often be spotted by means of a spectroscope, that analyses the light from the stars. Castor in the Gemini constellation was detected in this way.

NASA/ESA/CENTRE DE DONNÉES ASTRONOMIQUES DE STRASBOURG

Mega-Rockets Make A Comeback

For more than 45 years, no craft has been able to match the brute strength of the Saturn V moon rocket. But soon, a new generation of rockets with massive power will be able to take a short cut through the Solar System, making mining on asteroids a matter of routine.

Space missions require muscles

Booster rockets are the workhorses of space. They come in different categories depending on how much they can lift. The new guard of booster rockets are among the heaviest.

110 m
100 m
90 m
80 m
70 m
60 m
50 m
40 m
30 m
20 m
10 m
0 m

SMALL

EXAMPLE: EPSILON

Lifting capacity: Up to 2,000 kg

Tasks: Can lift 1,500 kg to an altitude of 500 km. Launched the world's first satellite, Sputnik 1, into its orbit

Height: 26 m

MEDIUM

EXAMPLE: DELTA II

Lifting capacity: Up to 20,000 kg

Tasks: Launched the Kepler telescope into its orbit around the Sun and carried the Opportunity and Spirit rovers to Mars.

Height: 39 m

HEAVY

EXAMPLE: ARIANE 5

Lifting capacity: Up to 50,000 kg

Tasks: Can launch heavy TV satellites into a geostationary orbit, in which they follow Earth's rotation.

Height: 52 m

SUPERHEAVY

Lifting capacity: 50,000+ kg

Tasks: Will be used for manned missions and missions to other planets. Will also lift large modules for the construction of new space stations. Only one existing rocket can lift 50+ into orbit.

Height: 70-111 m

By **Esben Schouboe**

NEW HEAVYWEIGHTS TO SOLVE FIVE PROBLEMS

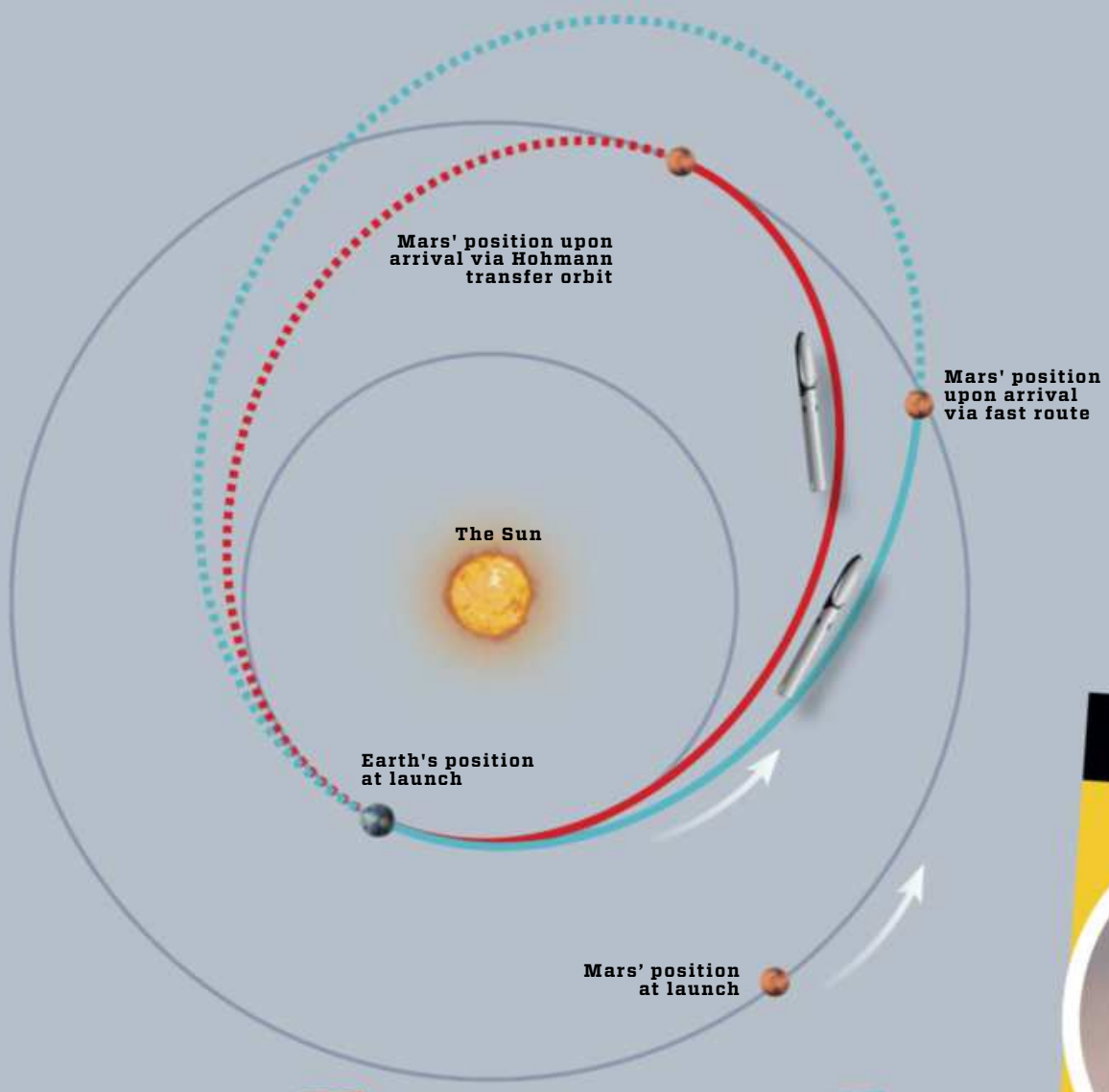
- COLLECT MATERIALS FROM ASTEROIDS
- TAKE SHORT CUTS IN THE SOLAR SYSTEM
- BUILD NEW LARGE SPACE STATIONS
- TAKE TOURISTS ON ONE DAY MISSIONS
- SEND HUMANS BACK TO THE MOON

The world's most powerful operating rocket, Falcon Heavy, was first launched in February 2018, the first shot in a new space race.

SPACEX

Extra engine power = faster space travel

A journey from A to B is easy to plan on Earth, as the two locations on the map do not move in relation to each other. In space, it is not that simple. In the Solar System, all planets are orbiting the Sun at high speeds. As Earth's orbit speed is about 30 km/s, all rockets automatically begin their journey at this speed. If the rocket is going to Mars, which is further away from the Sun than Earth, the engines must increase the orbit speed, allowing the rocket a new elliptical orbit around the Sun, which crosses Mars' orbit. But as Mars orbits more slowly than Earth, the rocket might travel too fast for the planet's gravitational field to capture it. It is expensive to equip the rocket with fuel for braking, so astrophysicists often plan Solar System missions via Hohmann transfer orbits, i.e. elliptical orbits, which reach the point furthest away from the Sun where the destination is, so the rocket is slowed down as much as possible by the Sun's gravity, when it arrives to the planet.



TRAVEL TIME: 9 MONTHS

Fuel saving costs months in space

The least energy-intensive route between Earth and Mars is via a Hohmann transfer orbit, by which the rocket gains just enough speed for its elliptical orbit to peak by Mars' orbit. So, the quantity of fuel is accurately calculated, making the launch much simpler, but the route is only open every 26th month due to the required planet positions.

TRAVEL TIME: 3 MONTHS

Short cut to Mars requires power and fuel

The new generation of rockets has more engine power and can hence bring more fuel and gain higher speeds. According to NASA's calculations, a rocket can travel from Earth to Mars in only 80 days, if it consumes more than three times as much energy as via a Hohmann transfer orbit. On the other hand, the rocket must brake sharply upon arrival to Mars.

The countdown hits zero, and 27 awesome rocket engines are activated. The world's most powerful rocket, Falcon Heavy, lifts off from the launchpad for the very first time, and thousands of spectators cheer ecstatically.

6 February 2018 was an important day in space history, as the huge Falcon Heavy completed its first test flight without any errors. Not since the legendary Saturn V moon rocket flew its last mission in 1973, had the world seen similar lifting power. Falcon Heavy's engines can lift 63,800 kg into an orbit around Earth – i.e. more than twice as much as its closest competitor, Delta IV Heavy. And Falcon Heavy is just the first of a new generation of heavyweight rockets. With new types of fuel and engines plus stronger materials, the new huge rockets will allow quick tourist space missions, mining on asteroids, and man returning to the Moon.

Rockets defeat gravity

The principle behind rocket propulsion was first described in physicist Isaac Newton's third law of motion: for every action, there is an equal and opposite reaction.

In connection with rockets, the principle is taken advantage of by accelerating gases out through nozzles. When the fast-moving gases leave the nozzle, an opposite force will push the rocket upwards. As soon as the force from the push exceeds gravity, the rocket will lift off from the ground. The rocket begins its journey in a vertical position, but on its way up through the atmosphere, it will travel more and more horizontally. Although the rocket quickly leaves the atmosphere, it is still influenced by Earth's field of gravity, and as soon as the engines are deactivated, it will start to fall back towards Earth. So, it must obtain a horizontal speed that will neutralise gravity's downward pull. A speed of at least 30,000 km/h is required to remain in orbit around Earth.

If the rocket is meant

CANDIDATE

BIG FALCON ROCKET

The SpaceX company is building its largest rocket, the Big Falcon Rocket. The top part of it will include 100 passengers and is fuelled by a fuel craft orbiting Earth. So, the vehicle gets enough fuel to take the fast Solar System routes, i.e. passengers are subjected to cosmic radiation for as short periods of time as possible.

SPACEX

Powerful rockets allow mining in space

More powerful rockets will allow mining companies to reach asteroids including valuable minerals more easily. The companies particularly focus on 3 types of asteroids.

CANDIDATE

FALCON HEAVY

■ The world's most powerful rocket. Its fuel – kerosene and oxygen – is very energy-dense, and the upper stage includes more than three times as much fuel as the second most powerful rocket, Delta IV. Consequently, Falcon Heavy can accelerate about 2 km/s faster, enabling it to reach much more asteroids.

SPACEX

C-TYPE ASTEROIDS ARE RIPE WITH ROCKET FUEL

75 % of all known asteroids are of the C type. They include large quantities of water in the shape of ice. The water can be split into hydrogen and oxygen to be used as rocket fuel. So, mining companies hope to use C-type asteroids as a kind of filling stations.

M-TYPE ASTEROIDS ARE FULL OF METALS

M-type asteroids are fragments of cores from larger asteroids. They are rich in metals such as gold, silver, iron, and nickel. According to experts, it is possible to extract the metals by using magnets to extract fragments though the loose surface.

S-TYPE ASTEROIDS INCLUDE PLATINUM

S-type asteroids are hard and stony, and are believed to include several different metals. These include much platinum, which is used in lots of electronics and is one of the most expensive metals. The S-type makes up about 17 % of all known asteroids.

LAURENCE GARVIE/ASU

to go further than an orbit around Earth, such as to Mars, it requires a speed of almost 58,000 km/h. Rockets are designed to obtain as much terminal velocity as possible, as this will allow them tro travel further into space.

Engineers are challenged

Unfortunately for rocket engineers, higher terminal velocity constitutes a challenge that is almost impossible to overcome. According to the classical rocket equation, which describes the way in which all rockets travel, fuel consumption increases exponentially with the rocket's terminal velocity. This means that the faster the rocket must be able to travel, the more of its total weight will be accounted for by fuel, leaving less space for equipment and people. 85 % of the weight on Saturn V's missions was constituted by fuel, 11 % were engines and hull, whereas the astronauts and their gear only made up 4 %.

As every kg counts, the choice of fuel is one of the first issues settled by engineers, when they develop a new rocket engine. The task of the engine is to convert the fuel in the tanks into fast emission gases. The speed of the emissions determines the terminal velocity of the rocket, so it is important to use fuel with high chemical energy. The most high-energy fuels such as liquid hydrogen are unfortunately highly unstable, increasing the risk of the entire rocket exploding.

So, most booster rockets use a highly refined version of kerosene, which is more reliable, but also less energy-efficient. Several private rocket companies are developing engines which can use a third and brand new fuel in the world of rockets – methane.

Methane's energy density is lower than that of hydrogen, but it is much easier to keep liquid in the tanks. Moreover, methane's density is lower than that of hydrogen, so the tanks need not be as large. Consequently, engineers save weight, but even with the perfect fuel, the energy is not only used for propulsion. Some of the force from the combustion in the engine is used to pump fuel about the rocket, as the majority of the weight must remain at the tip of the rocket during launch, allowing it to keep its balance. If the centre of gravity is located too far back, the immense forces could quickly make a rocket spin instead of staying on its course.

When the ideal fuel has been identified, engineers must focus on designing the rocket in such a way that it can withstand the most hazardous part of a space mission: its passing ▶

NASA

Monster rocket repeats historical mission

50 years ago, the most powerful rocket ever, Saturn V, sent the first humans to the Moon. In 2020, NASA will repeat the legendary Apollo 8 mission with an unmanned rocket, when the even bigger Space Launch System is launched for the first time.

1 Countdown reaches zero

0 DAYS, 0 HOURS, 0 MINUTES:

15 t of kerosene and liquid oxygen are ignited, and Saturn V lifts off from the ground. The acceleration subjects the astronauts to four times gravity (4 g).

0 DAYS, 0 HOURS, 0 MINUTES:

The unmanned, 111-m-high SLS rocket releases the immense power of its four nuclear engines (the same type as the space shuttles') and the two side rockets.

2 First used rocket parts detached

0 DAYS, 0 HOURS, 2 MINUTES:

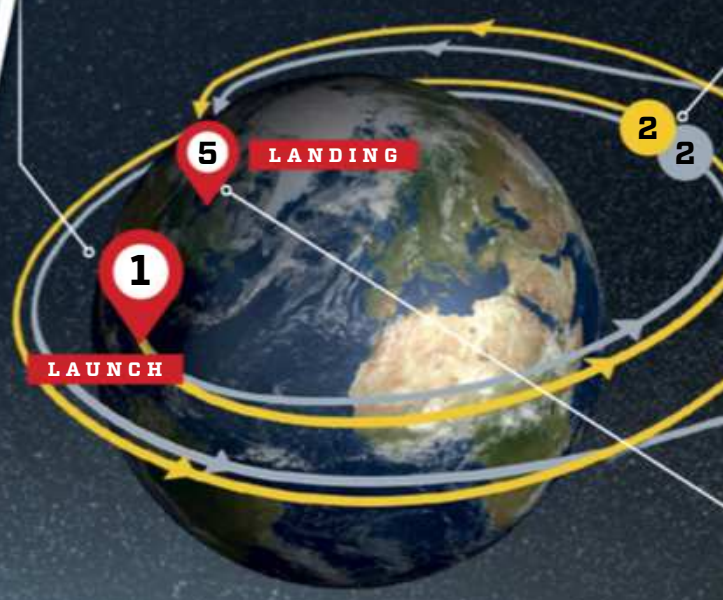
The first stage that lifted the rocket to an altitude of 68 km is deactivated and detached. Two seconds later, the next stage ignites with 4.4 million newton.

0 DAYS, 0 HOURS, 2 MINUTES:

The two booster rockets on the sides burn out and are detached at an altitude of 45 km. The four remaining engines lift the rocket at a force of 7.4 million newton.

NASA

1 NEWTON IS THE FORCE REQUIRED TO ACCELERATE 1 KG TO 1 M/S IN 1 SECOND.



In 2014, the Orion capsule was tested for the first time in preparation for the mission around the Moon in 2020.

NASA

5 Capsules land in the ocean

6 DAYS, 3 HOURS, 0 MINUTES:

After a powerful slow-down through Earth's atmosphere, that subjects the astronauts to about 7 g, the capsule lands in the ocean, and the crew is rescued.

25 DAYS, 12 HOURS, 0 MINUTES:

In its orbit around the Moon, Orion gets further away from Earth than any other crewed craft and returns at a low speed before finally hitting the ocean surface.

NASA

The legendary Earthrise photo was taken by Apollo 8 astronaut Bill Anders on 24 December 1968.

3 Missions head for the Moon

0 DAYS, 2 HOURS, 50 MINUTES:

The tip of the Saturn V rocket activates its engine, initiating the trans-lunar injection, i.e. the acceleration that pushes the rocket from its orbit around Earth towards the Moon at a speed of 38,959 km/h.

0 DAYS, 1 HOUR, 25 MINUTES:

The SLS rocket's second stage, the ICPS module, carries out a 20 minute activation of its rockets, increasing speed to 40,000 km/h and sending the Orion capsule towards the Moon.

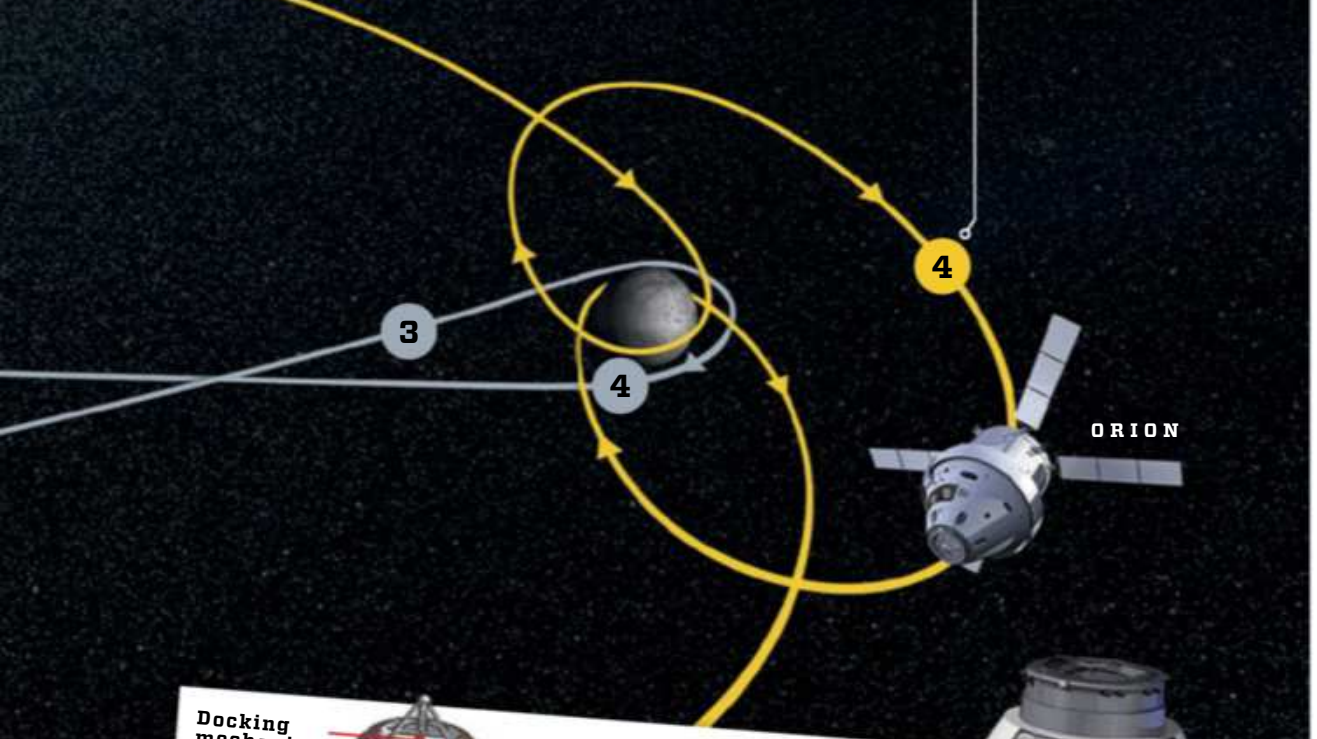
4 Capsules black out

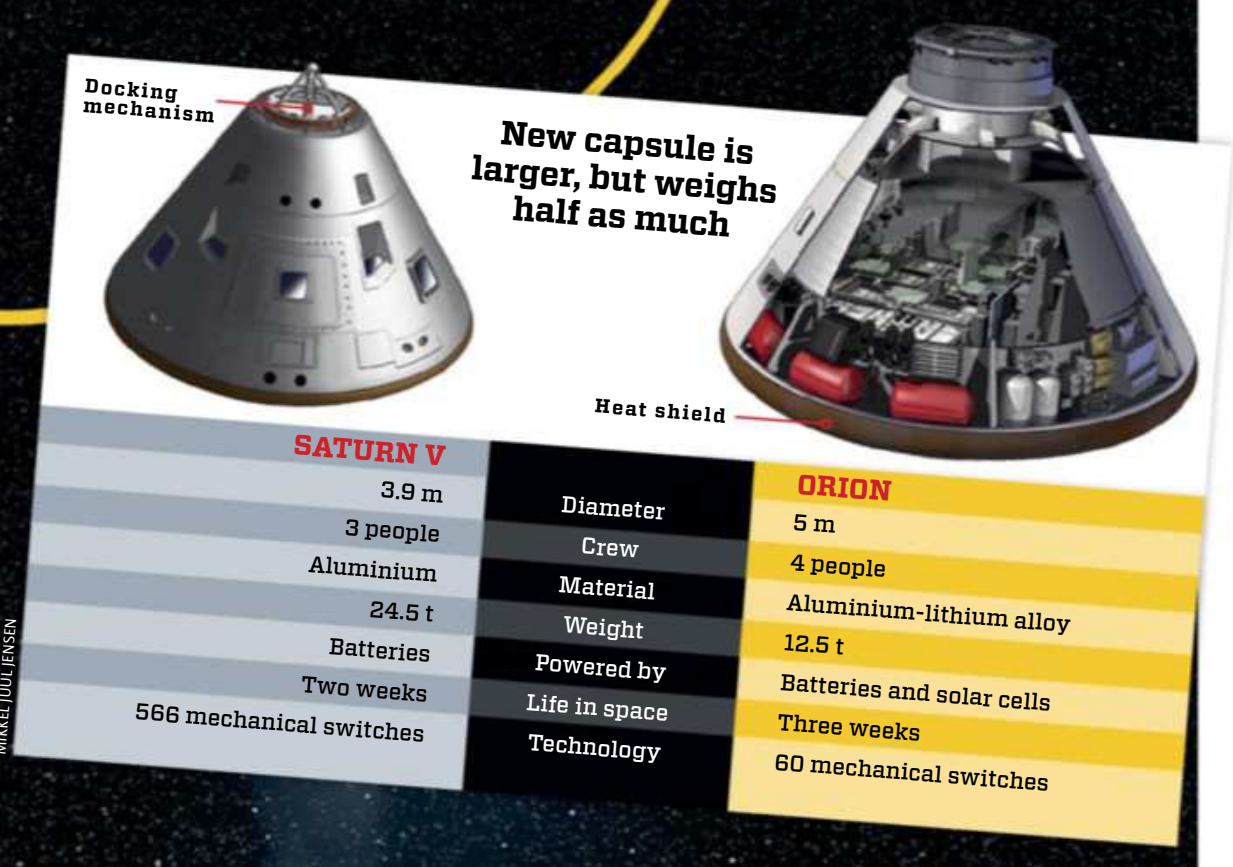
2 DAYS, 20 HOURS, 58 MINUTES:

For 30 minutes, the Apollo 8 astronauts have no radio contact with Earth, as they pass the far side of the Moon. When they can see Earth again, they take the first colour photo of our entire planet – the famous Earthrise picture.

4 DAYS, 7 HOURS, 18 MINUTES:

Orion is flung around the Moon only 100 km above the surface and is sent on into an orbit opposite of the Moon's rotation. Orion remains here for seven days.





MIKKEL JUUL JENSEN

up through the atmoshere, where it is subjected to immense forces due to air drag, affecting its exterior. In connection with the launch, engineers' major cause of worry is the max Q point. Max Q is the time of the flight up through the atmosphere, when air drag is at its maximum. If a rocket survives max Q, it will probably resist anything in space.

Space dreams come true

The air drag in the atmosphere and the sensitive weight balance mean that the load must be very consistent with the forces of the rocket. So, several different weight categories of booster rockets exist. The highest one, superheavies, can lift more than 50,000 kg into an orbit around Earth. Only this type of rocket can be used, when the great dreams of the space agencies are to come true in the 2020s by manned missions returning to the Moon and going all the way to Mars.

So, NASA is working on the last details of the Space Launch System (SLS), whose final version will be the largest rocket ever with a lifting capacity of 130,000 kg. But NASA is by no means the only player. The Russian Roscosmos space agency is cooperating with the Energia company to develop a rocket. The project, which is known as the Super Heavy Rocket, will be introduced in 2028. And in China, the CNSA space agency is testing the engines of the huge Long March 9 rocket, which, with a potential lifting capacity of 140,000 kg, will even outcompete the SLS, if it is completed.

It is no longer only the major national space agencies that develop huge rockets. The private space company Blue Origin has announced its next major project by the name of New Glenn. With a lifting capacity of 45,000 kg, the rocket is not very large, but unlike other rockets, New Glenn can be reused about 100 times. The SpaceX company, which now commands the most powerful rocket, Falcon Heavy, is busy developing an even larger craft, the Big Falcon Rocket (BFR), that will be a combination of a booster rocket and a spacecraft along the lines of the pensioned off space shuttle.

Engines are improved

The major difference between the new huge rockets and their predecessor, Saturn V, is the quantity of computer power. The digital revolution has had a major impact on what is possible in connection with modern aerospace activities, particularly when it comes to engine control. When the five powerful F-1 engines of the Saturn V rocket were activated, they more or less continued at the same

Recycling makes space tourism cheaper

Most rockets are made up of several stages, which are detached, as the craft travels into space. The largest, most expensive part of the rocket is the first stage, that might account for some 80 % of the launch price. So far, the expensive rocket stages have been dumped into the ocean after one mission, making aerospace activities so expensive that space tourism has been impossible.

But now, engineers have allowed the rockets to steer safely down the atmosphere and land on a platform to be reused. One of them is the New Shepard rocket that will fly into space and detach a manned capsule. The six paying tourists will experience four minutes in a state of weightlessness and see Earths' bend, before the capsule will once again head towards Earth carried by parachutes. The rocket's first stage will slow down shortly before contact with Earth, landing softly to be readied for a new launch.

In 2015, New Shepard was the first rocket to land on Earth after a space mission.

A ring equipped with **braking fins** unfolds, as the capsule above it is detached from the rocket in space.

At the bottom, you will find the **control fins**. They are controlled by computers, which adjust the fins' orientation several time a second on the way down the atmosphere.

BLUE ORIGIN

CANDIDATE

NEW GLENN

The Blue Origin company is developing the huge New Glenn rocket, which is to fly tourists into space and launch satellites into orbit as from 2020. New Glenn is much more energy-efficient than Saturn V and can lift some 45 t into an orbit around Earth. The rocket's first stage will be reused about 100 times.

force, until the tanks were empty. Falcon Heavy's 27 engines can vary their intensity via digital control. As soon as the rocket has lifted off from the ground, the main rocket's nine innermost engines are turned down to save fuel, until the craft reaches an altitude, where lower atmospheric pressure means that the energy of the fuel is better utilized.

3D printing makes rockets sturdy

Improved fuel and more powerful engines that are able to send rockets on ever longer missions require construction methods that produce durable rockets.

During launch, NASA's SLS rocket will be subjected to a heavy impact, when accelerated from 0 to almost 30,000 km/h in only eight minutes. At the same time, the temperatures in the interior of the rocket's engines will reach some 5,000 degrees, whereas the exterior hull must be able to resist space temperatures of hundreds of degrees below zero. In recent years, a new welding method and 3D printing of engine parts have made things easier.

Ordinary welding between two plates constitutes structural weaknesses of a rocket hull. It makes the surface uneven and so more subjected to the forces of air drag, making it difficult to guarantee the metal's subsequent strength. But with a new method known as friction stir welding, engineers can obtain wider welding. The welding method is carried out with a fast- rotating cylinder, which moves along the joint, forcing itself against the plates. The friction makes the plates melt, and the circular motion ensures an even distribution of the molten mass. In this way, you get a wide, transitional link between the two plates, which almost become one, as the welding hardens.

In other cases, engineers have managed to eliminate the need to weld by means of 3D printing. 3D printers have the advantage that that they can produce one-piece parts of the rocket with very high structural strength. In December 2017, NASA tested an engine with a 3D printed pogo accumulator, i.e. a sphere-shaped, hollow device that absorbs the impact occurring, when fuel flows through the engine under high pressure. The accumulator reduces the pogo effect, which is a hazardous phenomenon, that occurs when the vibrations become self-perpetuating. At worst, the pogo effect could tear the entire rocket apart. The 3D printed engine part functioned wery well, and NASA aims to take a closer look at which other parts can be made using a 3D printer.

Recycling causes rocket mania

Falcon Heavy's historical test launch proved that rocket engineers have come much further since the heyday of Saturn V. It was clear, when the rocket's first three stages landed synchronically and vertically on the ground after having launched the load into space; a feat that seemed impossible just a few years ago. Rocket recycling finally allows private companies to offer tourist missions into space that people can afford. The Blue Origin company is fine-tuning a rocket that can launch a small capsule with six passengers into space, and the first tickets will be put up for sale already next year. SCI

Powerful rockets assemble lunar station

Over the next decade, the space agencies behind the International Space Station will begin the so far most ambitious construction project in space: a space station orbiting the Moon, which will be a stepping stone for expeditions going further into space. With modules that weigh some 10,000 kg, it will be a mission that can only be handled by the most powerful rocket in world history.

MIKKEL JUUL JENSEN

CANDIDATE

NASA

SPACE LAUNCH SYSTEM

On its third mission in 2023, NASA's Space Launch System will begin the construction of the lunar station, when it launches the 10 t living module into an orbit around the Moon. The construction continues with a logistics module launched in 2025 and an air lock module in 2026.

FEDERATSIYA

ORION

LIVING MODULES

Two crafts can visit

The docking stations have been adjusted to fit the Russian craft for manned missions in space, and to fit NASA's Orion craft.

Ion engines hold station in position

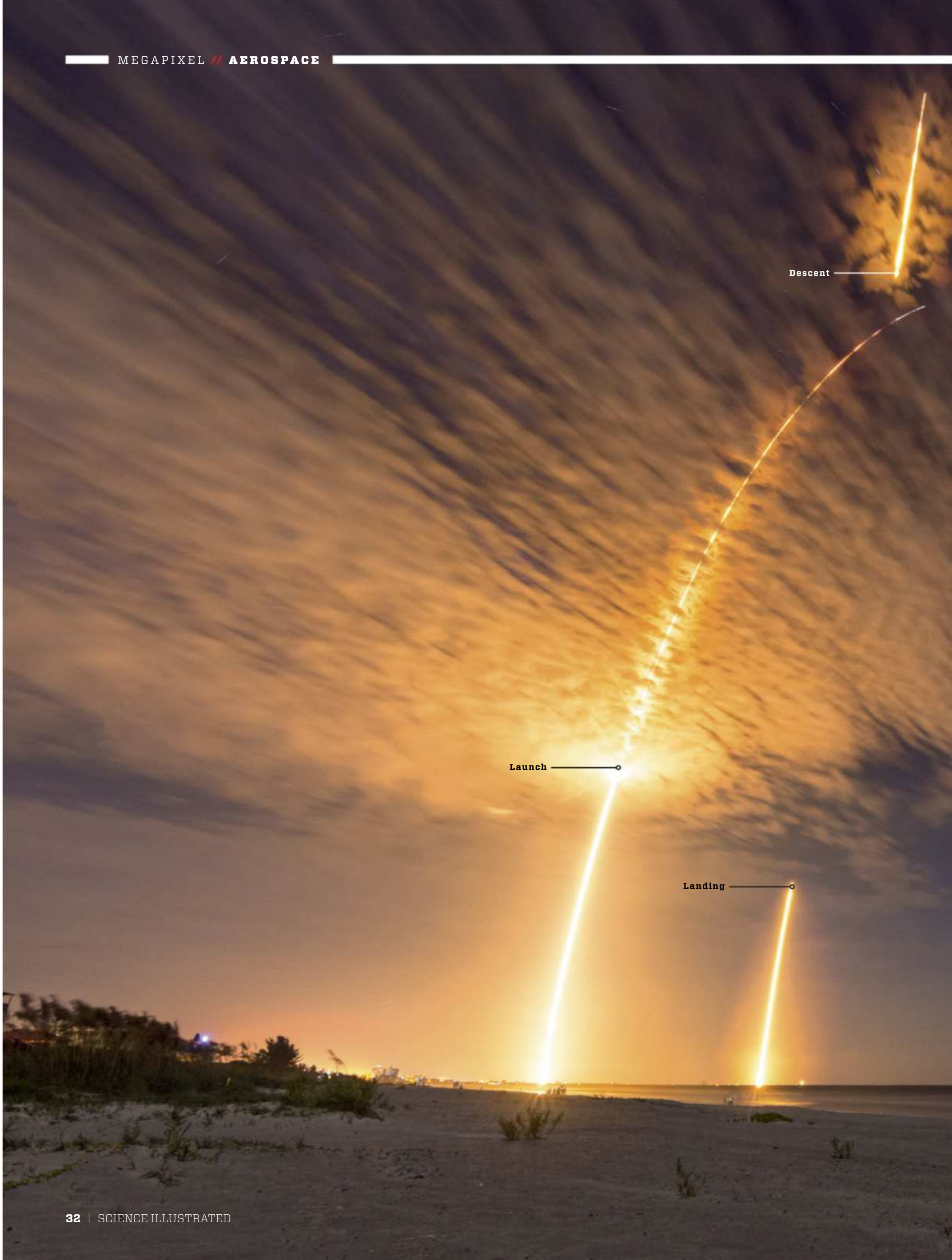
The Power and Propulsion Element module is equipped with ion engines. By means of electricity generated by solar panels, the engines fire ions into space, pushing the station and allowing it to make simple manoeuvres.

Not much space

The living modules will be cramped with an internal diameter of 4.5 m and room for six people at a time.

Air lock allows walks in space

An air lock enables astronauts to move onto the outside of the station, if repair, etc., is necessary.


Descent
Launch
Landing

Reusable rocket returns to Earth

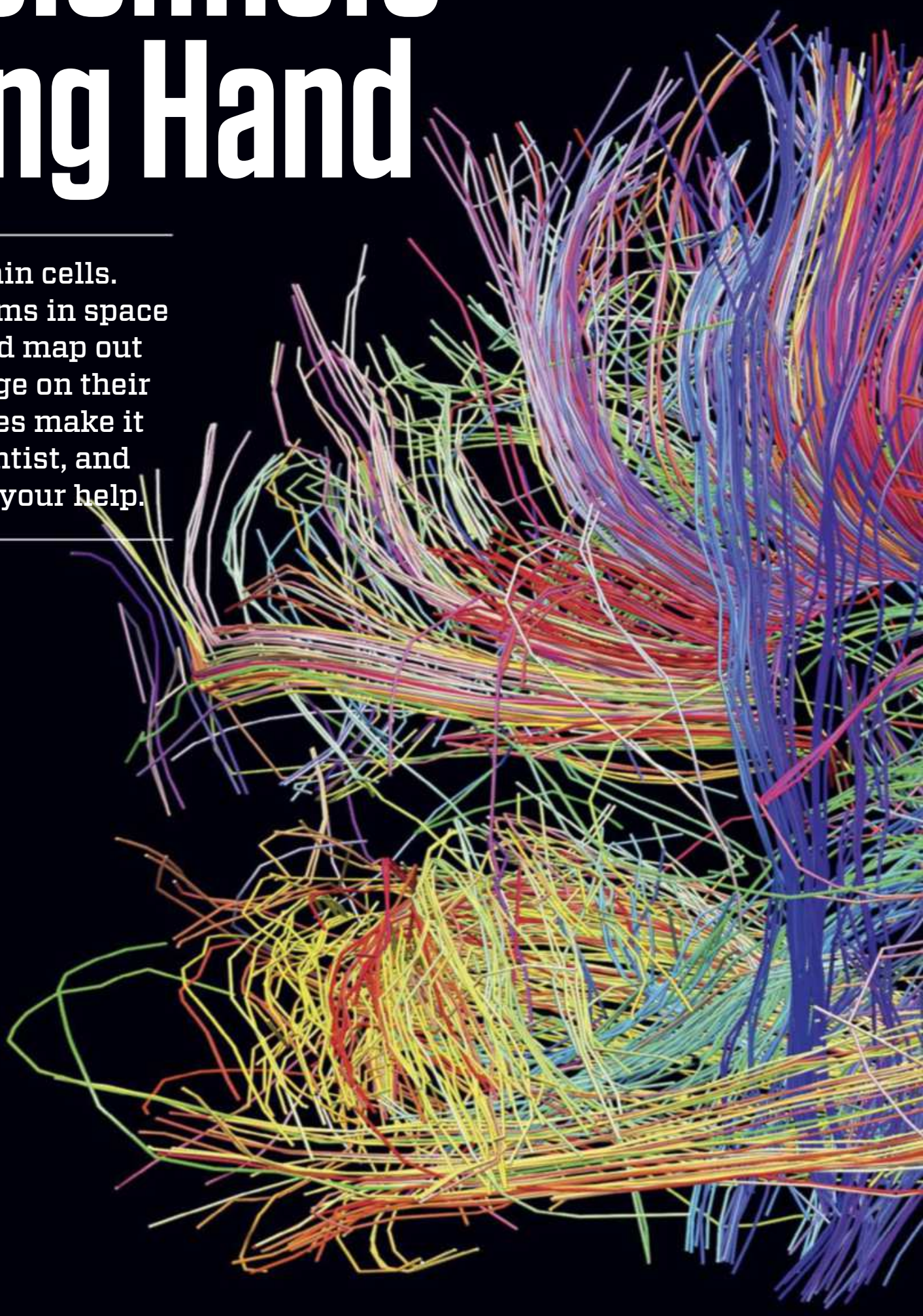
Falcon 9 from SpaceX is the first major rocket to land safely on Earth again after launch. The spacecraft is a two-stage rocket, of which one stage – the main section – can be reused. The image is a combination of three different photos taken with long shutter speeds during launch, descent, and landing near Cape Canaveral, Florida. The final version of the Falcon 9 rocket – Block 5 – was launched in May 2018. Its mission was to carry the world's largest communication satellite of 7,076 kg into space.

Photo // John Kraus

Spend your holiday in the service of science

Lend Scientists a Helping Hand

Draw links between brain cells. Find newborn solar systems in space images. Or count birds and map out the effect of climate change on their migration. Apps and games make it fun to be an amateur scientist, and real scientists depend on your help.



The EyeWire project is a game, in which you score points by painting links between brain cells.

COURTESY OF THE USC LABORATORY OF NEURO IMAGING AND ATHINOULA A. MARTINOS CENTER FOR BIOMEDICAL IMAGING, CONSORTIUM OF THE HUMAN CONNECTOME PROJECT – WWW.HUMANCONNECTOMEPROJECT.ORG

By **Gorm Palmgren**

Choose who you want to help:

ASTRONOMERS AND PHYSICISTS

- Search for new solar systems
- Move liquid and solve quantum problems
- Map out light contamination with your phone
- Find the next Higgs boson

DOCTORS

- Paint the brain's neurons in 3D
- Guess people's age and teach scientists about ageing
- Solve the mystery of cancer in your sleep

BIOLOGISTS

- Count birds and map out climate change
- Identify penguins in photos from Antarctica
- Fold proteins and develop new drugs
- Measure water quality with your phone

THE WISE SPACE TELESCOPE HAS PHOTOGRAPHED NEW SOLAR SYSTEMS.

A disc of dust and gas is condensing into asteroids and planets in a new solar system.

NASA & SHUTTERSTOCK

STUDY IMAGES:

Try to identify new solar systems

NASA would like help to find new stars in millions of telescope pictures.

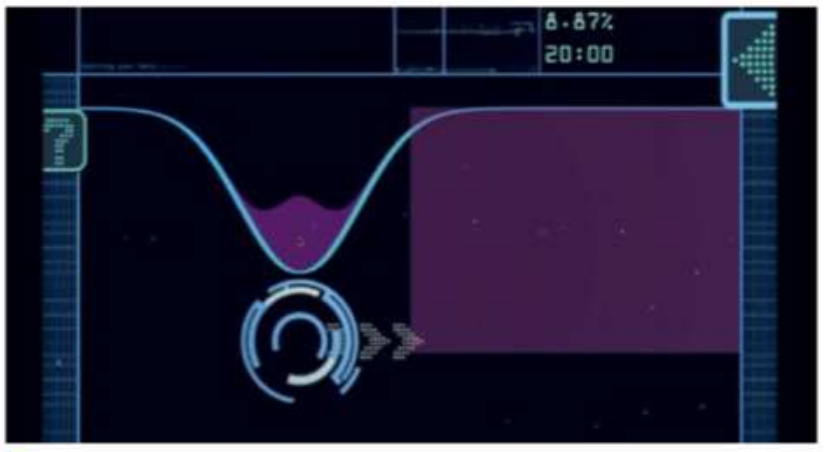
Solar systems form from huge clouds of gas and dust rotating new stars in the shape of flat discs. In an effort to find young stars, NASA in 2009 launched the WISE space telescope. The telescope's infrared cameras have taken millions of pictures of unknown objects. Some of them could be new solar systems. Others are galaxies, asteroids, or clouds of dust. Computers are not particularly good at telling the objects apart, so NASA needs amateur scientists to analyse the images. More than 30,000 people participate in the project, which identified the HD 74389 solar system: a star with an accompanying white dwarf 360 light years away.

PHYSICISTS

Move liquid and solve quantum problems

PLAY: According to quantum physics, a particle is in several different places at a time, and the odd quality can be used to create a quantum computer which is much faster than an ordinary computer. However, that requires such extensive calculations that modern computeres cannot handle the task. Instead, physicists from the Aarhus University in Denmark have developed the Quantum Moves game, in which you help scientists calculate the positions of atoms by moving liquid from one container to the next.

SCIENCE AT HOME

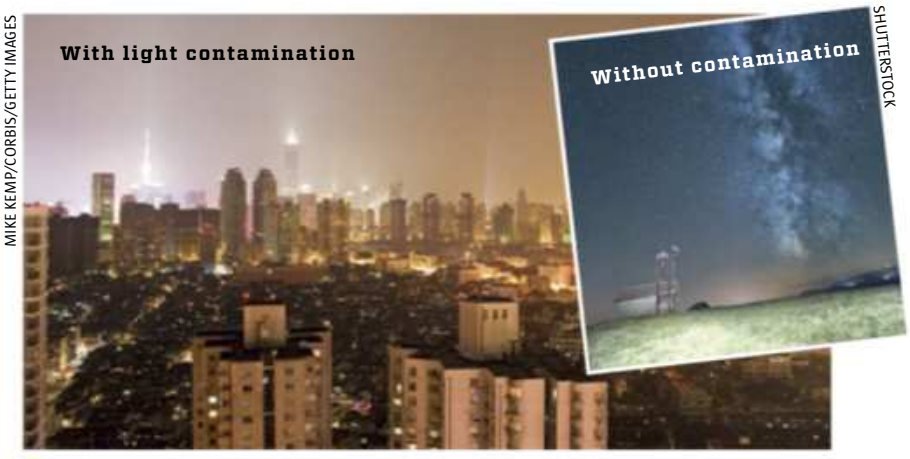


GET STARTED: scienceathome.org

Use your phone to map out light contamination

TAKE PHOTOS: Artificial light makes it hard to see stars in many places. The light is not only a problem for stargazers, rather also for many animals. The “Loss of the Night” research project maps out and compares light contamination with the behaviour of fish, birds, and bats. You only need to download an app and aim your phone at the night sky to make the app count the number of visible stars in the spot where you are and send the information to scientists along with the GPS coordinates.

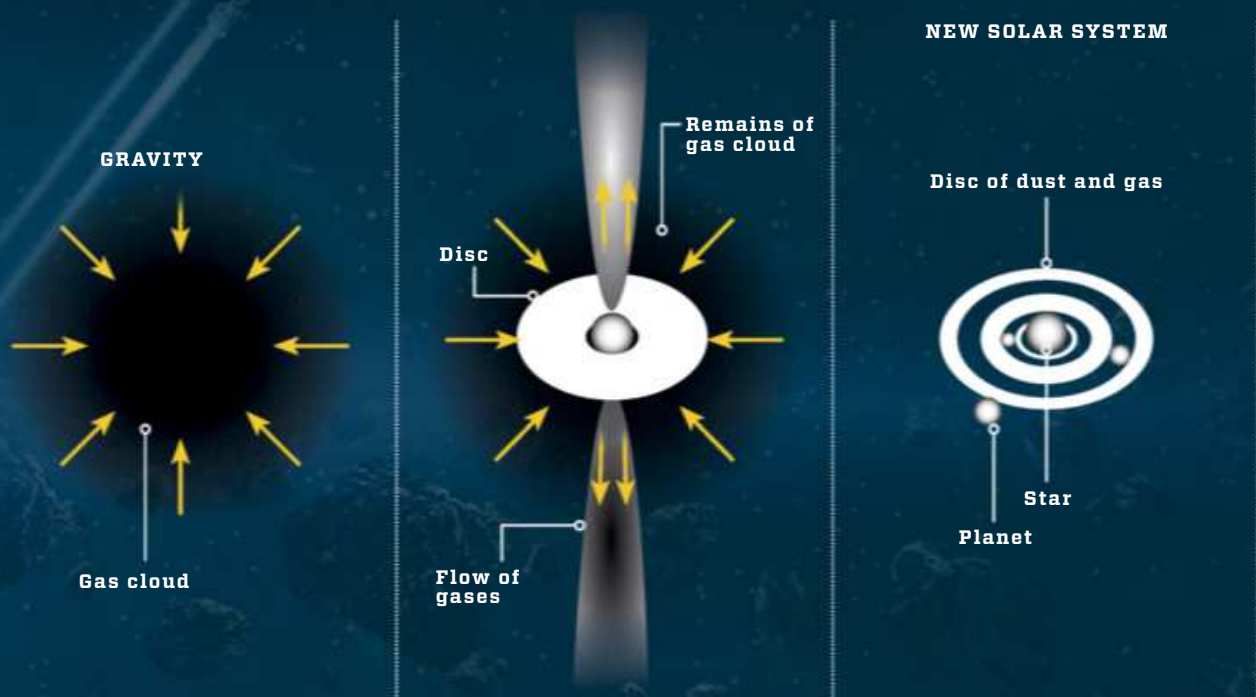
MIKE KEMP/CORBIS/GETTY IMAGES



SHUTTERSTOCK

GET STARTED: Download the Loss of the Night app.

NEW SOLAR SYSTEM FORMS FROM HUGE GAS CLOUD



Gas cloud produces molecules

1 The plasma of the universe, condenses in a cloud with a diameter of hundreds of thousands times the distance from Earth to the Sun. Gravity produces molecules of particularly hydrogen.

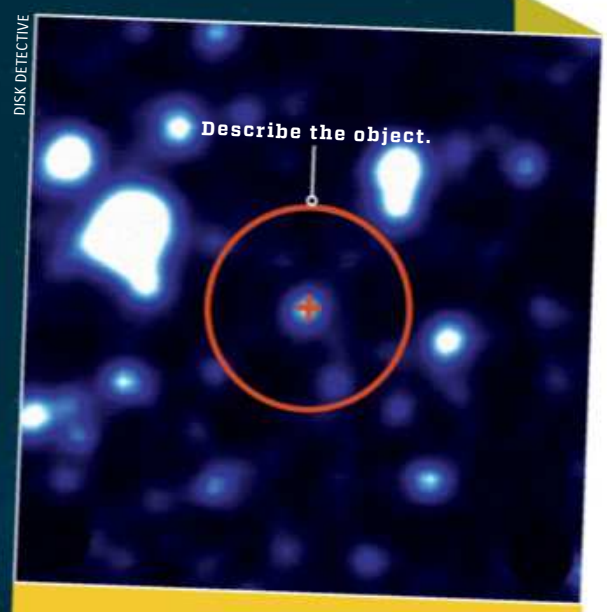
Gas cloud collapses into a star

2 Over 10-100,000 years, the cloud collapses under its own weight into a protostar surrounded by a rotating disc. The star absorbs material and makes gases flow out from the poles.

Disc of dust and gas becomes planets

3 The protostar and its rotating disc continue to attract molecules, until the gas cloud is completely gone. Over 350 million years, dust and gas in the disc condense into planets and other objects.

DISK DETECTIVE



What to do

You will be introduced to about 10 images of a shining object taken by several telescopes and at several different infrared wavelengths. Take a good look at the images and click to say if there is more than one object, whether it is completely circular, or if it is located at the centre of the picture. NASA uses the data to identify new solar systems.

GET STARTED: diskdetective.org

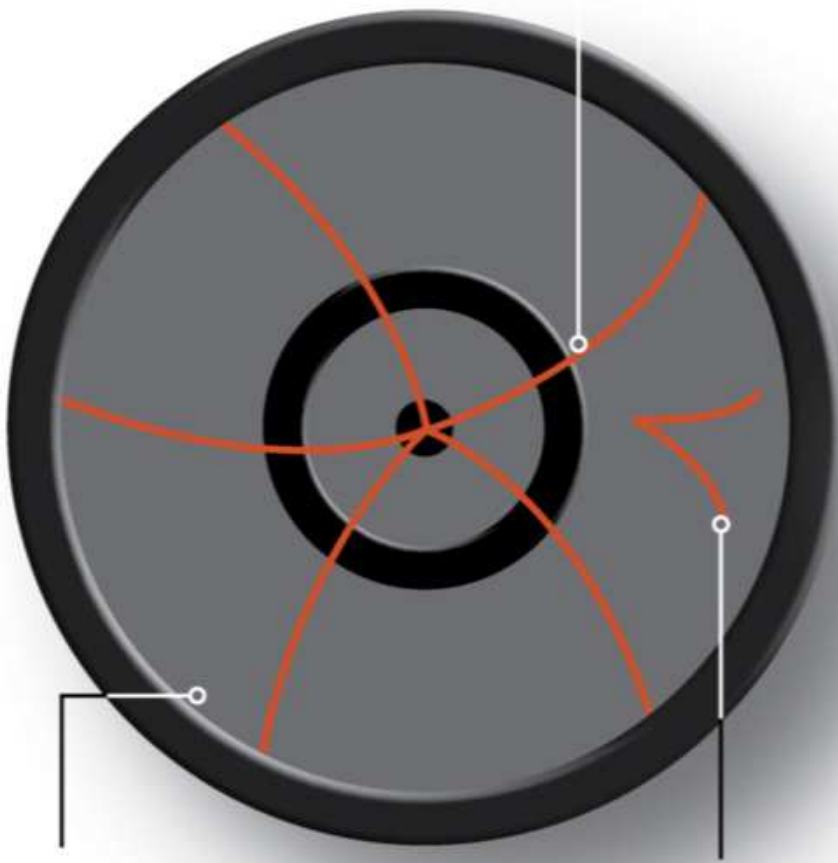
Find the next Higgs boson

The particle collisions in the LHC accelerator appear as lines in a circle. Find the lines that could be an indication of the next Higgs boson.

FIND LINES: The Higgs boson is an elementary particle that provides atoms with mass. The particle's existence has been predicted theoretically, but it has only been observed twice, so physicists are still searching for it in the LHC particle accelerator. There, protons and atomic nuclei collide at speeds close to that of light, so they are smashed into elementary particles. When charged particles affect the electrons of the surrounding atoms, it is registered in the ATLAS detector, which draws the particle paths as lines in a circle. Most lines radiate from the centre, but the problem is to find the lines that apparear at the sides. The off-centre vertices show that an uncharged particle decayed into a charged particle, perhaps indicating a Higgs boson..

GET STARTED: www.higgshunters.org

The paths of charged particles are shown as lines from the centre.



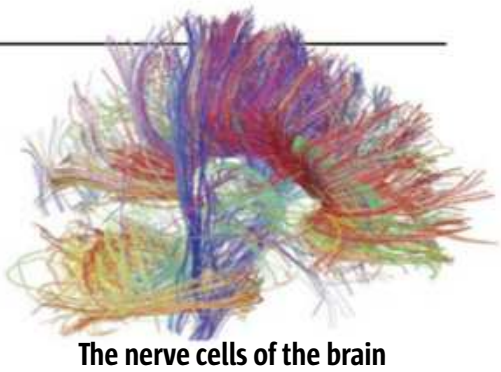
The detector registers particle collisions.

Lines on the periphery might indicate a Higgs boson.

The ATLAS detector registers proton collisions.

CERN

Paint brain neurons in 3D

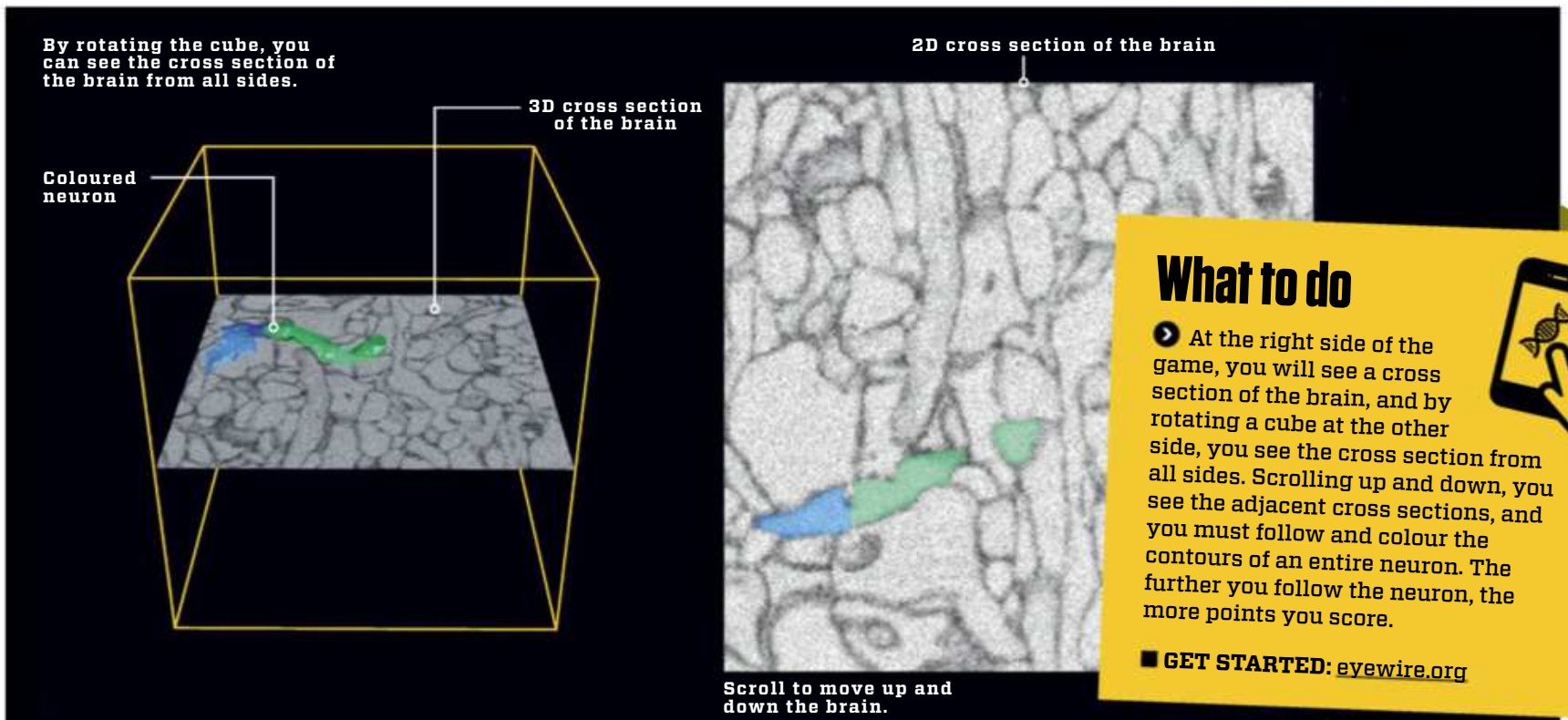


The nerve cells of the brain make up a network with billions of links.

WWW.HUMANCONNECTOMEPROJECT.ORG

Follow the winding path of a nerve cell through the brain and help scientists comb out the complex network of links.

PLAY: The human brain consists of some 100 billion neurons – or nerve cells – that ramify in a network of billions of links. Mapping out all neurons is a huge project, and consequently, scientists have scanned an entire sliced brain at a high resolution and developed a game, in which you have to colour the neurons. More than 250,000 people have played the game, and their results have been used to map out the nerve links of vision.



EYEWIRE.ORG

What to do

At the right side of the game, you will see a cross section of the brain, and by rotating a cube at the other side, you see the cross section from all sides. Scrolling up and down, you see the adjacent cross sections, and you must follow and colour the contours of an entire neuron. The further you follow the neuron, the more points you score.

GET STARTED: eyewire.org

DOCTORS

Guess people's age and teach scientists about ageing

PLAY: Age leaves its marks, but do we age gradually throughout life, or are some periods different from others? That is one of the questions which the scientists behind the AgeGuess online game would like to answer. You can upload pictures of yourself from different times in your life and try to guess the age of other people. Based on the results, scientists also hope to find out whether your appearance ages more slowly, as life expectancy rates increase.

SHUTTERSTOCK

GET STARTED: ageguess.org

Combat cancer in your sleep

SHARE YOUR CALCULATING POWER: Doctors want to be able to spot cancer as early as possible. By comparing all likely indicators, such as proteins that change shape or whose numbers increase/decrease, in patients and healthy people, they aim to identify the markers of cancer. This requires a lot of computer power, so the research project gets assistance from IBM's World Community Grid. 650,000 volunteers have donated the calculation power of their computers to scientists working with cancer, HIV, tropical diseases, etc. You choose which scientists to support, when you are not using the computer yourself.

WORLD COMMUNITY GRID

GET STARTED: worldcommunitygrid.org

Amateur scientists make major discoveries

Scientists use citizen science projects to collect and process large quantities of data with the help of ordinary people. Amateur scientists have found heavenly bodies and archaeological treasures.

NASA/ESA & HANNYSVOORWERP.COM

TEACHER FINDS MYSTERIOUS GREEN BLOB IN THE SKY

When she participated in the Galaxy Zoo citizen science project, Dutch teacher Hanny van Arkel discovered a mysterious green blob in a telescope image. The unknown phenomenon has been named Hanny's object. Probably, the blob is the remains of a galaxy affected by radiation from a quasar in the neighbouring galaxy.

ELFIEHALL & CHRISTINE GABRIELSE

NIGHT WALKERS SEE A BRAND NEW TYPE OF AURORA

A group of Canadians participated in the Aurorasaurus project, and when they saw a purple arc above the horizon, they knew it was no ordinary aurora. They named the discovery "Steve", and scientists now know that it occurs, when warm, electrically charged particles hit a special part of Earth's magnetic field.

NASA

STARGAZER IDENTIFIES FLASHING STAR

The participants of the Planet Hunters project study pictures from the Kepler space telescope. Adam Szewczyk of Canada found a star that flashes, as if something sometimes blocks out its light. The star, which was later named KIC 8462852, is the subject of intense studies to find the cause of the dimming.

STEFAN SAUER/DPA/RITZAU SCANPIX

SCHOOLBOY STUMBLES OVER VALUABLE VIKING TREASURE

Using a metal detector, 13-year-old amateur archaeologist Luca Malaschnitschenko found three silver conins from the 900s in a field on the island of Rügen, Germany. Archaeologists excavated some 600 silver coins, neck rings, Thor's hammers, and other jewellery that might have belonged to Danish King Harald Bluetooth.

13-year-old Luca found three Viking silver coins that formed part of a major treasure.

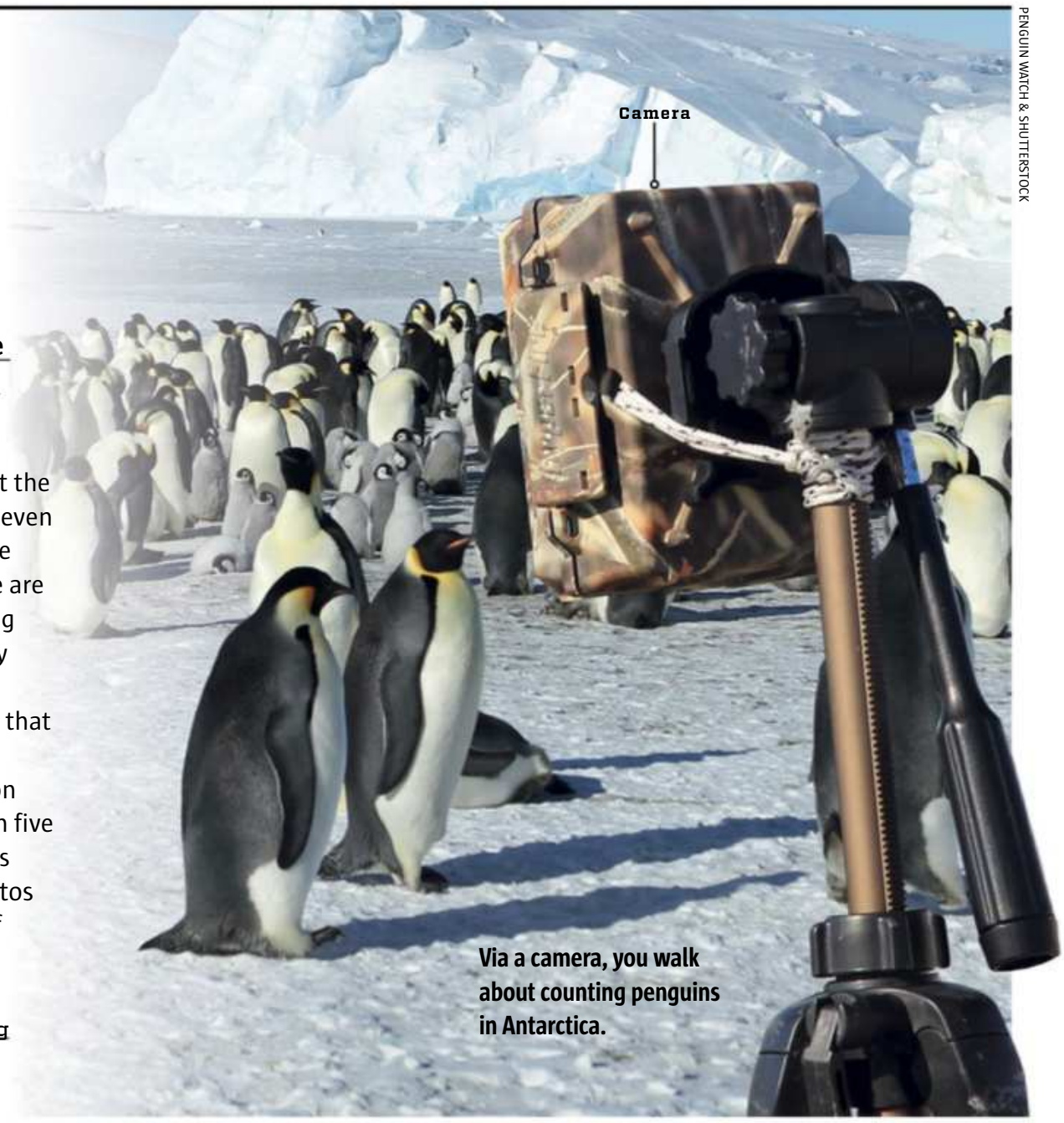
STEFAN SAUER/DPA/RITZAU SCANPIX

Spot the penguins in photos from Antarctica

Automatic cameras photograph the penguins of Antarctica. Count how many you can see in the pictures.

LOOK AT PHOTOS: Penguins are at the top of the food chain in Antarctica, so even minor population changes have a huge impact on the entire ecosystem. There are not many bird-watchers on the freezing cold continent, so scientists know very little about their numbers. A team of international scientists aim to change that via the Penguin Watch citizen science project. They have installed cameras on more than 100 deserted locations with five different penguin species. The cameras have taken more than six million photos so far. You must count the number of adult penguins, babies, and eggs.

GET STARTED: www.penguinwatch.org

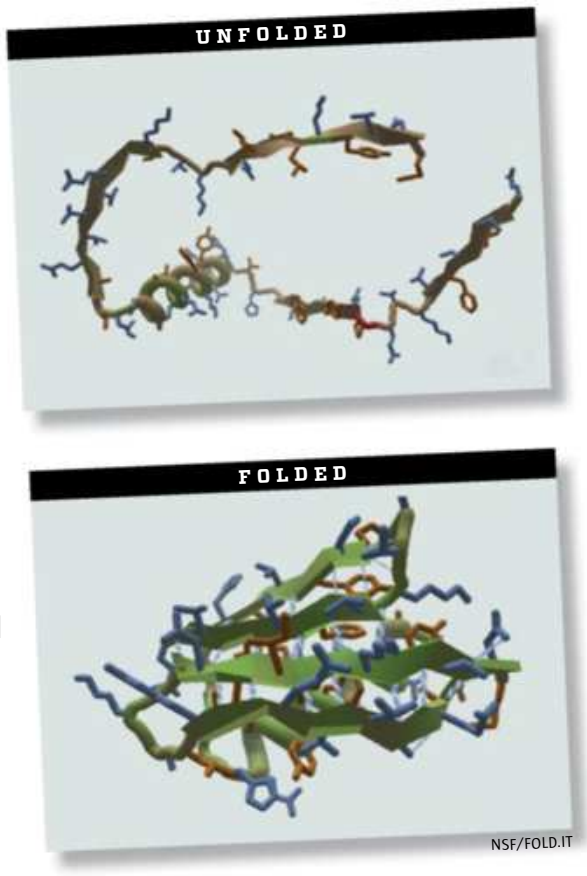


PENGUIN WATCH & SHUTTERSTOCK

Via a camera, you walk about counting penguins in Antarctica.

Fold proteins and develop new drugs

PLAY: Proteins are biological machines that can make muscles contract. They are made up of folded chains of molecules, and the foldings are vital for their functions. However, scientists have difficulties predicting how they fold in the body, so American scientists have developed the Foldit online game, in which you must fold proteins in 3D. You score points, when you find the most harmonic folds, in which molecules' attraction and rejection is balanced. The Foldit project has helped scientists develop new drugs.



NSF/FOLD.IT

GET STARTED: fold.it

EYEONWATER.ORG

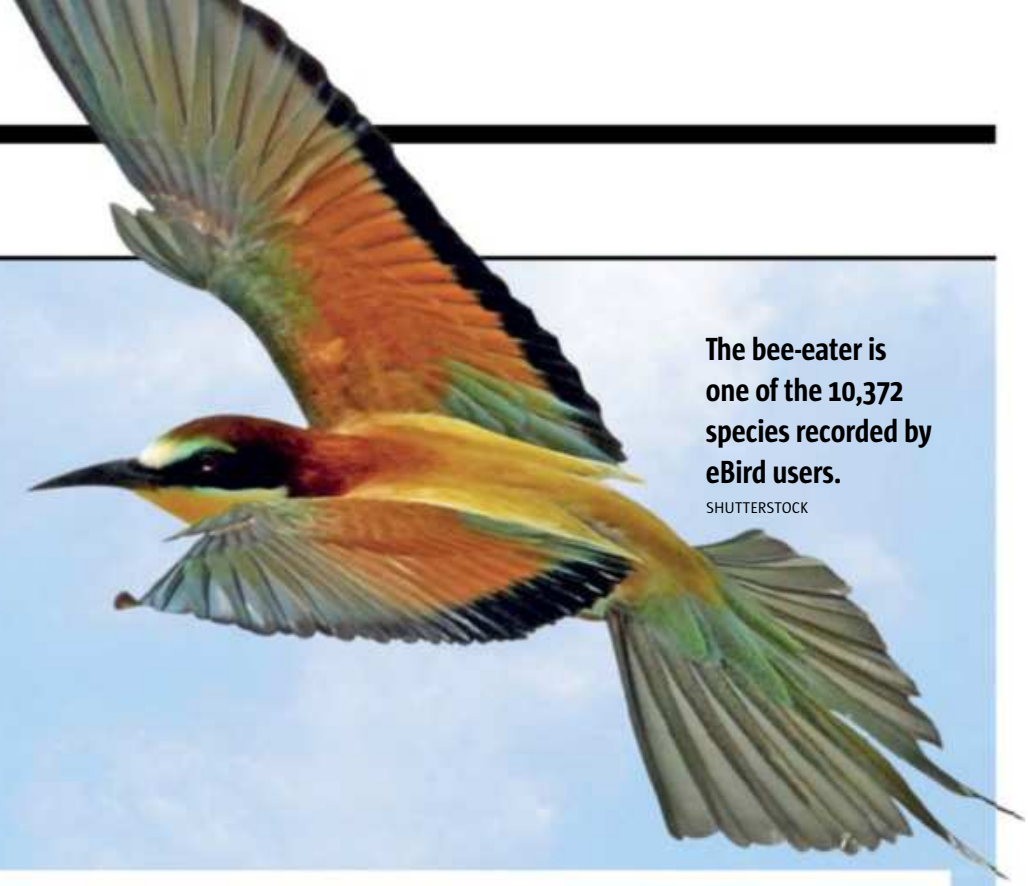
The water colour reveals whether oceans and streams are of low food value or full of algae.

Measure water quality with your phone

TAKE PHOTOS: The colour of the water allows a very accurate impression of the water quality of oceans, lakes, and streams. Bluish water is typically clean, whereas greenish water has more algae. In order to collect global water quality data, German and Dutch scientists have developed the EyeOnWater app. You only need to take a picture of the water surface, compare its colour to a colour scale, and upload everything together with the GPS coordinates of your location.

GET STARTED: eyeonwater.org and the EyeOnWater app

Count birds and map out climate change

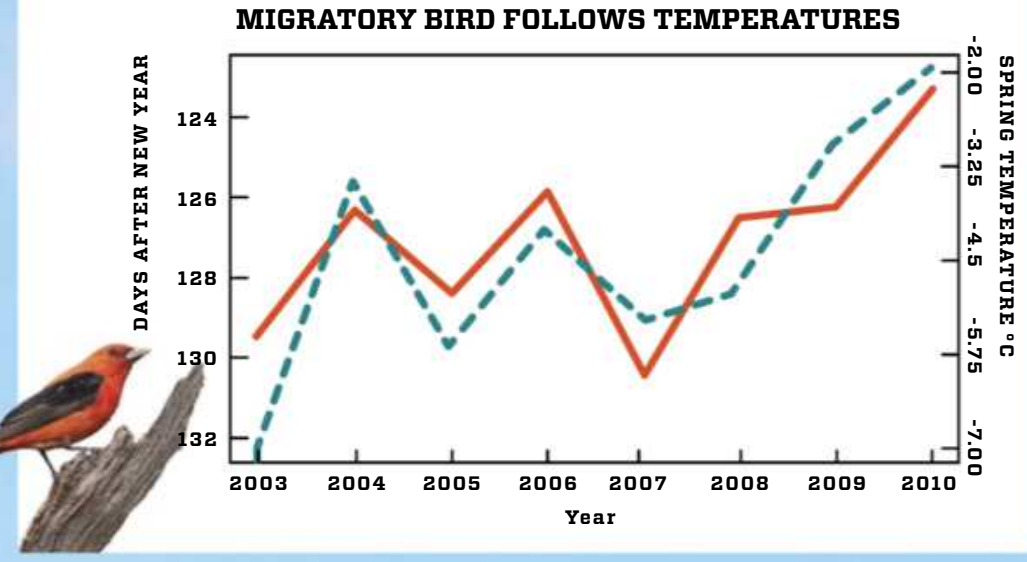


The bee-eater is one of the 10,372 species recorded by eBird users.
SHUTTERSTOCK

Birds migrate throughout the world, and local people are the best counters. Help count via the eBird project.

TAKE A FIELD TRIP: Scientists from the Cornell University in New York state have developed the eBird app, which is one of the most successful citizen scientist projects so far. More than 300,000 participants from all over the world have made more than half a billion observations of 10,372 different bird species. Amateur scientists' recordings show where the birds are, and how many there are at different times of year and day.

The data has helped scientists study bird migration patterns, population changes, and nature conservation projects, and their research has been published in hundreds of scientific articles. US scientists in 2017 used eBird data to predict how climate change will affect bird life. Other scientists have identified the areas in which bird conservation would have the greatest effect.



Birds arrive earlier

■ How are bird migration patterns affected by temperature and climate change? To get the answer, scientists from the University of North Carolina have used data from eBird stating when 18 bird species arrived to the US over a period of 10 years. It turns out that their arrival is determined by temperature. The scarlet tanager songbird has begun to arrive about eight days earlier over seven years, in which temperatures have risen by 3.5 degrees.

ARRIVAL DATE
The bird arrives to the US about eight days earlier than it used to.

TEMPERATURE
During the period, temperatures have risen by about 3.5 degrees.

What to do

› In the app, you enter where you mean to go to watch birds, and you get a list of all the bird species that have been observed in the area, so you can see when it is more likely to encounter individual species, and where the species have been observed. To get the most true and fair image of the population, you must indicate all the birds that you see and not only the interesting species.

■ **GET STARTED:** Get the eBird app.

SHUTTERSTOCK

Doctors are beginning to regard the ageing of the human body as a disease, which might be cured with drugs in the future.
SHUTTERSTOCK/CLAUS LUNAU

By **Jens E. Matthiesen**

CHALLENGE

Some questions are so substantial that they have been a mystery to scientists for centuries. No matter if they ever find the answers, the search for an explanation makes us wiser.

The Eternal Quest for the Fountain of Youth

The idea of the source of youth and eternal life has existed for as long as there have been humans on Earth. Still, it is not until the past 50 years that scientists have begun to discover why we grow old and what can be done about it. In the future, ageing will not be a fact of life, rather it will be considered a disease that can be treated. A miracle cure has not yet been developed, but scientists know where to search.

Have the first humans to live to be 150 years old already been born? Scientists who are working on solving the mystery of ageing disagree. Two American professors, Steven Austad and Jay Olshansky, took a bet in 2000. Austad claimed that the first person to celebrate his 150th birthday had already been born. Olshansky disagreed. The two scientists each placed $150 in a fund, which goes to the heirs of the one who is right. In 2016, none of them had changed their minds, and they decided to place another $300 in the fund. With a good rate of return, there might be a fortune waiting for the winner's heirs.

So far, we have no concrete evidence of a human older than 122 years. The record holder is Jeanne Calment of France, who died in 1997. The record has remained for more than 20 years, which might seem strange, as the world population is growing ever older, so there are lots of candidates to challenge it. Right now, the number of people of 65+ is growing larger than the number of kids below the age of 5 for the very first time in world history, and according to analyses, the trend will continue, i.e. the share of elderly people will keep on rising.

"This theory suggests that we could use chemical methods to prolong life.

AP/RITZAU SCANPIX

DENHAM HARMAN
Ageing researcher and chemist, who in 1956 developed the theory about free radicals causing the ageing process.

According to the WHO's most recent calculations, kids who are born now in the Western World can expect to be 79-83 years old. A decade ago, the numbers were 77-81, meaning that in just ten years, life expectancy has increased by a couple of years.

That is primarily due to the fact that we are becoming ever better at preventing, diagnosing, and treating diseases such as cancer, dementia, and arteriosclerosis. It is still those age-related diseases that most people in our part of the world die of. They just die later than they did a few decades ago.

As treatments are gradually improved, we will add more years to the average life expectancy, but according to some scientists, we are about to reach the upper limit of the life span of the human body. If we would like to live longer than that, we will have to find the fundamental causes of us becoming vulnerable to age-related diseases – i.e. the causes of ageing itself.

Ageing can be explained in many ways

Today, ageing researchers are beginning to consider ageing a disease in itself, against which they aim to find treatments and finally cure it. If they are successful, we will not only get rid of age-related diseases, we will also be able to avoid all the drawbacks of age: loose skin, weak muscles, brittle bones, poorly functioning organs, and failing vision and hearing.

The way to a cure against ageing begins with answering the question of why we get older. This can be addressed in several ways. Generally, some scientists will say that it is a natural and predetermined fact of life. Others will resort to more thorough biological explanations such as that as soon as we have had children and hence passed on our genetic material, there is no reason why we should go on living. Seen from the genetic point of view, it is much more important to be passed on to the next generation than to keep individuals alive, and so, evolution has not given "priority" to developing genes that make us live longer.

And yet others will have a more detailed approach, trying to find explanations in chemical processes in our bodies and cells. This approach is the one that could lead to longer lives for all of us. If the ageing processes can be mapped out down to the biochemical level in our cells, we might also find methods for interfering with the processes.

Mammals die after 1 billion heartbeats

Over the past century, ageing researchers have supported two different theories. According to the first one, our cells were designed for – and perhaps even programmed to – live for a specific period of time, after which they will shut down. According to the other, the unfortunate fact is that life wears down cells, so they will finally stop functioning. They sound like opposites, but both could be correct.

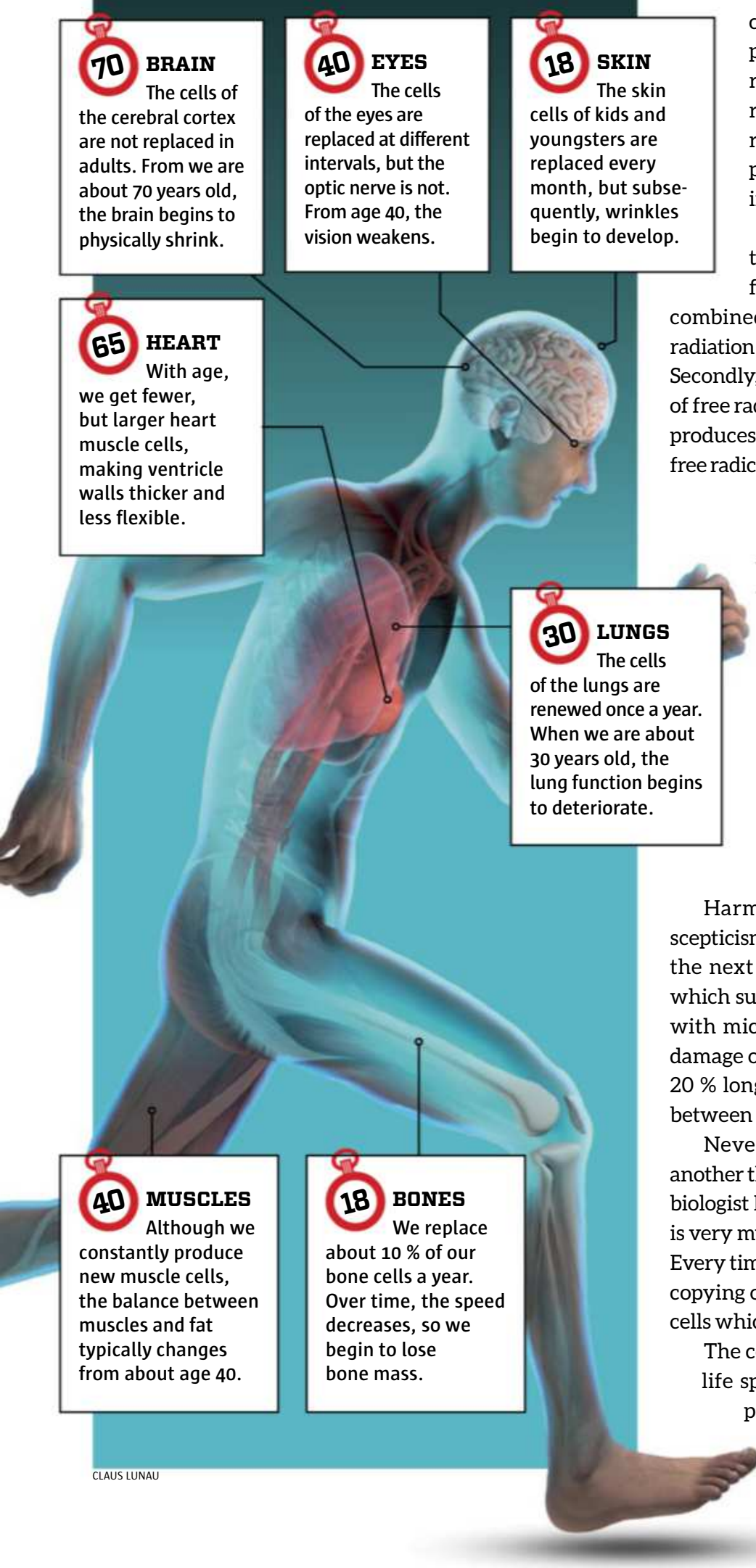
In 1908, German physiologist Max Rubner developed the idea that the life spans of mammals were not to be measured in days, months, and years, but rather in energy conversion. Rubner had discovered that the higher an animal's metabolism is, the more the organism is worn down, and the shorter its life span is. The recognition made him think of using the pulse rate as a measure of metabolism and so as the factor that determines life spans. He calculated that life ends after about one billion heartbeats, no matter if you are a hamster, a horse, or an elephant. Small mammals typically have higher pulse rates at rest than large animals, and so, hamsters have shorter lives – only three years as compared to elephants, who can grow up to 70 years old.

Rubner might have been inspired by what was happening around him. The industrialization swept across Europe, and it was obvious to compare the body to a machine. When a machine works fast, converting a lot of energy as compared to its size, it will wear down quicly and break down. Perhaps the exact same thing was the case for a biological system such as an animal body.

A human life typically lasts for more heartbeats than the lives of other mammals. On his/her 75th birthday, a human being has reached about 2.5 billion heartbeats, so the body or "machine" apparently tolerates more wear than that of animals. Still, Rubner's general idea that ageing is basically wear, that depends on the body's energy conversion, comes quite close to several modern interpretations of ageing. That is not least so for the theory that says that ageing is due to the accumulation of waste products in the cells. This theory was introduced 50 years after Rubner's ideas about heartbeats determining life spans. Its "father" was American chemist and physician Denham Harman, who later became a major

The body loses the race against time

Children and young people produce new cells all the time, keeping the organs in top shape. Later in life, the production of new cells can no longer follow suit, and the organs start to deteriorate. The process begins around the age of 18.



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player in ageing research. He began to research the ageing processes of the body by coincidence. In his early career, he carried out studies supported by the American armed forces. World War II had ended with the terrifying nuclear bombs dropped on Hiroshima and Nagasaki, and the nulear arms race of the Cold War had begun. The US authorities would like to learn more about how radioactive radiation could harm the cells of the body, and whether there was any way to prevent it. Harman worked as a chemist for the Shell oil company, researching how special oxygen compounds known as free radicals behave in oil products. Other scientists had discovered that free radicals also emerged in cells that were subjected to radiation, and that aroused Harman's interest. He realized that if he were to understand the biological processes in detpth, he needed more education, and in 1954, he had also become a doctor.

Harman was now ready to look into the idea that was to lead to a new theory about ageing. He followed a logical line of thought, by which he combined three observations. First of all, he knew that radiation seemed to boost the body's visible signs of ageing. Secondly, he knew that radiation produces large quantities of free radicals in cells. And thirdly, he knew that a cell also produces free radicals under normal circumstances, as the free radicals are a residual product of cell energy production.

Aggressive substances attack DNA

Free radicals are vere chemically active and easily combine with other molecules, and so, Harman imagined that they could harm important structures in cells, including the cells' DNA. He introduced his theory in a scientific article in 1956 – only three years after Nobel Prize laureates James Watson and Francis Crick solved the mystery of the structure of the DNA molecule. Harman fully realized the consequences. In the article, he writes:

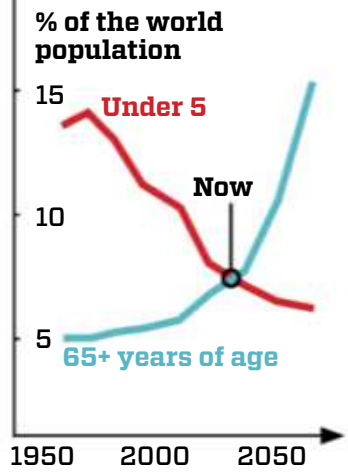
"This theory suggests that we could use chemical methods to prolong life."

Harman's theory was received with a mixture of scepticism and indifference in spite of the fact that already the next year, he published the results of experiments, which supported it. Harman had carried out experiments with mice, which he fed antioxidants, that prevent the damage of free radicals. The result was that the mice lived 20 % longer and so, Harman proved a clear relationship between free radicals and ageing.

Nevertheless, his research was overshadowed by another theory, which was introduced in 1959 by American biologist Howard J. Curtis. According to the theory, ageing is very much due to the accumulation of mutations in cells. Every time a cell divides, errors could result concerning the copying of its DNA, and such errors might finally produce cells which function poorly or not at all.

The consequence of this theory is that the limit to our life spans is somehow genetic. The theory was very popular in the years after Curtis introduced it, but since then, it has lost ground, as scientists ▶

The world population is getting ever older. Right now, the number of people of 65+ years is exceeding the number of children under 5. According to WHO projections, the trend will continue.



have discovered a series of mechanisms in our cells that allow them to repair DNA strands. When an error develops in the DNA of a cell, it is not necessarily passed on, when the cell divides.

Cell power stations are under fire

In 1972, Harman refined his theory about free radicals, focusing on cell mitochondria, i.e. cells' integrated power stations that generate energy for all cell functions. Harman knew that free radicals would primarily hurt a cell close to the place where it is formed, so it was logical to look at the mitochondria, which are responsible for the energy conversion in cells and so for the production of the harmful free radicals.

This turned out to be a good idea. Over the decades, numerous studies have confirmed that ageing is linked with the function of the mitochondria. In 2014, scientists from the SDU university in Denmark introduced a study, in which they had scrutinized the mitochondria of the blood cells of about 1,000 test subjects. Mitochondria contain their own DNA in the shape of tiny, ring-shaped structures, and the scientists simply counted how many DNA rings the test subjects had in the mitochondria of their blood cells. The first counts were carried out in 1997 and 1998, and the scientists could see that in people of 50+, the number determined the results of different physical and mental tests.

“We control how we age – all the way down to the interior of our cells.

SALK INSTITUTE

ELIZABETH BLACKBURN
Professor Emeritus. She was awarded the Nobel Prize for the discovery of the telomerase immortality enzyme.

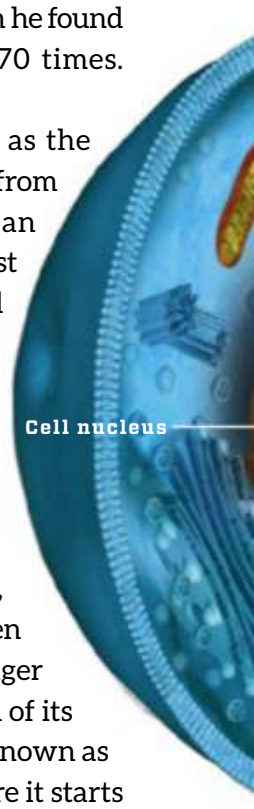
The test subjects with the poorest grip strength and ditto working memories were also the ones with the fewest DNA rings in the mitochondria. And when the scientists followed up on the study in 2012, they could see that the test subjects with the fewest DNA rings generally died earlier than the ones who had more copies.

Studies such as this one indicate that the function of the mitochondria is important for ageing, and it is reasonable to imagine that the DNA of the mitochondria is particularly subjected to being harmed by free radicals, as Harman predicted. Moreover, it opens wide perspectives that apparently, individuals do not lose DNA in their mitochondria at the same speed. If scientists find out why this is so, they might also be able to find a way to prevent or postpone the loss.

Consequently, Harman was one of the pioneers of the line of thought that ageing is not necessarily an inevitable process. Ageing is a disease that can be combated, if we find the right means to do it. Still, Harman believed that people can only live for a limited number of years. He doubted that life expectancy would ever come to exceed 85 years. He himself died in 2014 at the age of 98. Both physically and mentally, he remained active very late in life. He went for a run every day until he was 82, and he continued even longer as an unpaid scientist of the University of Nebraska.

At the same time as Harman got onto the theory of the free radicals, another American scientist made a discovery that led to another major breakthrough. At the Wistar Institute in Philadelphia, USA, a young anatomist by the name of Leonard Hayflick in 1961 carried out studies of human cells. His cultivated his cell cultures in culture dishes, which he observed over long periods of time. That should not have been a problem, as at the time, it was commonly accepted that in principle, cells were immortal, if they were cultivated in culture dishes under optimum conditions. So, Hayflick was surprised that some of his cell cultures seemed to lose breath. The cells simply stopped dividing. Hayflick was sure that he took well care of his cultures, but nevertheless studied his notes to see if there was something that the poorly-functioning cell cultures might have in common. There was. They were all about the same age. Hayflick immediately thought that there might still be a limit to how many times a cell can divide. Together with a colleague, he made follow-up experiments, in which he found out that ordinary body cells only divide 50-70 times. Subsequently, they “retire”.

The retirement age of cells is now known as the Hayflick limit, but another 10 years were to pass from his discovery, until scientists came closer to an explanation. It happened, when Russian biologist Alexey Olovnikov discovered that when a cell divides, it does not copy the full length of its DNA strands. The hereditary material of the cell nucleus is united in the chromosomes in the shape of rolled-up DNA strands. At the end of the chromosomes, you will find a number of DNA sequences known as telomeres, which become slightly shorter for every cell division. Finally, when the Hayflick limit of 50-70 divisions has been reached, the most recent generation will no longer divide. The reason why the cell does not copy all of its DNA strand is that its integral DNA copier, also known as polymerase, moves slightly into the strand, before it starts copying, and so, everything is not included. That might seem inconvenient, but like so many other things in nature, it still makes sense.



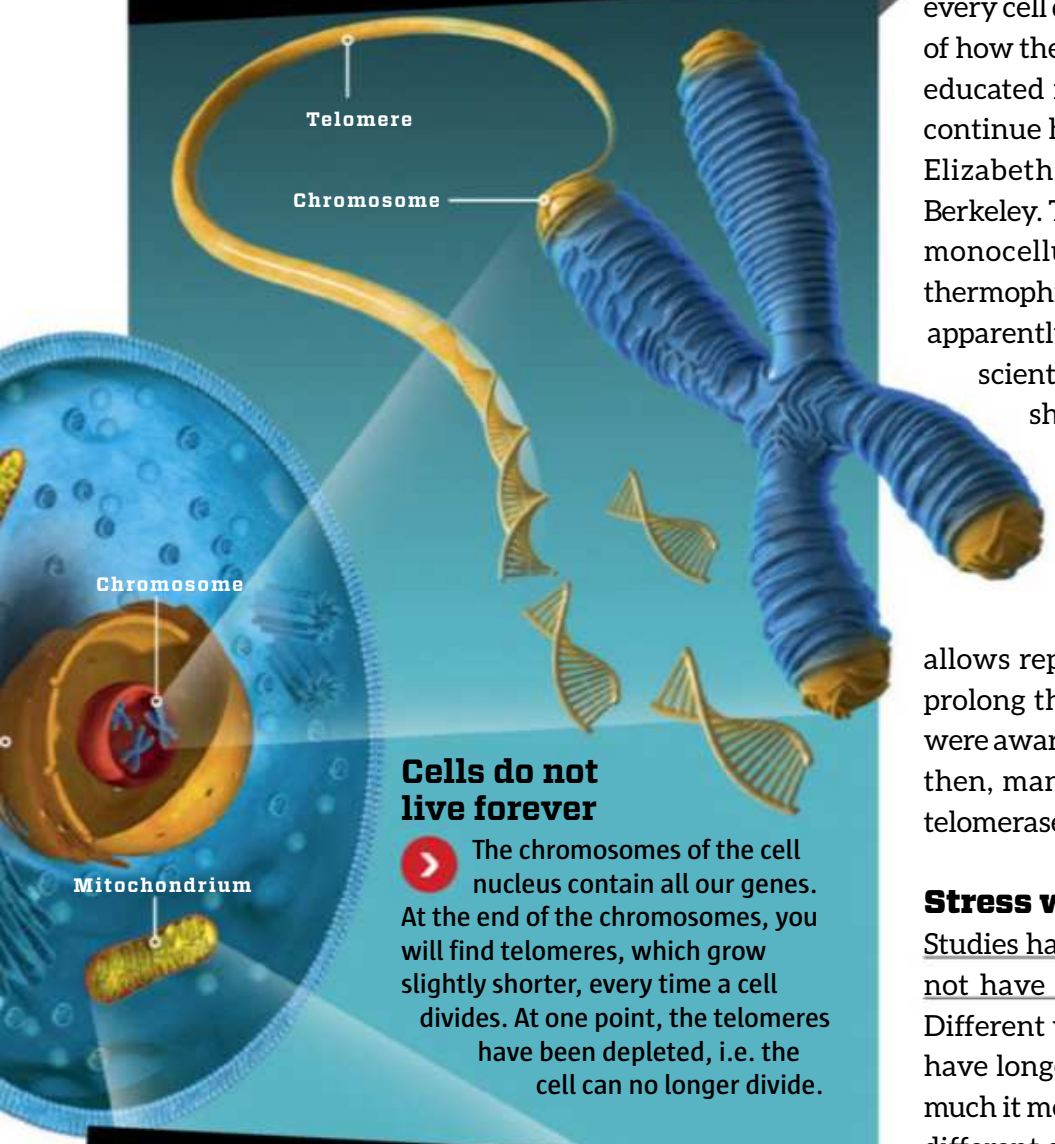
Cell expiry date protects against cancer

The task of the telomeres is to protect the genetic contents of a chromosome’s DNA strand. They can be compared to the small "cuffs" of plastic by the ends of shoelaces, which make sure that the laces do not become frayed. Without the telomeres, the ends of the chromosomes become sticky, meaning that there is a risk that they will connect with the ends of other chromosomes, causing chaos in the genetic information that could result in the cell ceasing to function and dying. Or an even worse scenario: it develops into a cancer cell. The telomeres play a dual role in cells. They protect the cell DNA, and they make sure that the cell cannot keep on dividing indefinitely. In a cell, minor damage and DNA errors occur all the time, and although the cell includes mechanisms that can repair the errors,

Cells are under attack from two sides

Two theories explain why our cells cannot go on dividing to renew our bodies. According to one, our cells have been programmed to have a limited life span. According to the other, our cells are destroyed by accumulated toxins.

THEORY 1: Cells have limited lives



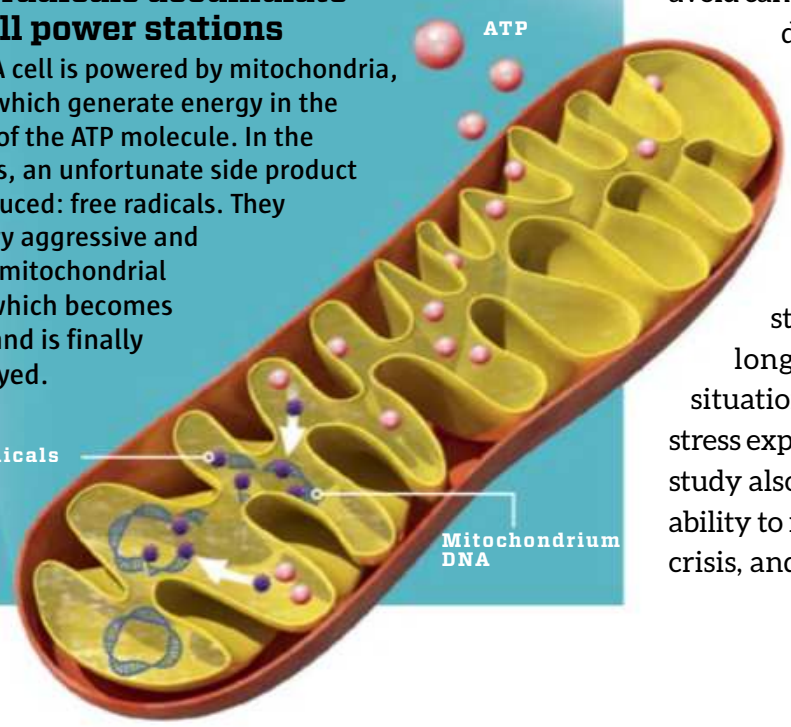
Cells do not live forever

The chromosomes of the cell nucleus contain all our genes. At the end of the chromosomes, you will find telomeres, which grow slightly shorter, every time a cell divides. At one point, the telomeres have been depleted, i.e. the cell can no longer divide.

THEORY 2: Cells are destroyed by toxins

Free radicals accumulate in cell power stations

A cell is powered by mitochondria, which generate energy in the shape of the ATP molecule. In the process, an unfortunate side product is produced: free radicals. They are very aggressive and attack mitochondrial DNA, which becomes worn and is finally destroyed.



CLAUS LUNAU

some of them will be passed on to the next generation. We all know what happens, when we use a photocopier to copy a page of text. If we continue to take copies of copies of copies, we end up with a result that is full of "scratches" and impurities and is impossible to read, or the text might even be misinterpreted.

All our cells have telomeres at the ends of their chromosomes, and in the vast majority of cases, they have limited lives.

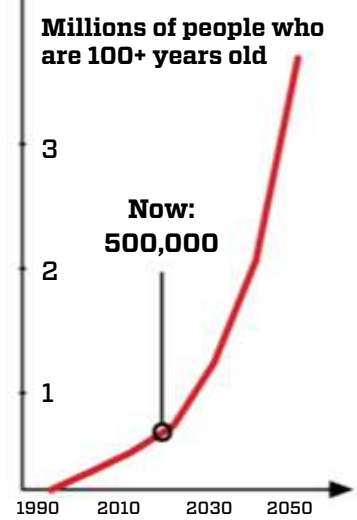
Only three types of cells are different: reproductive cells, stem cells, and cancer cells. Those cells have the ability to maintain the telomeres, so they will not become shorter for every cell division. In 1984, two scientists came on the track of how they do it. It happened, when a 23-year-old, newly-educated molecular biologist, Carol W. Greider, chose to continue her PhD studies under the guidance of biologist Elizabeth Blackburn of the University of California, Berkeley. The two scientists were both very interested in a monocellular organism by the name of Tetrahymena thermophile. The interesting thing about it was that it was apparently able to divide without any consequences. The scientists observed that its telomeres did not become shorter over time, indeed they sometimes grew longer. The secret turned out to be a completely unknown enzyme, which can reconstruct the telomeres. The scientists named the enzyme telemorase, and subsequent research has demonstrated that it is the same enzyme that allows reproductive cells, stem cells, and cancer cells to prolong their telomeres. In 2009, Greider and Blackburn were awarded the Nobel Prize for their discovery, and since then, many studies have confirmed that telomeres and telomerase play a central role in the ageing process.

Stress wears cells down

Studies have also shown that genetically speaking, we do not have the same starting points, when we are born. Different viariants of special genes mean that some of us have longer telomeres than others, but it is unclear how much it means. Studies including research animals point in different directions. Some show that individuals who are born with longer telomeres also live longer, whereas other studies fail to prove this. Finally, some studies demonstrate that people with shorter telomeres are better equipped to avoid cancer. The explanation might be that the risk of cells developing into cancer cells increases with the number of copies made.

Moreover, it is not only inerited factors that determine the length of the telomeres throughout life. The environment also plays a role. In 2000-2004, Elizabeth Blackburn carried out a study of mothers who had been subjected to stress for long periods of time. It turned out that the longer the mothers had been in a stressful life situation, the shorter their telomeres were. Long-term stress exposure apparently wears down the telomeres. The study also showed that a special group of mothers had the ability to regard their situation as a challenge rather than a crisis, and this ability also influenced the telomeres. In

Ever more people live to be 100 years old. 25 years ago, about 95,000 people in the world were 100+, but now is is half a million. According to UN statisticians, 3.5 million people will be more than 100 years old 25 years from now.



these women, they had not been worn as much. The result has made Blackburn conclude that by changing our conditions of life and our perspective on life, we could also change our ageing process:

"We control how we age – all the way down to the interior of our cells," she put in in a lecture in 2017.

Diabetes drug works against ageing

Blackburn's and other scientists' results show that the telomeres' influence on our life spans depends on both nurture and nature. But what about the medical possibilities? One obvious idea is that we could prolong our lives, if we were able to step up the production of telomerase or perhaps simply add the enzyme to our cells from the outside. Experiments with the C. elegans worm demonstrate that the creature lives longer, when scientists improve the effect of the enzyme, making its telomeres become longer.

But at the same time, other experiments show that the length of the telomeres is not crucial. Strangely enough, mouse cells live for a very much shorter period of time in the lab than human cells do, though the mouse cells have much longer telomeres.

Most scientists recognize that we need much more research to get the full impression of both telomerase and the function of telomeres, so even though telomerase has been named the "immortality enzyme", a miracle cure against ageing is not imminent. Moreover, it seems that there is a very delicate balance between the body's need for our cells to divide and the body's precautions against the fact that too many copies lead to cancer cells. Consequently, it is probably too risky to feed our ordinary cells telomerase. Instead, some scientists are developing the idea of improving the telomerase in stem cells. Studies have demonstrated that the enzyme's function in stem cells is reduced with age, and recently, scientists found out why. Researchers from the Arizona State University in the US discovered that telomerase includes a pause function that limits the speed at which the enzyme is working, as it is adding new DNA sequences to the telomeres. If the scientists manage to counter this pause function, they can improve stem cells' ability to restore body bones and organs.

> **It is highly likely that people who are born today could grow 1,000 years old.**

FABRICIO BOMJARDIM/BRAZIL PHOTO PRESS/LATINCONTENT/GETTY IMAGES

AUBREY DE GREY
Ageing researcher, mathematician, and the author of several books about ageing

The telomere theory and the theory of the free radicals are now very central to ageing research. One explains why we get worse at producing new cells, as we grow older. The other provides the answer as to why our old cells function more poorly over time. Those are the two areas that we need to focus on, if we would like to find a cure against ageing. There is every indication that the key to the cure is to be found in cell mitochondria. In 2014, a study showed that over the past 60 years, diabetics have consumed a drug that prolongs life. The drug, which is known as metformin, helps regulate the blood sugar level of diabetics, but over the past decades, scientists have become aware that it also has other beneficial effects on age-related diseases. Hence, a team of scientists from the Cardiff University in England decided to study the life spans of a group of diabetics who took metformin. Amazingly, it turned out that on average, they lived 18 % longer than a control group made up of healthy people. Several scientists now plan experiments, in which they intend to give the drug to healthy people. Steven Austad from the American Federation for Aging Research is trying to raise USD 65 million for what he has named "the first test of an anti-ageing drug on humans." According to Austad, the major effect of the drug is due to the fact that in some way, it makes the mitochondria's energy production more efficient, so fewer free radicals are released to possibly harm cells.

As evidenced by Austad's bet with his colleague, he is an optimist, when it comes to the life spans of future generations. And he is not the only one. English ageing researcher Aubrey de Grey has drawn attention to himself with even more wide-ranging predictions concerning the length of life. According to de Grey, ageing is basically to be considered the damage that is caused to our bodies and cells. He has arranged those into seven categories, and he believes that we are quite close to being able to repair all of them. The consequence is that according to de Grey, there is no upper limit to our life spans, and he predicts that in the very near future, we will experience medical breakthroughs that will make them accelerate. According to de Grey, the development can be compared to what we have experienced with aeroplanes. Only 115 years have passed, since the Wright brothers were the first to make an aircraft fly, but since then, the development towards the fighters and airliners that we know today has been extremely fast. Likewise, the breakthroughs within the seven damage categories will result in a number of practical treatmens, that will make our life spans increase drastically. De Grey's only reservation is that it is impossible to predict when the vital breakthrough will be made. In 2005, he put it like this:

"The first person to live to be 1,000 years old will probably only be 10 years younger than the first one to grow 150 years old."

Consequently, we cannot know when we will be able to determine, whether de Grey will be right. But we can with other of his predictions - such as this one that he made in 2018: "It is highly likely that people who are born today could grow 1,000 years old."

A hungry stomach boosts stem cells

While we are waiting for scientists to make us immortal, there are luckily ways in which we can prolong our lives ourselves. A well-known dietary recommendation is to choose food that includes lots of antioxidants such as the beta-carotene of carrots and the vitamin C of lemons. The idea is that the antioxidants can neutralize the free radicals, before they harm the interior of the cells. In recent years, questions have been raised about whether the antioxidants

that we consume have any effect on the free radicals in cells, but a new study from 2018 shows that they might. Scientists from the University of Colorado, USA, studied the effect of a special antioxidant by the name of MitoQ, which they had altered chemically, allowing it to stick to cell mitochondria. The scientists gave it to a group of people who suffered from arteriosclerosis, and it turned out to have a major effect. Already after two weeks on MitoQ, the patients' blood vessels had changed so much that they seemed 15-20 years younger.

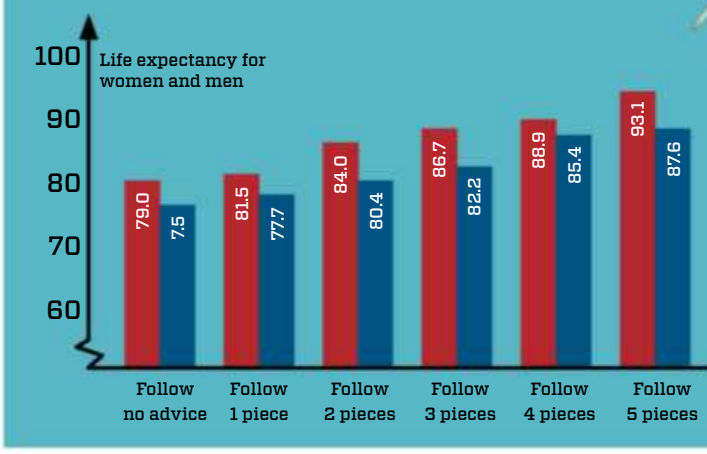
It is also a good idea to eat less. For decades, scientists have known that people who have a very low calorie intake or even fast generally live longer. There might be several explanations of this. Roundworm studies have shown that fast increases cells' ability to read a DNA strands' protein formulas correctly. And a brand new study involving mice indicates that fast directly influences the activity of stem cells. Scientists from the Massachusetts Institute of Technology (MIT) in the US made mice fast for 24 hours, subsequently studying the activity of the stem cells that provide the intestinal system with new cells. It turned out to be much higher than in stem cells from mice that had not fasted. The explanation is that the stem cells start to break down fatty acids instead of sugar, and that is apparently also a signal for doubling the production of new cells.

Finally, if we do not like to fast nor eat fruit and vegetables, we could choose to do what Jeanne Calment did. The old woman from France explained her longevity with the fact that throughout life, she had consumed her fair share of port, chocolate, and olive oil. Since then, research has confirmed that she was on to something. Moderate quantities of alcohol are good for the body, dark chocolate boosts the brain, and olive oil contains the healthy type of fat. On the other hand, it would be a good idea to quit smoking earlier than Calment did. She gave up tobacco when she was 117. SCI

Follow the advice and add 13 years to your life

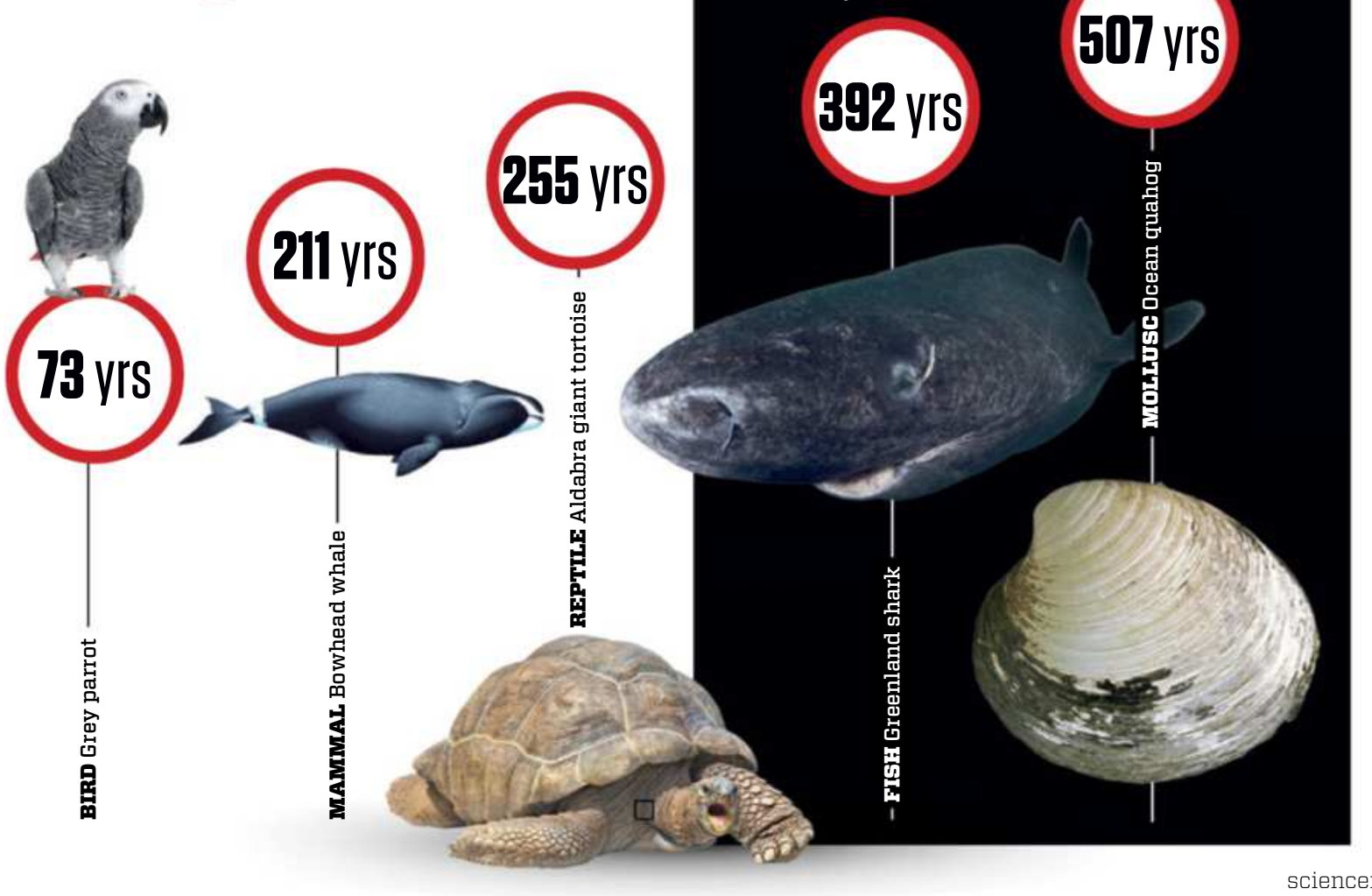
A large-scale American study shows that five life style factors have a major influence on how long a 50-year-old can expect to live. On average, those who follow all five pieces of advice live 13.1 years longer than the ones, who do not:

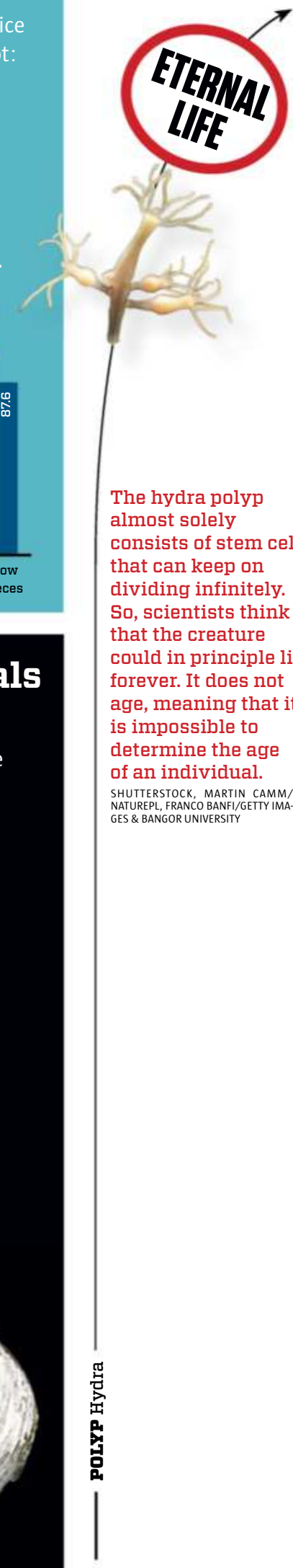
1. Do not smoke.
2. Eat a healthy diet.
3. Exercise regularly (at least 30 minutes/day).
4. Stay slim (your BMI must be 18.5-24.9).
5. Drink moderate quantities of alcohol (5-15 g/day for women, 5-30 g/day for men).



The most die-hard animals live in slow motion

Animal species that move slowly and have low metabolic rates save energy, and this seems to influence their life spans.
Or put differently:
Live slowly, die old.





The hydra polyp almost solely consists of stem cells that can keep on dividing infinitely. So, scientists think that the creature could in principle live forever. It does not age, meaning that it is impossible to determine the age of an individual.

SHUTTERSTOCK, MARTIN CAMM/NATUREPL, FRANCO BANFI/GETTY IMAGES & BANGOR UNIVERSITY

African Monkeys Sailed to America

At least 1,700 km of struggling against tropical storms and frothing waves. DNA and fossils have revealed that a small group of tough monkeys crossed the Atlantic Ocean millions of years before Columbus, changing the history of life for good.

SHUTTERSTOCK & NICOLAI AARØE

By **Jesper Milàn**

A small monkey blinks, gazing at the ocean. For a brief moment, it feels the sand between its fingers, before a loud bird call makes it escape between the trees of the forest. It is accompanied by a few peers, but the rest of its relatives are almost 2,000 km away. The small animal and its companions are in South America – some 40 million years ago – and they are the only monkeys on the huge continent, which is surrounded by vast oceans on all sides.

Today, the monkey's descendants have conquered the southern continent. Some 100 species exist in the huge forests, including howler monkeys, capuchin monkeys, Callithrix, and spider monkeys. But the South-American monkeys' mysterious origin arouses the interest of scientists. Where did they come from, and how did they suddenly end up on the continent? Charles Darwin found part of the answer, but his descendants mixted things up. Not until now, scientists have managed to reveal the ancient secret locked up in the genetic code of monkeys and map out the perhaps most incredible journey in the animal kingdom.

Darwin takes plants sailing

Charles Darwin's evolution theory created a problem that scientists did not have before. God had not placed the species of the world in the shapes and on the locations, in which they are now. They had evolved from one common ancestor, which later spread across the world. Some of the species – including the animals of the Galápagos Islands, which Darwin had studied in details on his round- the-world trip, were now to be found in remote islands, ▶

Seafarer descendants changed their noses

South American primates have evolved differently as compared to their African and Asian relatives. The most striking difference is right in the middle of their faces. The noses of the South American monkeys and apes are typically more flat, and their nostrils point to the sides, whereas those of African monkeys and apes are facing downwards. The latter group includes humans and other apes.

South American monkeys have stronger, more flexible tails that can be used to hold on to branches. Many African monkeys have developed large, often colourful pads on their hind parts, which they use to sit on and to send signals to their peers.

AFRICAN PRIMATES: Nostrils face downwards

SOUTH AMERICAN PRIMATES: Nostrils point to the sides

SHUTTERSTOCK

DNA and fossils reveal migration

Your DNA includes part of the secret about when South American monkeys parted from the African ones.

Six million years ago, the ancestors of humans and chimps had 100 % of their DNA in common –they were the same species. Now, humans and chimps share about 98.5 % of our DNA. This is because genes mutate, so differences occur over time.

Assuming that the differences occur at a steady pace, we can easily calculate when the common ancestor of humans and South American monkeys, the saki monkey, lived, only by counting the genetic differences between us and saki monkeys. However, it is not all that easy. The pace is not the same for all animals. South American monkeys' DNA changes faster than that of African monkeys – perhaps because their generations are shorter, or their metabolism is higher.

Scientists can allow for the challenges. The result is an accurate estimate of when our ancestors lived.

SHUTTERSTOCK

The white-headed saki monkey lives north of the Amazon River in the rain forests of South America.
SHUTTERSTOCK

separated from their closest relatives by endless oceans. If God had not placed them there, how had they arrived?

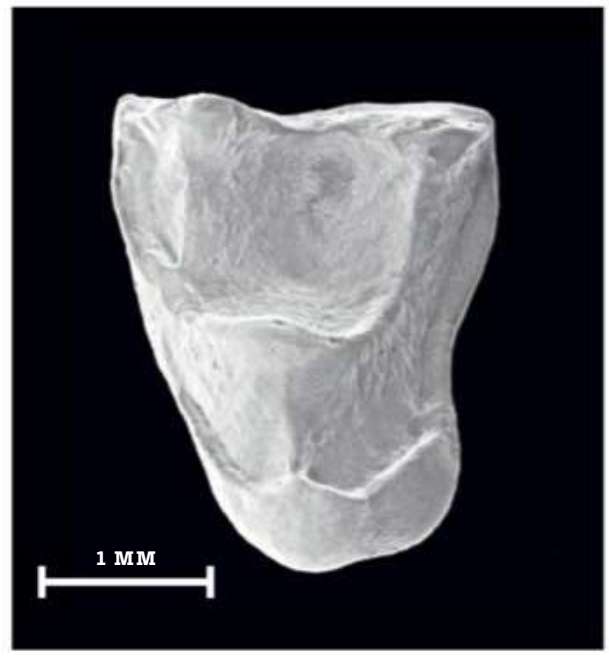
The Galápagos Islands are located some 1,000 km from the closest mainland, and as Darwin realised that the birds of the islands probably flew there, the plants of the islands caused more confusion. He concluded that the plants' seeds had been carried there by ocean currents. To test the theory, Darwin subjected plant seeds to a number of tests such as passing through the digestive systems of fish or remaining in a bottle of ocean water for months. Subsequently, he sowed them to find out if they were going to germinate. He got the best results with seeds stuck to entire branches. They could handle floating for at least 1,400 km.

Darwin concluded that natural rafts made of tangled branches must have been carried by ocean currents from the mainland to the islands, bringing viable seeds. He also proposed that the rafts could carry animals – explaining the presence of reptiles, snakes, and insects in the Galápagos.

His contemporaries disagreed. Darwin's explanation was too unlikely. Many of them thought that the animals had crossed oceans via major land bridges that had now sunk into the ocean. But over the next century, a new, ground-breaking theory emerged that would cause Darwin's rafts even greater problems.

Continents travel the world

A fossil in Brazil and an almost identical fossil in Namibia were both remains of the Mesosaurus reptile, which lived some 300 million years ago, and they have only been discovered in eastern South America and Western Africa. In 1912, the Mesosaurus played a vital role in a new theory developed by German meteorologist and polar explorer Alfred Wegener. He had noticed that the



36-million-year-old teeth from the Perupithecus monkey are the oldest fossil evidence of monkeys in South America.
KEN CAMPBELL/NHM

coastlines of South America and Africa fit each other like the pieces of a puzzle, and he concluded that the two continents had once been joined.

The Mesosaurus gave Wegener a good hand. The way he saw it, there was only one possible explanation of the fossils' separate locations: The animals had existed in one single, united continent that had subsequently broken in two.

In spite of Wegener's evidence, more than four decades passed before the theory of continental drift became widely accepted by scientists. But when it happened, biologists quickly realized that the theory could help them explain the locations of modern animals. If continental drift had separated the Mesosaurus fossils, it could also have separated the ancestors of the animals of Galápagos from those on the mainland.

Darwin's natural rafts were now

seriously questioned by most scientists. They were no longer necessary. The continents were the new rafts of scientists – and their slow motion seemed to be the perfect explanation of the fact that monkeys had spread across the world. The monkeys used to live on one united continent, but as the land mass split up, they had just followed suit.

DNA solves monkey mystery

In 1953, the theory of continental drift was accompanied by another scientific breakthrough: the disclosure of our hereditary material, DNA, and cientists quickly discovered that DNA tells the story of the past.

Remotely related animals have different versions of the same genes, because they descend from a common ancestor that had a primitive version of the genes. When the family tree divided, the genes developed differently, as mutations altered the DNA'.

The more ancient the common ancestor, the more the genes have changed. By counting the genetic differences between two animals, it is hence possible to get an idea of when their common ancestor existed.

The methods for reading animal's DNA have become much more efficient in recent years, and scientists have learned more about how quickly genes mutate. The result is a clearer impression of the history of life on Earth. We know now that the common ancestor of humans and chimps lived some six million years ago, whereas the ancestor of killer whales and cows existed 59 million years ago.

Exact dating is the key to solving the mystery of the South American monkeys. A series of genetic studies have revealed that the common ancestor of the monkeys of South America and Africa lived some 41 million years ago. However, scientists know for almost certain that South America lost contact with Africa about 100 million years ago. When the South American monkeys parted from the African ones, the Atlantic was already 1,700 km wide in the narrowest spot.

The monkeys had not just been carried by the continents, they had taken the trip themselves. And the easiest route from Africa to South America was across a huge ocean. Darwin's rafts of vegetation went from an unlikely explanation to being the only one possible. And the monkeys are not the only ones to go on incredible journeys.

Migration makes the history of life

Two forceful hurricanes hit the Antilles in 1995. Once the storms had died down, a local fisherman discovered a group of tangled trees that had ended up on a beach of the island of Anguilla. The trees included a small group of green iguanas – a species that did not already exist on Anguilla. The iguanas probably came from the island of Guadeloupe 280 km away. When scientists went to Anguilla in 2011, they discovered that the iguanas had established an entire population.

Reports from the early 1900s tell similar stories: ships passed by large rafts of vegetation in the Pacific Ocean– one of them with an area of thousands of m^2 and inhabited by monkeys, birds, and snakes.

The probability of a natural raft carrying an animal across a huge ocean is undoubtedly modest, but the history of life spans hundreds of millions of years, and consequently, it is suddenly likely that one single or even many animals have taken the strenous journey.

That is the impression that DNA research is increasingly providing us with. Some animals have ended up in their present locations thanks to the slow motion of the continents, but they are ofen a minority. A list of South America's terrestrial mammals – those that can neither fly nor swim – shows that 73 % of them date back from animals that sailed. SCI

TOP 5 LONGEST ANIMAL MIGRATION

Cute little rodents. And tough seafarers. The ancestors of guinea pigs defied the unpredictable Atlantic millions of years ago. But their journey cannot be compared to anyphaenidae's migration across the world's three biggest oceans.

1 ANYPHAENIDAE

DNA has revealed that anyphaenidae of the Amaurobioides genus sailed from South America to South Africa, on to New Zealand, and back to South America, establishing new populations on each location.

STEVE KERR

2 NORONHA-SKINK

The small noronha skink lizard exists on an island off the coast of Brazil, but its closest relatives are in Africa. The lizard crossed the Atlantic some 3.3 million years ago, when the ocean was 2,800 km wide.

SHUTTERSTOCK

3 CAVIOMORPHA

Some 40 million years ago, a small group of rodents crossed the Atlantic on their way to South America. Today, their descendants include caviomorpha and approximately 242 other fuzzy species.

GETTY IMAGES

4 SOUTH AMERICAN MONKEYS

Some 40 million years ago, when a few African monkeys crossed the Atlantic, the ocean was 1,700 km wide in the narrowest place. They might have taken the long swim along with the ancestors of guinea pigs.

SHUTTERSTOCK

5 GALÁPAGOS TORTOISE

A few million years ago, the huge Galápagos tortoise travelled from South America to the Galápagos Islands. And it probably did not use a raft. Tortoises are sturdy enough to float on the ocean for months.

WILLEM KOLVOORT/NATUREPL

Storms and ocean currents carried monkeys

A long series of unlikely events sent a few monkeys across thousands of km of open sea. The mission ought to have come to a bad end, but the monkeys ended up conquering South America.

CLAUS LUNAU

AFRICA

SHUTTERSTOCK

PLANTS MAKE UP RAFT

1 Natural rafts are produced in many lakes and swamps–particularly following storms, when lots of branches, roots, and aquatic plants are accumulated by the current.

RHETT A. BUTLER/MONGABAY

MONKEYS SAIL ON THE RIVER

2 Monkeys and other animals can take refuge on the rafts, which might measure thousands of m^2. After heavy rain, the river might carry the raft to the ocean.

OCEAN CURRENT

ATLANTIC OCEAN

MICHAEL POLIZA

LONG JOURNEYS ON OCEAN CURRENTS

3 The raft is captured by the South Equatorial Current, which carries it west across the Atlantic Ocean. The journey to South America takes at least 2-3 weeks. En route, the monkeys can feed on plants, insects, and rainwater, that have collected on the raft.

DORLING KINDERSLEY/GETTY IMAGES

NATIVES THREATEN NEWCOMERS

4 The dangers are not over, once the monkeys have landed. But in spite of new, unknown diseases and dangerous predators – including 2-m-high terror birds – the monkeys survive and establish a new population in South America.

SOUTH AMERICA

The innovative Chinese I-plane concept is a waverider aircraft with an extra wing on top.

MIKKEL JUUL JENSEN/SHUTTERSTOCK

MORE WINGS = MORE LIFT

The I-plane can seat about 50 passengers, as an extra set of wings produces a potent lift by capturing compressed air that flows up along the top of the cabin.

SUBSURFACE RESEMBLES SURFBOARD

The aircraft is a waverider design, i.e. it has a flat, surfboard-like subsurface, which rides on the shock wave generated by the plane at supersonic speeds.

IMPROVED ENGINE ACCELERATES PLANE

A ground-breaking new engine type, that unites four different technologies, carries the craft from the ground and up to seven times the speed of sound.

By **Kristian Bjørn-Hansen**

The Biplane Returns at a Speed of 8,600 Km/H

Two sets of wings and a 4-in-1 rocket engine accelerates a Chinese plane to up to seven times the speed of sound. The design kick-starts a new era of hypersonic aircraft.

Three planes leave Beijing for New York at the same time. An ordinary Airbus A320 airliner, the pensioned-off supersonic Concorde, and the new Chinese I-plane design, which is a biplane with two sets of wings.

In the imagined scenario, the Airbus A320 and the Concorde will land in New York 14 and six hours after take-off, respectively. A businessman, who travelled on the I-plane, is in a meeting in New York after only two hours, and he can get back to Beijing again and get a good night's sleep, before the Airbus A320 ever reaches New York. The trick behind the I-plane's hypothetical feat is a new engine type combination, which can accelerate the plane to hypersonic speeds, i.e. seven times the speed of sound: Mach 7.

The stability of the I-plane at such extremely high speeds is due to the two sets of wings, which also increase the load capacity and seems to minimize the supersonic booms caused by speeds of Mach 1+. The combination of innovative design and the TRRE engine makes the Chinese aircraft quite a sensation. If the I-plane takes off as planned in 2025, it will be at a speed of 8,600+ km/h.

Plane surfs on shock wave

Hypersonic aircraft are planes that can fly at speeds of Mach 5+ or what corresponds to about 6,200 km/h at sea level. Normally, the speed will be reached in thinner air layers, where the speed of sound varies slightly depending on temperatures, etc. At such high speeds, flying is hazardous, and so, the speeds have primarily been confined to drones and rockets. However, the I-plane design allows for a hypersonic passenger plane race.

The most successful aircraft design for hypersonic flight is the waverider design, which functions according to the same principle as a surfboard. Any craft travelling through the air pushes air in front of it. At supersonic speeds, the air drag turns into a wave that causes a boom of up to 200 decibels, as the plane passes through it. The higher the speed, the more powerful the pressure wave and the drag that it makes up. In other words, a waverider plane surfs on the drag by pointing its nose upwards at a specific angle and maintaining the pressure under the craft on a carefully developed, flat, or slightly inwardly curved subsurface.

Several planes compete in the supersonic race

Lockheed Martin SR-72

The unmanned American SR-72 spy plane is designed for bombing and scouting. The highly secret project might already have been completed.

- **TOP SPEED:** 7,350+ km/h.
- **ENGINE:** TBCC engine – a combined turbojet and ramjet/scramjet engine like I-plane's.
- **STATUS:** Source claims it to be completed.

CASIC Teng Yun

The Chinese Teng Yun is to lift small spaceplanes to launch at an altitude of 30-40 km. Both planes can land on the ground again unaided.

- **TOP SPEED:** Some 7,350 km/h.
- **ENGINE:** TRCC engine – a combined rocket and ramjet engine + a rocket-powered spaceplane.
- **STATUS:** To be delivered in 2030.

Skylon

A British spaceplane with a long body and short wings with integrated engines. It is to take off, escape the atmosphere, and land unaided.

- **TOP SPEED:** Some 6,300 km/h.
- **ENGINE:** Sabre engines – a unique combined engine design, 20 years in the making.
- **STATUS:** Test flights in 2025.

LOCKHEED MARTIN/CASIC/REACTION ENGINES

The I-plane also takes advantage of the waverider principle, but the Chinese scientists behind the concept concluded that the design involves a number of weaknesses. Intense shock waves make aerodynamics at hypersonic speeds too unpredictable to make a stable waverider design, and wave-rider planes are very thin and fragile and leave too little space for passengers and other cargo. So, the Chinese scientists added two extra wings, which tackled many of the major challenges of hypersonic flight in recent wind tunnel tests.

Double wing balances air flow

The I-plane still needs to pass a long series of tests, before the craft can take off, but if the two extra wings perform just as efficiently in real life as in the first tests, the plane will be stable, able to carry more load, and is seemingly less noisy than other supersonic aircraft.

The wings were added, when the scientists noticed that at hypersonic speeds, compressed air flowed up along the top side of the plane. They concluded that the flow could be used, so they placed another set of wings at the top of the plane, and subsequent tests showed that the design was much more stable and generated more lift than the clean-cut waverider design.

The powerful lift allows the plane to bulge on the top side, leaving space for the craft to one day being able to load up to five tonnes of goods or some 50 passengers. So far, waverider planes have only been able to carry one single person.

Moreover, the I-plane's extra wings will alter the pressure, splitting up and minimizing the sound of the supersonic boom. So, supersonic and hypersonic aircraft may one day be allowed to fly above land, which is now illegal in China, the US, and major parts of the world. The ban was vital for the Concorde never becoming a major success.

Predictable hyperspeed

Hardly any biplanes have been made since the 1930s due to increased weight, air drag, and poor fuel economy, but plane designers' experiments will now apparently allow biplanes a comeback in the shape of the I-plane.

Aerodynamics and plane design are notoriously hard to calculate, particularly at hypersonic speeds, as countless factors affect the plane's lift and resistance. At ordinary speeds of less than that of sound, an object such as a car, a plane, or a wing will split the air into flows around the object. In the case of a plane, successful aerodynamic design will accelerate the air across the craft, forcing it in a downward, backward direction. The motion causes underpressure above the plane, allowing the air flow passing the subsurface to push the object upwards.

As a plane accelerates to supersonic speeds, the rules of lift and aerodynamics become unpredictable, and hypersonic speeds are even more complicated. At around Mach 5, the laws of aerodynamics hardly apply anymore. At almost 6,200 km/h, the resistance does not come from the air, but rather from the waves that the plane produces.

As the I-plane's extra wings seem to counteract supersonic booms and reduce the extent of waves that could cause turbulence, etc., scientists have found a design that can manage the extremely high speeds.

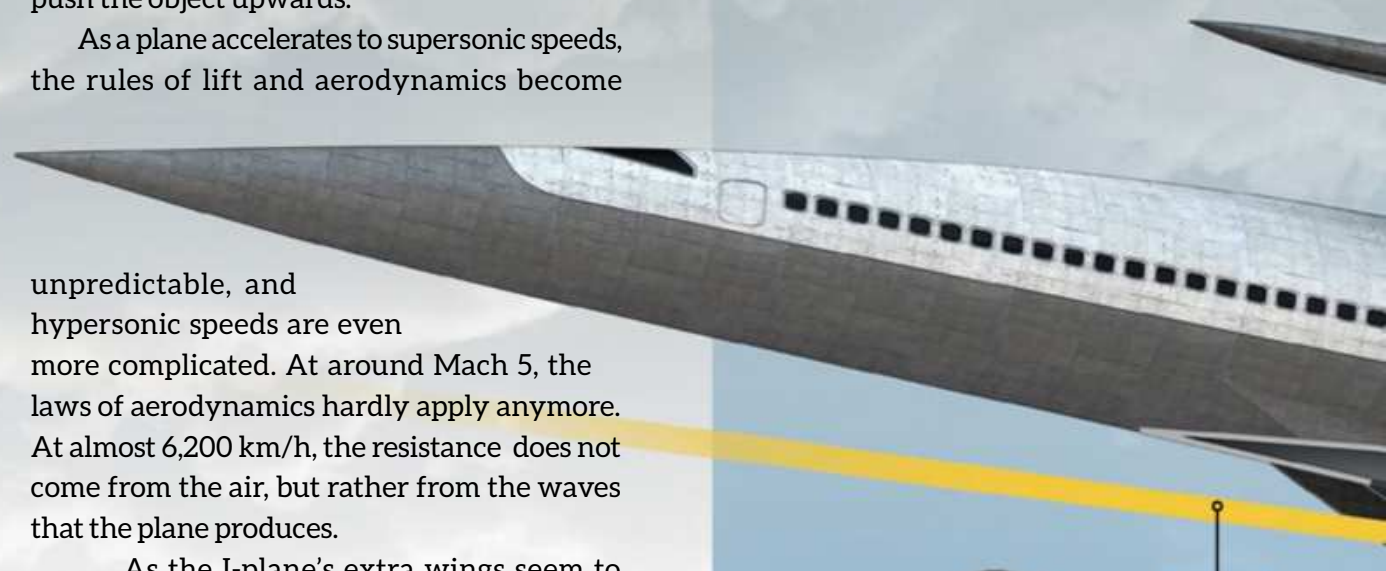
Supersonic aerospace activities

The future existence of the I-plane also requires that its TRRE engine passes a series of tests in 2025. The engine is the first of its kind to combine four engine types in the same system, and it could pave the way for hypersonic aircraft. So, the I-plane design might be interesting in several ways.

Much of the hypersonic race is aimed at space. Taking off from a runway, carrying goods, astronauts, or tourists into space, and landing safely on the ground again is a challenge that hypersonic planes hope to handle in the future. If the I-plane can function as a reusable lifting module, the plane will reduce the costs of aerospace activities considerably, perhaps allowing more and more frequent space missions.

However, the Chinese and American militaries also closely observe the development of hypersonic planes, whose high speed reduces the distance between the great powers, i.e. the technology constitutes a threat that they must be prepared for.

In relation to the general public, the I-plane and its competitors could kick-start a new era, in which air traffic makes the world even smaller than today. The demand for supersonic passenger flight is rising in an increasingly globalized world. The Concorde flew at Mach 2.2, but was scrapped in 2003 after a tragic crash and subsequently years of losses. The I-plane promises to be successful, so the dream of travelling to remote corners of the world in only three hours is more realistic than ever.



TAKES OFF WITH JET ENGINE

A traditional plane engine – a turbojet – accelerates the I-plane by sucking air into a compressor. Compressed air is mixed with aircraft fuel and combusted. The energy discharge causes propulsion.

BOTTLED OXYGEN AND ROCKET INCREASE SPEED

When the plane is airborne, a rocket engine gradually takes over the propulsion in a separate channel. The engine uses bottled oxygen, which is mixed with fuel and ignited, accelerating the plane to Mach 3.

RESISTANCE COMPRESSES AIR

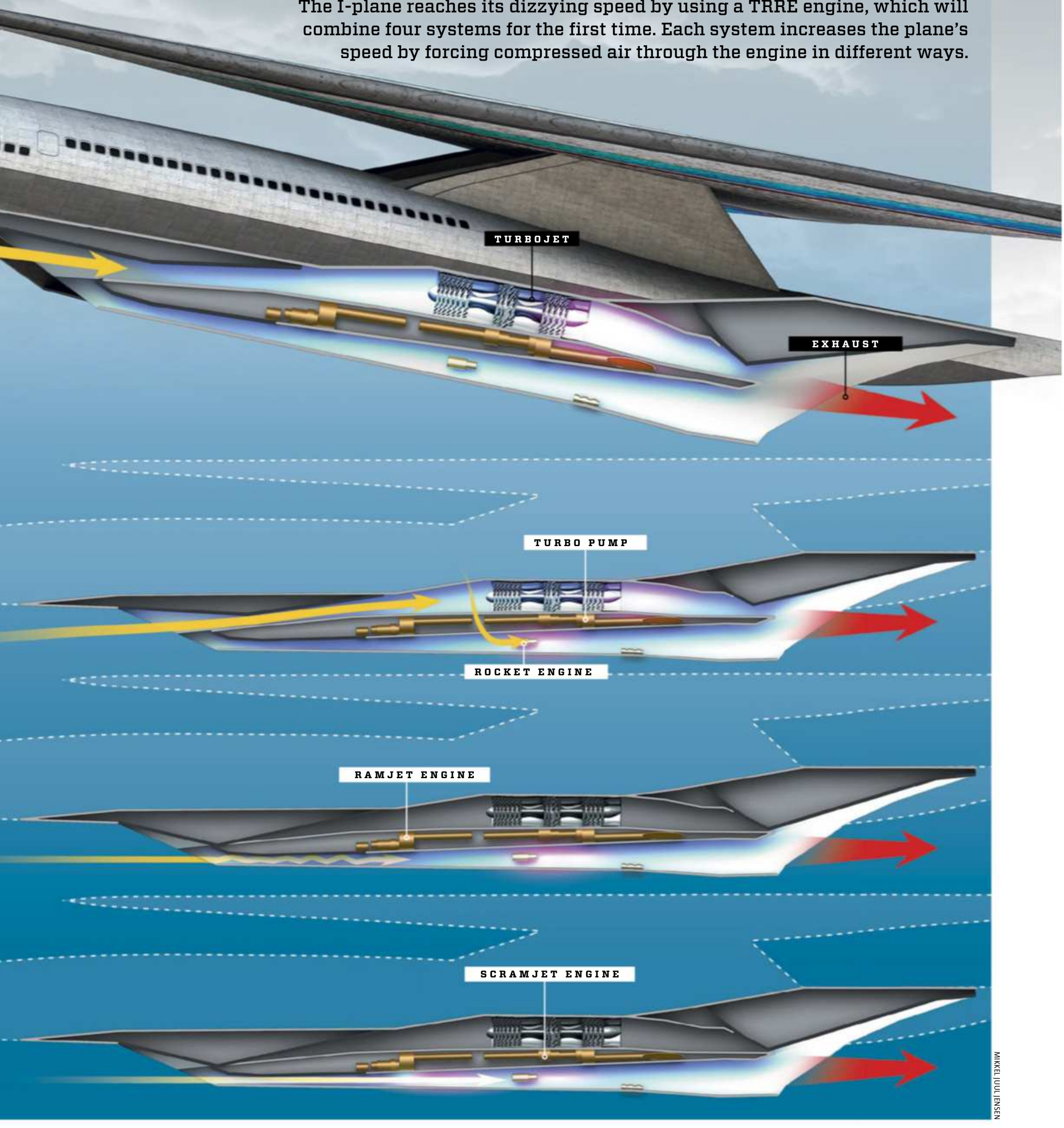
A ramjet engine only works at speeds of Mach 3+. The aircraft design compresses, heats, and slows down the air to a suitable speed for efficient combustion. The ramjet engine increases the speed to Mach 6.

HYPERSONIC AIR IS SPED UP

A scramjet engine accelerates the plane to Mach 7 or some 8,600 km/h hardly without slowing down the incoming air before combustion. A scramjet only works at hypersonic speeds.

From 0 to 8,600 km/h with 4 engines

The I-plane reaches its dizzying speed by using a TRRE engine, which will combine four systems for the first time. Each system increases the plane's speed by forcing compressed air through the engine in different ways.



MIKKEL JUUL JENSEN

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MA/SI62

SCIENTISTS HAVE SOLVED THE MYSTERY OF HOW BALL LIGHTNING CAN SAIL STABLY THROUGH THE AIR.

During a thunderstorm, lightning can produce odd, shining balls, called ball lightning. The balls sail through the air for up to one minute, before they disappear.

SHUTTERSTOCK

By **Niels Hansen**

Twisted Magnetic Fields Produce Ball Lightning

For centuries, people have told stories about luminous balls that suddenly appear in the air during storms. Now, scientists have revealed that magnetic mess in the atmosphere could be the cause of the enigmatic phenomenon.

Thick, grey clouds from the English Channel slowly drift across the small seaside town of Paignton in South-Western England. In mid-afternoon, the first heavy drops fall, while 71-year-old Michael Dodd is in his living room, watching TV. Suddenly, he hears a deafening bang, and the power fails. A few seconds later, a glowing, bluish ball the size of a beach ball with an orange tail of light sails through his window, drifting across the room close to Michael Dood, who is in shock, and out his terrace door. Once outside, it crosses the parking space in front of the small cluster of houses for senior citizens and disappears out of sight.

The event, that took place in September 2017, is an example of ball lightning – an enigmatic, glowing ball with a typical diameter of up to one metre, which suddenly appears during a thunderstorm, drifting quietly across open spaces or through occasional living rooms, only to suddenly disappear. Scientists have struggled to understand how the ball-shaped lighting forms, and now a team of Finnish and American physicists have been the first to recreate the process, which probably causes the odd phenomenon.

History is ripe with shining balls

The earliest accounts of phenomena that might have been ball lightning are more than 2,000 years old and exist in Estruscan works of art and the writings of Greek philosopher Aristotle. One of the earliest reliable accounts is from 1638, when, according to several sources, the church of Widecombe-in-the-Moor in Southern England was struck by ball lightning in the middle of service. The ball shattered parts of the roof and pushed the church benches over, setting them on fire. Four people were killed.

Similarly dramatic examples also exist in modern times, such as ball lightning inside planes. This happened on 15 December 2014 to flight BE-6780 from Aberdeen to the Shetland Islands. The cabin crew saw a shining ball appear brieflty close to the cockpit door a few seconds before lightning struck the plane's radar equipment, causing an electric system error. However, the pilot regained control of the aircraft, turned back, and landed safely in Aberdeen 35 minutes later.

In spite of the many accounts of ball lightning, there is not much persistent tangible evidence and scientific explanations of the odd phenomenon.

Matter can exist in five different states

- **PLASMA:** Extreme temperatures split atoms into their tinier components.
- **GAS:** The atoms of the matter are separated and not positioned in a specifc pattern.
- **LIQUID:** The atoms are located close together, but not in a well-organized pattern.
- **SOLID:** The atoms of the matter are densely packed, often in a specific pattern.
- **BOSE-EINSTEIN CONDENSATE:** Extreme cold means that the atoms are densely packed in such a low energy state that they behave as one superatom.

Odd condensate is the fifth state of matter

Matter can exist in five different states. On Earth, matter exists naturally in three states, changing from solid to liquid to gas, as temperatures rise. When temperatures are too high for gas – such as inside the Sun – a fourth state is produced: plasma.

The very opposite of plasma is Bose-Einstein condensate, which requires extreme cold. The condensate has special qualities which scientists can use to observe and control atoms. The condensate is so cold that almost all atoms end up in the lowest possible state of energy. That is a very special state, which means that atoms lose their individual identity, making up one large superatom instead. A Bose-Einstein condensate with a superatom which consists of millions of atoms is defined as one object, and it is so large that it can be seen with the naked eye.

Optical illusion

So far, scientists have had most difficulties explaining the balls' ability to remain stable for up to one minute, before they disintegrate. In traditional physics, the behaviour of ball lightning is so unlikely that an article in the Physics Letters from 2010 claimed that they do not exist. According to the authors, the balls had to be optical illusions produced on the retina by the forceful magnetic fields of thunderstorms.

Since the article was published, Chinese scientists have registered and analysed natural ball lightning using scientific equipment. The lightning occurred in the Tibetan Plateau in 2012 and had a diameter of five metres – much larger than the one metre mesaured by typical ball lightning. It also had a much shorter life of 1.6 seconds. The scientists' analyses showed that the ball's most important ingredient was silicon oxide and carbon from the ground, which ordinary lightning had partly converted into plasma by heating it to some 30,000 degrees.

The recordings proved that ball lightning exists, but they did not reveal the process that makes lightning shine and live as stable balls. That discovery has only just been made in an experiment carried out by the Finnish and American team of physicists.

ROMAN TREGUBOV/YOUTUBE

Ball lightning occurs suddenly and quickly disappears. Few recordings of it exist.

Ball lightning was accidental

The aim of the scientists' experiment was originally quite different, as they wanted to be the first to produce a special magnetic ball in the quantum world – the most basic level of physics research. Subsequently, the scientists learned that by producing the ball, they had accidentally proved a more than 20-year-old ball lightning theory.

The theory, which was introduced by Spanish professor Antonio F. Ranada in 1996, describes an internal structure of ball lightning, which explained all the unusual qualities, including how ball lightning can exist for such a long time. The structure that Ranada described mathematically was a type of electromagnetic knot of entangled, ring-shaped, magnetic field lines that occur in a plasma of charged air molecules. The rings are stable, because they bite their own tails, so there is neither a beginning nor an end, and hence, they cannot be untangled.

The scientist and his team never got any further, as it was not possible to prove their theory, which was forgotten for more than 20 years – until the Finnish and US scientists' experiment produced the magnetic field lines in the freezing contrast of red-hot plasma: the Bose-Einstein condensate.

The condensate is the fifth state of matter, which was only discovered in 1996. In the lab, scientists produced a very thin, microscopic cloud of 200,000 freezing cold rubidium atoms. The condensate was manipulated by means of a magnetic field, making the magnetic knots appear by themselves. The structure was maintained long enough for the scientists to be able to map out its characteristics, which are completely consistent with the about 20-year-

NATURE

Atmospheric short circuit causes lightning and luminous balls

In 2012, the world saw the final proof of the existence of ball lightning, when scientists recorded ball lightning and observed, how it was born by lightning. But not until now, scientists have confirmed an about 20-year-old theory abut how the balls are keptstable by magnetic lines in plasma – by recreating the process in plasma's freezing contrast.

1 In large clouds, charged precipitation particles are separated, as the positive ones are light and rise, whereas the negative ones are heavy and fall. The ground is positively charged, as the bottom of the cloud repels negative charges, causing a voltage difference.

2 The negative cloud and the positive ground attract. A thin channel of highly ionized air stretches from the cloud to the ground and vice versa. When they meet, the result is a short circuit, which causes an electric connection between cloud and ground.

Ion channel

Ion channel

old prediction of the interior of ball lightning.

Knots generate unending energy

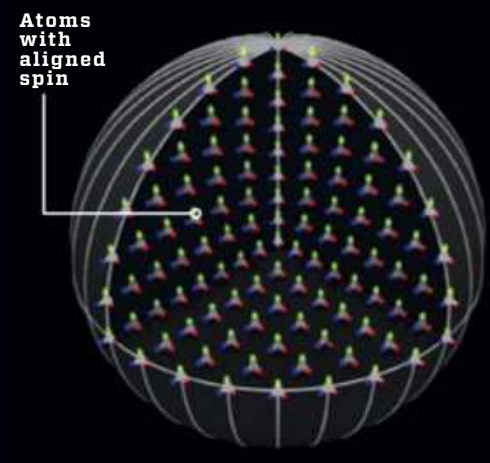
Scientists have still not shown why ball lightning neither slowly burns out noremits heat radiation, when direct contact with lightning causes severe burns. However, the experiment is very important – not only for the understanding of ball lightning, but perhaps also for the development of fusion energy.

Fusion is when two light atomic nuclei fuse to generate energy such as in the interior of stars. It is a pure and almost inexhaustible source of energy – that is if scientists can make it work in reactors.

One of the problems that are still standing in the way of functional fusion reactors is the "trapping" of the 100-million-degree-hot plasma which the reactor must hold. No materials can tolerate such temperatures, but if scientists are correct to assume that knots hold the glowing plasma of ball lighning together, even larger knots might be created to keep a check on the reactor's plasma. In this way, nature's huge energy discharges might be the key to controlling the infinite energy source of the future. SCI

LABORATORY

Magnetic rings make ball stable



Atoms align in one direction

1 An extremely thin gas of about 200,000 atoms is cooled close to absolute zero, -273.15 degrees, producing a Bose-Einstein condensate, in which almost **all atoms are in the lowest possible energy state.** Scientists align the spin of the individual atoms – a special property of the quantum world – with a magnetic field.

Rings get tangled up

2 The scientists alter the magnetic field, making the atoms' spin rotate and producing rings. The spin direction of an atom points at another atom, which points at another one, etc., until an atom's spin direction points back at the first atom: **a ring has been completed.** The rings are stable and make up circular, electromagnetic fields.

Magnetic rings are twisted

3 The condensate is filled with rings, which have become entangled. The process produces a knot of electromagnetic rings, which is twisted, as the spin directions are still rotating. The knot maintains **an overall magnetic field for the ball,** holding individual components in place – like the interior of ball lightning is kept stable, according to theory.

DAVID HALL

3 **The short circuit means that the cloud is no longer insulated** from the ground, and the result is a huge spark – what we call lightning – between the two. Where lightning strikes, the ground is heated to about 30,000 degrees for a few milliseconds.

Lightning

30,000 °C

Oxygen

Gas

5 In the air, oxygen is added to the silicon bubble. The process generates energy (heat and light) – **ball lightning**. According to scientists, the ball is stable due to magnetic rings in the bubble.

4 **The heat makes carbon in the ground steal oxygen from** silicon oxide, which makes up the majority of sand in the ground. The process results in silicon, which rises as an extremely hot bubble.

SHUTTERSTOCK

Disease revealed by our breath

By means of an electronic nose, 17 diseases can now be diagnosed with a degree of accuracy of 86 %.

- LUNG CANCER
- BREAST CANCER
- MULTIPLE-SCLEROSIS
- CROHN'S DISEASE
- IRRITABLE COLON

SHUTTERSTOCK

By **Ulla Raaschou**

Doctors Can Sniff Out Disease

Sick or healthy? Soon, doctors will make diagnoses by having an electronic nose sniff at our breath. New scientific research links specific smells to different diseases, and we can even smell some of them ourselves.

Joy Milne, a retired nurse, carefully smells at a sweaty white T-shirt. She is searching for a special tree and musk-like body odour, which she noticed the first time in connection with her husband, who suffered from Parkinson's disease. When she has determined whether the owner of the T-shirt is ill or healthy, she gets another T-shirt. And so, the experiment goes on, until she has smelt 12 T-shirts, of which six have been used by Parkinson's patients and the rest by a healthy control group. Milne's sensitive nose places all the T-shirt owners in the right categories – except from one person from the control group, whom she diagnoses to be a Parkinson's patient.

The simple experiement, which was carried out at the University of Edinburgh, has helped scientists find out how diseases might be diagnosed in the future. Today, most final diagnoses are made based on samples of bodily fluids or tissue taken from the patient's body, and the methods can be both expensive and physically demanding for the patient. If the odours that our bodies give off all the time can be captured and analysed to determine what is wrong with us, it will be possible to make diagnoses much earlier and more easily, without any inconvenience for the patient.

The experiment with Joy Milne shows that we have a surprising ability to smell disease, but if smell is to be used as a real diagnosis tool, scientists must find out exactly which smelling molecules the body emits in connection with individual diseases. For this purpose, Israeli physician Hossam Haick has developed an electronic nose that detects and analyses the volatile organic compounds, VOCs, that cause most smells. By making the electronic nose smell people's breath, Haick has so far diagnosed 17 different diseases – including breast cancer, schlerosis, and several intestinal conditions.

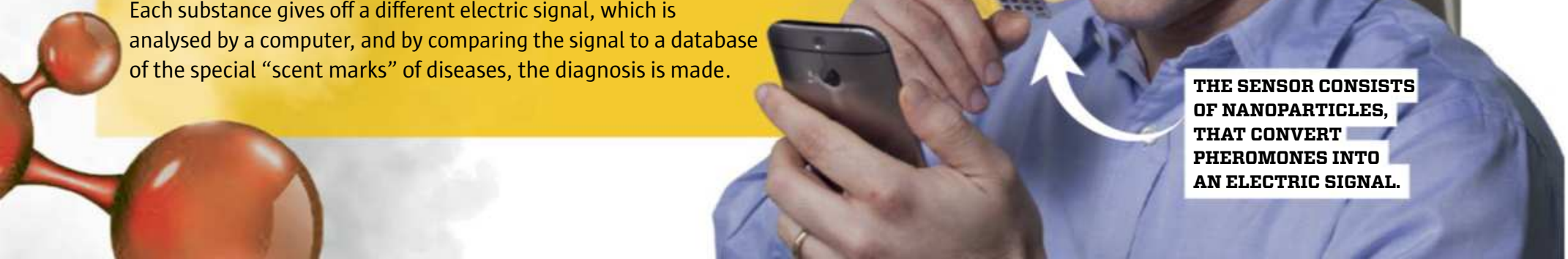
Every disease has a smell

Hossam Haick's electronic nose has identified a wealth of volatile organic compounds, which previous research has already linked with diseases, but so far, the challenge has consisted in the fact that one organic compound can be related to several diseases, and so, scientists have not been able to link the discovery of one organic compound in a person's breath with a specific diagnose. Haick's experiments are different, because he is looking for patterns in the distribution of the volatile compounds. According to his theory, each disease ▶

// ELECTRONIC NOSE

Nanoparticles sniff at disease substances in our breath

Physician Hossam Haick has developed a new electronic nose that can diagnose diseases based on the specific make-up of substances they emit in a person's breath. The "nose" detects the same volatile organic compounds as our own nose, only it is much more sensitive. The person's breath is sent past a layer of nanoparticles, which are electrically conductive. The nanoparticles are surrounded by an organic material that detects the smelling gases, and when the material interacts with the gases, the electrical resistance changes. Each substance gives off a different electric signal, which is analysed by a computer, and by comparing the signal to a database of the special "scent marks" of diseases, the diagnosis is made.



Physician Hossam Haick breathes on an electronic nose sensor, which transmits data to a computer.

THE SENSOR CONSISTS OF NANOPARTICLES, THAT CONVERT PHEROMONES INTO AN ELECTRIC SIGNAL.

TECHNION – ISRAEL INSTITUTE OF TECHNOLOGY

produces its own combination of organic compounds, so if he can prove a disease's special "smell print" in the breath, the person probably suffers from the disease.

A total of 1,404 people from five different countries have contributed their breath to Haick's studies, and the results are very promising. Based on nothing but breath, the electronic nose can diagnose the disease with a success rate of up to 86 %. So far, Haick has identified the breath marks of 17 different diseases, and now, the challenge consists in mapping out the special smell patterns of more diseases and recording them in a database. The aim is to enable ordinary doctors to use the quick and painless method to determine what is wrong with their patients.

Mice smell brain injury in urine

At the Monell Chemical Senses Center in Philadelphia, scientists are studying whether smells can also reveal how physical injuries affect the body. Based on mouse experiments, they have concluded that the make-up of the body's breakdown products changes, when the mouse's brain is subjected to external influence. And other mice can learn to identify peers with concussions only by smelling their urine.

Scientists do not yet know the exact substances that cause the smell of concussion. The substances could come from the immune system or be produced by intestinal bacteria. If scientists find out which substances the smell consists of, how long after the blow to the head it occurs, and how long it lasts, it could be an important new diagnosis tool for doctors. Concussion does not always cause evident symptoms, and so there is a risk that it is not identified in time. With diagnoses based on smell, doctors can quickly determine if a person had a concussion in a sports or traffic accident and monitor whether the treatment works.

Doctors smelt faeces

Electronic noses are not part of doctors' medicine bags yet, but the idea of detecting disease by its smell is not a new one. Around 2000 BC, Chinese doctors smelt tuberculosis, and in Ancient Greece, doctors smelt the faeces and urine of royal babies every day to rate their health.

During both world wars, infections in soldiers were a major problem, and wounds infected by the Clostridium perfringens bacterium typically developed into gangrene. Back then, there were no other ways to detect the bacterium, so doctors taught themselves to identify it based on smell. Today, some trained nurses can recognize the type of diarrhoea that is caused by the Clostridium difficile bacterium only based on the smell of the faeces. But it does not necessarily require medical training to smell disease. Experiments have shown that we apparently all have the ability to smell disease already in its early stages.

At the Karolinska Institutet in Sweden, neurologist Mats Olsson has tested what happens to body odour, when the immune system is activated by disease. Four in eight healthy test subjects were injected with LPS, which causes a severe, but harmless immune reaction, whereas the other four were injected with salt water. Four hours later, the participants' T-shirts were collected, and 40 other test subjects were asked to describe their smell. The "verdict" was unambigous: The people whose immune systems had been activated secreted a sweat that smelt worse or more "unhealthy" and much more heftily than the control group's sweat.

According to Mats Olsson, the ability to identify immune reactions in others might have meant something to human survival. The experiment shows that the human nose is able to detect disease long before the patient has visible symptoms, and the ability probably allowed us to avoid contact with sick peers.

Several other experiments have shown that our sense of smell is not as bad compared to that of other species, as scientists used to believe. Measured by the number of smell receptors in the nose, it is not impressive, but on the other hand, the part of the brain that analyses and interprets the olfactory perception has turned out to be much more complex than in animals.

In connection with some smells, humans are even better than animals at identifying the molecular signals. That may be due to our smell receptors being particularly sensitive to smells that are relevant to our species.

Joy Milne's nose predicts disease

Eight months after the experiment, in which Joy Milne of the UK smelt T-shirts from Parkinson's patients and compared them with healthy people, scientists received sad, but scientifically interesting news: One of the people of the control group had been diagnosed with Parkinson's.

Joy Milne identified all six Parkinson's patients based on the smell of their T-shirts, but apparently made one mistake: She diagnosed one of the people in the control group to be a Parkinson's patient, and now she had been proved right. To scientists, this emphasizes the immense potential of smell as a diagnostic tool. SCI

CHRIS WATT

Joy Milne noticed a specific smell in her husband, when he developed Parkinson's disease. In an experiment, she diagnosed Parkinson's patients based on the smell of their T-shirts.

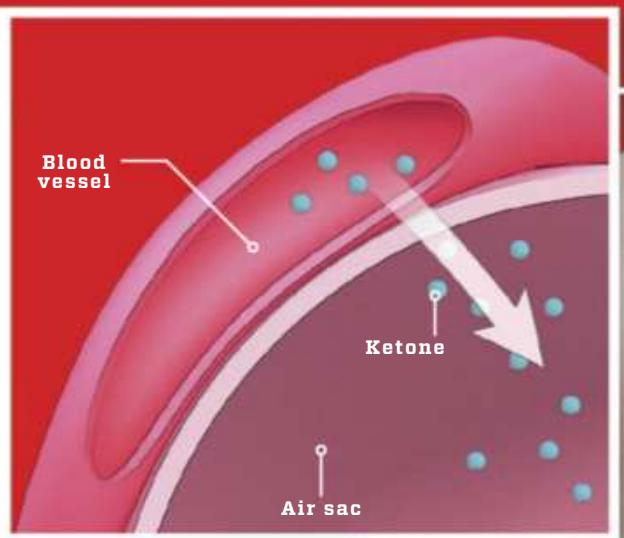
Disease smell in breath, body odour, and urine

When we get ill, it causes changes such as in the immune system, metabolism, and the biology of the skin, producing specific waste products. Some of them make our breath, sweat, or urine smell.

BREATH

DIABETICS HAVE ACETONE IN THEIR BREATH

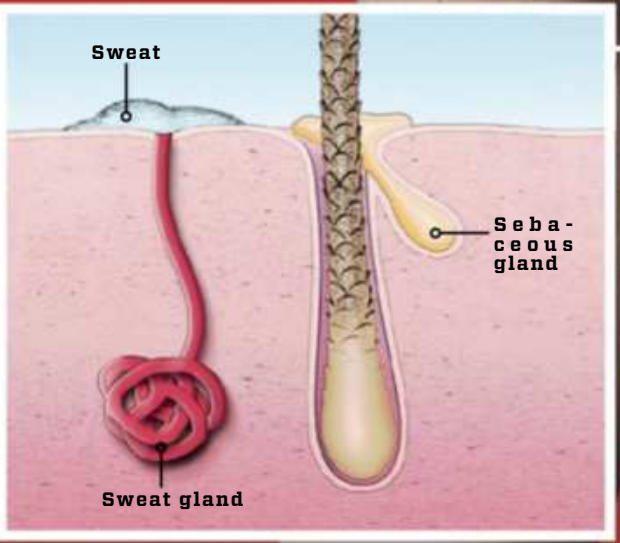
A person with untreated diabetes cannot break down carbohydrates, and as the body lacks nutrition, it starts to burn fat deposits, producing free fatty acids, which are converted into ketones in the liver. In the small air sacs of the lungs (alveoli), the substances are transferred to the breath, which smells like acetone. The smell could also be an indication of other diseases, by which the body gets too little nutrition.



SWEAT

HYPERMETABOLISM CHANGES BODY ODOUR

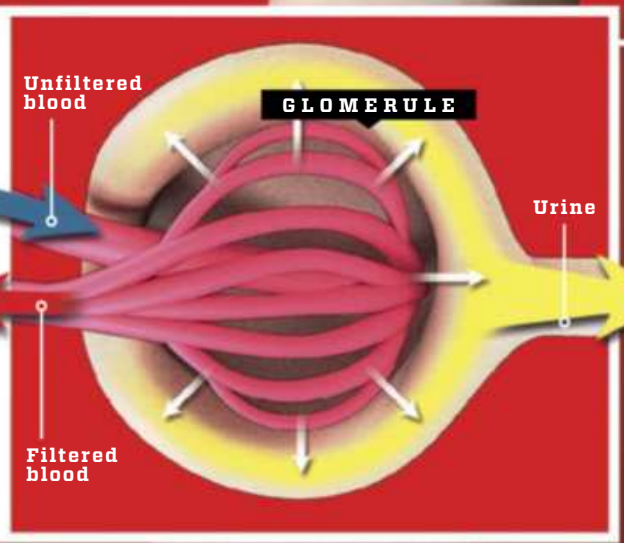
When bacteria and microscopic fungi break down sweat and sebum on the skin, secreting waste products, and BO. People with hypermetabolism often sweat more, and allergies can make the skin's sebaceous glands secrete more, so the microorganisms get more nutrition. When the immune system is impacted, the quantity of microorganisms on the skin could cause a more pungent body odour.

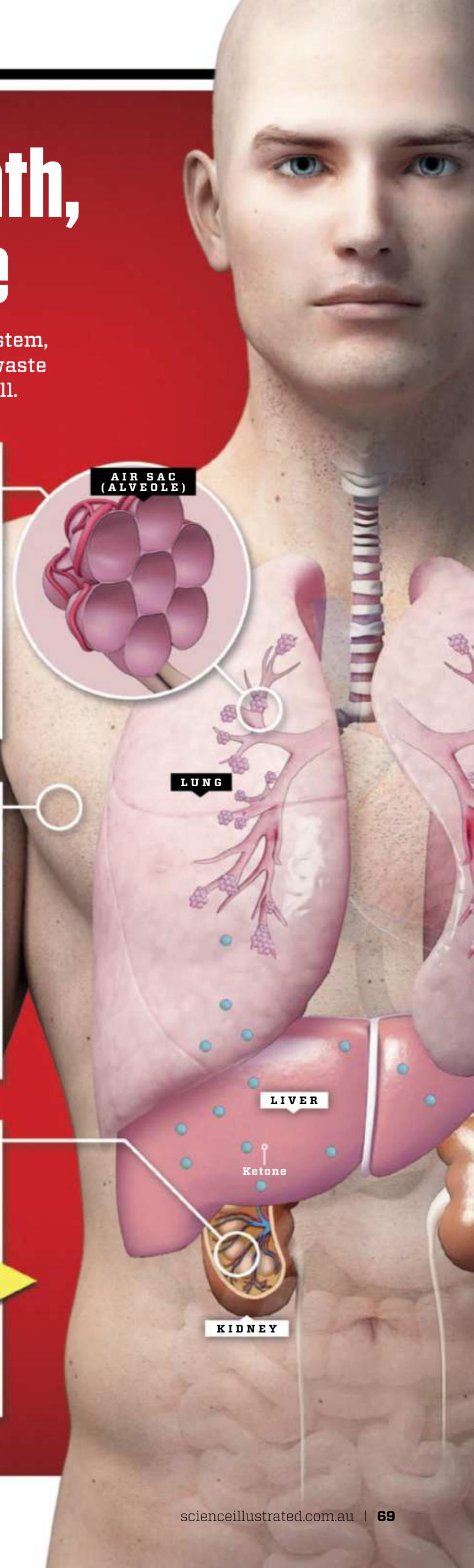


URINE

CONCUSSION LEAVES EVIDENCE IN URINE

Concussion and infections change the make-up of the body's breakdown products, probably due to the immune system or intestinal bacteria. In the kidneys, the blood vessels produce thousands of bundles (glomeruli), where the breakdown products are filtered into the urinary system, and concentrated on their way towards the urethra. In a urine sample, they can be smelled by an electronic nose.





MIKKEL JUUL JENSEN

The World's Biggest Machine Gets an Even Bigger Brother

The gigantic LHC particle accelerator is a major success, but the ambitious physics experiment has failed to identify dark matter. Now, scientists aim to build a new device to collide particles so forcefully that the Big Bang is recreated.

CERN'S HUGE RINGS WERE ESTABLISHED OVER 60 YEARS

CERN scientists study the tiniest building blocks of atoms by making particles collide at high speeds and examining the resulting fragments. As physicists have searched for ever rarer particles, the energy of the experiments has been boosted – and so the size of the rings.

Old accelerator is the LHC's workhorse

1 1959 The Proton Synchrotron was the first CERN device that was able to accelerate protons and hence produce much more powerful collisions than previously. Today, it pre-accelerates protons, before they go into the LHC.

- **Name:** Proton Synchrotron
- **Circumference:** 628 m
- **Highest energy:** 28 GeV

Huge ring revealed the weak nuclear force

2 1976 In the Super Proton Synchroton, protons collide with antiprotons. In 1983, scientists used it to identify the W and Z particles, which are responsible for the weak nuclear force. The discovery earned the Nobel Prize in physics.

- **Name:** Super Proton Synchrotron
- **Circumference:** 6,900 m
- **Highest energy:** 450 GeV

By **Rolf Haugaard Nielsen**

A small bundle of protons are heading for a violent death. By means of radio waves, scientists pump ever more energy into the bundle, which travels through the narrow tube at a speed close to that of the light. A few cm away, an identical bundle is speeding through a second tube in the opposite direction. As the bundles pass through huge detectors, physicists make them collide with a force that cannot be matched by any other device in the world. The protons are pulverized, and the detectors now try to identify any new, exotic particles that might originate in the cloud of shattered protons.

This is how physicists from the European Organization for Nuclear Research, CERN, have studied the tiniest building blocks of the universe for decades. Since 2009, they have used the tremendous LHC accelerator, which has been a major success in many ways, but even the world's largest particle accelerator has failed to do one thing.

Already when the experiments began, physicists hoped that the high-energy LHC collisions would result in the theoretical dark matter, which is vital for astronomers being able to explain how the galaxies can rotate so fast without ejecting their stars in all directions. But the particles of darkness have not been identified, and so, CERN and 70 research institutions throughout the world plan to build the accelerator of the future, the Future Circular Collider (FCC). The huge device will have a circumference of 100 km and be able to collide protons seven times more forcefully than the LHC.

Invisible twins save theory

In 2012, when LHC scientists identified the Higgs boson, it was a monumental discovery. The existence of the particle is the definitive proof that history's most comprehensive and successful physics theory, the standard model, is correct. The standard model is a classification of elementary particles, that can be divided into two types – atomic building blocks and power-carrying particles.

Among the atomic building blocks, you will find 12 particles: six different types of quarks, three types of electrons, and three ▶

With a circumference of 27 km, the LHC accelerator is located on the border between Switzerland and France.Its successor, the FCC, will be almost four times larger.

GOOGLE EARTH

The LHC's predecessor found atom ingredients

3 **1989** The LEP was the first accelerator in the tunnel which now includes the LHC. By colliding electrons and positrons, physicists proved that all matter consists of 6 types of quarks, 3 types of electrons, and 3 types of neutrinos.

- **Name:** Large Electron-Positron Collider
- **Circumference:** 27,000 m
- **Highest energy:** 209 GeV

The world's biggest machine solved the mystery of mass

4 **2008** In 2012, the LHC accelerator identified the Higgs boson, which provides all other particles with mass by connecting to them. The discovery definitively proved the standard model – the theory describing elementary particles.

- **Name:** Large Hadron Collider
- **Circumference:** 27,000 m
- **Highest energy:** 13,000 GeV

Huge ring to end the search for dark matter

5 **2035** CERN's next giant project is to build the Future Circular Collider (FCC). With more than seven times as much energy as the LHC, it is to finally determine if the invisible dark matter consists of twin particles. When the FCC opens, the LHC will become a pre-accelerator, which feeds particles to the new ring.

- **Name:** Future Circular Collider
- **Circumference:** 100,000 m
- **Highest energy:** 100,000 GeV

types of neutrinos. With these basic ingredients, all atoms in the universe can be produced. The standard model also describes three of the four fundamental forces of nature – the electromagnetic force, the strong nuclear force, and the weak nuclear force, which each have their own force-carrying particles. The most well-known is the photon, which is the force-carrying particle of the electromagnetic force. However, scientists have not been able to find a force particle, which carries the fourth force, gravity.

So, physicists have developed quantum gravitational theories, in which the mass attraction between bodies is produced via exchange of force-carrying particles known as gravitons. But the theory only works out right mathematically, if each elementary particle has an invisible twin. This means that the standard model's atomic building blocks such as quarks must have force-carrying twins known as squarks, whereas force-carrying particles such as photons must have atomic building block partners known as photinos. Those were the twin particles that physicists hoped the LHC would find. Twin particle discoveries would not only pave the way for a theory that can explain all phenomena in the universe, but rather also be the proof that dark matter exists, solving a major problem for astronomers, who cannot explain how stars can orbit the centres of galaxies so fast without being chucked away – unless gravity from invisible dark matter hold them in place.

LHC is not sufficiently powerful

In physics, mass and energy are two sides of the same coin. The heavier the particles are, the higher their energy, and so, particles' mass is often measured in gigaelectron volts (GeV). After analysing billions of LHC proton collisions, physicists have concluded that the twin particles must at least have a mass of 1-2,000 GeV. But the heavier the particles, the more energy is requires to produce them in accelerators. The LHC might not be able to produce such heavy particles – the Higgs boson only weighs 125 GeV. So, physicists need a new huge accelerator which can generate much more energy.

2,000

GeV is what scientists think that dark particles weigh– 16 times the Higgs boson.

Higgs boson to be studied

The FCC accelerator will be completed in 2035, but already now, CERN project staff is working on its design. Very few details have been revealed at this point, but there is every indication that the accelerator will be built in a tunnel with a circumference of 100 km. The huge size is due to the fact that charged particles such as protons emit radiation, when their paths are bent, causing them to lose energy. The large circumference minimizes the bend and so the energy loss, reducing the quantity of energy to be pumped into the particles, as they circulate in the ring.

According to FCC Deputy Study Leader Frank Zimmermann, the tunnel will most likely end up including more than one accelerator. First of all, engineers will probably be asked to build an electron accelerator, in which electrons will collide with their antiparticles, known as positrons. Collisions between electrons and positrons are simple, as they are not made up of smaller particles. In the collisions, the electrons are converted into pure energy, which is subsequently converted into particles with corresponding energy, which the detectors pick up. So, the collisions are purer and easier to analyse, making an electron accelerator perfect for accurate measurements.

The new device will be able to generate millions of Higgs bosons, whereas the LHC will only generate abut 1,000 up until 2035. A Higgs boson is the elementary particle responsible for everything in the universe having mass. Physicists know that a Higgs boson combines with the other elementary particles and that the particle's mass depends on the strength of the coupling. Electrons combine with Higgs bosons with a modest force, and hence, they have a small mass, whereas quarks are heavier, as they have more powerful couplings. With the new device, physicists will be able to take a closer look at the coupling mechanism.

After a few years, the electron accelerator will be scrapped and replaced by a proton accelerator. Protons have a 2,000 times larger mass than electrons and can provide much more high-energy collisions. And unlike the electron accelerator, it can be used to spot new particles. Proton collisions can provide physicists with a record high collision energy of 100,000 GeV, which might be necessary to produce the twin particles. The disadvantage of proton accelerators is that it is difficult to analyse the collisions. Protons are made up of small atomic building blocks known as quarks and the force- carrying particles of gluons, and so, the cloud of particles that spreads in the wake of a proton collision is much more complex than in the case of electrons.

If the accelerator spots twin particles, it will be the discovery of the century, as it would solve a series of physics and astronomy problems. And if the FCC does not identify dark matter, scientists will know that twin particles do not exist, as in that case they will be too heavy. So even another failed attempt will make scientists wiser. SCI

The large CMS detector is one of four LHC detectors. In 2012, it contributed to identifying the Higgs boson.

CERN

New Huge Accelerator Will Recreate the Big Bang

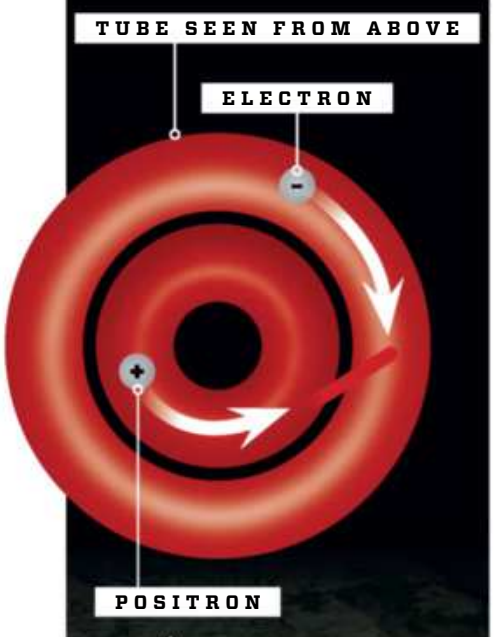
SHUTTERSTOCK

In 2035, CERN will be ready to make experiments with the first of two giant accelerators with a circumference of 100 km. The first one will study the Higgs boson. The next one will search for dark matter and recreate the primordial soup of the universe.

FUNCTION 1: RESEARCH

Huge ring to mass-produce Higgs bosons

Electrons and positrons are directed into separate tubes. As electrons and positrons have different electric charges, a magnetic field will send them separate ways. The tubes pass through four detectors, in which the particles collide. The collisions will produce millions of Higgs bosons and teach physicists more about how the atomic building blocks get their mass by combining with the Higgs bosons.

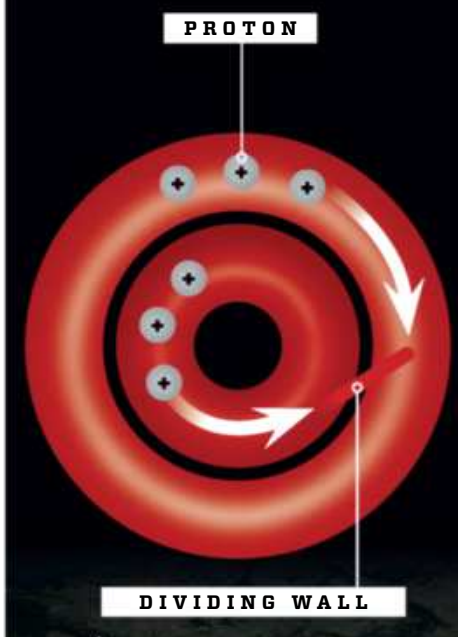


Positrons and electrons have opposite charges and react differently to the same magnetic field.

FUNCTION 2: DISCOVERY

Proton collisions to reveal dark twin particles

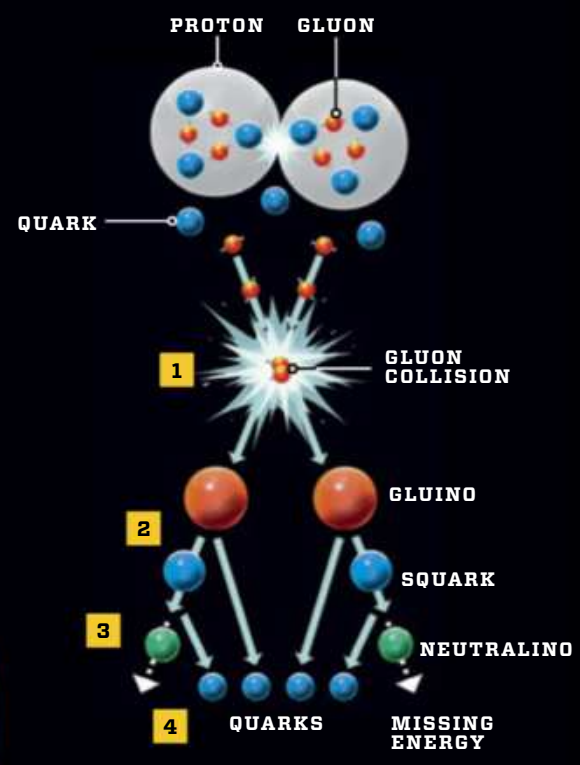
Even with lots of force in the new FCC accelerator, it will be a challenge to trace dark matter in the shape of twin particles. That is because dark matter is made up of particles which do not interact with matter. This means that scientists cannot build a detector that can measure twin particles directly, as dark matter will just pass right through it. However, dark matter has mass and so energy, of which scientists can find traces in the detector.



Protons are accelerated in opposite directions by two powerful magnetic fields, before they collide.

1 When protons are shattered, they spread their contents of quarks and gluons. When two gluons collide, they turn into their **twin particles, gluinos**.

2 Each gluino will quickly decay into a quark and the quark's **twin particle, which is known as a squark**.



3 Each squark decays into **a quark and a neutralino**. Neutralinos disappear and cannot be spotted by the detector.

4 Four quarks remain, and as physicists know the energy from the gluon collision, they can measure if energy corresponding to two neutralinos is missing.

FUNCTION 3: TIME TRAVEL

New accelerator brings scientists closer to Big Bang

A split second after the Big Bang, the universe consisted of a "soup" of free gluons and quarks, which are the ingredients of protons and neutrons. By colliding lead cores with lots of protons and neutrons at record speeds, the FCC recreates the soup less than a nanosecond after the Big Bang, so physicists can observe the formation of the universe on a small scale.

Lead cores obtain a speed of 99.98 % of that of light, before they collide.

LIGHT = POWER, FOOD, AND MATES

Luminous skeletons and glowing bottoms. A series of creatures have develped the ability to shine as an important tool in the struggle for survival.

In 2017, scientists discovered that UV light causes blue, glowing patterns on the chameleon's skull. Small bone "lumps" absorb the short wave light, re-emitting it at a longer, visible wavelength. The light helps the creature find a mate.

DAVID PRÖTZEL/ZSM/LMU/PETE OXFORD/NATURE PICTURE LIBRARY

CHAMELEON | Glowing bone helps camouflage champion find a mate.

By **Nynne Sørgaard**

The hind part of the glowworm larva lights up, when luciferase reacts with oxygen in the creature's bottom. The bluish green light attracts insects, which the larva captures in long, sticky silk threads. The hungrier the larva, the brighter the light.

SOLVIN ZANKL

GLOWWORM | Hungry larvae attract prey by means of shining bottom.

Thousands of small, bioluminescent light organs hide the firefly squid from its enemies. The blue flashes on the lower side of the body make the creature blend in with the ocean surface. The light is also used to communicate and to attract prey.

SOLVIN ZANKL

FIREFLY SQUID | Blue flashes hide squid from enemies.

The scorpion's external shell includes pigments that shine under the effect of UV light. The shell functions as a kind of warning lamp: when the UV light is strong, and the shell lights up, the nocturnal creature takes shelter. Only in dim UV light, such as that reflected from the Moon, does the scorpion venture out to find food.

CHARLIE HAMILTON JAMES/RICHARD GARVEY-WILLIAMS/ALAMY/ALL OVER

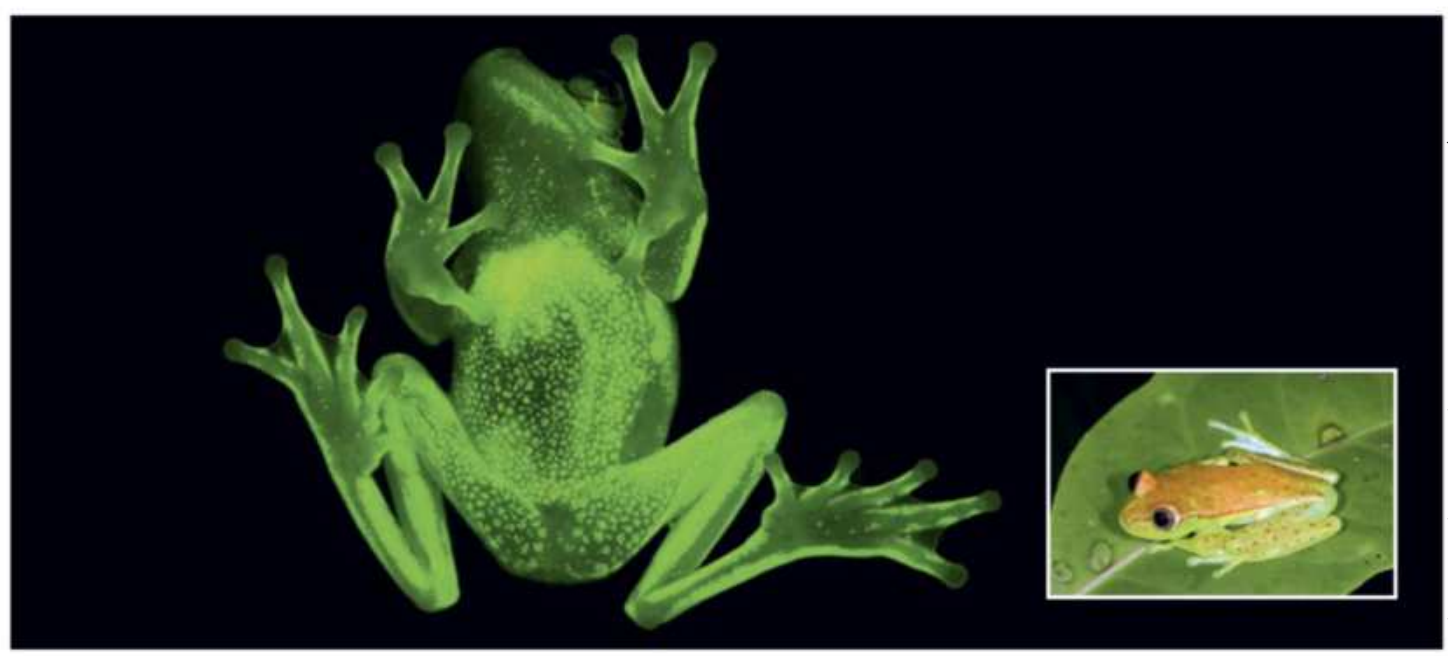
SCORPION | Luminous body forces scorpion to take shelter.

SOLVIN ZANKL

The small, nocturnal sea-firefly reacts to motion in the water such as from large marine animals by liberating a secretion, that lights up in blue, as it reacts with oxygen in the water. The blue "cloud" is probably meant to make the 3 mm creature look bigger.

SEA-FIREFLY | Waves make the sea light up in blue blotches.

The nocturnal polka-dot treefrog has developed a biological night light. Luminous molecules in lymph, skin, and glands shine under the influence of UV radiation. The light corresponds to 18 % of the light from a full moon, helping the frog navigate in the dark.



JULIAN FAIVOVICH AND CARLOS TABOADA/MACN-CONICET/MORLEY READ/SPL

POLKA-DOT TREEFROG | Frog has integrated night light.

PATRICK PELLETIER/DOUG PERRINE/NATURE PICTURE LIBRARY

PhotoDoc

LIGHT = POWER, FOOD, AND MATES.

The flower hat jelly's luminous tentacles include GFP, a highly fluorescent protein. The intense, green light attracts the small fish, on which the creature feeds. The prey probably mistakes the light for chlorophyll, which colours plants and algae.

FLOWER HAT JELLY | Colourful jellyfish uses light to cheat prey.

Instant Expert: Volcanoes

Our planet has a deadly skin condition

More than half a billion people throughout the world live near a volcano. Volcanoes are usually surrounded by fertile farmland, and cheap energy is often easily available. On the other hand, volcanoes are temperamental, and nobody knows exactly when the next eruption will come.

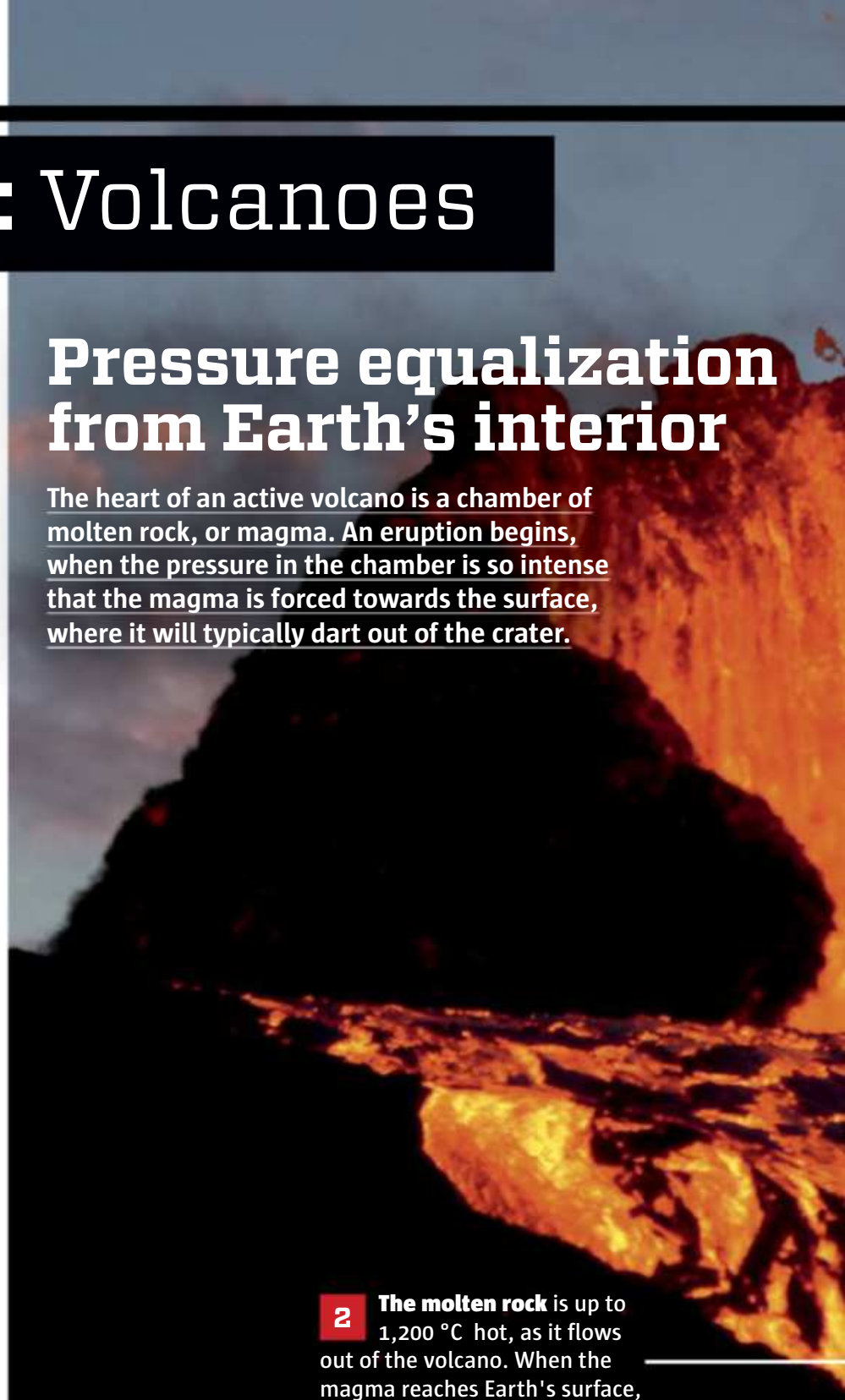
Volcanoes are Earth's natural relief valves. When too much magma is under too much pressure close to Earth's crust, a volcano develops – or an existing one erupts one more time. There are volcanoes on all continents, including Antarctica but the majority of the volcanoes in the world are located in places, where the tectonic plates meet. Their most frequent occurrence is the "Ring of Fire" in the basin of the Pacific Ocean.

The exact number of volcanoes is unknown, as it depends on how you define a volcano – whether it must be active, and if all craters in major volcanic areas count as separate volcanoes. It is estimated that 1,300-1,500 volcanoes exist that have erupted over the past 10,000 years. Moreover, there is a large quantity on the bottom of the oceans. Some volcanoes are only a crack in the ground, while others develop over millions of years, ending up as the South American Ojos del Salado, which rises to an altitude of almost 6.900 m, making it the world's highest volcano.

Just like sizes and shapes of volcanoes, their temper is determined by the type of magma which powers them. Some magma flows easily out of the crater and down slightly inclining slopes. Other types are viscous, flowing with much more difficulty, possibly causing "constipation", i.e. almost acting as a plug. Volcanoes with highly viscous magma are ticking bombs. If the pressure keeps on rising below the plug, the volcano will end up exploding in an inferno of fire, glowing red-hot magma, and ash.

Pressure equalization from Earth's interior

The heart of an active volcano is a chamber of molten rock, or magma. An eruption begins, when the pressure in the chamber is so intense that the magma is forced towards the surface, where it will typically dart out of the crater.



2 **The molten rock** is up to 1,200 °C hot, as it flows out of the volcano. When the magma reaches Earth's surface, it is cooled.

One of the most active volcanoes in the world is located on the French island of Réunion in the Indian Ocean.

// VOLCANO TYPES

There are several types of volcano. Generally, the liquid magma's content of gases and silicon determines the shape of a volcano. Easy-flowing magma often produces wide, flat volcanoes, aka shield volcanoes, whereas the more viscous magma types often result in high volcanoes such as stratovolcanoes and dome volcanoes.

Shield volcanoes are produced by easy-flowing magma, resulting in a volcano that resembles a knight shield with its front side facing upwards. The slopes only incline slightly, and even low shield volcanoes cover major areas. The slopes incline the least at the centre.

Stratovolcanoes are volcanoes like the ones that kids draw – with a steep top and less inclining sides. In this way, they are easy to distinguish from shield volcanoes. Stratovolcanoes are made of alternating layers of lava and ash, and they are often large.

Volcanoes with very viscous magma are often dome volcanoes. The domes emerge, because the magma only flows a few metres, before it hardens. In this way, the volcano is constantly plugging itself up, so each new eruption starts with an explosion, by which the top is shot off.

1 **Magma shoots** out of the volcano crater due to the high pressure from the underground. Small balls of fire (volcanic bombs) fly in all directions.

3 **The flow stops,** when the magma has cooled to about. 800 °C. Hardened magma is known as lava. It is often porous due to small pockets, from which the gas of the magma escaped.

// HISTORY'S WORST VOLCANIC ERUPTIONS

Volcanoes have claimed about 300,000 lives over the past 500 years. The causes of death are both direct (lava flows) and indirect (famine due to failed harvests).

Casualties	Volcano	Year	Primary cause of death
92,000	Tambora, Indonesia	1815	Famine
36,417	Krakatau, Indonesia	1883	Tsunami
29,025	Mt. Pelée, Martinique	1902	Ash
25,000	Ruiz, Colombia	1985	Mud avalanche
14,300	Unzen, Japan	1792	Explosion, tsunami
9,350	Laki, Iceland	1783	Famine
5,110	Kelut, Indonesia	1919	Mud avalanche
4,011	Galunggung, Indonesia	1882	Mud avalanche
3,500	Mt. Vesuvius, Italy	1631	Avalanche, lava
3,360	Mt. Vesuvius, Italy	79	Ash

Pompeii victim, when Mt. Vesuvius erupted in 79 AD. Casting.

Rain causes volcanic eruption

Weather, climate, and volcanoes interact in different ways. If the eruption is sufficiently severe, major quantities of ash and sulphur are ejected into the atmosphere, where the particles reflect the sunlight, causing a cooling of up to several degrees at ground level in the following years.

On the other hand, it also seems as if the weather can directly trigger a pending eruption, as evidenced by the active Soufrière Hills dome volcano on the island of Montserat. There, a high number of eruptions occur in connection with the heavy rain that falls in the area. The water seeps into nooks and crannies, where it evaporates in the encounter with the very hot magma. Vapour takes up more space than water, and so, the pressure inside the dome rises, sometimes making it collapse.

The seasons apparently also affect volcanoes. In the northern hemisphere, much more eruptions take place in the winter than in the summer. The physical explanation of the phenomenon has to do with the boundless quantities of water that "travel" from the northern to the southern hemisphere and back annually. The process causes a rhythmical pressure change in the magma chambers that feed volcanoes.

Heavy rain affects the Soufrière Hills volcano on the island of Montserrat. So, the volcano is constantly monitored.

Trivia

PUT YOUR KNOWLEDGE TO THE TEST


q. 6

1. With its unique ancient statues and lack of trees, Rapa Nui is better known to English speakers as what?

2. Pitcairn Island was settled by members of the mutinous crew of which famous English ship?

3. Originally meaning "moveable personal property" and related to the word "capitalism", what word refers to both sexes of the most common domesticated ruminant?

4. An urban legend involving the US government doing psychoactive experiments on teenagers in the 1980s, centred around *Polybius*, which was a what?


q. 8

5. With a three-chambered heart, unique elliptical red blood cells, and a distinctive long neck, which foul-tempered mammalian group has only seven species, found in Africa, the Middle East, and South America?

6. Which is the largest walled city in Europe, and inspiration for a popular board game of the same name?

7. A 66 ton chunk of iron in a field in Namibia is actually a remarkably well-preserved what?

8. Virgin Galactic's SpaceShipTwo is currently the only licensed commercial aircraft able to fly faster than what?

9. Which high-end sports car maker built an electric hybrid supercar in 2013, with a name that literally means "The [Name of Company]"?

10. Which sea creature has a name that means cloak, but refers to the type of blanket-shaped trap traditionally used to catch it?

Trivia Countdown (use fewer clues, get a higher score!)

	5 POINTS	4 POINTS	3 POINTS	2 POINTS	1 POINT
1. TECHNOLOGY **Name this instrument**	An early version of the instrument was invented by Zhang Heng of China and was in use already around 132 CE.	Modern versions of the instrument record motions in 3 directions, of which one is vertical and two are horizontal.	The instrument is used throughout the world, recording movements every day – some more forceful than others.	Its measurements are recorded as lines on a chart. A needle moves rapidly when extremely energetic events occur.	The device is used to measure the magnitude of seismic activity such as earthquakes and nuclear explosions.
2. LINGUISTICS **Name this language**	In the 1500s, the language changed into a modern variant, promoted by writers such as Gil Vicente, the playwright.	"Cashew", "emu", and "marmalade" are from the language, which is one of the Iberian Romance languages.	Spoken in Angola, Cape Verde, Mozambique, and East Timor. It's often mistaken for another European language.	The most closely related language is Galician, but many words and some of the grammar come from Spanish.	About 200 million people speak the language as their native tongue. The highest number of them in Brazil.
3. AEROSPACE **Name this spacecraft**	On 23 March 2001, the craft left its low Earth orbit to crash into the Pacific off New Zealand just as planned.	Its mission lasted three times longer than first expected, despite a long series of problems such as fire and collision.	The name of the craft has more than one meaning, such as *peace* and *world*, but it specifically refers to a Russian village.	The craft was made up of seven modules linked in 1986-1996. One cosmonaut spent 437 days in a row on board.	This manned space station was meant to have a successor, but Russia decided to support the larger ISS instead.

ANSWERS ON p82!

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SPECIES: Grey Mangrove

SCIENTIFIC NAME: *Avicennia marina*

DISTRIBUTION: All mainland Australian states, Arabian Peninsula, Red Sea, Persian Gulf, South Africa and Somalia

ICUN CONSERVATION STATUS: Least concern

PHIL BENDLE

LIFE BELOW THE SALT

This grey mangrove propagule has anchored itself in the sand and turned itself upright.

Most of the so-called higher plants - land plants with trunks and branches, fruit and flowers - don't do so well in salt water. Even elevated salinity in the soil is enough to kill many species of tree, and salinity is a major problem in inland Australia as water-tables fall in times of drought (or through excessive irrigation).

One exception to the "salt is bad" rule is the grey mangrove. This is the species found in Australia, and it's one of the toughest trees on the planet.

Usually, Australian plants and animals are restricted into bands more or less associated with climate and rainfall. Up north, we get the remains of ancient rainforests. Down south, more temperature species and the "dry sclerophyll" eucalypt forests. Inland, hardy desert plants.

But grey mangroves are found in every state, even in Western Australia where there are huge gaps in populations. A mangrove forest at the Albrohos islands is 500km from the next group of trees at Bunbury, and 300km from one at Shark Bay.

The secret to the grey mangrove's success is of course its tolerance for salt water. A unique adaptation allows it to take sea water in, and excrete the salt from its leaves. But the grey mangrove can also tolerate *less* salty conditions, such as in times of flood.

Another challenge living in estuarine conditions is the lack of oxygen in the soil. The grey mangrove deals with this via its distinctive pneumatophores, or aerial roots.

As well as acting as anchors against the tide, the pneumatophores are able to absorb oxygen directly from the air. All plants breathe oxygen through their roots, but usually underground.

The final challenge for a tree that lives in an environment that's frequently underwater is in germinating offspring. Seeds can sink and rot. So the mangrove uses a structure called a propagule.

About the size of a walnut, the propagule floats in a natural orientation that points the eventual roots toward the ground and the stem to the sky. It allows the new tree to get enough light, while also finding nutrients.

Because of their relationship with salt water, grey mangroves are an excellent indicator of water quality, climate change, and the overall health of a coastline.

TRIVIA ANSWERS 1. Easter Island **2.** HMS Bounty **3.** Cattle **4.** An arcade game **5.** The Camelids **6.** Carcassonne **7.** Meteorite **8.** Sound **9.** Ferrari (LaFerrari) **10.** Manta Ray **Trivia Countdown – Name this instrument:** Seismograph **Name this language:** Portuguese **Name this spacecraft:** Mir space station

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