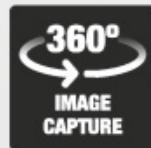


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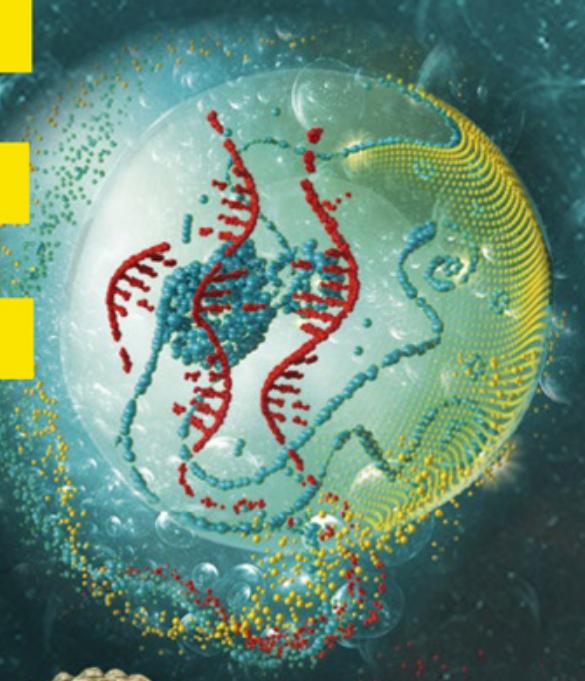
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**EDITORIAL**

Editor Anthony Fordham  
afordham@nextmedia.com.au

**DESIGN**

Art Director Malcolm Campbell

**ADVERTISING ENQUIRIES**

Advertising Manager  
Di Preece  
dpreece@nextmedia.com.au  
ph: 02 9901 6151

Production Manager Peter Ryman  
Circulation Director Carole Jones

**INTERNATIONAL EDITION**

Editor-in-Chief Sebastian Relster  
International Editor Lotte Juul Nielsen

**BONNIER INTERNATIONAL**

**MAGAZINES**  
International Licensing Director  
Julie Smartz  
Art Director Hanne Bo  
Picture Editors Allan Baggesø,  
Lisbeth Brønnich, Peter Eberhardt

**nextmedia**

**NEXTMEDIA**  
Chief Executive Officer David Gardiner  
Commercial Director Bruce Duncan

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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.

## Trust Me, I'm a Scientist!



Could the reason so many people seem to find it so hard to trust the things told to them by scientists, be because scientists are constantly saying: "Trust us, we're know what we're talking about"?

When it comes to believing "the truth", there are two distinct aspects to our knowledge: what we've learned from another person or figured out in our heads, and what we've directly experienced or observed in the real world.

As a product of at least 500 million years of evolution, your brain comes with a bunch of pre-programmed responses to certain things, which tend to increase your survivability. Colloquially, we call them "instincts".

Some of them are obvious: be super-alert around the edge of very tall cliffs, resist any urge to touch fire, suspend breathing when your head is underwater, and so forth.

Others are more subtle. Big eyes and big teeth? Scary! Looks like a snake? Also scary! Loud buzzing insect with orange or yellow parts? Stingy! Air feels unsettled? Shelter time, storm coming! Plant has plump red berries?... actually this one can go either way, but being able to spot food on plants like birds can, is part of why we have such good colour vision.

Anyway, when it comes to deciding how to act in a situation we've never been in before, we combine these instinctive responses with knowledge we already have about similar situations, and we imagine a solution, and then do it. We figure it out for ourselves, as it were, and we see the results. Were we wrong? Well, the experience now shows us how to be right. Adjust solution! Remember it for next time. Self-teaching works!

But we gained even more survivability by being able to also teach each other: to be told by someone else about something, and therefore - incredibly if you think about it - learn from an experiences we personally have never actually had.

The risk, of course, of making decisions based on something someone else has told you, is that people can be wrong. Or they can deliberately lie. Or you can misunderstand what they told you.

Our brains deal with this (at least partly) by not worrying too much about getting the absolute optimal results for any given problem. We solve problems in what's called a heuristic way - which can be more or less described as "near enough is probably going to turn out to be good enough".

On top of that we have the ability to go "well, I'll start acting in this way and then adjust my reactions as new data arrives". The "we'll work it out as we go along" method, as it were.

And that was fine for tens of thousands of years.

Sure, a lot of people died, and a lot of mistakes were repeated over and over, but we got smarter, and we started pooling our knowledge using things like writing, and we got smarter still.

Then, as a result of pooling knowledge, and building on existing knowledge by saying "okay so, this stuff that's written down is right, I can just take it as read I don't need to figure it out myself, let's do the next thing" is that we developed this philosophical concept called "the right answer".

Nature doesn't really deal in absolute right answers. Nature, like our brains, operates on a near-enough-is-good-enough system. Just one example - animals don't evolve to be perfect for their ecological niches, rather they evolve to be the least terrible at exploiting their niche.

Human civilisation brought with it this idea that there can be an optimal solution for a problem. Not for every problem, necessarily, but many. And yet! We continually improve even what we thought was the "perfect solution" because there are always individuals who say no, no I don't accept that perfect solution, I think we can do better.

And that's how you get new inventions, and better scientific theories, and more accurate models and descriptions of how the universe works.

Which brings us, of course, to climate change. Climate change is something so huge, so all-encompassing, it's almost impossible for the non-specialist individual to even perceive it. To "believe" in climate change - unless you yourself have been out there gathering temperature readings or whatever - is to take the word of people who you almost certainly don't know, haven't met, and whose work you probably find very difficult to understand.

Evidence and observations showing climate change is happening do exist. But most of us haven't seen them, not with our own eyes. We've only ever seen summaries, abstracts, pretty graphs.

And sadly, for some people, this makes climate change seem like something that's completely made up. Someone tells them something - the climate is changing - but they just can't feel it. So, believing in or doubting climate change is a wholly intellectual exercise. It doesn't trigger any of our instinctual responses. And for some people, this doesn't just make it seem unreal, it make it seem explicitly false.

I'm not excusing this kind of thinking, and I'm certainly not saying we should tolerate or indulge it. I'm just saying this might go some way to explaining why, for some people, the most correct-feeling response to being told by experts who have dedicated millions of hours to making sure that yes, this is real, the climate is changing... is to say "Naaaaah."

**Anthony Fordham**

afordham@nextmedia.com.au

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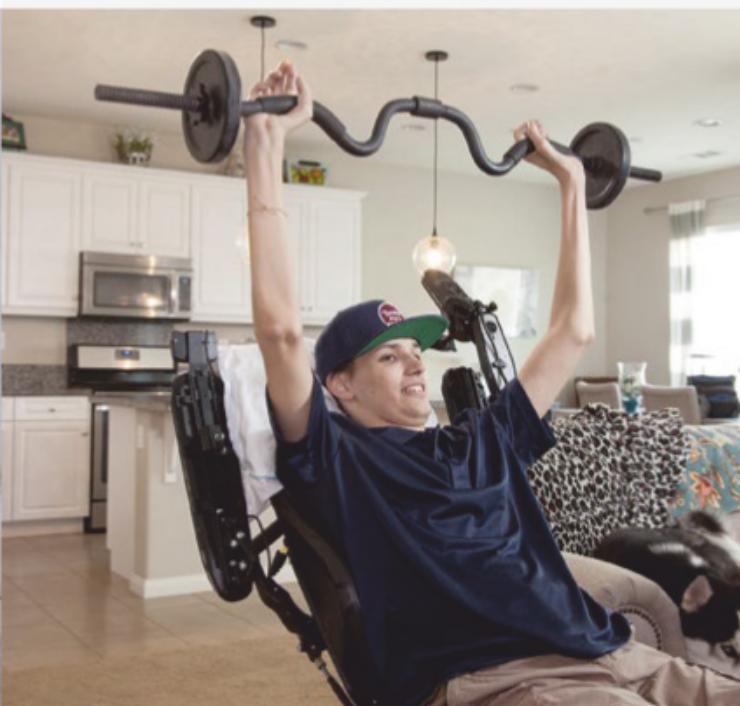
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## Extinct palace atop an extinct volcano

 Once, there was intense volcanic activity in the area that is now central Sri Lanka. Today, the volcanoes are long extinct, but a 200-m-high rock column rises above the jungle as a frozen relic from the island's tectonic past. The Sigiriya rock is the result of the decomposition caused by the elements, which eroded the volcano's surface over millions of years, leaving only the hardened lava in its interior. A drone allowed the shooting of this close-up of the rock's top, that once included a Buddhist monastery and a royal palace.

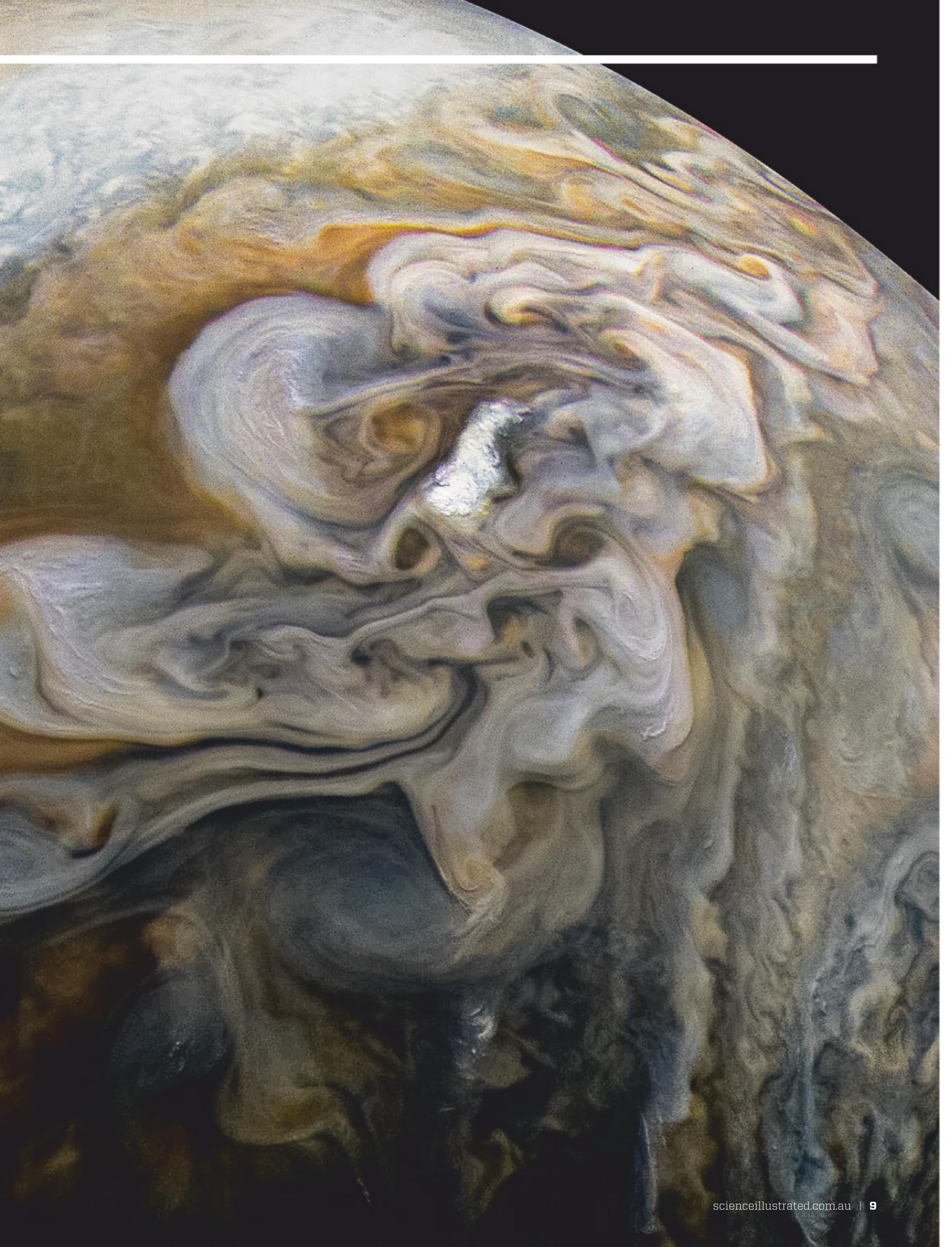
Photo // Jerome Courtial



## Space probe zooms in on Jupiter's extreme weather

 Jupiter is covered in dark bands and light zones produced by storms with wind speeds of up to 600 km/h. The dark bands are warm, descending gas, the light zones are rising clouds of frozen ammonia. The Juno space probe is rotating the gas giant at a distance of 4,200+ km, allowing it to take close-ups. The probe's data has revealed that the rotating bands and zones are dissolved at a depth of 3,000 km. Deeper inside the planet's interior, the magnetic field attracts the gases in one flow rotating in the same direction.

Photo // NASA



# Gold reveals cancer

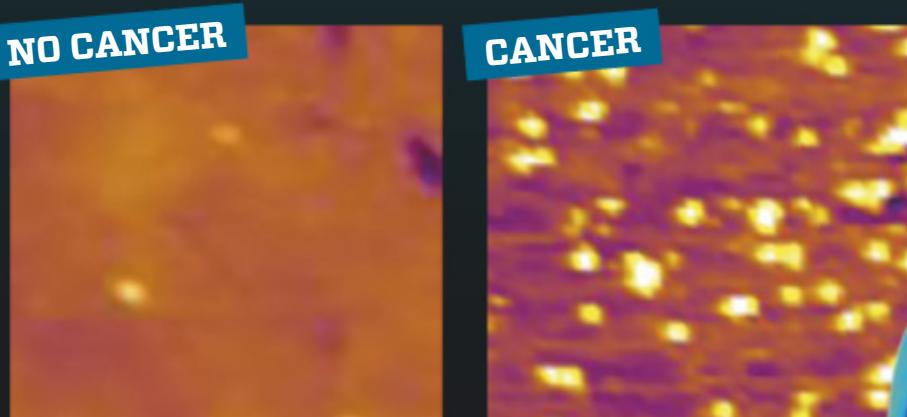
Today, doctors cannot make a simple test for cancer in the entire body, but in the future, a blood sample with gold particles might be enough to spot the killer early.

**MEDICINE** Today, doctors must take a series of steps to make a cancer diagnosis, rather than carry out a quick, general test which covers the entire body. But they may be able to one day – based on gold. Scientists from the University of Queensland have discovered that gold nanoparticles bind to cancer cell DNA.

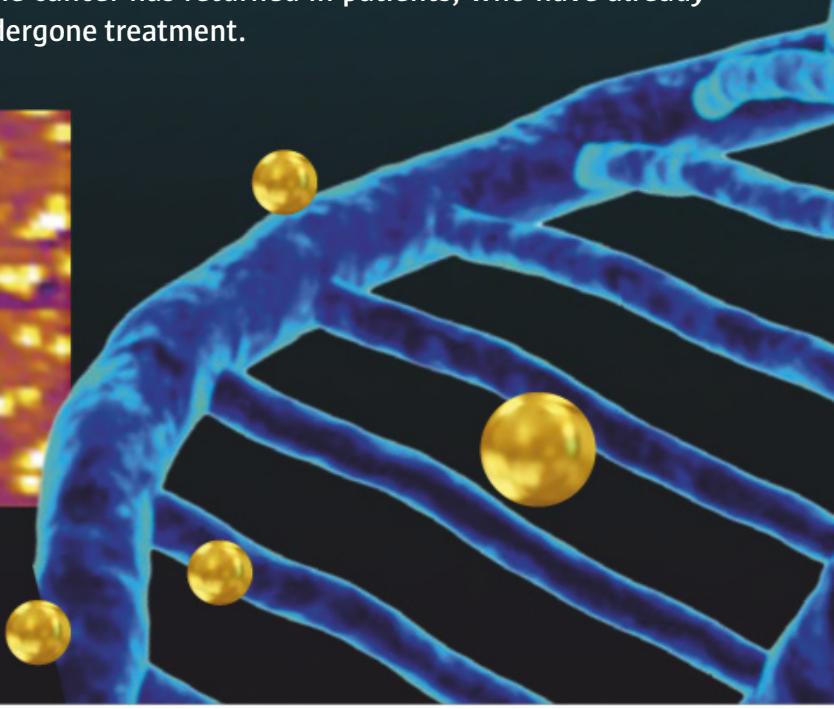
All body cells send tiny DNA fragments into the blood stream, so a simple blood sample would be sufficient to reveal the presence of cancer cells. The explanation is that our DNA strands, which include the genes, are also lined with other molecules such as methyl. These molecules determine how active the individual genes are. In normal

cells, methyl is evenly distributed along a DNA strand, but in cancer cells, the molecules clump together. The lumps make cancer DNA fold more loosely than DNA from healthy cells, allowing gold particles to bind to methyl. So, the cancer DNA attracts many gold particles, which can easily be observed in a microscope.

Scientists tested the gold method on 200 people, of whom some had cancer. In about 90 % of the cases, the cancer was revealed. The method will not be used for some time to come, and it will probably first be employed to see if the cancer has returned in patients, who have already undergone treatment.



Gold nanoparticles reveal if there are tiny fractions of cancer cells in a blood sample. Concentrations of gold light up in the microscope, if the sample is from a cancer patient.



## Was this whale a Russian spy?

**BIOWEAPONS?** In April 2019, Norwegian fishermen working in the Barents Sea encountered an unexpectedly tame Beluga Whale. While the whale was unusually friendly and approached boats in the area to interact with the crew, what really tipped them off was the unusual harness the animal was wearing.

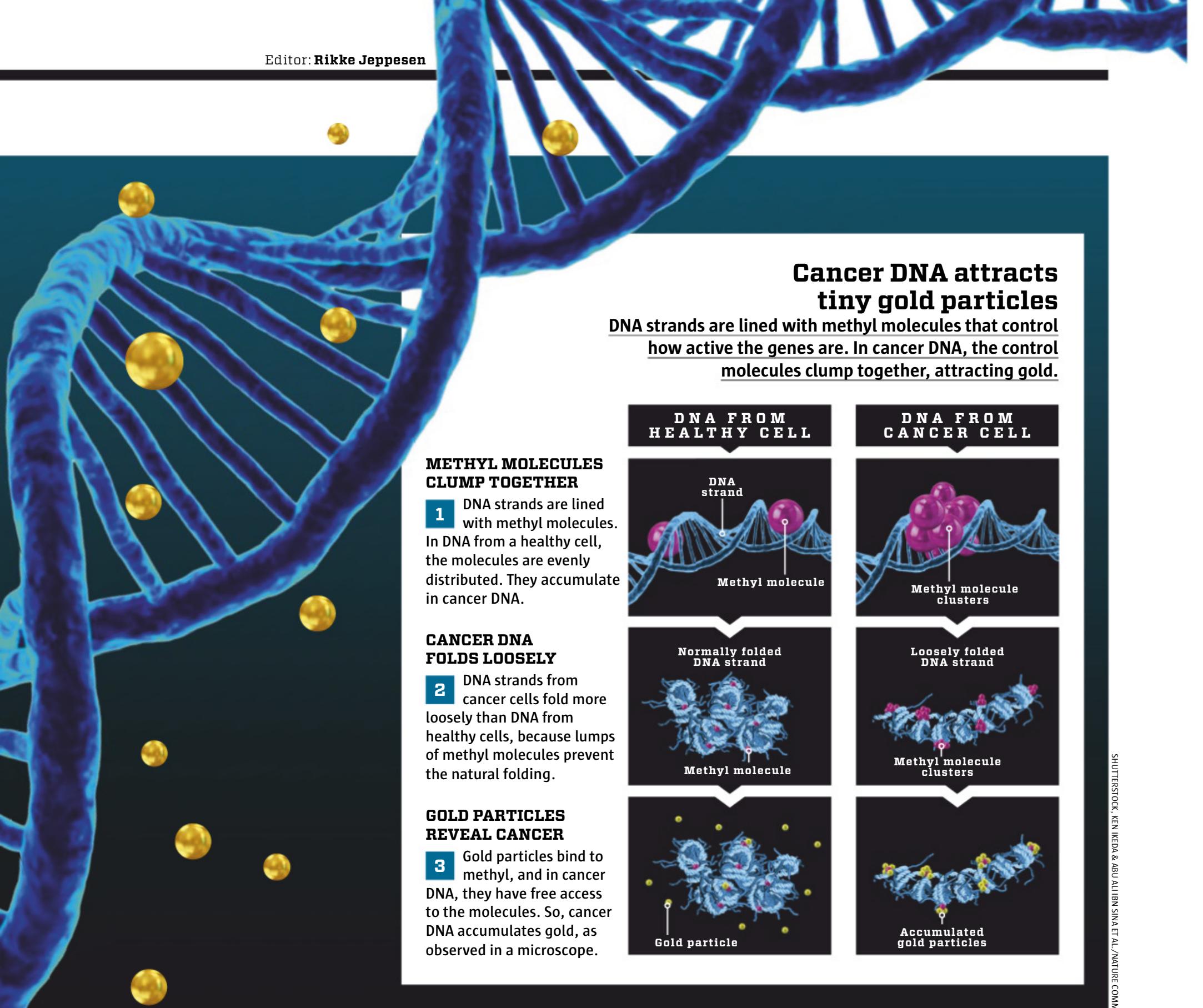
Scientists routinely attach trackers and GPS devices to whales to gather data on migration patterns, but these are normally done with an adhesive that dissolves over time. This whale had no device attached, but the harness - consisting of straps and buckles - wasn't like anything scientists usually used (or would be able to get ethical approval for).

One of the fisherman eventually cut the harness off the whale, and they discovered "Equipment of St Petersburg" written on the straps. Russia's scientific community was quick to insist it had nothing to do with the whale, and that the harness was most likely an escapee, or reject, from a military experiment or program.

The Murmansk Sea Biology Research Institute is supposedly working with the Russian navy on militarising cetaceans.



Whale researchers are worried about the Beluga's prospects for survival in the wild, because it's so tame.



## Cancer DNA attracts tiny gold particles

DNA strands are lined with methyl molecules that control how active the genes are. In cancer DNA, the control molecules clump together, attracting gold.

### METHYL MOLECULES CLUMP TOGETHER

**1** DNA strands are lined with methyl molecules. In DNA from a healthy cell, the molecules are evenly distributed. They accumulate in cancer DNA.

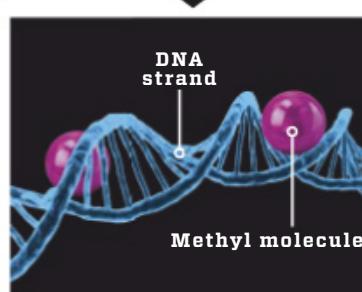
### CANCER DNA FOLDS LOOSELY

**2** DNA strands from cancer cells fold more loosely than DNA from healthy cells, because lumps of methyl molecules prevent the natural folding.

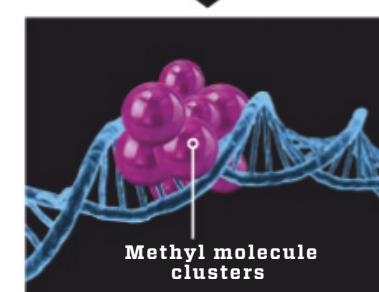
### GOLD PARTICLES REVEAL CANCER

**3** Gold particles bind to methyl, and in cancer DNA, they have free access to the molecules. So, cancer DNA accumulates gold, as observed in a microscope.

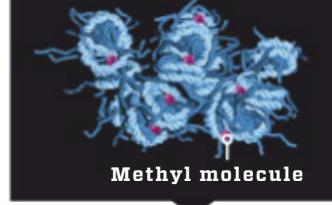
DNA FROM  
HEALTHY CELL



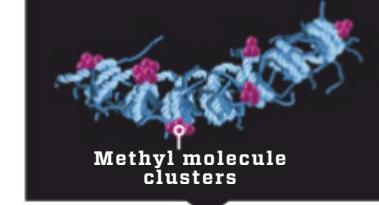
DNA FROM  
CANCER CELL

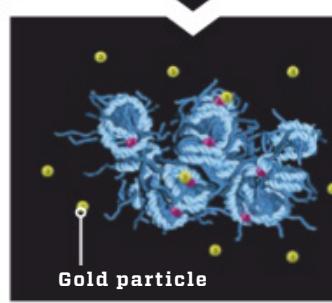


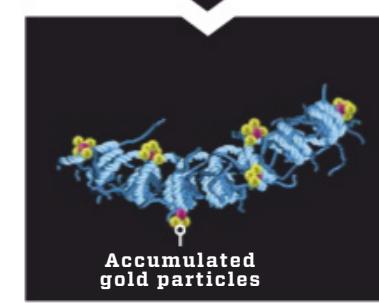
Normally folded  
DNA strand



Loosely folded  
DNA strand







SHUTTERSTOCK: KEN IKEDA & ABU ALI BIN SINA ET AL./NATURE COMM.

## Robotic plant seeks out the light

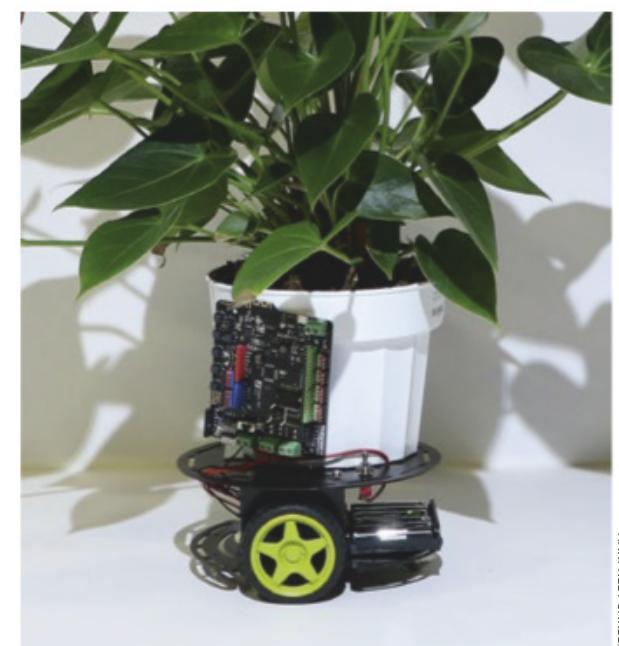
**TECHNOLOGY** If plants could move, would they? Scientists from the Massachusetts Institute of Technology in the US have given a plant entirely new kind of life. It moves freely about to seek out the ideal light conditions.

Plants are naturally equipped with sensors that read conditions around them such as light, temperature, and soil moisture. They use the information to grow in the most appropriate direction, but also to follow the Sun's motion across the sky.

Plant cells communicate by means of electric impulses – just like the cells of our nervous system. Consequently, the scientists were able to equip their plant with electrodes, which pick up electric signals, passing them on to a small rover on wheels. The result is a

mixture of a plant and a machine, which the scientists have named Elowan. In experiments, in which the scientists alternately activated and deactivated two lamps on either side of Elowan, it resolutely went to the lamp that was turned on.

Although Elowan might immediately seem like a fun hobby experiment, it is indeed very serious. According to the scientists, allowing plants' sensory apparatus and technology to interact opens wide perspectives. In the future, it might be possible to make plants control the direction of solar panels on all houses during a day to obtain as much sunlight as possible. Plant rovers could also be used to control and ensure optimum temperatures and humidity in major office buildings.



HARPREET SAREEN

**"Elowan"** is a crossbreed between a plant and a machine. It senses where the light comes from, approaching the source.

## BY THE WAY

### UNDERGROUND LAVA BUBBLES FAR AWAY FROM VOLCANO

When a volcano crater fills with lava, the glowing mass might come from afar. US geologists have used radar data from satellites to observe a major area by a volcano in Nicaragua. The measurements reveal that lava causes land uplift of 6-7 cm more than 3 km away. So, the monitoring should be done from afar.

GETTY IMAGES



### AND TALKING OF VOLCANOES ...

#### VOLCANO RELEASES GASES FROM GLACIER

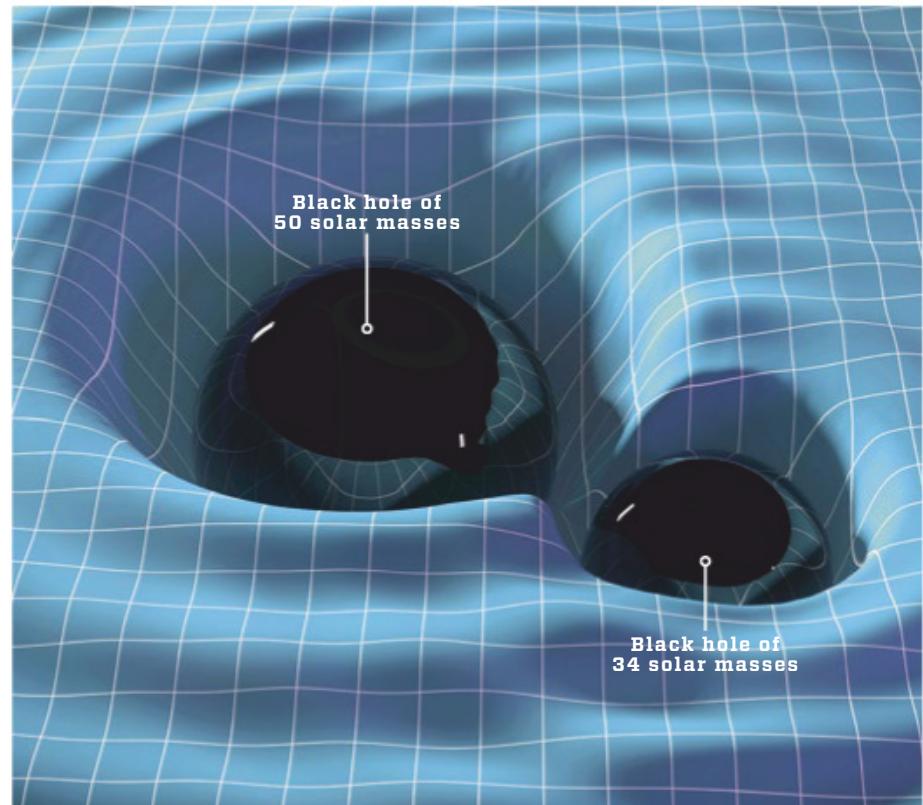
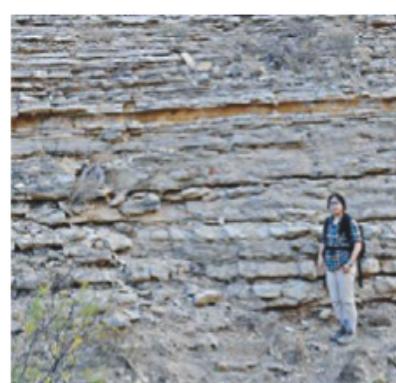
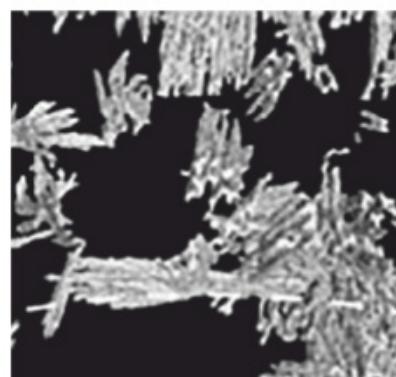
Iceland's Katla volcano is the reason huge quantities of methane escape the Sólheimajökull glacier. The gas is captured under the glacier, rising into the atmosphere, as the heat from the volcano melts the ice. In the summer, 41 t of methane gas is released every day.

#### CRYSTALS PREDICT VOLCANIC ERUPTIONS

In liquid lava, small crystals are produced that reveal how an eruption will develop. English scientists have discovered that if the lava only contains a few crystals, the eruption will be quick, while the lava will flow rapidly and spread a lot. This data is important for improving evacuation plans.

#### VOLCANIC ERUPTIONS PRODUCE SHALE OIL

Geologists have discovered that the shale oil in North America was probably produced by volcanism 100 million years ago. Shale oil is thin layers of crude oil in rock. The volcanoes probably brought nutrients to the surface, making the quantity of microorganisms explode. Today, they have turned into oil.



The biggest cosmic collision ever measured was between two black holes with a combined weight of 84 solar masses.

### Black holes collide in record clash

**ASTRONOMY** When physicists first measured gravity waves with the LIGO detector four years ago, it was sensational. The signal came from two black holes that had swallowed each other. Now, scientists have discovered that since then, it has happened nine times.

Gravity waves were predicted by Albert Einstein in his relativity theory. Einstein provided us with a new understanding of space, when he added time as a fourth dimension. His theory involves that the 4D space time is distorted by gravity waves that travel through the universe. We can only measure the biggest ones that occur in the most violent events of the universe such as the fusion of black holes, and even then, it requires extremely sensitive detectors. The

LIGO detectors consist of long tunnels, in which laser light travels back and forth between mirrors. When a gravity wave passes by, it moves the mirrors less than the diameter of an atom, as recorded by the detectors. Among the new observations is the fusion of two black holes of 50 and 34 solar masses. They are located nine billion light years away, and the collision happened some five billion years ago. Since then, the gravity waves have travelled towards us.

Scientists hope that more gravity wave measurements could solve the mystery of the black holes. It remains unclear, how often they fuse, and if the collisions were more common in the past.

# 166,000,000

**sexillion tonnes** - corresponding to 84 times the Sun's mass - is the total weight of the two biggest black holes, the fusion of which scientists have observed.



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## New slimming pill to give us brown fat

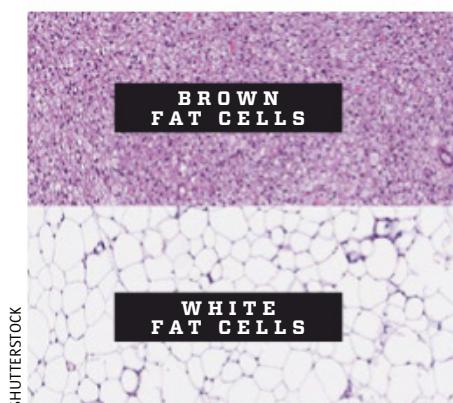
**MEDICINE** Australian scientists have discovered a gene that determines whether mice become fat or not – no matter what they eat. The scientists hope that the discovery can lead to a pill which can combat overweight in humans.

The special gene is known as RCAN1 and codes for proteins that determine the distribution of white and brown fat in the body. White fat accumulates and causes overweight, whereas brown fat burns energy and has a slimming effect.

The scientists made several experiments with mice, in which the RCAN1 had been blocked, and the result was that the animals' white fat cells changed into brown ones. So, the mice could eat a very fat diet without gaining weight. The scientists subjected the mice to a fat diet over different periods of time – from eight weeks to six months, but the result was the same in all experiments: the mice remained slim, no matter if they were physically active or not.

The scientists aim to find out if the same gene in humans has the same function. Humans have both brown and white fat just like mice. As babies, we have lots of brown fat, but the quantity is reduced, as we grow older.

The discovery could lead to a very simple slimming pill, which will counteract the proteins which the gene codes for.



One gene determines how many brown and white fat cells mice have and so how slim they are.



Tadpoles can change from harmless herbivores into aggressive cannibals.

## Hungry tadpoles become vicious cannibals

Biologists have discovered a new, powerful evolution driver that converts herbivores into ferocious predators.

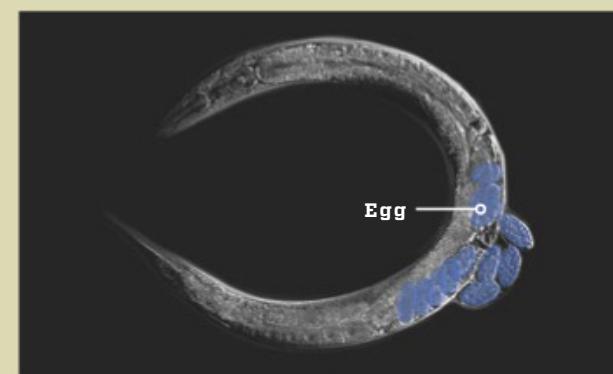
**BIOLOGY** Although ponds look peaceful, life beneath the surface can be harsh. Some animals turn into aggressive cannibals, if food is scarce. And new research by the University of North Carolina in the US shows that this adaptability can be a strong evolution driver.

The scientists studied toad species, whose tadpoles have this special gift. If there is lots of algae in the pool in which they grow up, they develop small mouths and long alimentary canals that fit the plant food. But if there is not enough food, they develop powerful jaw muscles and sawtoothed mouth parts. They become aggressive predators that are ready to eat each other. The flexible development ensures that part of the species survives the crisis. The

scientists discovered that one toad species, *Spea bombifrons*, held on to the strategy, so all tadpoles are now carnivorous cannibals, no matter how much food is available.

Other scientists have discovered a similar phenomenon in the *C. elegans* roundworm. When there is plenty of food, the female lays her eggs and continues her life. If food is scarce, she keeps the eggs inside her, until they hatch, and subsequently, the offspring eats her up from within. In some cases, the mothers do not even lay eggs, i.e. they will always sacrifice their lives for the offspring. The scientists found out that the change is due to a mutation of one single gene. So, that is all it takes to turn a species into cannibals.

## Worm offspring's first meal is the mother



### IN GOOD TIMES, THE MOTHER SURVIVES

**1** When there is plenty of food around her, the *C. elegans* worm lays eggs, leaving eggs and offspring to manage on their own.



### IN HARD TIMES, THE MOTHER DIES

**2** When food is scarce, the female worm keeps her eggs inside her body, until they hatch. The larvae avoid starvation by eating their mother from within.



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## Our ancestors hunted Siberian unicorn

**PALAEONTOLOGY** A prehistoric rhinoceros nicknamed the Siberian unicorn roamed the tundra, when modern man arrived to the region, according to new research.

The rhino with the Latin name of *Elasmotherium sibiricum* weighed more than 3.5 t and had an impressive horn in its forehead, which was probably about 1 m long. So, the animal was at least 1 t heavier than modern rhinos, and it had much longer legs.

Palaeontologists used to think that the prehistoric rhino went extinct some 200,000 years ago, but new dating reveals that the species lived up until about 35,000 years ago. The dating was carried out by scientists from the Natural History Museum in London, and they examined a total of 23 finds of bones from the rhino, such

as a skull from their own collection. The dating was made using a new and more accurate method, by which scientists used the Carbon 14 method to date individual amino acids extracted from the bones. Moreover, they managed to isolate the fossils' DNA for the first time, indicating that already 43 million years ago, the Siberian unicorn's line of development separated from the line of modern rhinos.

The new dating means that the Siberian unicorn lived at the same time as Neanderthals and modern man, who probably hunted the rhino. Other finds have demonstrated that ice age humans did not hesitate to hunt animals of this size.



The prehistoric rhino known as "the Siberian rhino" lived in Siberia up until 35,000 years ago.

### MODERN RHINO HAS 245 PREDECESSORS

- At least **250** different rhino species existed on Earth.
- Today, there are only **five** rhino species left.
- The horn consists of **keratin**, which is also what makes up hair and nails.

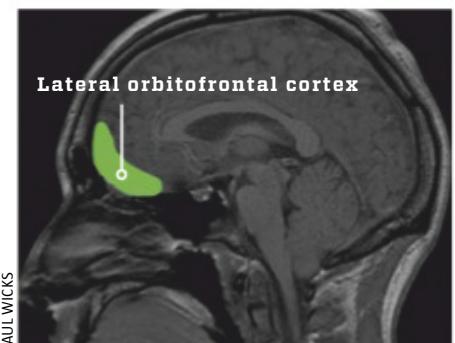


### LOCAL FOCAL POINT



## Termites build huge structure

Deforestation in Brazil has exposed a landscape with small "pyramids" produced by termites over 4,000 years. The pyramids take up an area corresponding to the UK and are the world's biggest structure made by living creatures. The pyramids are made of soil that the insects remove, digging underground systems.



PAUL WICKS  
A brain area right behind the eyes seems to play a very central role for our mood.

## Current in brain cheers up the depressed

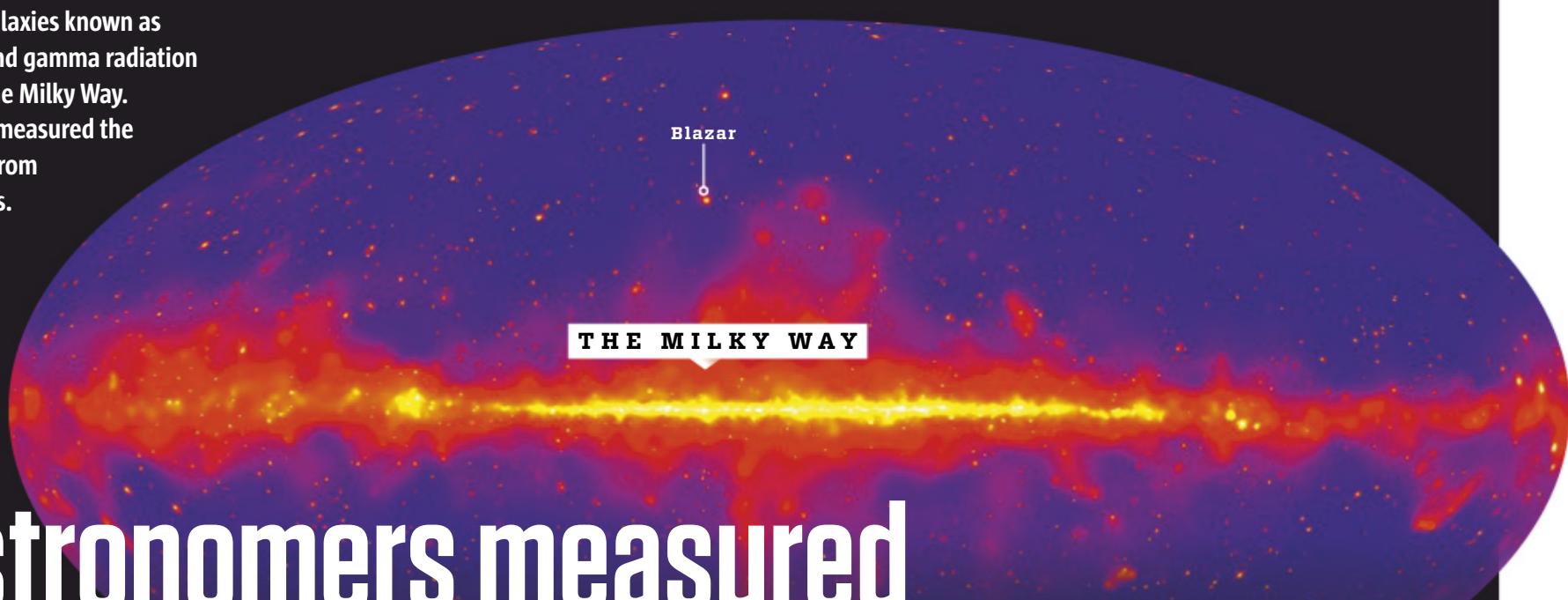
**HUMAN BRAIN** Depressed people cheer up, when scientists electrify a very specific brain area.

Neurologists from the University of California in the US discovered the effect, when they used electrodes to stimulate different brain regions in 25 epilepsy patients. Before the experiment, the patients underwent a thorough examination which revealed that some of them showed signs of depression. So, the scientists had a unique opportunity to study if the mood of the patients changed, when electrodes sent small electric shocks through different brain areas.

When the scientists stimulated a specific area, the lateral orbito-frontal cortex, patients with medium severe or severe depression said that their mood improved markedly. The area is linked with our emotions and the satisfaction we might feel when we make decisions. As soon as the scientists stopped stimulating the area, the patients' mood deteriorated. Patients without depression felt no difference.

Our mood is controlled by several brain centres, but the new study shows that the area behind the eyes is important, perhaps because it is linked with many other centres.

Remote galaxies known as blazars send gamma radiation towards the Milky Way. Scientists measured the radiation from 739 blazars.



# Astronomers measured all light in the universe

Seven new stars light up in our galaxy annually. Astronomers have calculated how much light exists in the universe, so they can understand the histories of all stars.

**ASTRONOMY** How much light exists in the entire universe? What sounds like an impossible question, astronomers have now answered. The stars of the total of two trillion galaxies have emitted  $4 \times 10^{84}$  photons - light particles - in the life time of the universe. The number, a 4 followed by 84 zeros, is so incredible that it is hopeless to compare it to anything we can understand, but to astronomers, it is valuable.

American scientists calculated the number using NASA's Fermi Gamma-ray Space Telescope. The space telescope measures the intense gamma radiation coming from blazars. Blazars are remote, bright galaxies that have a highly active, supermassive black hole at the centre. As matter rotates towards the black hole, huge quantities of

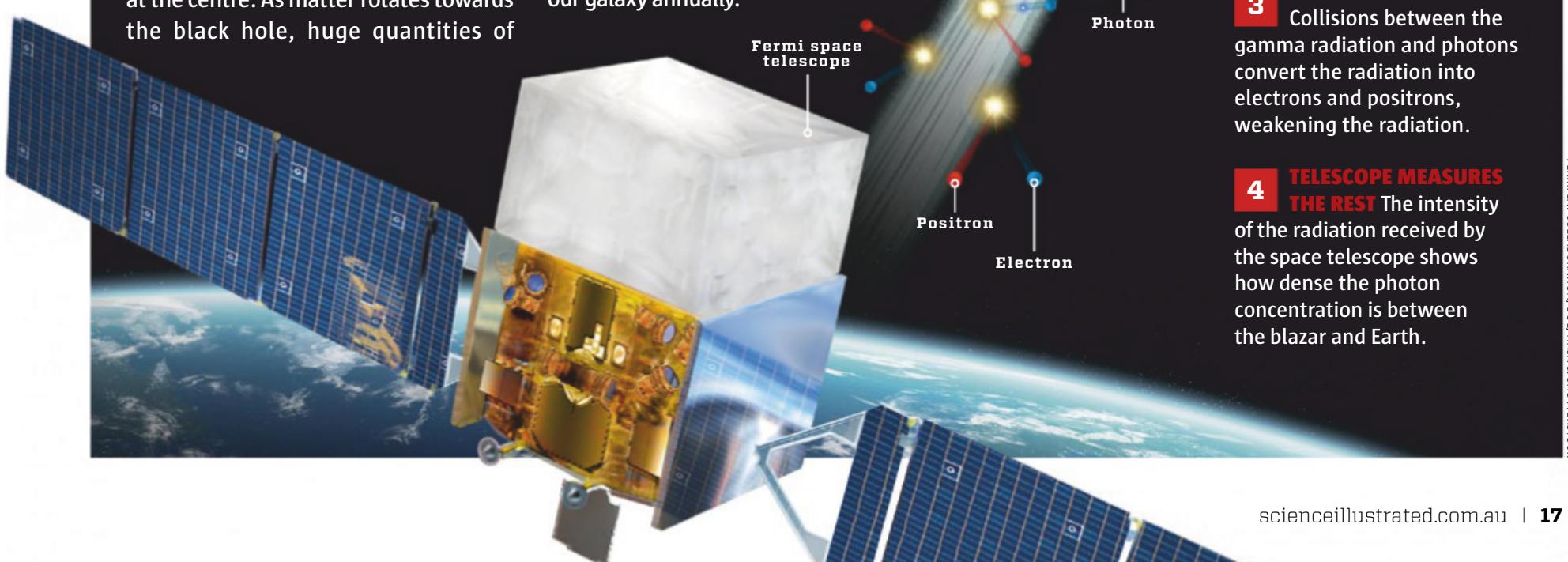
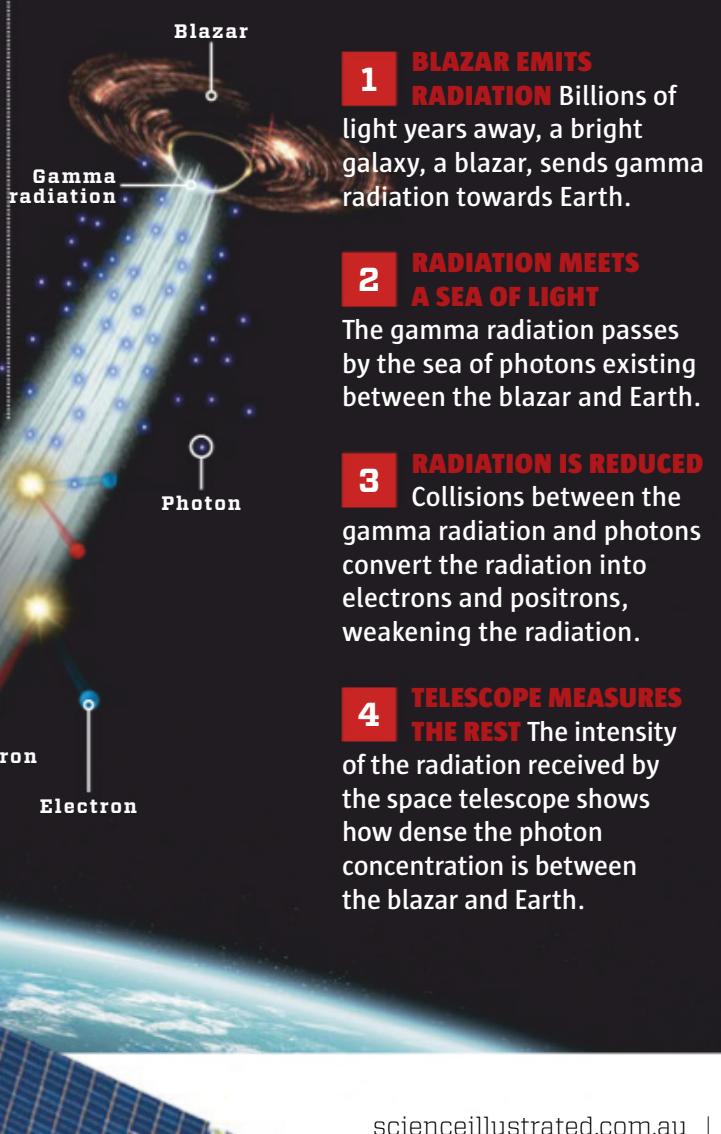
friction energy are produced, of which some is emitted as concentrated light beams of gamma radiation directed towards Earth.

The gamma rays encounter a sea of photons that move in all directions through the entire universe. The photons absorb some of the gamma rays, so the intensity of the radiation that reaches the telescope reveals the density of photons in intergalactic space. The rest is "simple" mathematics, but with incredibly large numbers.

The new insight has taught astronomers that the rate of star formation in the universe peaked 11 billion years ago and remains strong. Now, some seven new stars light up in our galaxy annually.

## Gamma radiation reveals invisible light

**Astronomers can calculate the density of photons in the universe by measuring how much gamma radiation reaches Earth.**





## How did Earth get so much water?

I heard that water came to Earth with comets, etc. But how did the water originate – where does it come from, and how did it enter the comets?

**ASTRONOMY** Water consists of oxygen and hydrogen. While hydrogen is very common in the universe, oxygen is a limited resource, which is only produced in large stars and distributed throughout the universe via huge star explosions known as novas and supernovas.

The matter in our solar system came from a supernova flinging a cloud of material in all directions. Somewhere in the cloud, the density was slightly higher than in the other parts. The increased density caused stronger attraction, collecting more material, increasing the attraction, etc. Finally, enough matter had united for fusion processes to begin, and the Sun was born. The collection of material made the Sun and the cloud around it rotate ever faster in a protoplanetary disc. Over time, the material of the disc was sorted, so different elements accumulated at different distances from the Sun.

At the distance at which Earth is located,

particularly high quantities of oxygen accumulated. As the temperature of the disc fell, the oxygen condensed into oxygen-rich molecules – including water. The molecules united into still bigger lumps, and over time, a wealth of small, watery planets originated in Earth's present orbit.

Gradually, many of the small planets collided, so there was finally one dominant body in Earth's present orbit, a kind of proto-Earth. The young planet was liquid, and just like in the disc surrounding the Sun, the material was sorted, and the water collected near the surface. Earth's interior was still very hot, and intense volcanism brought large quantities of water to the surface, where it fell as rain in storms, that lasted millions of years.

When the proto-Earth had formed, gravity attracted the last water in the shape of the other small watery planets in the same orbit around the Sun. The water was released, as the planets collided with Earth or burned up in the early atmosphere.

$O_2$   
SUPERNOVA

### OXYGEN REACTS WITH HYDROGEN

**3** The disc material is divided into rings. At the distance at which Earth is located, the majority of the oxygen accumulates and forms other molecules, including water.

$H_2O$

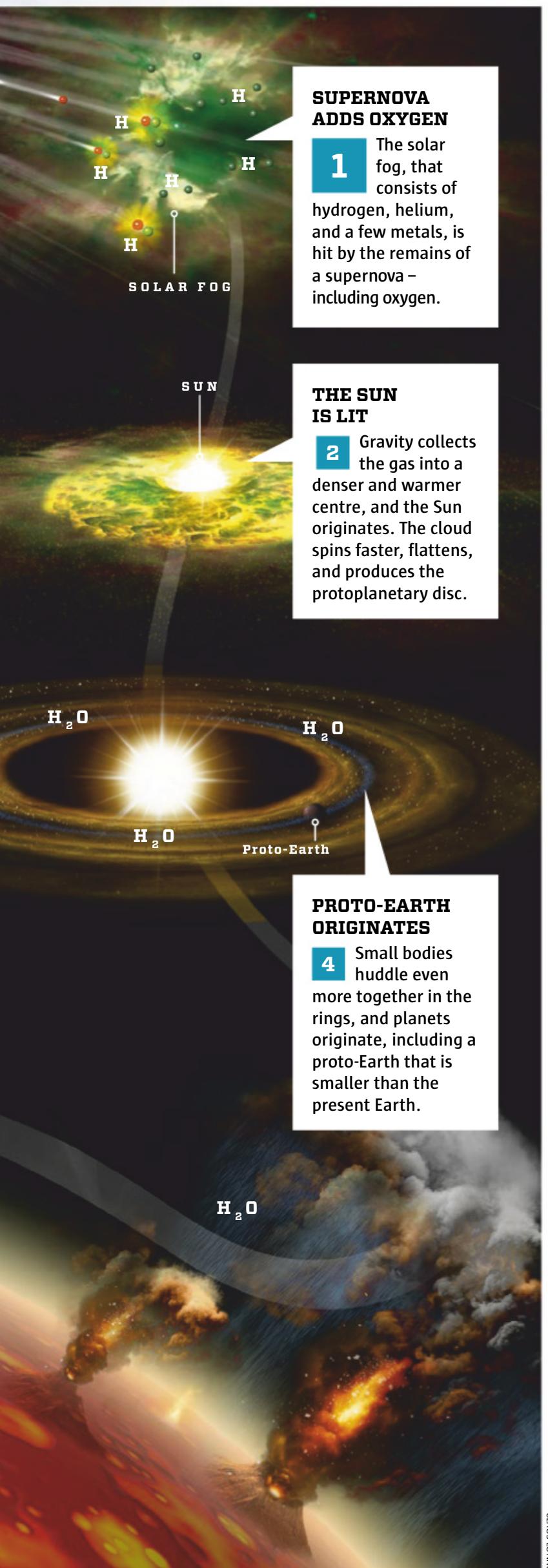
### WATERY PLANETS STRIKE

**6** The proto-Earth clears its orbit around the Sun of the other small planets. The planets are rich in water, that is released, as they strike or burn up in the atmosphere.

### VOLCANOES RELEASE WATER

**5** At an early point, the material is sorted, and the water collects close to the surface. Volcanoes release water from the underground, that falls in the shape of rain.





### SUPERNOVAS ADDS OXYGEN

**1** The solar fog, that consists of hydrogen, helium, and a few metals, is hit by the remains of a supernova – including oxygen.

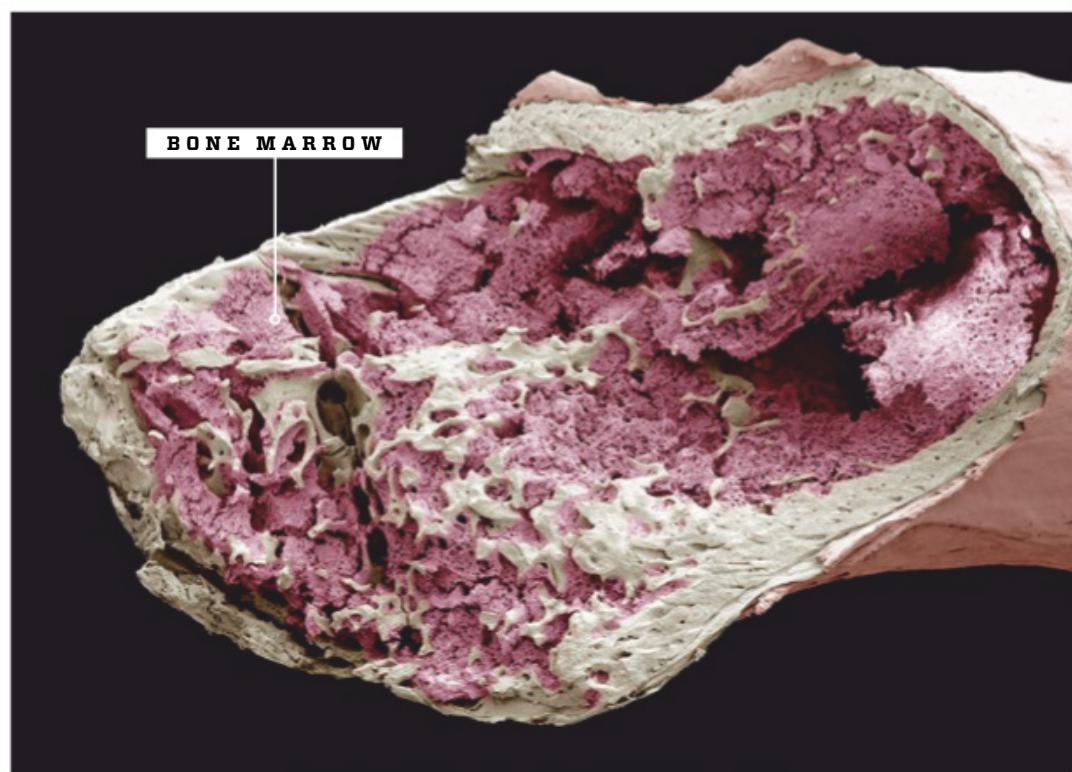
### THE SUN IS LIT

**2** Gravity collects the gas into a denser and warmer centre, and the Sun originates. The cloud spins faster, flattens, and produces the protoplanetary disc.

### PROTO-EARTH ORIGINATES

**4** Small bodies huddle even more together in the rings, and planets originate, including a proto-Earth that is smaller than the present Earth.

## INSIDE THE BODY



STEVE GSCHMEISSNER/SPL

## Where do red blood cells come from?

Your bone marrow produces 200 million red blood cells a second, which include iron, amino acids, vitamin B12, folic acid, and more. The blood cells are packed with haemoglobin, which carries oxygen to your other cells.



### RED BLOOD CELLS

**WHERE:** Form in the bone marrow of primarily hips, femurs, and back.

**WHAT:** Disc-shaped cells that carry oxygen and carbon dioxide via the blood.

## Why can't everyone drink milk?

**HUMAN BODY** As we grow older, the ability to tolerate milk ceases in the majority of the world population. The problem is the milk's content of the small, high-energy sugar molecule of lactose. The molecule cannot be absorbed into the intestines, rather it must be broken down into glucose by the lactase enzyme, before the energy can be used. If not, the lactose will upset the intestines, resulting in diarrhoea and perhaps even malnutrition.

Almost all people have the gene that produces lactase, but its activity normally decreases after breastfeeding. In South America, Asia, and Sub-Saharan Africa, less than 20 % of adults can tolerate milk,

but particularly Northern Europeans have a gene mutation that keeps the lactose gene active throughout life.



SHUTTERSTOCK

Only one third of the world's adult population tolerates milk.

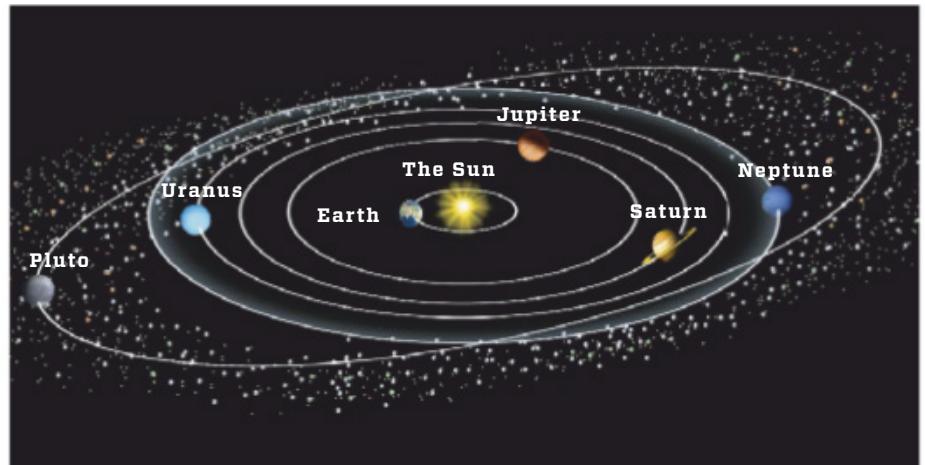
## What is the Kuiper Belt?

**ASTRONOMY** In the coldest regions of the Solar System, beyond Neptune's orbit, billions of large and small heavenly bodies orbit in a region known as the Kuiper Belt.

Astronomers estimate that the Kuiper Belt stretches about 4.5 billion km and includes hundreds of thousands of objects with diameters of 100+ km. But so far, only 1,300 Kuiper Belt objects have

been located. One of the biggest ones is the dwarf planet of Pluto, which has a diameter of some 2,300 km.

The small worlds are hard to spot in telescopes, and so, the heavenly bodies have not been studied very closely. In January, NASA's New Horizons space probe reached the remotest Kuiper Belt object so far – the snowman-shaped heavenly body of Ultima Thule.



CLAUS LUNAU

The Kuiper Belt is located more than 8 billion km from the Sun and stretches some 4.5 billion km.

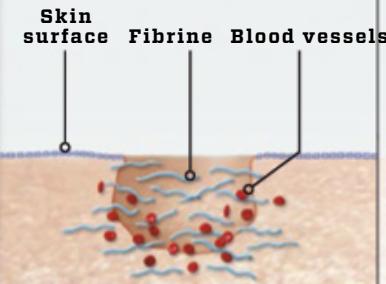
## ⊕ INSIDE THE BODY • How does a wound heal?

Unlike almost all other organs except the liver, the skin has a unique ability to regenerate. Even relatively large wounds can often heal without scar formation. The different white blood cells of the immune system are responsible for wound healing via inflammation.

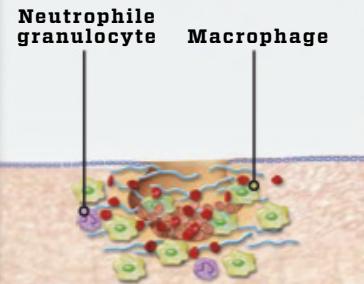


### Inflammation boosts natural healing

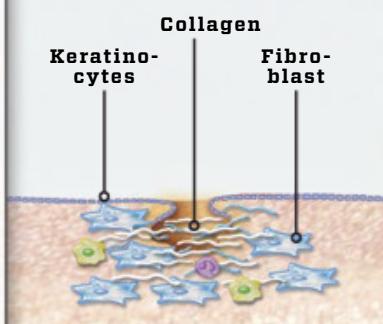
**1** The skin's healing process begins by the damaged blood vessels contracting. The fibrine protein is released, making the blood coagulate, so the bleeding stops.



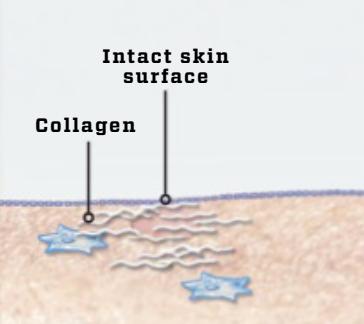
**2** An inflammatory reaction is triggered by neutrophile granulocytes, while macrophages secrete biochemicals, which send a signal that the wound should close.



**3** Fibroblasts, that produce collagen, and keratinocytes go to the wound to regenerate the dermis and its fine blood vessels.



**4** After den growth phase, the maturation phase takes over, replacing the temporary solutions with durable repair.

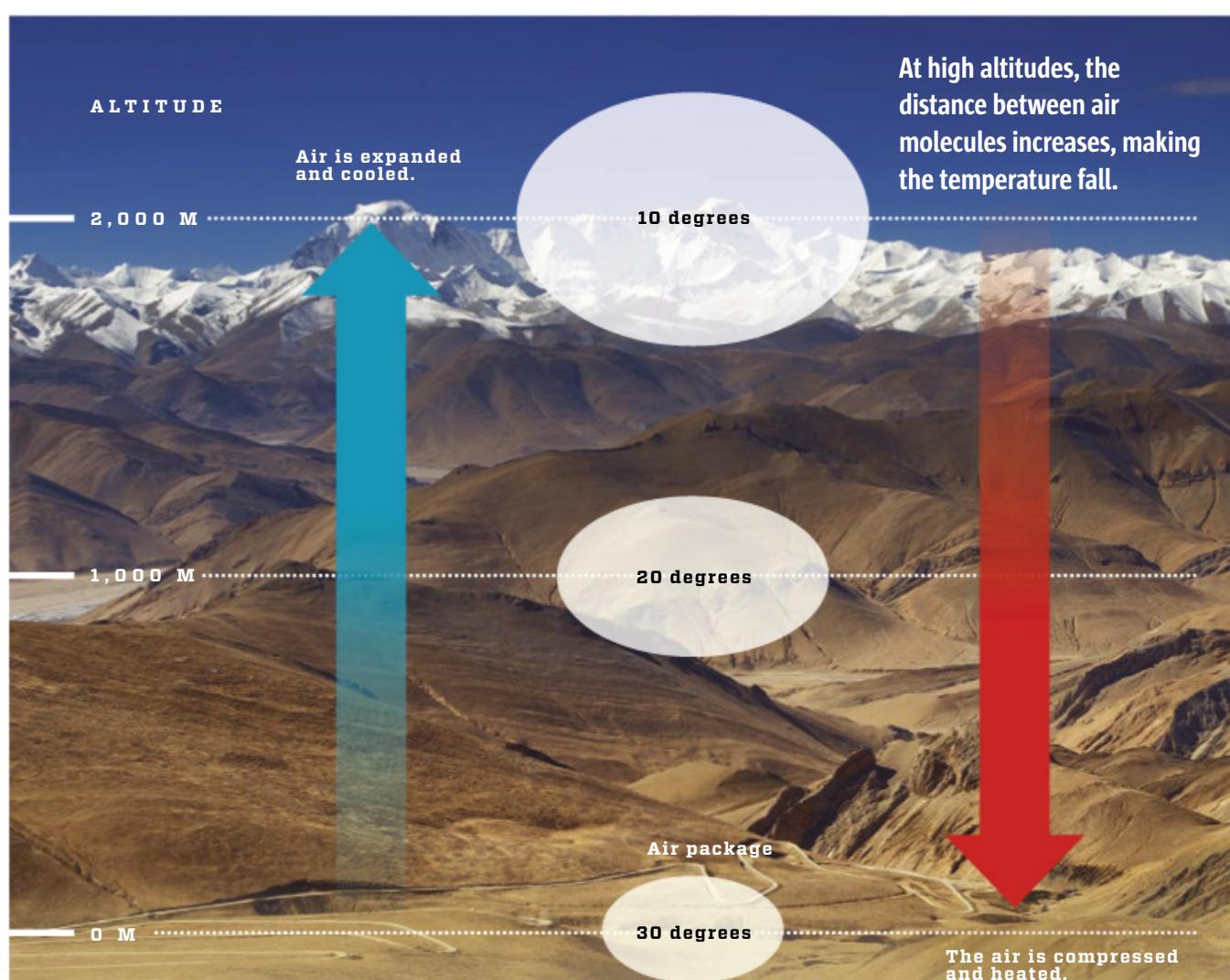


## WHAT DOES PETROL'S OCTANE NUMBER MEAN?

When the mixture of air and petrol is compressed in car engine cylinders, it might self-ignite. Known as knocking, the phenomenon wears the engine very much and consumes energy. To prevent self-ignition, iso-octane is added to the petrol. Octane 95 means that the petrol has qualities corresponding to it consisting of 95 % iso-octane. The higher the octane number, the more the mixture can be compressed without self-igniting.



Octane is added to petrol in order that it does not self-ignite in the cylinders of car engines.



# Why is the air colder at high altitudes?

Cold air is heavier than warm air, so why does air grow colder with altitude?

**METEOROLOGY** The air gets colder with altitude, because it expands. When air expands, the kinetic energy of the air molecules - what we experience as different temperatures - must cover a larger volume. The result is that the air molecules collide more rarely with both each other and with objects in the surroundings, leading to falling temperatures.

When the air expands with altitude, it is due to reduced atmospheric pressure. It's because the quantity of air in the atmosphere is reduced

with altitude. The weight of the overlying air determines the pressure.

However, the warm air is not always the lower layer. On clear nights, the ground becomes very cold, as the lack of clouds allows thermal energy to escape. This cools the air at the bottom of the atmosphere, and because it has the same pressure as the surrounding air, it remains by the ground. Meteorologists even talk about cold air rolling into dips in the landscape, where the temperature can be several degrees lower than at the top of hills nearby.

## THE ATMOSPHERE CONSISTS OF SEVERAL GASES

- **Nitrogen:** 78 %
- **Oxygen:** 21 %
- **Argon:** 0.93 %
- **Carbon dioxide:** 0.031 %
- **Neon:**  $1.8 \cdot 10^{-3}$  %
- **Helium:**  $5.2 \cdot 10^{-4}$  %
- **Crypton:**  $1.14 \cdot 10^{-4}$  %
- **Hydrogen:**  $5 \cdot 10^{-5}$  %
- **Xenon:**  $8.6 \cdot 10^{-6}$  %

## Which animals have to eat the most food?

**ZOOLOGY** The metabolism of animals – and hence also their appetite – depends on their size, body temperature, and physical activity. Generally, small, active animals eat relatively more than large, slow animals. A shrew typically eats at least its own weight in one day, whereas an animal such as an elephant only eats around 5% of its body weight per day.

Apart from the animal's own physics, the surroundings play a role. Animals in cold surroundings generally eat more than animals that live in

warm places. Generally, birds have the most appetite, as they are small and have a high body temperature and a high activity level – even though the appetite may vary a lot from one species to the next.

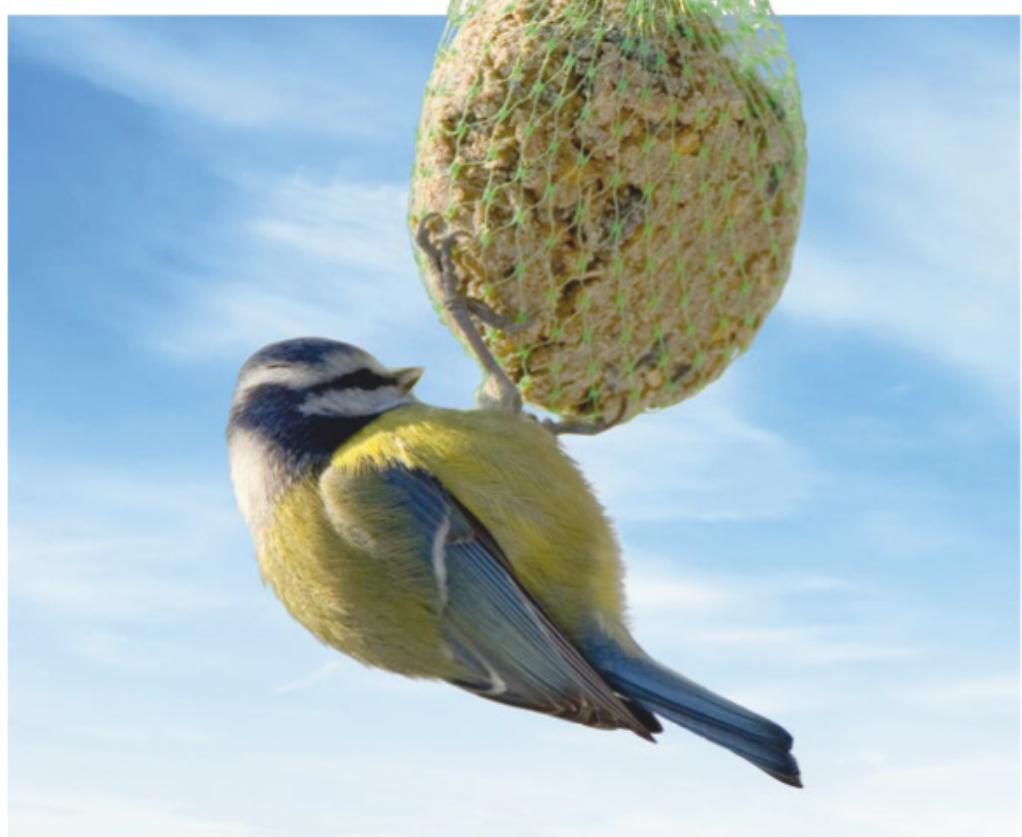
### BIRDS EAT THE MOST

#### ■ Birds

**Activity level:** High  
**Body temperature:** High  
**Appetite level:** 11

#### ■ Reptiles

**Activity level:** High  
**Body temperature:**  
 Varies  
**Appetite level:** 2



THINKSTOCK

Small birds such as this blue tit have a high metabolism and will eat anything from insects and worms to berries and seeds.

## WHAT IS THIS? • Light pillars in a clear and frosty sky



When light is reflected or refracted in particles in the atmosphere, light pillars appear over Northern Scandinavia.

Light pillars arise, when artificial light from Earth's surface hits the lower side of small, shiny particles in the air and is reflected downwards again, so we can observe it.

Light pillars can be observed in Northern Scandinavia in severe frost. The light is reflected in a kind of fine, floating "rain" of ice crystals known as diamond dust.

The Sun can also produce a light pillar known as a solar pillar, and the Moon can produce a moon pillar. There, ice crystals in high, thin clouds are typically responsible for the beautiful display.

SCIENCE SOURCE/IMAGESSELECT

IS IT REALLY TRUE THAT ...

# ... space junk is a major problem?

How much space junk is orbiting Earth, and how big a problem is it for space agencies?

**AEROSPACE** According to the most recent data, about 7,500 t of space junk is orbiting Earth in the shape of almost 30,000 objects of 10+ cm, whereas 750,000 objects of 1-10 cm and no less than 166 million sized 1 mm-1 cm are orbiting.

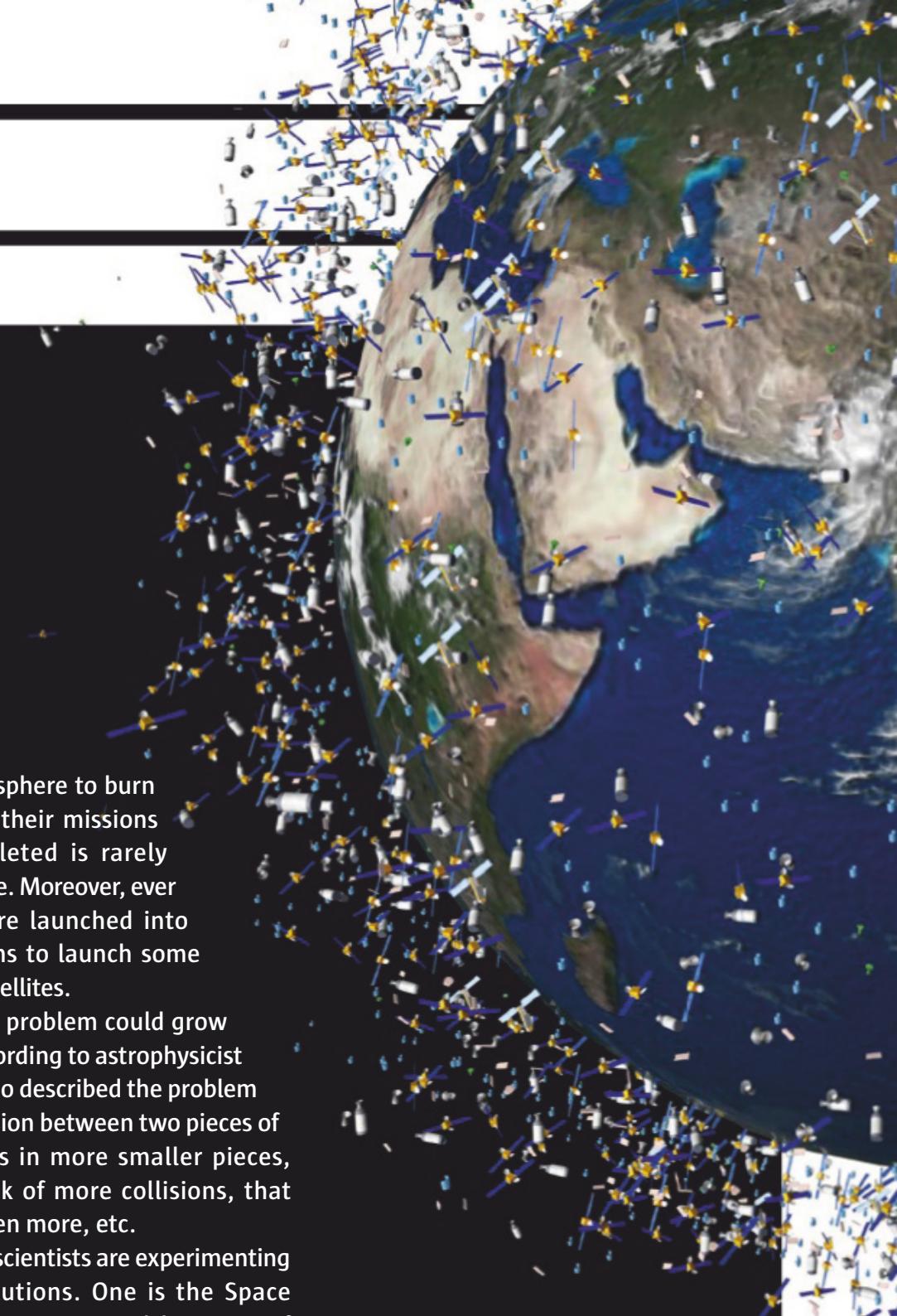
The junk is particularly made up of pensioned off satellites and remains of rocket engines from space missions. The junk is orbiting at speeds of up to 28,000 km/h, so even small objects can cause major harm. The European Space Agency, ESA, averagely gets one warning a week of junk on a collision course with one of its 10 satellites in a low Earth orbit. The satellites must make evasive manoeuvres, which require fuel and reduce their lives. The International Space Station (ISS) must also make evasive manoeuvres in the case of objects with diameters of 1+ cm.

The rule that satellites must be programmed

to enter the atmosphere to burn up 25 years after their missions have been completed is rarely observed in practice. Moreover, ever more satellites are launched into orbit. SpaceX plans to launch some 12,000 Internet satellites.

The space junk problem could grow exponentially, according to astrophysicist Donald Kessler, who described the problem in 1978. Each collision between two pieces of space junk results in more smaller pieces, increasing the risk of more collisions, that would result in even more, etc.

Consequently, scientists are experimenting with possible solutions. One is the Space Fence, which can spot space junk by means of radar on Earth. And from 2020, the ISS will be equipped with a laser gun, which is meant to eliminate space junk.

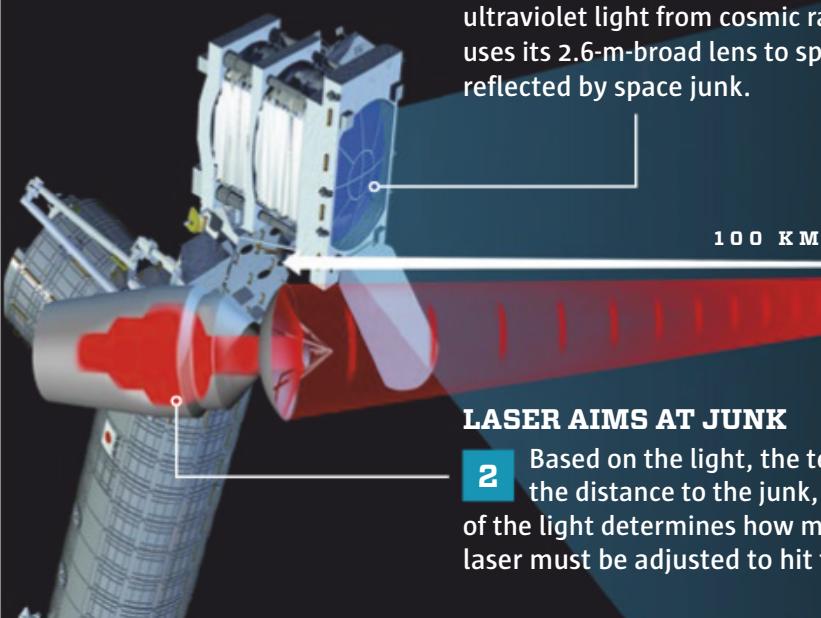


166+ million pieces of space junk are orbiting our planet.

## Laser shoots down space junk

### TELESCOPE SPOTS JUNK

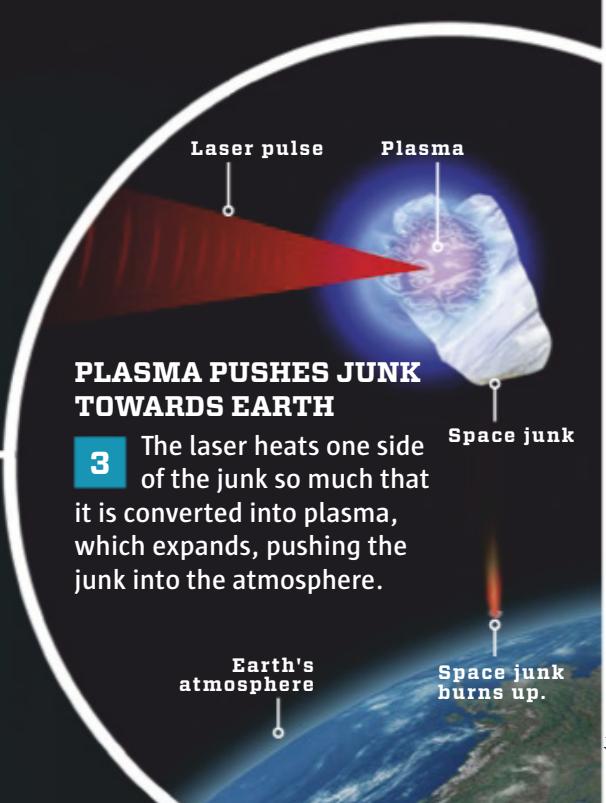
1 The EUSO telescope, which was originally developed to detect ultraviolet light from cosmic radiation, uses its 2.6-m-broad lens to spot light reflected by space junk.



2 Based on the light, the telescope calculates the distance to the junk, and the direction of the light determines how many degrees the laser must be adjusted to hit the junk.

### PLASMA PUSHES JUNK TOWARDS EARTH

3 The laser heats one side of the junk so much that it is converted into plasma, which expands, pushing the junk into the atmosphere.



ALLAN HØJEN & ESA

# Finding the origins of

# THE FIRST LIFE

- The origin of life was a team effort. New experiments have changed scientists' idea of the primordial soup that nurtured our early ancestors. The breakthrough will soon allow us to create new life in the lab.

**CHAPTER 1:** LIFE ORIGINATED ON DRY LAND

**CHAPTER 2:** SCIENTISTS PUSH THE MILESTONES OF LIFE

**CHAPTER 3:** MULTICELLULAR LIFE ORIGINATED 25 TIMES

PROTEINS  
HELPED RNA

RNA HELPED  
PROTEINS

FAT HELPED RNA  
AND PROTEINS

## CHAPTER 1

# LIFE ORIGINATED ON DRY LAND

Darwin imagined that the cradle of life was a small lake. Others have proposed the ocean floor. Microhips and quick chemical analyses challenge the old theories and brought scientists closer than ever to the enigmatic environment that nurtured Earth's first life.

The geyser sends a cascade of very hot water towards the sky. The next second, it falls down again as dense, warm rain that refills a series of small, almost dry pools in the barren landscape. The place is Earth, but it is not the Earth that we know today. The landscape is located in one of the few terrestrial areas - a series of volcanic islands in an almost never ending ocean. The planet is still very young, but somewhere in this hostile world, a confusion of chemical reactions are building the very first life - the life that has since conquered all regions of the planet, from red-hot rock deep in the ground to snow-covered mountain peaks.

The leap from inanimate molecules to life is among the most central in Earth's history. But how did it happen - and not least where? The two questions are closely linked. The processes that founded the genetic code, built the first proteins, and united all of it in a small, protected package, depended closely on the environment in which they took place, so if we can find out how life's first reactions took place, we can also calculate where they took place. And scientists are close to a breakthrough. They have realized that earlier theories of life's first chemistry were too simple, and new technology has for the first time brought them the tools to recreate the chemical confusion that produced the first life.

## Darwin preferred a warm lake

When life originated remains a mystery. Discoveries of seemingly organically produced carbon in 4.3-billion-year-old Australian minerals indicates that it happened relatively quickly after Earth formed. But that is not necessarily so. Perhaps life did not originate until 3.7 billion years ago. From this period,

scientists have found evidence of photosynthesis in Greenland rock. In spite of disagreement about the fossils, scientists agree that life cannot have originated any less than 3.5 billion years ago. Based on the DNA of living organisms, geneticists have calculated that the common ancestor of all life on Earth must have lived at this time.

The ancestor, which is also known as LUCA - the last universal common ancestor, probably had the biological characteristics shared by all organisms, from the most simple of bacteria to the biggest whales, including cell membranes made of fat, a genetic code based on DNA, and an army of proteins to catalyse chemical reactions, carry building blocks, and hold all cell parts together. Consequently, those features are central for scientists, when they try to understand the formation of the earliest life.

The earliest known theory of the origin of life was proposed by Aristotle of Greece ►

All organisms from bacteria to plants and animals are related and share the same basic building blocks.  
SHUTTERSTOCK





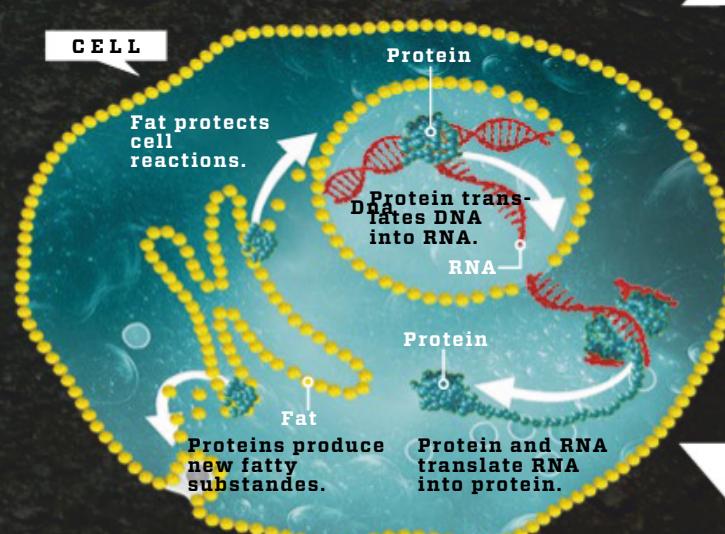
New ground-breaking experiments have caused many scientists to believe that the cradle of life was a pool like this one.

SHUTTERSTOCK

## The building blocks of life cooperate in your cells

All Earth's organisms, including yourself, owe their lives to molecular cooperation – a partnership that could very probably be traced all the way back to the earliest life on Earth.

CLAUS LUNAU



### DNA and RNA build new proteins

DNA includes "shop drawings" of individual proteins. RNA passes on the DNA's information and helps build the proteins.

### Proteins build DNA and fat

Proteins make sure to copy our DNA, when a cell is about to divide. They can translate DNA into RNA and build cell membrane fat.

### Fat protects proteins and DNA

Fat delimits a cell from the outside world and produces space in the cell, in which proteins, DNA, and RNA can perform their chemical reactions.

## CHAPTER 1

► some 350 years BC. According to his theory, life originates spontaneously all the time from non-living material. This idea was rejected by French biologist Louis Pasteur in 1859. He knew that a nutrient-rich, but sterile liquid will not spontaneously become the home of bacteria and fungi. Not until it gets in contact with the air – and so the organisms that exist in the air – will life originate.

The experiment helped develop the theory that many scientists support today: that life on Earth only originated once and has since developed in many directions and spread to all corners of the planet. This triggered the search for the enigmatic place that nurtured the very first life.

One of the first scientific theories of what the cradle of life must have looked like was proposed by English scientist Charles Darwin. In a letter to his friend, botanist Joseph Dalton Hooker, Darwin in 1871 described how the first proteins could originate in a small, warm lake with nitrogen and phosphorus compounds, light, heat, and electric voltage differences. So, the proteins could react with each other to form more complex compounds. Darwin's theory was brief, but it inspired a ground-breaking experiment 80 years later.

#### RNA could manage on its own

American chemists Stanley Miller and Harold Urey in 1952 set out to recreate the conditions of the early Earth with water and a mixture of methane, hydrogen, and ammonia. As an energy source, they added artificial lightning. The result was amino acids – the fundamental building blocks of proteins. The experiment showed that it was rather easy for some of life's most basic molecules to originate under the conditions that probably existed early in Earth's history.

Five years later, Miller carried out the experiment again with a slight change. He added the chemical compound of hydrogen sulphide. Hydrogen sulphide is a typical gas from active volcanoes, and those were plenty on the young Earth, so the adjustment made sense. For unknown reasons, Miller never managed to analyse the result of the new experiment. That happened 50 years later, when one of his students, chemist Jeffrey Bada, found the sealed samples. Bada analysed them using modern methods, and the result proved even more interesting than the original experiment.

The chemical blend and artificial lightning

had formed no less than 23 amino acids, including some containing sulphur, which is among the most critical for life on Earth – such as methionine, that triggers the formation of protein in our cells.

But proteins are only one element of life on Earth. The origin of the genetic code that now consists of DNA has caused scientists several problems. Many now think that the code originally consisted of RNA, which has a more simple structure than DNA and involves the major advantage that it can both function as code and as an enzyme. Modern cells use it as a type of messenger, that can pass the DNA's instructions on inside a cell, and as an enzyme that helps build proteins based on the instructions.

The two qualities mean that in theory, RNA can copy itself, and that has made some scientists propose that RNA is the most central molecule in the early development of life. They imagine an RNA world, in which RNA was the only one carrying out the tasks that now require DNA and proteins. The early RNA strands could read their own code and create new RNA strands based on the code. DNA and proteins arrived later, because they made the system more stable and reliable. This idea of the origin of life has dominated scientific research in recent decades, but a new theory is on its way to toppling the RNA world.

#### Chips recreate primordial soup

Scientists have not yet managed to create an RNA molecule that can copy itself under the conditions that existed on the young Earth. And even if they do, it is difficult to explain how such a complex molecule could have originated all by itself. So, many now support another hypothesis: RNA was never alone – it got help from the beginning.

The hypothesis originated based on a new field of research: systems chemistry. Scientists work with chemical compounds including a high number of different molecules. The ►

# Four environments might have nurtured life

Scientists have searched for the cradle of life in many different environments – from hot springs on the ocean floor to craters left by space rocks. Now, they have narrowed down the group to include four promising candidates.

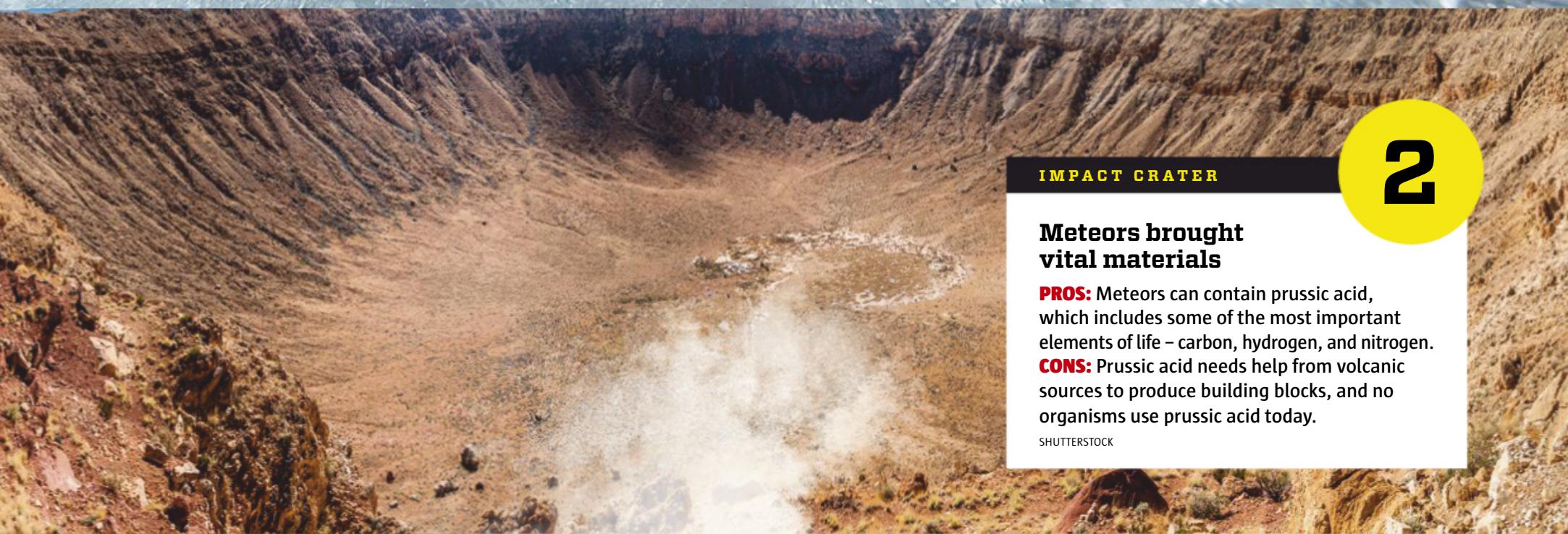
SEE THE WINNER  
ON THE NEXT PAGE ➤➤➤



**1****ICE****Ice might have built the genetic code**

**PROS:** Freezing and melting of ice could help build chains of RNA, etc., and the low temperatures stabilize the new molecules.

**CONS:** It is not clear, whether ice was present on the young Earth, and many reactions depend on higher temperatures.

SHUTTERSTOCK**2****IMPACT CRATER****Meteors brought vital materials**

**PROS:** Meteors can contain prussic acid, which includes some of the most important elements of life – carbon, hydrogen, and nitrogen.

**CONS:** Prussic acid needs help from volcanic sources to produce building blocks, and no organisms use prussic acid today.

SHUTTERSTOCK**3****VOLCANIC SOURCE****Geysers can produce the building blocks of life**

**PROS:** Geysers and hot springs contain important organic matter, and they allow the formation of fat membranes and amino acid and RNA chains.

**CONS:** Scientists struggle to understand exactly how RNA or DNA can originate under the conditions existing in a volcanic source.

SHUTTERSTOCK**4****OCEAN FLOOR SPRINGS****Underwater sources produce cell-like pockets**

**PROS:** Hot springs on the ocean floor produce small pores in the rock, which can protect chemical reactions the way cell membranes do today.

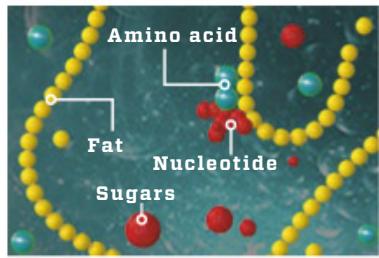
**CONS:** The likelihood of the right types of molecules meeting in sufficient quantities is limited in the huge water masses of the oceans.

RALPH WHITE/GETTY IMAGES

# Geysers united the building blocks of life

Life originated in a small volcanic pool, which regularly dried out. Chemists have now found a place that can both supply the right materials, bring them close together, and make them cooperate to generate the first life.

SHUTTERSTOCK

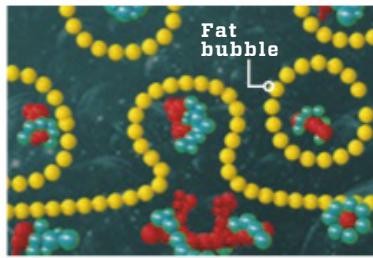


## Simple materials react in pool

Reactions between simple molecules such as fatty acids, amino acids, and sugars produce the basic building blocks of the genetic code, nucleotides.

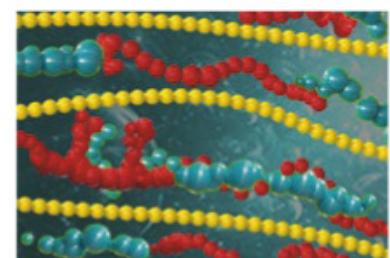
## Drying brings molecules together

When the water evaporates, layers of fat are produced. Between the layers, both amino acids and nucleotides can produce long chains.



## Water forms initial stage of cells

The materials are dissolved in water again, and cell-like fat bubbles are produced, in which the organic chains can produce more complex materials.



## Repeated cycles increase complexity

A cycle of dry and wet conditions makes the materials more complex. Finally, a system of materials occurs, that can protect and copy itself.

... AND THE  
WINNER  
IS:

3



**Life becomes all wet**

► Via natural selection, more die-hard cells are created with enzymes that carry out the tasks that used to require drying. Life has originated and can manage in a wet environment.

► experiments can take place on microchips, where it is possible to control the quantity of all the mixture's components and the physical conditions surrounding the molecules. Scientists can all at once test a wealth of different mixtures and observe the exact materials produced in the reactions.

Systems chemistry's complex mixtures are probably the closest we come to the primordial soup in which life originated, and the field has already contributed major breakthroughs. In 2017, scientists tested a mixture of fatty acids and amino acids to discover that the fat could combine the amino acids in pairs – an important step in protein formation. Other experiments have shown that amino acids can help produce RNA based on simple molecules.

Systems chemistry has solved many of the problems of the theory of the RNA world. By including fat, amino acids, and other molecules in the equation, scientists now have a better idea of how complex genetic code can originate. And by making proteins cooperate with RNA all the way from the start, it is easier to understand how the first enzymes were able to copy themselves. The result is that we are now close to solving the mystery of how life originated.

#### New insights

Close cooperation between life's early building blocks is only half the explanation of the origin of life. A special combination of physical conditions was necessary for the right chemical reactions to take place. Also in this case, systems chemistry has produced new insights.

In 2017, Australian and US scientists described an experiment, in which they mixed fatty acids and nucleotides – the basic building blocks of RNA. First, they subjected the mixture to warm, acid conditions and then let it dry and become wet again several times.

The result was long chains of up to 100 nucleotides wrapped in tiny fat bubbles.

Other experiments carried

out by chemists from NASA's Centre for Chemical Evolution have shown how nucleotides can originate from even simpler molecules. The formation of the first nucleotides is one of the most enigmatic steps towards life, as it involves particularly demanding chemical reactions. But NASA's scientists revealed how mixtures of simple matters such as melamine, barbituric acid, and different kinds of sugar could easily produce molecules resembling RNA's basic building blocks. And those molecules can be combined into a chain – a type of initial stage of genetic code. Like in the experiment from 2017, the key to their breakthrough was a cycle of wet and dry conditions.

Similar experiments have shown that the same type of cycle can produce chains of amino acids and even trigger a simple type of DNA strand copying. The results have convinced many scientists that the alternating wet and dry conditions are central in the formation of life. And they have found the ideal place.

#### Life originated on dry land

Darwin preferred a warm lake. Later, scientists continued the search for the cradle of life below the ocean surface. Now, many of them focus on the land of the young Earth. The volcanic activity was much more intense than it is today – and the activity attracted the attention of scientists. Throughout the landscape, there were hot springs and geysers like the ones that exist today in Iceland or Yellowstone National Park in the US. Here and there, small depressions in the landscape were alternately filled with water from geysers and dry.

The small pools around Earth's oldest geysers have the very qualities needed for the first life. They were rich in a series of important organic substances and minerals, they were warm, and their wet and dry cycles could produce the building blocks of life and trigger the basic processes of life.

Systems chemistry has brought scientists close to the cradle of life, and the new insight will probably soon allow them to create new life in the lab. If so, it will be a milestone, but some scientists consider this relatively unimportant. According to them, new life forms frequently without posing a threat. We – and our entire biological family, from bacteria to blue whales – constantly out-compete the new life, as we have an evolutionary lead of almost four billion years.

# NEWS ABOUT THE HISTORY OF LIFE

## SCIENTISTS PUSH THE MILESTONES OF LIFE

Photosynthesis, cell nuclei, legs, and spines - life has achieved a lot, since it originated four billion years ago. But new discoveries now change where and when life's major milestones occurred.

SOME 4 BILLION YEARS AGO

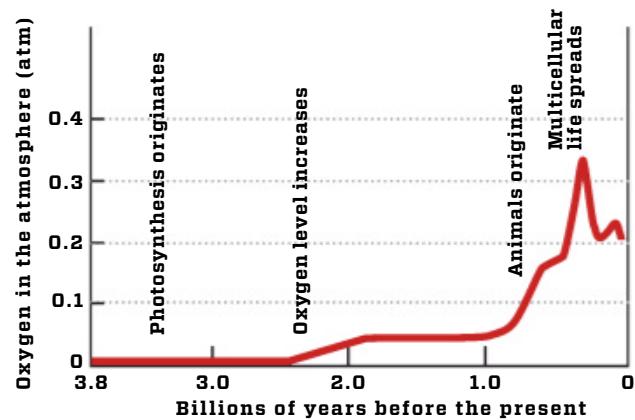


3.4 BILLION YEARS AGO

### Early bacteria oxidize Earth

Until 2018, scientists thought that photosynthesis developed 2.7 billion years ago. Now, genetic analyses show that it was 3.4 billion years ago, but for the first billion years, all the oxygen of the photosynthesis was bound in minerals rather than released into the atmosphere.

SHUTTERSTOCK



472 MILLION YEARS AGO

### Plants take roots on dry land

New discoveries from South America show that a series of plant species had settled on dry land already 472 million years ago. 20 million years later, the ancestors of insects landed, and our own ancestors followed some 400 million years ago.

ED RESCHKE/GETTY IMAGES



The first terrestrial plants resembled modern liverworts.

450 MILLION YEARS AGO

### Vertebrates succeed along the coast

Today, coral reefs are the homes of a huge variety of fish, causing some scientists to believe that ancient reefs ensured the success of early vertebrates. But new research reveals that the success began much closer to the beach.

NOBUMICHI TAMURA





**1.9 BILLION YEARS AGO**

### Scientists find missing link

► Eucaryotes – cells with a nucleus – include humans, but their origin is a mystery. In 2015, scientists found a group of archaeabacteria on the ocean floor, which could have "fathered" the eucaryotes about 1.9 billion years ago.

R.B. PEDERSEN/CENTRE FOR GEOBIOLOGY/UNIVERSITY OF BERGEN, NORWAY

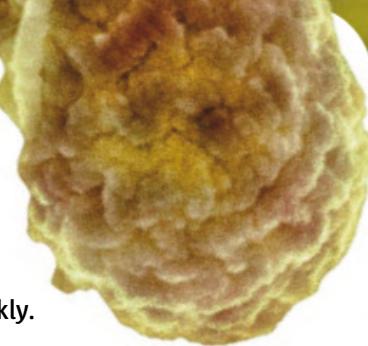


**1.2 BILLION YEARS AGO**

### Sex boosts evolution

► Bacteria can share genes via specific bridges – an ability that originated early in the history of life and helps species adapt quickly. But fossils indicate that real sex, by which gametes merge into new offspring, did not originate until 1.2 billion years ago.

SPL



**550 MILLION YEARS AGO**

### Animals develop legs

► The first animals with legs – the ancestors of insects and annelids – originated in the Cambrian 541-485 million years ago. Or so scientists thought, until 2018, when they found footprints on fossil, 550-million-year-old Chinese ocean floor.

VIRGINIA TECH



**660 MILLION YEARS AGO**

### Sea sponge was the world's first animal

► In 2018, American scientists found chemical evidence of a 660-million-year-old creature – a sea sponge, which is 100 million years older than any previously known evidence of animals. Genetic analyses indicate that animals originated already some 800 million years ago.

ZONGJUN YIN



Early vertebrates evolved close to the shore and dry land.

## CHAPTER 3

# MULTICELLULAR LIFE ORIGINATED 25 TIMES

The leap from monocellular to multicellular is one of the major feats in the history of life, but new research shows that monocellular organisms' genes take the leap easily - so easily that they took it over and over again.

**A** group of alga cells cling to each other in a densely packed, ball-shaped lump. Then the ball falls apart. The individual elements drift away and begin to produce new, large, ball-shaped lumps. The otherwise monocellular algae have developed a type of primitive, multicellular life. But this important evolutionary step did not take millions of years. It took 350 days - and it happened in an American lab.

The scientists behind the experiment, which was carried out in 2017, managed to force a monocellular green alga to become multicellular by subjecting it to a hungry predator: a monocellular ciliate that feeds on algae. The presence of the ciliate meant that algae which tended to form lumps stood a 50+ % better chance of surviving than their lonely relatives.

The change to multicellularism is one of the most important events in the history of life, but the alga experiment shows that the step is surprisingly easy to take. Fossils and DNA have revealed that life on Earth has taken the step at least 25 times - and probably many more times. Now, scientists are close to understanding, why monocellular organisms are made to cooperate.

## Multicellularism materialised late

Almost all the life forms you see in your everyday life are multicellular. That is true for you, the blackbird outside the window, the flowers of the potted plant, and the fungi in the woods. Some multicellular organisms are extremely simple - they consist of cells that have united into a kind of permanent colony.

Others, such as you, are much more sophisticated. They are characterized by being able to develop new, completed offspring based on gametes. And their individual cells are highly specialized in spite of each individual cell containing the same DNA. Specialization means that cells develop to carry out specific tasks - such as nerve cells that send electric signals throughout the organism, or the immune cells that protect against disease. Terrestrial plants and multicellular fungi often include 10-20 different cell types, whereas animals, including humans, have up to 200.

Multicellularism offers organisms such as animals obvious advantages. They can move efficiently, allowing them to seek out optimum environments, they can hunt, and they can escape. But multicellularism has not always existed, and scientists do not know exactly when the first multicellular organism originated. Some finds indicate that very simple versions existed already 2-3 billion years ago. These organisms were probably groups of loosely cooperating cells resembling the lumps of the alga experiment more than animals, plants, and fungi.

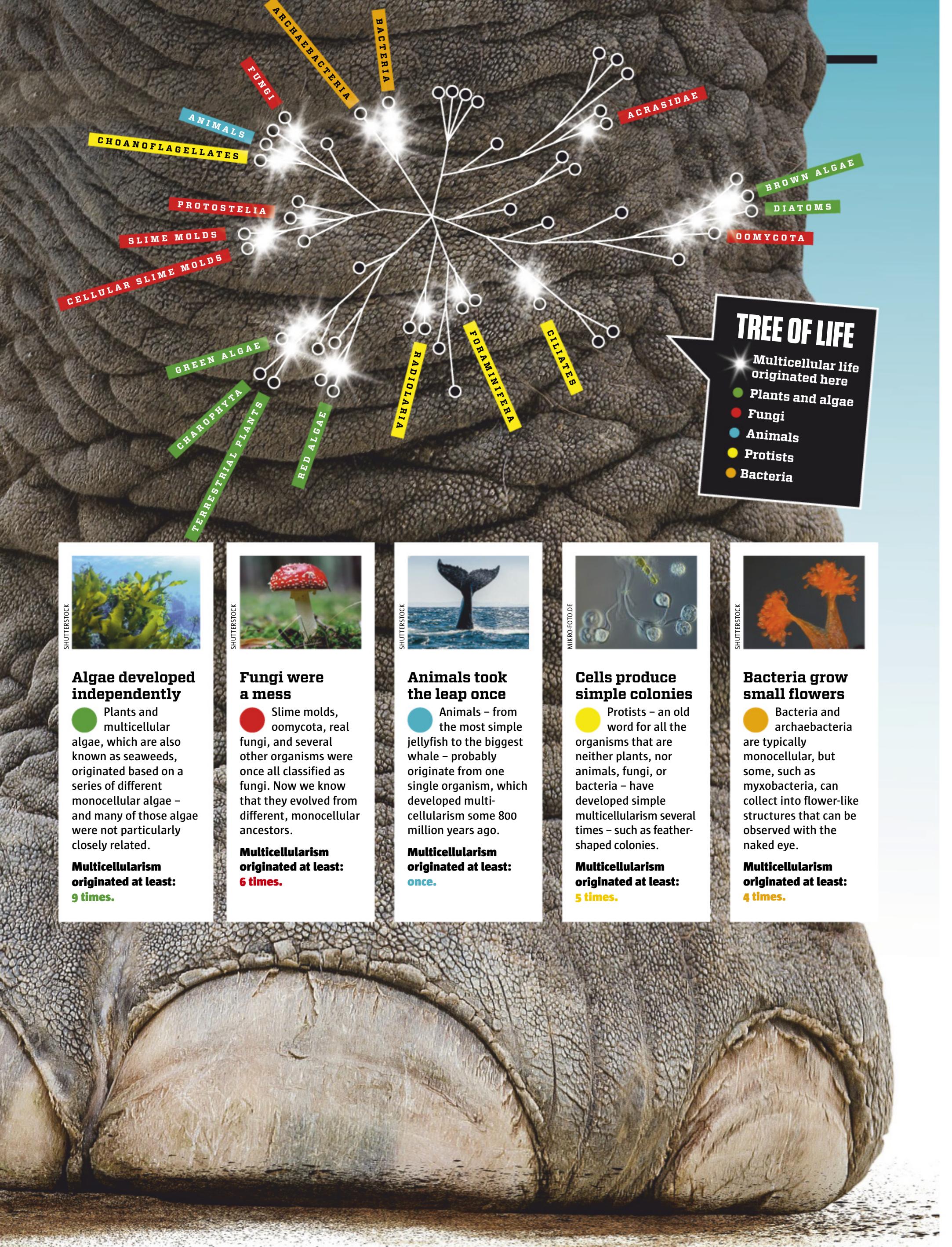
The first sophisticated multicellular life probably originated 750-660 million years ago. At that time, monocellular life forms had ruled the world for more than three billion years. The long wait indicates that the transition was difficult, but this conclusion is inconsistent with other evidence. Scientists have taken a close look at the immense diversity of multicellular organisms in the world today ►

# Seaweeds have nine different ancestors

Multicellular organisms' genes reveal that many of them developed their multicellularism independently of each other.

SHUTTERSTOCK





### Algae developed independently

● Plants and multicellular algae, which are also known as seaweeds, originated based on a series of different monocellular algae – and many of those algae were not particularly closely related.

**Multicellularism originated at least: 9 times.**



### Fungi were a mess

● Slime molds, oomycota, real fungi, and several other organisms were once all classified as fungi. Now we know that they evolved from different, monocellular ancestors.

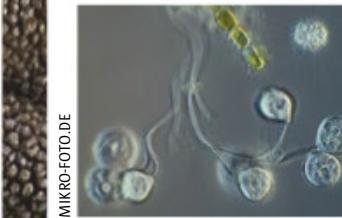
**Multicellularism originated at least: 6 times.**



### Animals took the leap once

● Animals – from the most simple jellyfish to the biggest whale – probably originate from one single organism, which developed multicellularism some 800 million years ago.

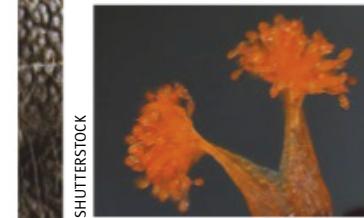
**Multicellularism originated at least: once.**



### Cells produce simple colonies

● Protists – an old word for all the organisms that are neither plants, nor animals, fungi, or bacteria – have developed simple multicellularism several times – such as feather-shaped colonies.

**Multicellularism originated at least: 5 times.**

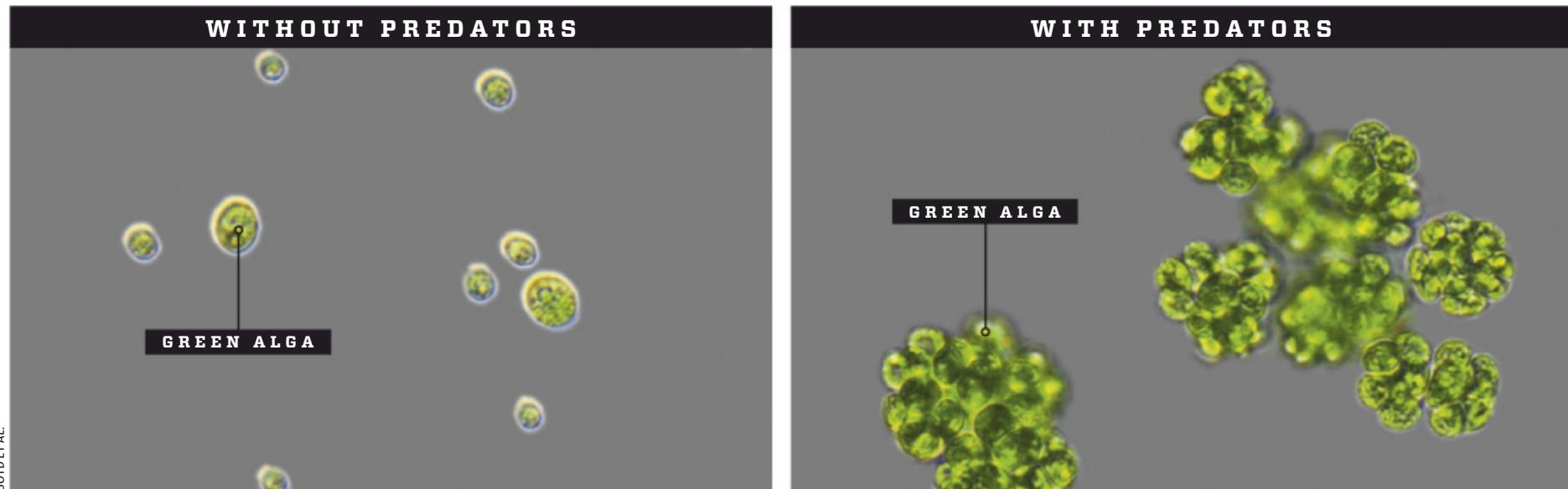


### Bacteria grow small flowers

● Bacteria and archaeabacteria are typically monocellular, but some, such as myxobacteria, can collect into flower-like structures that can be observed with the naked eye.

**Multicellularism originated at least: 4 times.**

## CHAPTER 3



When the monocellular *Chlamydomonas* was subjected to the tiny *Paramecium* predator, the alga quickly developed multicellularism. The new multicellular form stood a some 2.5 times bigger chance of surviving the predator's attack than the old, monocellular form.

► and discovered that they developed their multicellularism independently of each other. Plants, animals, and fungi developed based on three different monocellular ancestors. And among red algae, green algae, brown algae, and diatoms, multicellularism originated at least five times. Modern multicellular life can be traced back to at least 25 different monocellular ancestors – and the number is probably more than 50. Now, scientists try to find out why the immense explosion of multicellular life took three billion years to get started.

### Enemies produced unity

Earth's oxygen level was much lower than today for the first 34 billion years of our planet's history. Not until 850 million years ago, did the level increase – shortly before multicellular life seriously accelerated. The coincidence has made some scientists propose that the low oxygen level had held back multicellular life. But not according to British palaeontologist Nicholas Butterfield. He thinks that multicellular organisms could easily have overcome the lack of oxygen by pumping water across a surface that can absorb the oxygen – like in fish gills.

Instead, Butterfield proposes that sophisticated, multicellular life was long in coming, because the transition required a major change of the cells' coordination skills. In organisms like ourselves, such an ability makes sure that each cell produces the right proteins at the right time, ensuring that our cells can take care of different tasks, in spite of the fact that they have the same DNA, that they stop dividing, when growth is not necessary, and that some commit suicide in the common interest.

A difficult transition to improved coordination explains why multicellularism was long in coming – but not why it suddenly originated a wealth of times in different organisms. The answer to that question is probably that the difficult transition is not so difficult, when the right evolutionary motivation exists. The advantage of multicellularism is particularly that it protects against predators. But during the first three billion years of the history of life, predators were small and simple – there was no pressure on life to become multicellular. Approximately 800 million years ago, a more sophisticated predator originated, and that made a long series of organisms clump together in self defence.

Over a brief period of time, several different groups managed to take the leap to multicellularism, and American biologist Nicole King might have found the answer to the question of why it went so fast. By studying monocellular choanoflagellates, King and her colleagues discovered that monocellular organisms have versions of many of the genes that are essential to our own multicellularism. Genes which ensure that our cells are linked, can communicate with each other, or kill themselves to avoid cancer and other diseases that threaten the common interest. In monocellular organisms, the genes are used for other tasks such as capturing food or sensing the outside world, but it only takes minor corrections to alter their functions.

So, monocellular organisms already have all the tools needed to become multicellular, and hence, multicellularism originated over and over

again. Since our own ancestors took the leap, they have adjusted their genes over millions of years, so our bodies have now achieved almost incredible coordination between every one of their 37 trillion cells. But scientists have discovered that once in a while, we experience a relapse into the monocellular state.

### Relapse explains cancer

In 2017, Australian scientists headed by biologist David Goode researched how the activity of a number of genes in cancer cells differed from the normal one. Goode revealed that the genes that have changed the least since our monocellular originators are very active in cancer cells. On the other hand, the genes that have developed more, have been inactivated in cancer cells. The conclusion is that cancer originates, when mutations break down the mechanisms that ensure the ability of cell coordination – boosting the selfish mechanisms that are necessary for a monocellular organism.

Cancer is a change from multicellularism to monocellularism, and the cancer cells behave like monocellular parasites that attack our bodies. Some rare cancer types such as sticker tumours, which affect dogs, are even able to spread from one body to another via sexual contact – like gonorrhoea and other bacteria.

In recent years, Scientists have learned much more about our ancestors' passing from monocellularism to multicellularism, but it is now clear that their discoveries can do more than teach us about the past: they can help us understand how our cells can relapse into monocellularism and so contribute to future cancer treatments. **SCI**

# Cells are made for cooperation

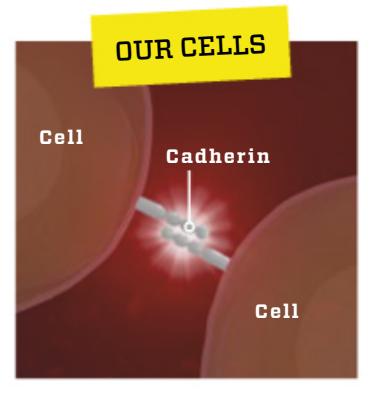
A series of proteins ensure that our bodies stick together and that our cells cooperate as a whole. But microscopic choanoflagellates have revealed that the proteins also exist in monocellular organisms. And there, they serve a very different purpose.

CLAUS LUNAU

Choanoflagellates are among the animal kingdom's closest relatives, but they only measure a few micrometres.

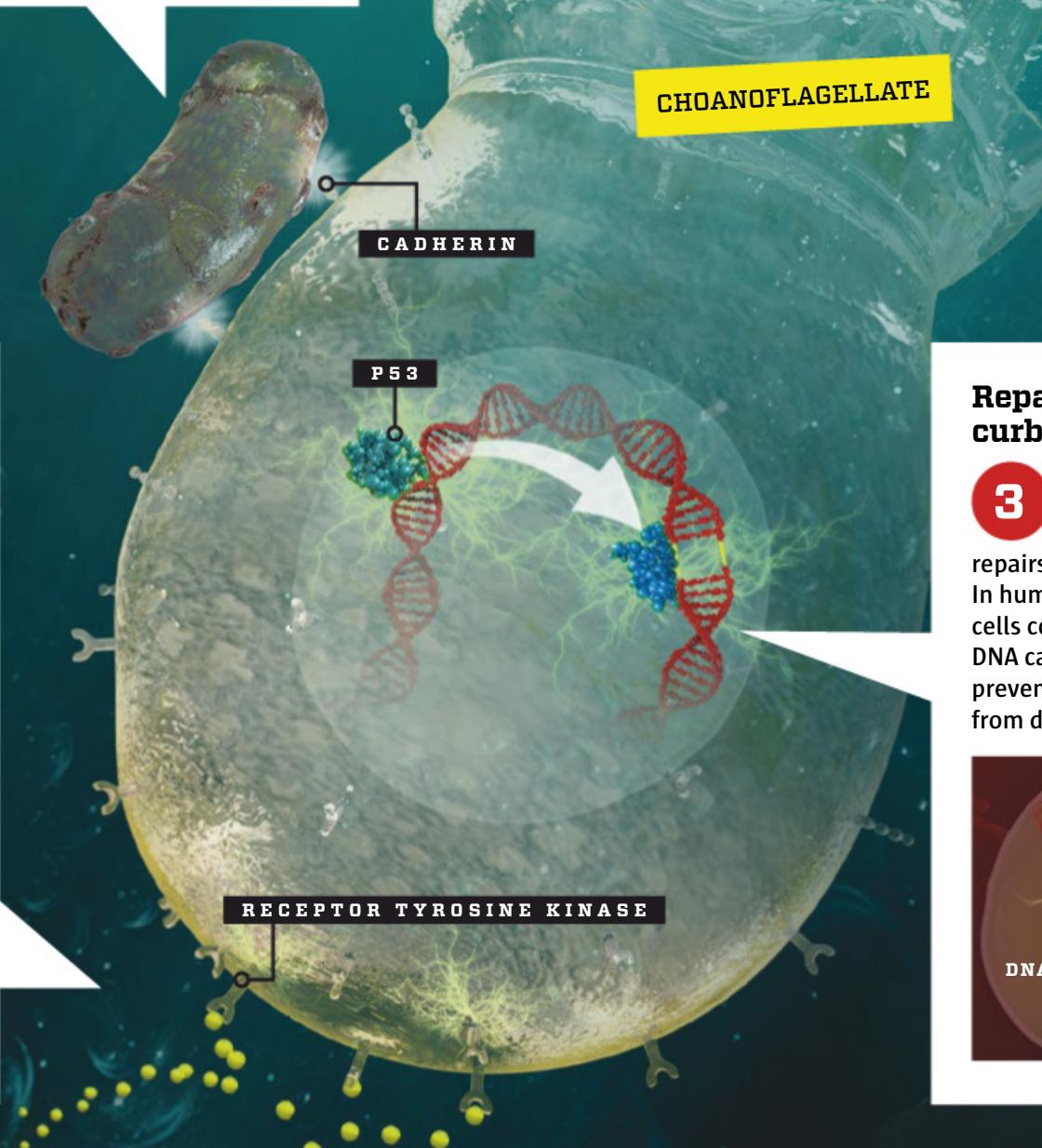
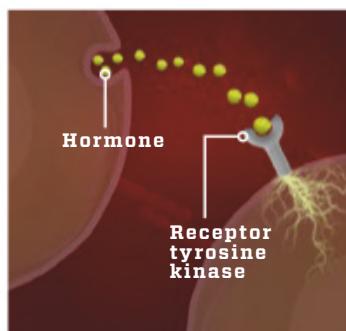
## Hunting tool holds your cells together

**1** Choanoflagellates have cadherins on their surfaces that help them capture bacteria. In our bodies, cadherins are used to hold cells together, so we do not fall apart.



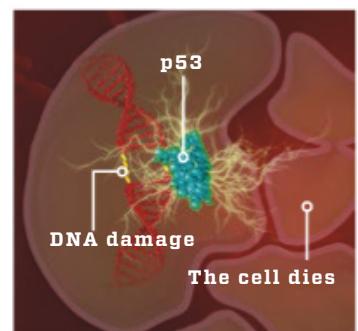
## Sensory apparatus receives signals

**2** In order to sense molecules in the water around them, choanoflagellates use receptor tyrosine kinase. In humans, the same receptors ensure that our cells can receive signals, such as hormones, that the body's other cells send.



## Repair tool curbs cancer

**3** In humans and choanoflagellates, the p53 protein repairs damaged DNA. In humans, it also makes cells commit suicide, if the DNA cannot be repaired – preventing damaged cells from developing into cancer.



New launch pads to prevent

# SPACEPORT TRAFFIC JAM

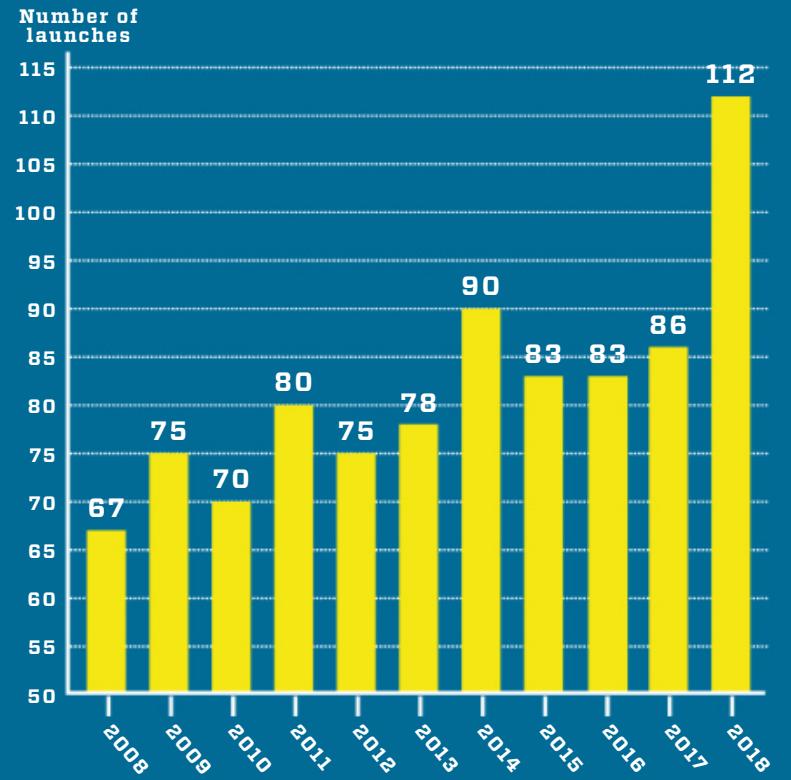
► The number of launches is increasing, and space rockets queue up. A new generation of spaceports are in the pipeline to end the traffic jam, launch huge rockets towards other planets, and offer tourists cheap flights.

At the Kennedy Space Centre, rockets leave the assembly shop to be taken to the launch pad by one of the world's largest vehicles.

NASA

## The number of space departures is rising

In 2018, the annual number of launches exceeded 100 for the first time in 30 years. The number could have been higher, if we had more spaceports.



**R**ight now, the A'Mhòine peninsula in northern Scotland is just a deserted peat bog, but the uninhabited landscape will soon be the scenic surroundings of Europe's new space adventure: the continent's first commercial spaceport is going to be built in the early 2020s.

Space Hub Sutherland, which it will be named, is not the only one. In the UK, another spaceport is planned in the Cornwall region, and a company in Sweden intends to build a spaceport in the city of Kiruna. India, Indonesia, and Singapore are planning spaceports, and the same is true for Australia and New Zealand, while the US – which already has 10 – has another handful in the pipeline.

The new spaceports are mushrooming everywhere, because technological advances and a new space race between private space

companies have sent the price of a ticket skydiving. Today, NASA pays an average of DKK 130,000 per kg of cargo the agency launches into space, while the price per kg of private aerospace companies can be as low as DKK 32,000. The low prices lead to more launches, which has generated long queues by the launch pads.

### Spaceports use Earth's rotation

When a new spaceport is on the drawing board, engineers' most important consideration is its location. Two particular points must be taken into account. First of all, it must be located in a deserted area, so the rockets have a safe distance to anything that could take a hit, and moreover, the engineers need to consider the degree of latitude of the spaceport location, as it determines the destinations offered by the spaceport.

The world's most famous spaceport, the

Kennedy Space Centre in the US, is an example of both considerations. The Apollo missions were launched from there aboard history's most powerful rocket, Saturn V. The huge rocket had an engine power of 33,000,000 newton – 100+ times that of a Jumbo jet – and was 110+ m high. When Saturn V was just a project on the drawing board, it was clear that the rocket required a spaceport that could handle its size and forces. So, NASA in 1962 began to buy land on Merritt Island, Florida, on the American East Coast.

The location was chosen, because Florida is one of the places in the US that is closest to the Equator. A location close to the Equator involves two advantages. First of all, it is where Earth rotates at maximum speed from west towards the east. Although a rocket is launched vertically from the ground, it will gradually point its nose in a horizontal direction, as it escapes the atmosphere. If the

# Long space missions begin at the Equator

When engineers look for a good spaceport location, they consider anything from transport for huge rocket parts, to the speed of Earth's rotation.

## Open sea catches used rocket parts

- **SPACEPORT:** Kennedy Space Centre
- **LOCATION:** Florida, US East Coast
- **OPENED:** 1962

The biggest US spaceport is located on Merritt Island off Florida. Rockets are launched towards the east over the Atlantic, where they can let go of the rocket's used stages without striking inhabited areas. This was the place from which all Apollo and space shuttle missions were launched.

## European spaceport is ideal for high orbits

- **SPACEPORT:** Guiana Space Centre
- **LOCATION:** Kourou, French Guyana
- **OPENED:** 1964

The European Space Agency's primary spaceport is located far away from Europe in the South American jungle. With a location only 500 km north of the Equator, rockets get the maximum boost from Earth's rotation of 1,650 km/h. So, ESA's spaceport is ideal for the launch of satellites, that are to enter into high orbits such as the geostationary orbit, where they follow Earth's rotation accurately – or for long missions, in which a probe must escape Earth's field of gravity.



# WHAT IS AVAXHOME?

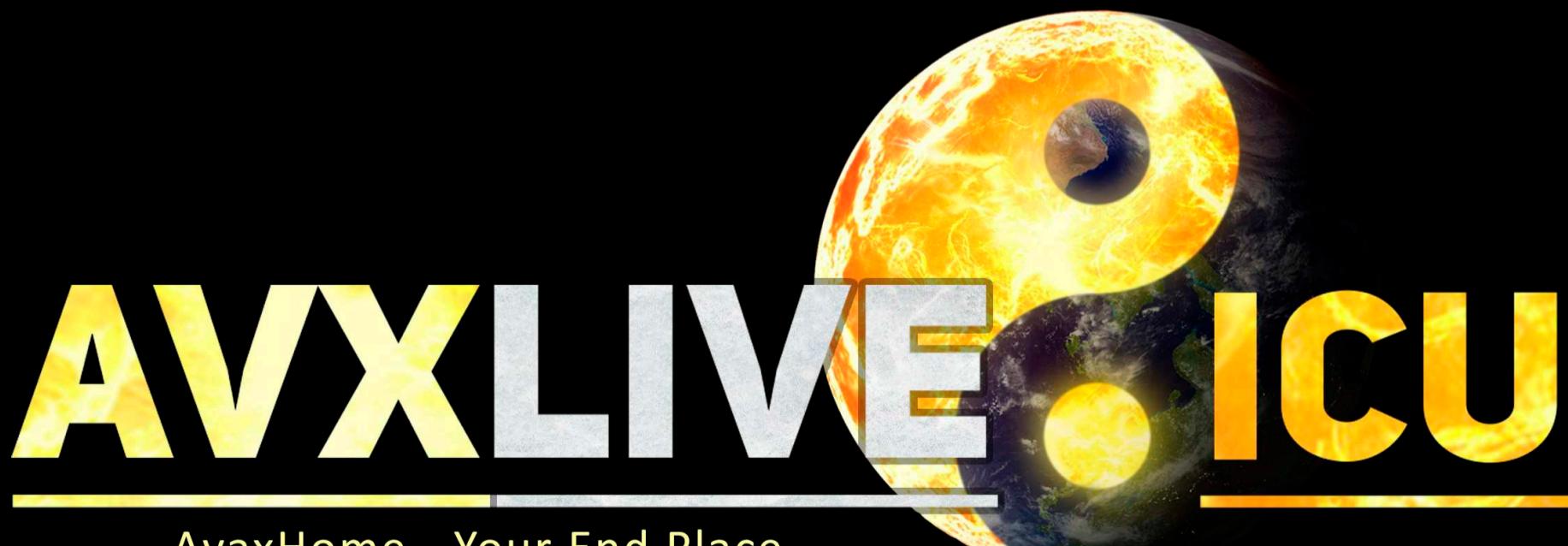
# AVAXHOME -

the biggest Internet portal,  
providing you various content:  
brand new books, trending movies,  
fresh magazines, hot games,  
recent software, latest music releases.

Unlimited satisfaction one low price  
Cheap constant access to piping hot media  
Protect your downloadings from Big brother  
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages  
Brand new content  
One site



We have everything for all of your needs. Just open <https://avxlive.icu>

rocket does not achieve a high speed parallel to Earth's surface, it cannot enter into an orbit and will start to fall back, as soon as the engines are deactivated.

A horizontal speed of about 28,000 km/h is required to enter into a low Earth orbit. If a rocket is launched near the Equator, it has, already before the engines are activated, a horizontal speed of 1,650 km/h thanks to Earth's rotation, and consequently, it requires less fuel to enter into orbit.

The other advantage of

launching close to the Equator is that it is located very close to one of the most attractive orbits around Earth - the geostationary orbit. This orbit is ideal for TV and communication satellites, etc., as at this altitude, they will follow the planet's rotation. As observed from Earth, the satellite will always stand still in the sky, so satellite dishes can maintain the signal.

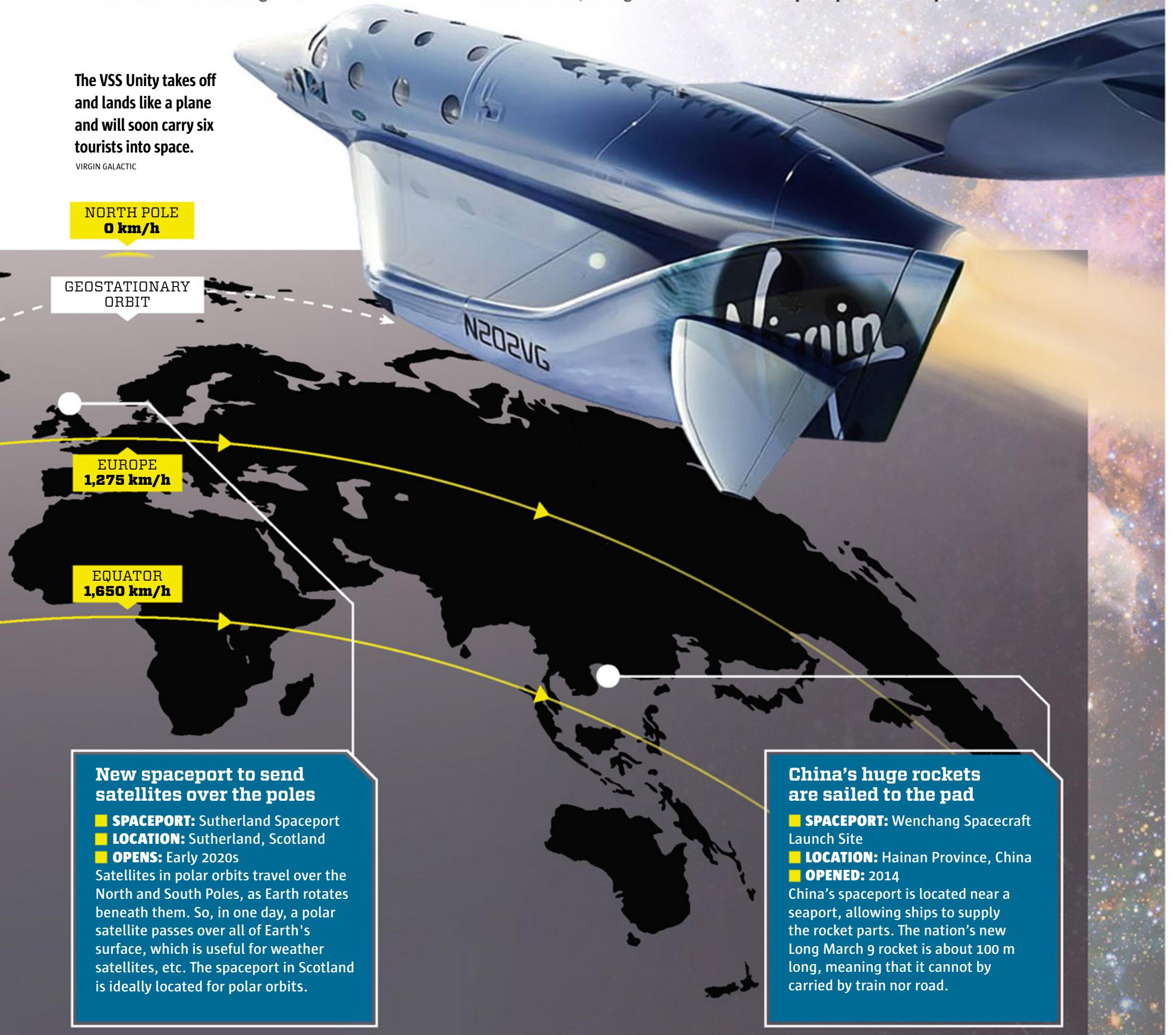
Polar orbits are also attractive. The satellites fly perpendicularly to the North and South Poles many times a day, as the planet rotates beneath them, taking them across all

of Earth's surface in 24 hours. They are often launched from ports near the poles.

### New type of spaceport in demand

The distances in space around Earth are so long that the orbits can still include millions of satellites, and that is a good thing, as in the next few years, the number of satellite launches is expected to explode.

The most important limitation is weight. The technological development with more computer power in less space has meant that ►



► satellites can now be built in shoe box sizes with the same or more functionality than satellites of hundreds of kg had a few decades ago. The small satellites or "smallsats" can be launched in groups of more than 100 at a time. As the price per kg of equipment launched into space is falling, more companies and nations have been able to afford launches. In November 2018, the Euroconsult company estimated that some 7,000 smallsats would be launched over the next 10 years. That is a sextupling as compared to the previous decade. Spaceports such as the Kennedy Space Centre are built to facilitate a few major launches, and consequently, they are poorly equipped to get the launch pad ready for new launches all the time. This means that the increasing number of launches has triggered a demand for more spaceports with a capacity for minor launches, and such a port has been built by the Rocket Lab company in New Zealand. With its own light rocket - the Electron - which only measures 17 m and weighs 12.5 t, the company hopes to be able to carry out a launch every three days, when operating at full capacity.

### Engineers customise launch pads

The new and smaller launch pads can now be designed much more accurately than they



Currently, VAB is ready to house NASA's upcoming Moon rocket, SLS. Although the rocket becomes the world's largest and will measure 111 meters in height, there is plenty of space under the 160 meter high roof. The building can accommodate a total of four assembled SLS rockets.

# 1125

**Burn time, in seconds, of NASA's new Space Launch System, the most powerful rocket ever.**

used to. Today, engineers particularly use 3D software to design and test shapes and materials, before the construction work begins.

By means of a computer programme, they can calculate how far away the flames would extend from a rocket taking off, depending on the type of fuel and the rocket's weight. This makes it possible to adapt the platform to individual launches, which engineers have used in the case of the new Launchpad 39C of the Kennedy Space Centre. The platform is located in the same complex as the historical Apollo and space shuttle launchpad 39A.

The launch pad's only permanent structure is a concrete platform, on which engineers can install the required modules from a mobile assembly kit between launches. The most important module is the elevated launch body, on top of which the rocket is attached. Below the body, engineers can install flame buckets, which are square steel boxes with angled

plates which bend the flames 85 degrees to the sides, i.e. perpendicular to the platform. In this way, the concrete platform is protected as much as possible. Both the body and the flame buckets rest on a steel carpet that is rolled out and attached to the concrete platform. The carpet absorbs the heat from the rocket in order that the flames cause a minimum of harm to the platform.

### Huge rockets coming up

At the same time as satellites and rockets shrink, and spaceports offer ever more flexibility in order to adjust to the requirements, aerospace is also moving in the very opposite direction. A new generation of huge rockets is under development as we speak.

NASA is applying the finishing touches to its new huge rocket, the Space Launch System, which will have a lifting capacity of 130 t. At the same time, the Chinese space agency is developing the Long March 9 rocket with a capacity of 140 t, and the SpaceX company is putting its money on the Starship vehicle, which, aided by a huge booster rocket, can lift at least 100 t and is 100 % reusable. In comparison, the world's currently most powerful rocket, Falcon Heavy, can lift around 64 t.

The powerful vehicles make other demands on the facilities of the spaceports. NASA's old space shuttle platform, 39A, is now the only one that can handle Falcon Heavy's intense forces. Unlike the 39C's mobile



NASA's huge transporter measures 35 x 40 m and is the world's biggest self-powered vehicle.

JIM GROSSMANN & KIM SHIFFLETT & NASA

LASERS GUIDE THE VEHICLE IN POSITION AT AN ACCURACY OF 6 MM

# Huge vehicle carries 5,000 t of rocket equipment

At a top speed of 1.6 km/h, NASA's huge Crawler Transporter completed the nerve-racking stroll from assembly shop to launch pad with the largest rockets of all times tied to its back.



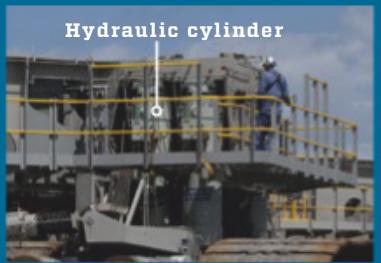
## SMALL WHEEL CONTROLS HUGE VEHICLE

► In the control cabins, there is a 15-cm-wide, red steering wheel, which is turned to change the crawler's direction. Moreover, a button by the driver's left hand side controls the speed. On his right side, meters indicate altitude and platform angle, if the ride is up or downhill.



## DIESEL POWERS ELECTRIC MOTOR

► Two huge diesel engines with a total of 5,500 HP supply energy for the electric motors that power the crawler. The advantage of electric motors is that unlike combustion engines, they supply the wheels with the same force, no matter if the vehicle moves or not.



## SUSPENSION KEEPS ROCKET ON EVEN KEEL

► Shortly before the crawler reaches the launch pad, it must climb a hill with an incline of 1.5 m. 16 jacks consisting of hydraulic cylinders keep the vehicle's platform horizontal, in spite of a total load of up to 5,000 t.



## HEAVY CATERPILLARS ENSURE GRIP

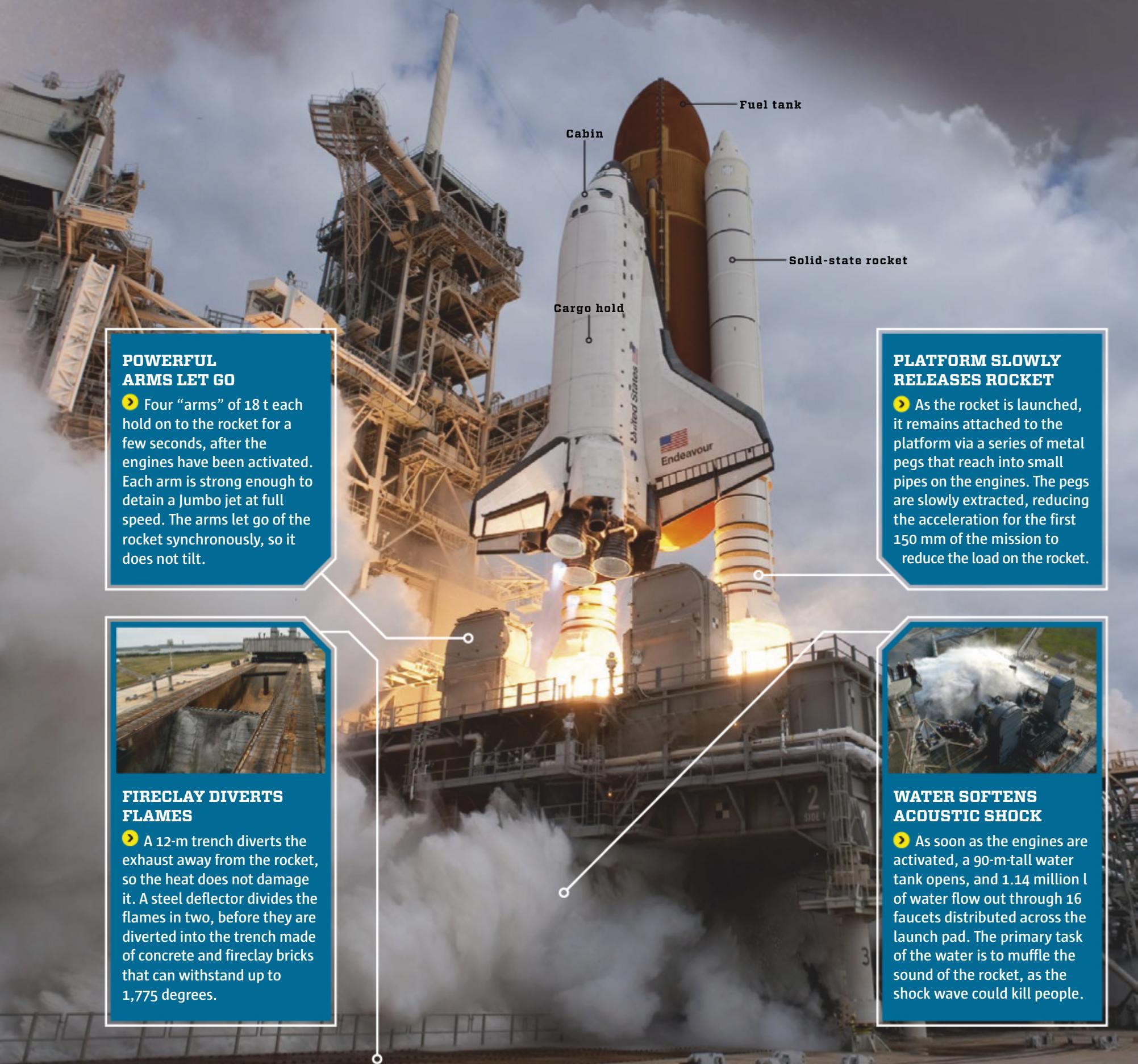
► Under each of the platform's four corners, you will find two huge caterpillars. Each caterpillar is made up of 57 shoes – robust steel plates that weigh 950 kg each. So, the crawler ensures its road grip with a total of 456 shoes weighing a total of 433 t.

UNLADEN, THE CRAWLER WEIGHS 2,721 T - FULLY LOADED, IT WEIGHS UP TO 8,500 T

THE PLATFORM CAN BE KEPT PLANE WITH A DEVIATION OF 0.15 DEGREES

# Water and powerful arms protect the space rocket against itself

A space rocket includes such extreme powers that it would be torn apart, if the platform did not protect it. A deep flame trench and millions of litres of water ensure that the rocket is launched safely.



► platform, the permanent installation of 39A is surrounded by powerful water cannons, which spray more than one million litres of water beneath the rocket, when the engines are activated. The primary cause of the water is not to cool the platform below the rocket, rather to dampen the acoustic shock from the roaring engines. Air bubbles in the water absorb the sound waves, compress them, and heat them, so the shock wave is damped considerably from a sound level of some 200 decibels to 150. Such intense pressure waves are not just lethal to humans, they could also harm the rocket itself, as the waves are reflected back from the platform. 150 db correspond to the sound of a jet plane 25 m away. It is not lethal, but could rupture your tympanic membranes.

#### Space mission starts horizontally

A third new trend in the spaceports of the world is horizontal runways like the ones that we know from airports. They are tested in Spaceport America in the US, etc., and the idea is particularly pursued by private companies that offer space tourists a quick trip into space 100+ km from Earth.

In the summer of 2018, Virgin Galactic

tested its SpaceShipTwo consisting of a plane and a rocket-powered spacecraft. The plane takes off just like any other and climbs to an altitude of some 15 km, where the spacecraft is disengaged and its rocket engine activated. The engine accelerates the vehicle's speed to 1,000+ km/h in less than eight seconds, continuing the acceleration for another 62 seconds.

The rocket reaches a maximum speed of 4,200 km/h, after which the engines are deactivated, and the vehicle glides the rest of the way to the other side of the Kármán line at an altitude of 100 km above Earth. The mother vehicle and the rocket return to the spaceport separately, landing like a plane. SpaceShipTwo will seat eight people – two pilots and six passengers – and the company aims to launch the first paying customers into space in 2019.

#### Space tourism coming up

NASA's own plans of expanding the Kennedy Space Centre in the future also involve horizontal runways, but with a particular twist. Instead of having wheels, the space planes are to be shot off on a runway with electrically conductive tracks. The plane is accelerated to a high speed before it takes off,

and scramjet engines take over.

An ordinary jet engine functions by sucking air in at the front and compressing it by means of turbines, before it is ignited and shot off at the back with a lot of force. In a scramjet engine, the plane's high speed ensures compression of the air inside the engine, allowing the aircraft to reach speeds of 10 times the speed of sound, which is sufficient to reach space.

The horizontal takeoff technologies involve the major advantage that they can be built in many places on Earth or be incorporated into existing airports.

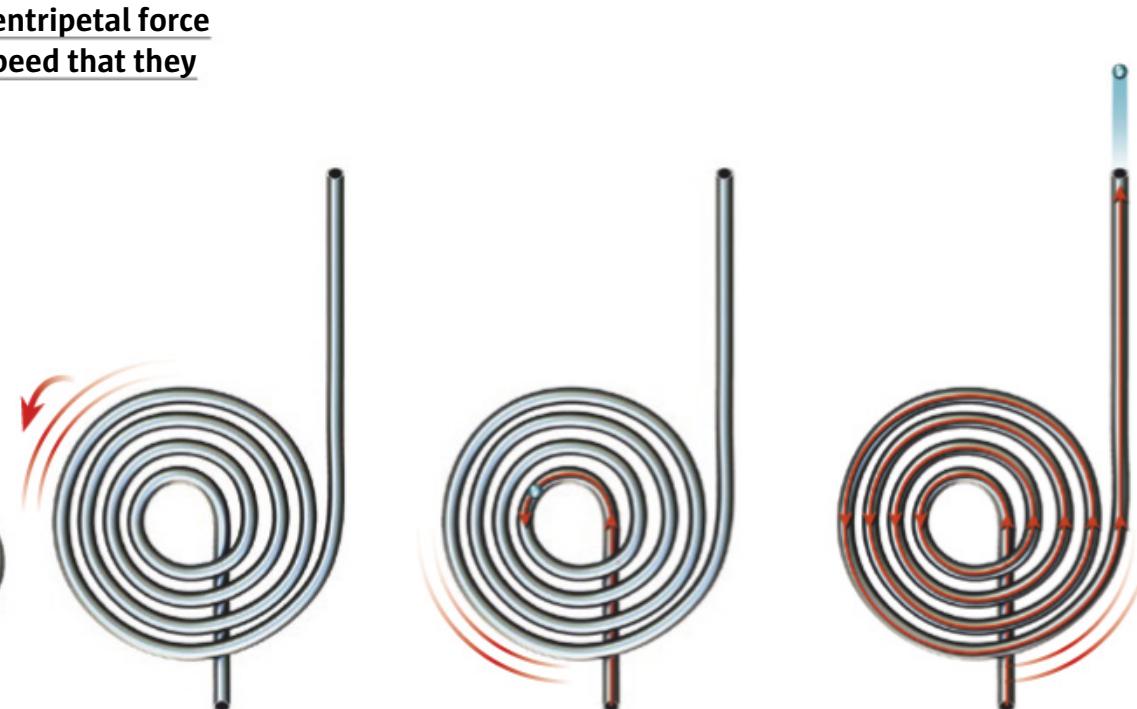
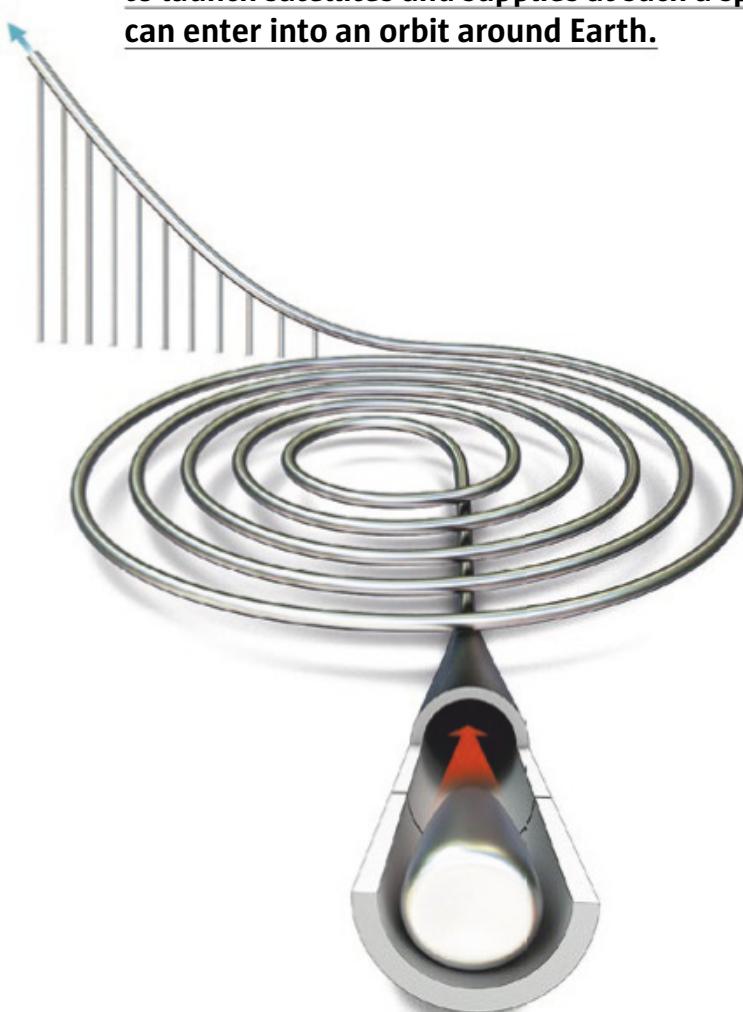
Experts expect the future of spaceports to be ever more integrated into big cities, in the same way as airports are today. The extremely fast vehicles, that are being developed and which can reach space, will at some point be used to fly from continent to continent – via space. That could save a lot of time, because there is plenty of room in space, and the air resistance is very much reduced.

With Space Hub Sutherland, Europe is now taking its first step on the way to forming part of the future global network of spaceports, in which the departure signs will include destinations on the other side of Earth and in space. **SCI**

#### WILD VISION

## Future vehicles to be flung into space

**The Slingatron launch system will use the centripetal force to launch satellites and supplies at such a speed that they can enter into an orbit around Earth.**



**1** **The Slingatron consists of a spiral tube.** The entire spiral construction is moved in circles – like a wine glass – at a speed of up to 60 rotations per minute.

**2** **A space capsule is entered** into the tube and experiences the centrifugal force, which accelerates the capsule, until it reaches a speed of 25,000 km/h.

**3** **The capsule ends up travelling straight towards space.** The capsule's aerodynamic shape reduces the heat generated due to air resistance.

MIKKEL JULIENSEN

# THEY WILL WALK AGAIN

2.5 million people have lost the ability to move their arms or legs as a result of spinal cord injury. Unlike other parts of the body, the spinal cord cannot heal itself, and scientists have been looking for a cure for centuries. But continuous advances in science and technology have brought a "cure" for spinal injury closer than ever...

**CELL TRANSPLANTS** link nerves again.

**COOLING** slows down breakdown of the body.

**ELECTRIC IMPLANTS** send signals from brain to muscles.



Cells from the olfactory bulb linking the nose and the brain have allowed Darek Fidyka of Poland to walk again.

CARLA VAN DE PUTTELAAR

# CELL TRANSPLANTS

## ■ Name: Darek Fidyka

### Cell injection makes paralysed man walk again

In 2010, 36-year-old Polish firefighter Darek Fidyka was attacked and stabbed in the back with a knife 18 times. Fidyka's spinal cord was cut, and he lost all sensation and muscle control from the waist down. He faced life in a wheelchair, but following the

world's first transplant of cells from the nose to the spinal cord, Fidyka can now walk with a walking frame.

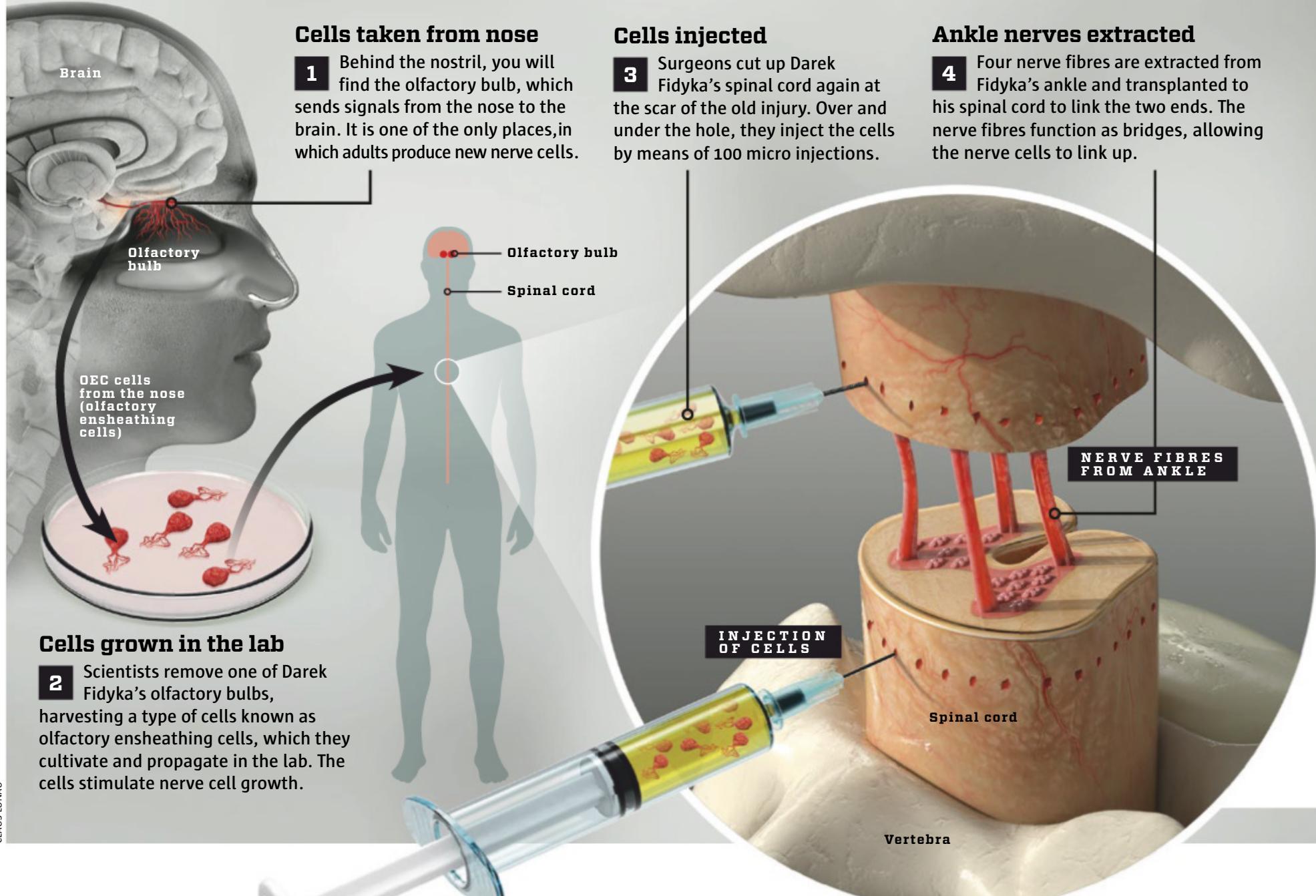
**The cell transplant has enabled Darek Fidyka to walk with support in spite of spinal cord injury.**



CARLA VAN DE PUTTELAAR

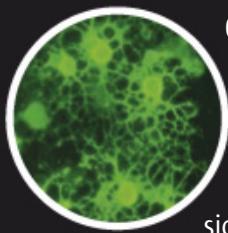
# Doctors move cells from the nose to the spinal cord

Behind the nose, in Darek Fidyka's brain, doctors extract a special type of cells, which are injected into the spinal cord, where they make nerve cells link up again.



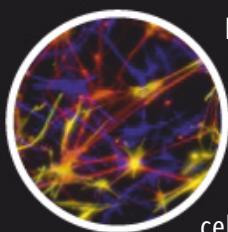
## CELLS FROM THE ENTIRE BODY TO HELP PARALYSED

Cell transplants could be the cure of the future for 2.5 million people who have been paralysed as a result of spinal cord injury. Several types of cells are now being tested.



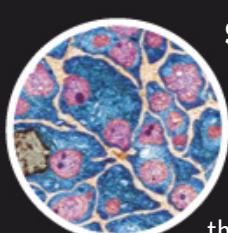
### Oligodendrocyte stem cells

**(AST-OPC1)** from fertilized eggs recreate the myelin layer around nerve cell axons, which is necessary for them to send signals to the muscles. So far, 17 people with spinal cord injury have gained more mobility in this way.



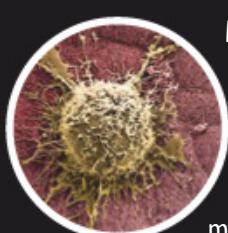
### Nerve stem cells

are cells from the central nervous system, which can develop into many cell types. They can restrict inflammation, replace lost cells, and stimulate the regeneration of nerves.



### Schwann cells

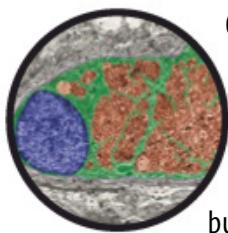
normally produce insulating myelin sheaths for nerves outside the central nervous system, but in several experiments, they have proved to be able to regenerate spinal cord myelin sheaths.



### Mesenchymal stem cells

are stem cells from connective tissue that protect nerve cells, produce growth promoters, moderate inflammation, and might prevent scar formation.

Clinical testing has been initiated.



### Olfactory ensheathing

cells from the olfactory bulbs of the nose stimulate nerve cell growth and produce bundles to grow along. Darek Fidyka regained his sense of touch and motion after a cell transplant. More experiments have been initiated.

SILVIA RICCARDO/SPL & RICCARDO CASSANI INCONI/SPL & THOMAS DEERINCK, NCMIR/SPL & SPL & JOSE CALVO/SPL



24-year-old Kris Boesen became paralysed in his upper body in a traffic accident three years ago, but after transplant of AST-OPC1 stem cells, he can now use both his arms again.

In March 2016, American couple Rodney and Annette Boesen get a message that most parents fear. Their 20-year-old son has been in a traffic accident. The son, Kris, has broken his neck, is on life support, and probably permanently paralysed from neck to toe – except for one of his arms that he can move up and down.

However, doctors give them a bit of hope: Kris is eligible to participate in an experiment with an entirely new treatment. Less than a month later, doctors inject 10 million stem cells directly into Kris' injured spinal cord.

The result is a miracle. After three months, Kris Boesen can use both his arms and hands, write his name, eat without help, use his phone, operate an electric wheelchair, and hug his friends and family.

Kris Boesen is not by far the only one who has experienced waking up after an accident to a life that is totally changed. In the US, some 17,500 people suffer spinal cord injury annually, and globally, 2.5 million people live with the consequences. Many do not only lose the ability to move most of their body muscles, they cannot feel touch, control their bladder and bowel functions, or have sex the way they used to be able to.

For 100+ years, scientists have been searching for an efficient treatment of spinal cord injury without making much progress, but in recent years, scientists have produced ever more success stories. Never before have so many clinical tests been going on – such as cell transplants from other parts of the body and electrode implants. This promises well for all the patients who must live with the effects of spinal cord injury every day.

### The body harms itself

Kris Boesen's story begins on 6 March 2016, when the 20-year-old man loses control of his car, colliding with a tree, after which the car hits a telephone mast. Kris Boesen is injured, and the most badly affected is his neck, spine, and spinal cord.

In Kris and others who suffer severe injury, it triggers a chain reaction of biological processes in the body that determine how the person will be doing in the long run.

During the first 48 hours after the injury, the acute phase, many cells die due to swelling, bleeding, and local oxygen shortage, and on top of this, the immune system triggers an inflammatory condition, which is to protect the body against bacteria and get rid of all the dead cells. However, the inflammation

# Spinal cord links body and brain

The spinal cord is protected by the spine's 24 vertebrae, which are divided into three regions that control different parts of the body. The higher the injury is located, the more nerve links are cut, so more of the body is paralysed.

SHUTTERSTOCK

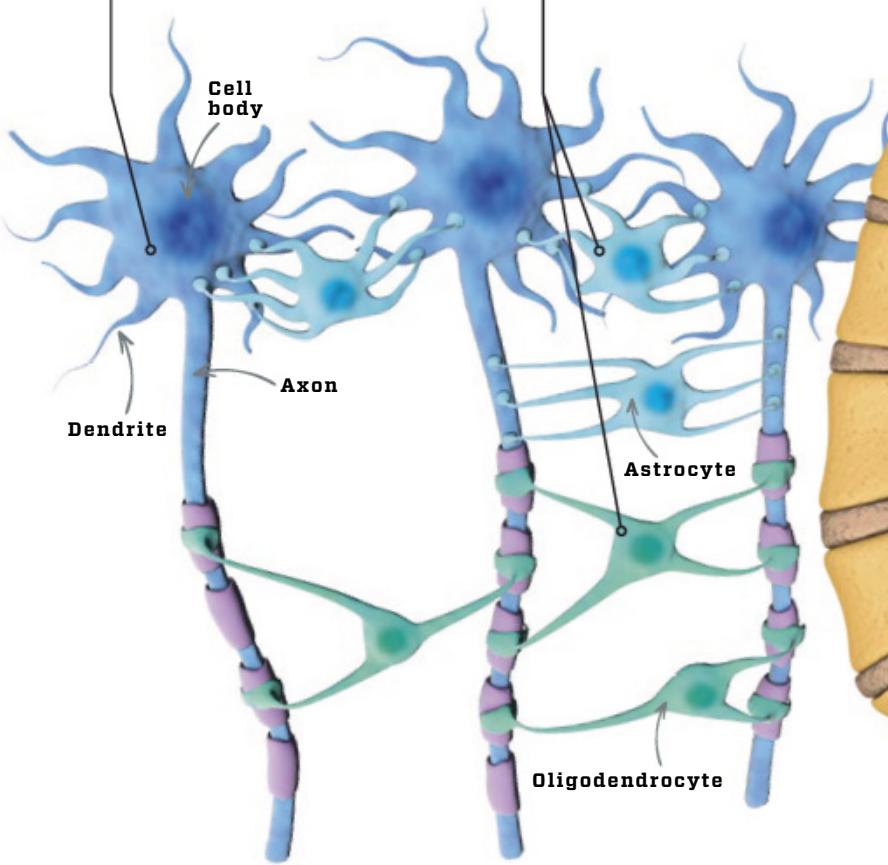
- From the **cervical vertebra region**, the nerves send electric signals to and from arms, shoulders, hands, etc., and to the midriff, which is the body's most important breathing muscle.
- From the **thoracic vertebra region**, the nerves send signals to and from the stomach muscles, the musculature between the ribs, etc.
- From the **loin vertebra region**, the nerves send signals to and from hips, legs, feet, sex organs, intestines, and bladder.

## The spinal cord consists of two cell types

SHUTTERSTOCK &amp; GUNILLA ELAM/SPL

■ **THE NERVE CELLS** of the spine are known as spinal nerves. Motor spinal nerves send signals into the body, whereas sensory spinal nerves send signals in the opposite direction. Nerve cells consist of a cell body, one or more dendrites, which receive signals from other nerves, and an axon, that links the nerve with the muscles.

■ **GLIA CELLS** are cells that protect and support the nerve cells of the central nervous system such as by producing the insulation around them or storing nutritious molecules. Examples of glia cells are oligodendrocytes, which are insulating, and astrocytes, that repair spinal cord injury.



► means that even more cells die.

A cell type that suffers very much during the acute phase is oligodendrocytes, which produce myelin sheathes, the insulation around the nerve axons that connects them with the muscles. Without the insulating layer, the nerve cells cannot communicate with arms, legs, and organs.

After the acute phase, another cell type, astrocytes, play a decisive role. They start by dividing very quickly, producing a spinal cord scar, and the very scar formation is probably one of the reasons why the body cannot heal spinal cord injury on its own.

However, the scar formation is only one of many limiting factors. As an unborn baby develops, the axons, which link the nerve cells with the muscles, grow longer, as the body grows. But in the adult nervous system, axon growth is inhibited by specific proteins. The proteins help ensure that the axons do not grow inappropriately, but in the injured spinal cord, the same proteins prevent that the nerve paths can link up around the injury.

### Could cause cancer

In March 2016, when Kris Boesen is admitted into the Keck Hospital, University of Southern California, a clinical experiment is carried out. He accepts to become part of the experiment, which involves having 10 million stem cells – i.e. cells that can develop into many other types of cells – injected into his injured spinal cord.

At this point, the method has only been tested on animals – and on humans using much more limited doses. Kris Boesen is the first person to be treated with a number of cells that scientists consider sufficient to be able to remedy paralysis. But the dose is also so high that it might have unknown side effects. So, the Boesens are warned that the treatment involves a risk of Kris developing cancer tumours or losing the minimum use of his one arm that he has been left with.

Charles Liu is the surgeon and scientist who heads the surgery about one month after Kris' accident. Liu is the head of the USC Neurorestoration Centre, and together with his team of surgeons, he carefully injects the 10 million stem cells into Kris' cervical spine.

The stem cells, which are known as AST-OPC1, are initial stages of the cells that produce the nerve cells' insulating myelin layer. AST-OPC1 are developed from embryonic stem cells, the first cells from fertilized eggs, which can develop into all cell types of the body. The

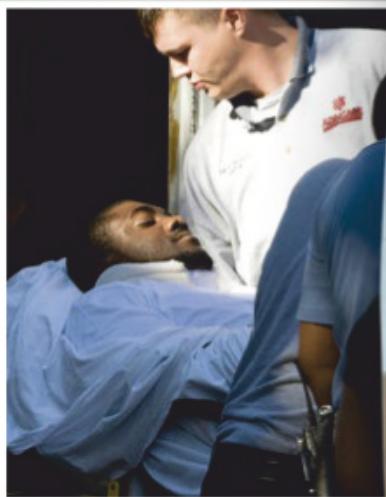
# COOLING

## ■ Name: Kevin Everett

### Cold saves football player's mobility

During a National Football League match in 2007, American football player Kevin Everett collided with an opponent and had his spine injured at the neck. He was paralysed from the shoulders down, but immediately had cold liquid injected into his body to slow down the breakdown processes resulting from the injury. A few months later, he could walk again.

**Kevin Everett was cooled right after the accident.**



## Body temperature of 33 °C prevents cell death

Immediately after Everett's accident, doctors inject 4 °C cold salt water into his blood vessels and place him under a cooling blanket. For 24 hours following surgery, in which the spine is put back in place, his temperature is reduced to 33.3 °C. The cold is meant to slow down the body's own breakdown processes in four ways.



**Thanks to the cooling, Everett walks again four months after the accident.**

**1.** The cooling reduces the metabolism, i.e. the energy requirement is reduced, so cells that lack oxygen can survive longer and pass unharmed through the acute phase.

**2.** In case of bodily injury, the immune system releases neurotransmitters, cytokines, that cause inflammation, destroying the nerve cells. By cooling the body, the production of neurotransmitters is slowed down, so

the immune system damage is limited.

**3.** The area around the spinal cord injury swells, killing the nerve cells due to the pressure and because it blocks the oxygen supply. The cooling impedes the swelling like an ice bag on a sprained ankle.

**4.** The cooling prevents several other harmful processes in the acute phase, such as programmed cell death, i.e. cells that were already dying can survive after cooling.

scientists hope that the cells will integrate themselves into Kris' tissue and develop into cells that support and protect nerve cells.

In animal tests, AST-OPC1 have already made scientists hopeful, as the cells have three characteristics that are key to being able to treat spinal cord injury.

First of all, AST-OPC1 can liberate neurotrophic factors that help the nerve cells grow. Secondly, the cells can stimulate blood vessel formation, and finally, they are able to restore the insulating myelin sheaths. All three

factors are key to the nerve cells being able to reestablish the lost connection to the brain.

### New cells admitted

Kris Boesen's stem cell surgery is followed by rehabilitation, and already after two weeks, Kris can feel the first signs of improvement. After three months, his upper body mobility is markedly better, and he can use his arms, hands, and fingers.

Before the treatment, Kris was totally dependent on the help of other people in

connection with even the most trivial of matters. About four months after the surgery, he can eat, brush his teeth, lift a weight, and write his name.

After one year, surgeon Charles Liu and his colleagues can observe from MRI scans that the transplanted cells have become integrated and produced tissue in the area in which Kris' spinal cord was injured. And, not least, the scientists can conclude that there seems to be no severe side effects of the treatment.

Kris Boesen is the first patient in a group ►

# ELECTRIC IMPLANTS



CASE WESTERN RESERVE UNIVERSITY/CLEVELAND FES CENTER

## ■ Name: Bill Kochevar

### Moves his arm again after severe bike crash

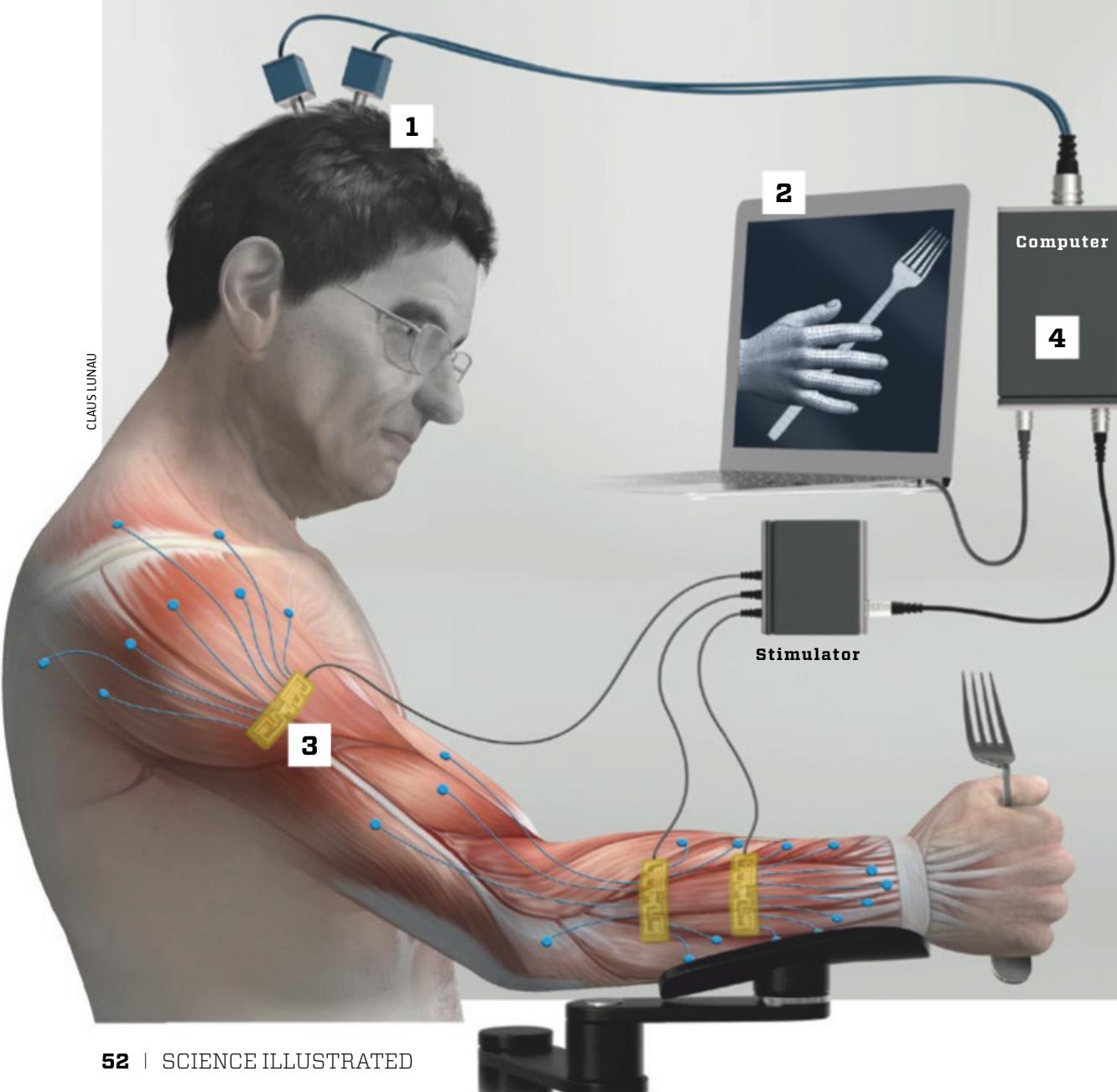
During a bike ride in 2009, 45-year-old Bill Kochevar of the US did not see a truck in front of him slow down. He hit the back of

**Bill Kochevar was paralysed from the neck down, but electrodes in the brain allowed him to eat on his own.**

the truck head first and suffered spinal cord injury. The accident paralysed him from the neck down, but eight years later, in 2017, he was the first person to get a neuroprosthesis, that has allowed him to move the arm and eat and drink unaided.

# The brain controls the arm, bypassing the spinal cord

The nerves in Bill Kochevar's spinal cord are still injured, but scientists have produced a short cut for brain signals. Electrodes have been implanted into his brain and linked with a computer, which sends a signal to the muscles, when he wants to move his arm.



### Electrodes inserted in the brain

**1** Scientists insert two electron rows into the part of Kochevar's brain that used to control his right arm and hand. Via cables, the electrodes are linked with a computer that registers the brain's signals.

### Learns to control virtual arm

**2** Over four months of training, Kochevar practices moving a virtual arm only by thinking about the motion. The aim is to teach the computer the brain signals required to carry out each motion.

### Electrodes stimulate muscles

**3** Kochevar had 36 muscle-stimulating electrodes transplanted to his upper and lower arm. The electrodes stimulate the muscles over a period of 18 weeks to improve his muscular strength.

### Moves arm by power of thought

**4** Scientists link the electrodes in the arm with the computer, which is linked to the electrodes in Kochevar's brain. When he thinks about a motion, the computer decodes his brain signals and – bypassing the spinal cord – sends a signal to the electrodes in the arm muscles. The signal makes the muscles carry out the motion that Kochevar is thinking about.

► of six, who all receive the treatment that involves 10 million AST-OPC1 cells. After 12 months, all patients have recovered their ability to move parts of their bodies that used to be paralysed. In a new series of experiments, the scientists are doubling the number of cells to 20 million in the treatment of 12 other patients. Again, the result is positive. After a year, 17 in 18 patients have markedly improved their mobility.

### New drug links nerves again

Kris Boesen's story and the experiments with AST-OPC1 are by no means the only ones. Many other new treatments of patients with spinal cord injury have produced promising results and are being tested further in clinical experiments.

One category of experiments focuses on drugs that, in one way or the other, can slow down the harmful processes that the body triggers in the case of acute spinal cord injury. Doctors hope to be able to reduce the extent of the injury and protect the cells that did not die immediately. One example of a drug, from which scientists expect a lot, is minocycline – an antibiotic that can bypass the barrier that surrounds the spinal cord and the brain. Minocycline impedes inflammation and cell death, and both in animal experiments and the first experiments with humans, the treatment seems to be safe and improve the mobility of some patients with acute spinal cord injury.

Another type of treatments focus on the recovery of the injured tissue and the lost connections such as by stimulating the body's own regeneration mechanisms and manipulating the inhibiting factors that prevent the regeneration of nerve cells.

New research in electrical stimulation of the spinal cord also promises a bright future for people with spinal cord injury. Several patients who used to be in a wheel chair have, after experiments with this type of treatment, begun to walk again – without a link between the brain and the spine.

Quite a lot has happened with 24-year-old Kris Boesen, since he lost his ability to use his body from the neck down in March 2016.

"I only existed. I did not live my life," Kris says about the time after the accident. Thanks to the cell transplant, his quality of life has improved greatly, but the struggle does not end here.

Kris hopes that he will walk again one day. He has already experienced some motion in his legs, and considering the number of scientific breakthroughs, an efficient treatment might be imminent. **SCI**

## Exoskeletons wake up the nerves

In recent years, many different types of exoskeletons have been developed, which people with paralysis can attach to their bodies to get mechanical help to walk and stand. But it turns out that the exoskeletons might not only help the patients walk.

In 2016, scientists reported a surprising effect of a one year training programme for paralysed people, who were to learn how to walk with the exoskeletons. Eight patients obtained improved motion and feeling in the paralysed part of the body and improved bladder and bowel functions. According to scientists, the training activates the brain's link to the nerves that are still alive after the spinal cord injury.

To study the effect of the exoskeletons in more detail, several experiments are in progress. Scientists are looking at the patients' cardiovascular functions, bone density, muscle mass, walking speed, and spinal cord regeneration.

**Motorized exoskeletons make paralysed people walk, but they also involve other advantages.**

PARKER HANNIFIN CORPORATION





## MEDICAL FRONTIERS

Millions of people swear by alternative medicine. But does any of it even work? Thorough studies now reveal what is efficient and what is not.

### What is herbal medicine?

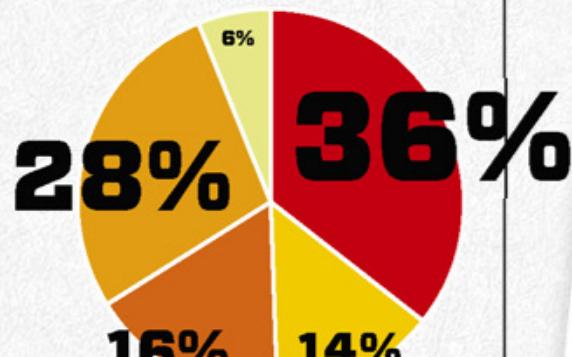
Herbal medicine is the use of parts or extracts of plants – leaves, roots, flowers, bark, and fruit – for the treatment or prevention of disease. The use of herbal medication is rarely based on knowledge of individual drugs' contents, rather on people verbally passing on their experience.

# 64%

of all new medication approved in 1981-2010 originated from plants, animals, mushrooms, or microorganisms.

# 60,000-

year-old discoveries demonstrate that Stone Age people used herbal medication. And the same was probably true throughout most of human evolution.



- Synthetic, no connection with natural product
- Synthetic, inspired by natural product
- Synthetic version of natural product
- Modified natural product
- Purely natural product



ANDREA SOLERO/AFP/RITZAU SCANPIX

### \$60 BILLION

the average global sales of herbal medication since 2010. The amount is expected to grow by 12 % annually over the next several decades.

# 4

**BILLION PEOPLE** – i.e. 80 % of the world population – use herbal medication on a regular basis, according to the WHO. In developing countries, herbs are often the primary source of drugs.

# Can herbs cure diseases?

► Pain, high blood pressure, and allergy can be treated with ingredients from plants. So, scientists are searching for new drugs in nature, but in their eagerness to find active ingredients, they might forget a scientific rule: no effect is also important.

**A** cloud of plant spores blow across the field full of butter-coloured St. John's-wort plants to descend onto the small leaves. Quickly, the spores begin to grow between the cells of the leaves, causing them to wither within a few days. But the leaves have a secret weapon. In small glands, they keep the chemical warfare agent of hypericin, that destroys the fungus' cell walls, killing the uninvited guest. As soon as the plant registers the infection, it increases the production – much to the farmer's delight. The chemical weapon has a completely different function in humans, to whom the dried leaves are sold under the nickname of "green antidepressants" due to the ingredient's well-documented antidepressive effect.

And the St. John's-wort is not a unique case. Scientists have isolated hundreds of thousands of chemical compounds, which plants use to protect themselves. Some of them have clear medical effects, whereas the influence of many others is only based on oral tradition. And that makes the market for herbal medication difficult to navigate in – particularly because the scientific studies do not necessarily provide us with a better impression of what is true and false. In some cases, scientists consider test results that cannot prove a beneficial effect of the herbs as uninteresting, leaving them in their desk

drawers; a dangerous pitfall, which could provide a false impression that herbal drugs work better than they really do.

## Plants killed Socrates

The use of herbal drugs dates thousands of years back in time. Long before modern medicine was established, people discovered

that the leaves, fruit, and roots of plants can influence the body in different ways. In the past, many plants were known for their poisonous qualities. When tribespeople in the Amazon rainforest went hunting, their arrow heads were poisoned with curare, and after Greek philosopher Socrates had been sentenced to death some 2,400 years ago, he was forced to drink hemlock juice with a deadly content of toxic alkaloids.

Many plants also proved to have a beneficial effect, and already in Antiquity, doctors got on the track of willow bark, which was prescribed in the shape of tea against pain, fever, and inflammation. In the late 1800s, a German chemist found out that the beneficial effect was due to the bark's contents of salicylic acid, and by means of a simple chemical change, the drugmaker Bayer converted the natural ingredient into acetyl salicylic acid, which now forms part of familiar drugs such as Aspirin and other painkillers. Similarly, the wise women of the past used dried leaves from the common foxglove plant for the treatment of heart

conditions, long before scientists found out that the plant includes digoxin, that makes the heart beat more slowly and with more force. And in the same way, a long series of other modern drugs originated from nature. Often, scientists do not know for sure which ingredients of the plant have the ►

**5,000**

**billion - yes \$5 trillion - is the expected world sales of herbal medication in 2050.**



SHUTTERSTOCK

► medical effect. That is true for perforate St. John's-wort. Until a few years ago, scientists believed that it was all about hypericin, but new studies indicate that other ingredients of the plant such as hyperforin also contribute to influencing the quantity of neurotransmitters in the brain and so contribute to the antidepressive effect.

In 2009, a complete analysis of the results of several scientific studies, a meta-analysis, reached three conclusions as to the plant's effect on depression: that perforate St. John's-wort works markedly better than placebo for the treatment of depression, that the plant is just as efficient as ordinary antidepressive medication, and that it has fewer side effects. The

analysis, that was carried out by German doctor Klaus Linde from Technische Universität München, was a complete analysis of a total of 29 studies, which other scientists had carried out and involving more than 5,000 test subjects. In 2016, a similar meta-analysis with 7,000 test subjects made the same three conclusions, and so, the plant earned itself a place on the list of herbs with a documented effect on severe diseases. Other well-documented types of herbal drugs are peppermint against irritable colon and geranium against bronchial infection.

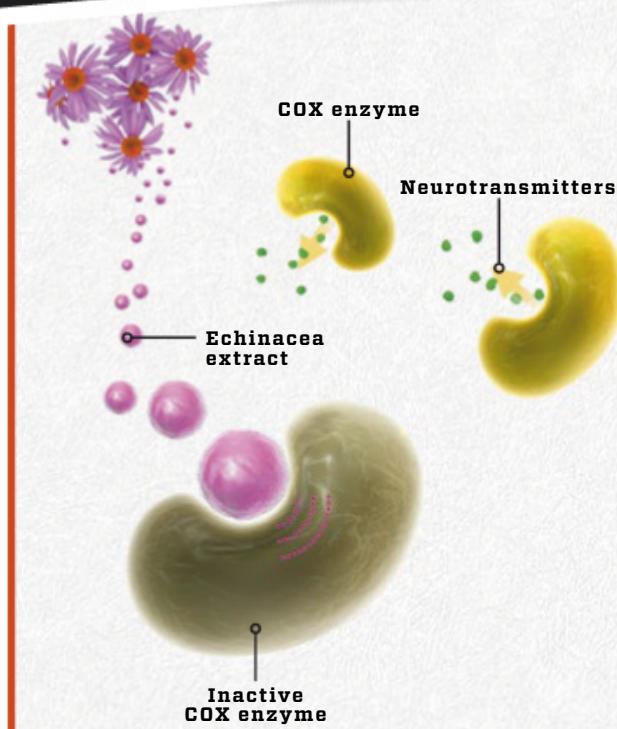
### Roots can affect the memory

Health food shops, supermarkets, and pharmacies also sell many herbs with a more dubious effect. Scientific experiments do not

support the effect of the popular Echinacea garden plant against cold. In a meta-analysis from 2014, scientist Marlies Karsch-Völk from Technische Universität München, Germany, compared the results of 24 studies with a total of 4,631 test subjects, which other scientists had carried out. The analysis concluded that preventive treatment with Echinacea in the shape of either dried plant parts, juice, or extracts from the roots only reduced the risk of getting a cold by 10 %. And if Karsch-Völk allowed for the statistical uncertainty, the effect was dubious. Not even the ginseng plant's highly praised ability to improve the brain's total mental processes, the cognitive function, is very convincing in scientific experiments. In an analysis from 2010 including nine studies, scientist Jian- ►



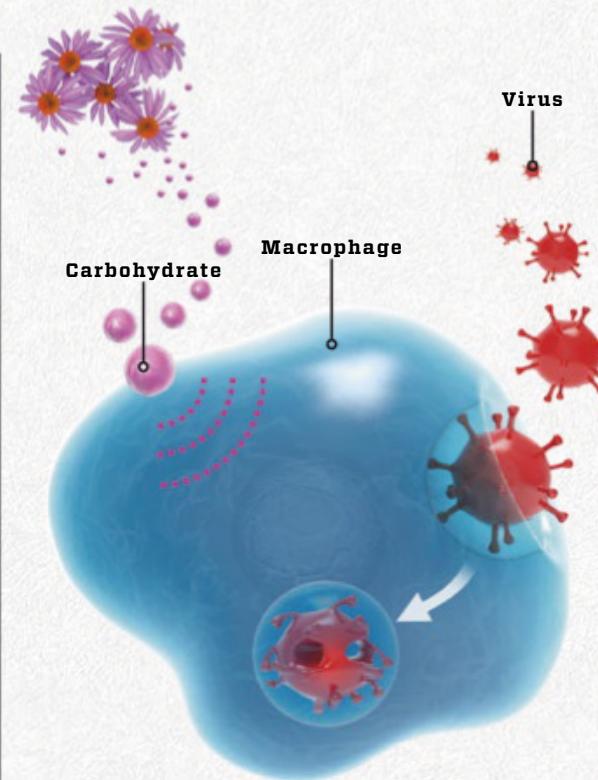
### THE CLAIMED EFFECT OF THE TREATMENT



DOCUMENTATION: **NONE**

#### Reduces inflammation

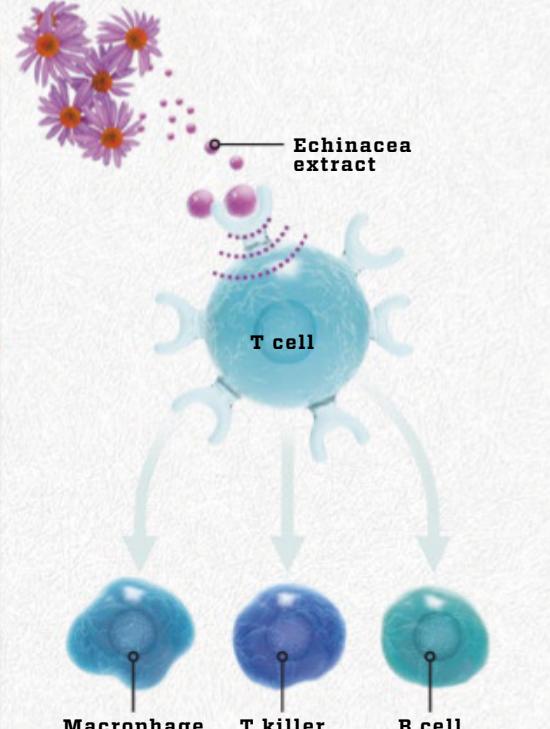
► Echinacea blocks the COX enzyme, which is normally a catalyst for the neurotransmitters that trigger the human body's inflammatory reaction. The Echinacea stops the inflammation.



DOCUMENTATION: **REASONABLE**

#### Stimulates macrophages' appetite for virus

► Complex hydrocarbons from the Echinacea plant stimulate the immune system's waste collectors, macrophages, which combat virus by consuming it.



DOCUMENTATION: **DOUBTFUL**

#### Mobilises the immune system

► Echinacea extracts activate some of the immune system's white blood cells such as T cells, which subsequently activate other immune cells such as macrophages, T killer cells, and B cells.

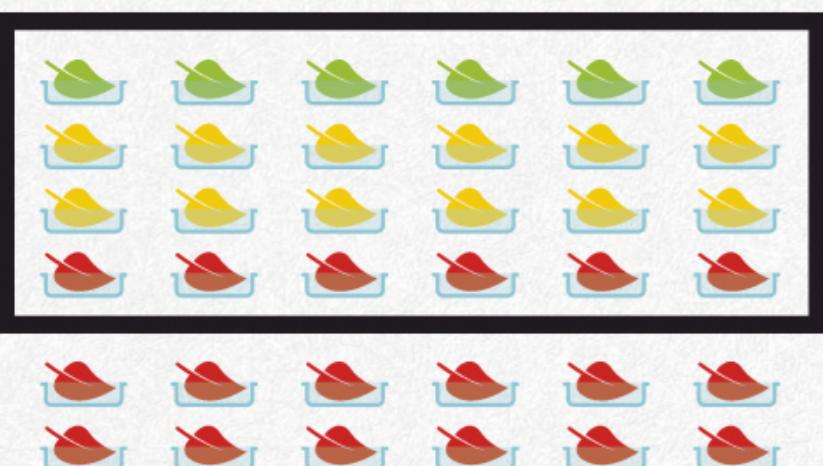


# Negative results must be included

**PUBLICATION BIAS:** Some scientists carry out a kind of self-censorship, by which only positive results are published. The publication bias might give the wrong impression of a treatment.

- TREATMENT HAS FORCEFUL EFFECT
- TREATMENT HAS SLIGHT EFFECT
- TREATMENT HAS NO EFFECT
- EXPERIMENTS THAT ARE PUBLISHED

## WRONG



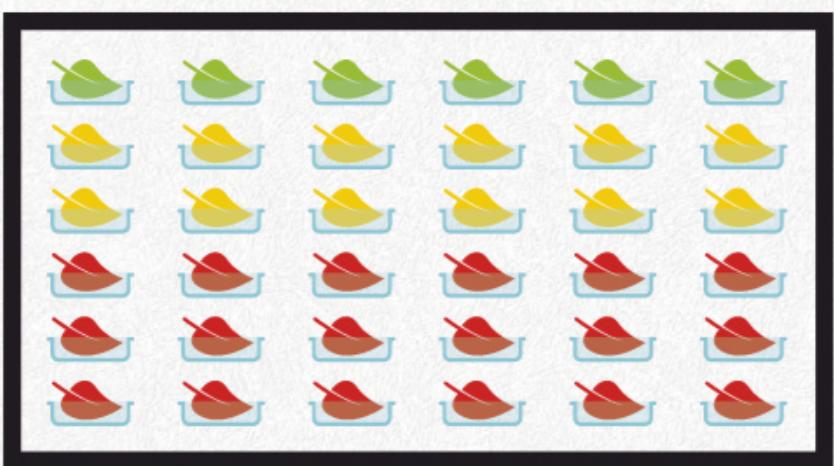
### “FAILED” EXPERIMENTS ARE FORGOTTEN ABOUT

► The scientists behind an experiment that fails to document an effect of a specific treatment consider their results uninteresting and the experiment as having failed. Consequently, they choose not to publish the study. The scientists behind a meta-analysis, which is a complete analysis of the results of several scientific studies within the same field, also choose not to include studies with negative results.

**25 %**

of the published studies show that the treatment has a marked effect on a given disease.

## RIGHT



### ALL RESULTS ARE PUBLISHED

► Although an experiment demonstrates a negative or unexpected result, which does not conform with the scientist's original theory, the scientist still chooses to publish the study, so others can get access to it. The scientists behind new meta-analyses meant to draw conclusions based on as many studies as possible both include studies with negative and positive results, so the positive ones are not favoured.

**16 %**

of the published studies show that the treatment has a marked effect on a given disease.

## IMPORTANCE

### Self-censorship could cause false claims

► It is problematic, when scientists choose not to publish their negative results, or when meta-analyses, that are to draw conclusions based on several studies, mainly include positive results. Studies have shown that if less than one in five experiments with negative results is published, scientists might give false claims the seal of approval.

Experiments with a positive result stand a better chance of being included in meta-analyses, according to a study.





## DOES THE TREATMENT WORK?

# Plants relieve depression

The content of active ingredients in leaves, fruit, and roots is low, which is one of several reasons why it can be difficult to prove a clear effect of the treatment in medical experiments. However, perforate St. John's-wort is one of the plants that have a well-documented effect on the brain, when it comes to affecting neurotransmitters and treating depression.

## SCIENTIFIC VERDICT

- No effect
- Probably no effect
- No reliable evidence
- Probably some effect
- Well-documented effect

- **Memory loss:** maidenhair tree
- **Asthma and allergy:** butterbur
- **Depression:** St. John's-wort
- **Irritable colon:** peppermint
- **Nausea:** ginger
- **Bronchial infection:** geranium
- **High cholesterol level:** garlic
- **Anxiety:** kava
- **Heart failure:** common hawthorn
- **Cold:** echinacea
- **Arthritis:** dog rose
- **Poor blood circulation:** horse-chestnut

**DOCUMENTATION: NONE**

► Cheng Dong from the Medical School of Nantong University in China concluded that a daily dose of 200-400 mg of ginseng extract caused a slight, but statistically correct improvement of the short-term memory and the ability to respond. On the other hand, there was no effect on the ability to concentrate and the brain's calculation capacity. Jian-Cheng Dong concluded that ginseng can probably improve some aspects of the brain function, but that there were too few studies to make a final conclusion.

### Willpower required

A general problem in connection with herbal medication is that the products have rarely been very thoroughly tested. Chemist Giancarlo Cravotto from the University of Turin, Italy, in 2010 demonstrated that 12 % of the most widely used types of herbal medication in the Western World had not been subjected to any kind of scientific studies. Consequently, we know nothing about which substances the herbal drugs include, whether it is safe to consume them, or if it has a beneficial effect on human health. 20 % of popular herbal medication has been subjected to chemical analyses, so at least we know, if it includes substances with a known or assumed effect, and 50 % have been tested on animals to see if the medication is toxic or has severe side effects. But only 16 % has been tested in clinical trials on humans. The lack of

documentation is also well-known by the American health authorities, that have a special national centre for alternative medicine, NCCIH. On its website, 52 herbs are mentioned that are often used as medication against different conditions. In 44 of those, the NCCIH has discovered that no type of research has been carried out, or the research is so poor that there is no documented effect. In some cases, consumers are consequently left in a state of uncertainty, if they try to ease their symptoms with herbal medication.

And although the product has been tested on humans in clinical studies, that is not necessarily a seal of approval of its effect. One of the most widely used and thoroughly tested types of herbal medication is cranberry juice for the treatment of and prevention of urinary tract infection, but

according to a meta-analysis from 2013, the effect of the red drink is very much a myth. Scientist Ruth Jepson from Scotland's health authorities compared the results of 24 studies including a total of 4,473 test subjects and concluded that the preventive effect of the juice was very slight and not

statistically significant. She also noted that many of the studies involved a substantial drop-out of test subjects – up to 55 % in one study, because they did not manage to drink one large glass of cranberry juice every day. The treatment also requires some kind of willpower on the part of the patient and is

perhaps not suitable for those, who prefer easy solutions. The same is true for other types of herbal medication, in connection with which it might be troublesome to prepare one ginger shot per day or eat a garlic, which causes smell to the inconvenience of other people. However, the



**Horse-chestnut can probably not relieve poor blood circulation.**

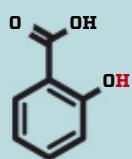
// SLIGHT CHEMICAL CHANGE WORKS MIRACLES

# Natural herbs became chemical drugs

Plants produce countless chemical compounds to protect themselves against insects, other pests, etc. Many of the ingredients also influence humans, and with slight chemical changes, they can be converted into efficient drugs.



**NATURAL INGREDIENT:**  
Salicylic acid

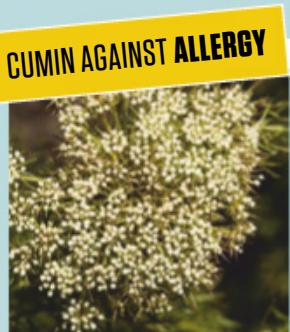


**MODIFIED INGREDIENT:**  
Acetylsalicylic acid

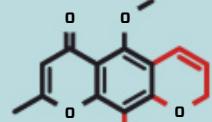


**Drug:**  
Aspirin, Treo,  
Kodimagnyl

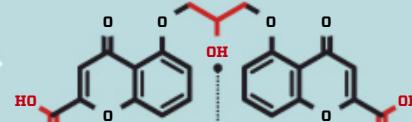
The molecule is supplied with an acetyl group.



**NATURAL INGREDIENT:**  
Khellin

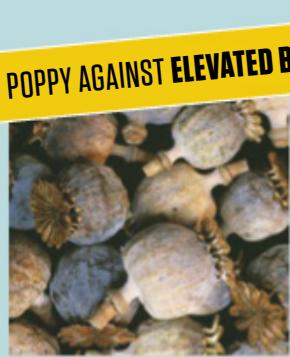


**MODIFIED INGREDIENT:**  
Natrium cromoglycate

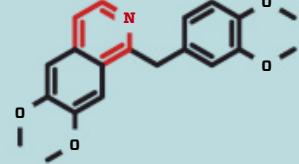


**Drug:**  
Lecrolyn,  
Lomudal

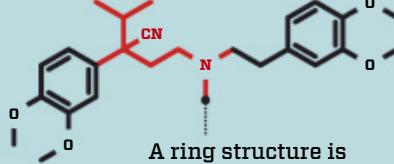
Two identical molecules are combined to reduce side effects.



**NATURAL INGREDIENT:**  
Papaverine

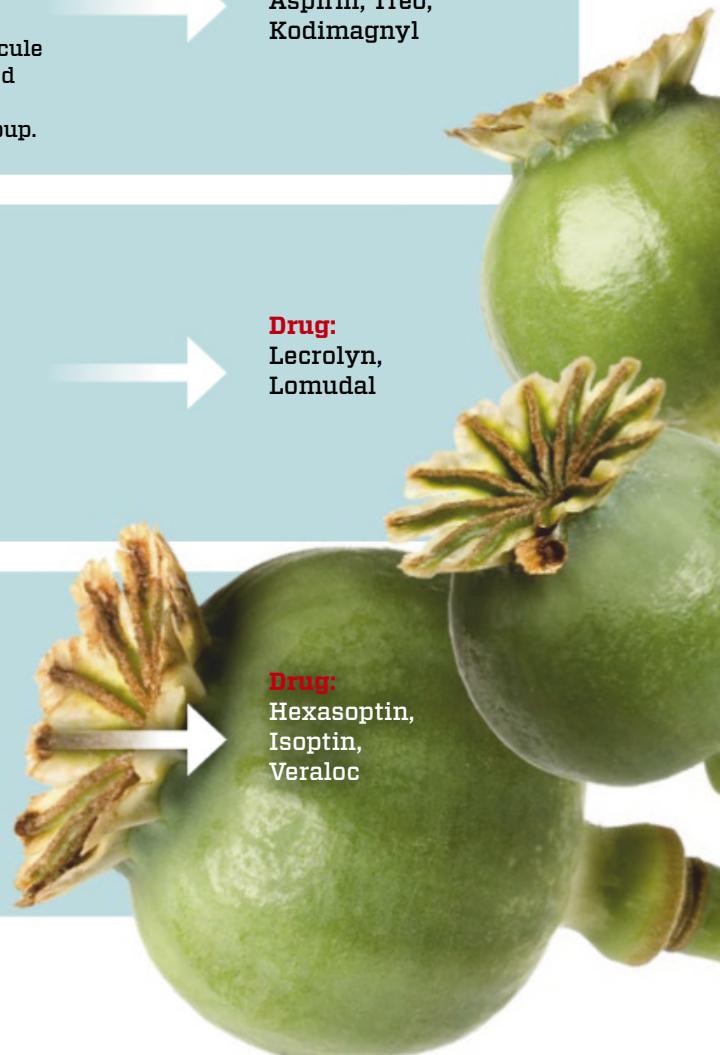


**MODIFIED INGREDIENT:**  
Verapamil



**Drug:**  
Hexasoentin,  
Isoptin,  
Veraloc

A ring structure is opened, so the effect becomes more focused.



considerable drop-out also makes up a scientific problem, if scientists do not allow for it in their conclusions. If the sickest patients give up cranberries in favour of antibiotics to get well faster, it will only be the least sick who are left in the study. And they of course have an easier time getting well – increasing the risk of the red liquid seeming to be more efficient than it really is.

## Positive stories stand alone

Another type of distortion of the studies of herbal medication take place, when the positive stories are allowed to stand alone. That is not only true in the ordinary communication between people, but very much also in scientific works, because many scientists do not want to publish their negative results – both because it could be interpreted as if the experiment failed and

because it might simply seem uninteresting to the scientists themselves. The phenomenon, which is known as publication bias, is well-known in all types of clinical testing, but particularly in studies of herbal medication. The bias is often manifested in connection with meta-analyses, in which the scientists behind the analyses mainly choose to include studies with positive results in their final conclusion. Biologist Ken Naumann from the Langara College in Vancouver, Canada, in 2018 published a thorough statement of the reliability of scientific studies concerning herbal medication. An analysis of 160 meta-analyses published in 2010-2014 showed that no less than 90 % of the analyses based their conclusions on a doubtful foundation, as they attached much more importance to studies with a positive result of the effect of herbs. So,

the bias makes up one of herbal medicine's major reliability problems.

In other words, we do not yet have the full scientific support for replacing pill glasses with roots, leaves, and extracts. On the other hand, most scientists agree that the herbs generally have fewer side effects than ordinary drugs, because the plants usually include lower concentrations of several active ingredients, whereas pills prescribed by doctors usually contain a high concentration of one active ingredient. And in the cases, in which their effect is indeed well-documented, there is surely advantages to be derived from herbs. **SCI**

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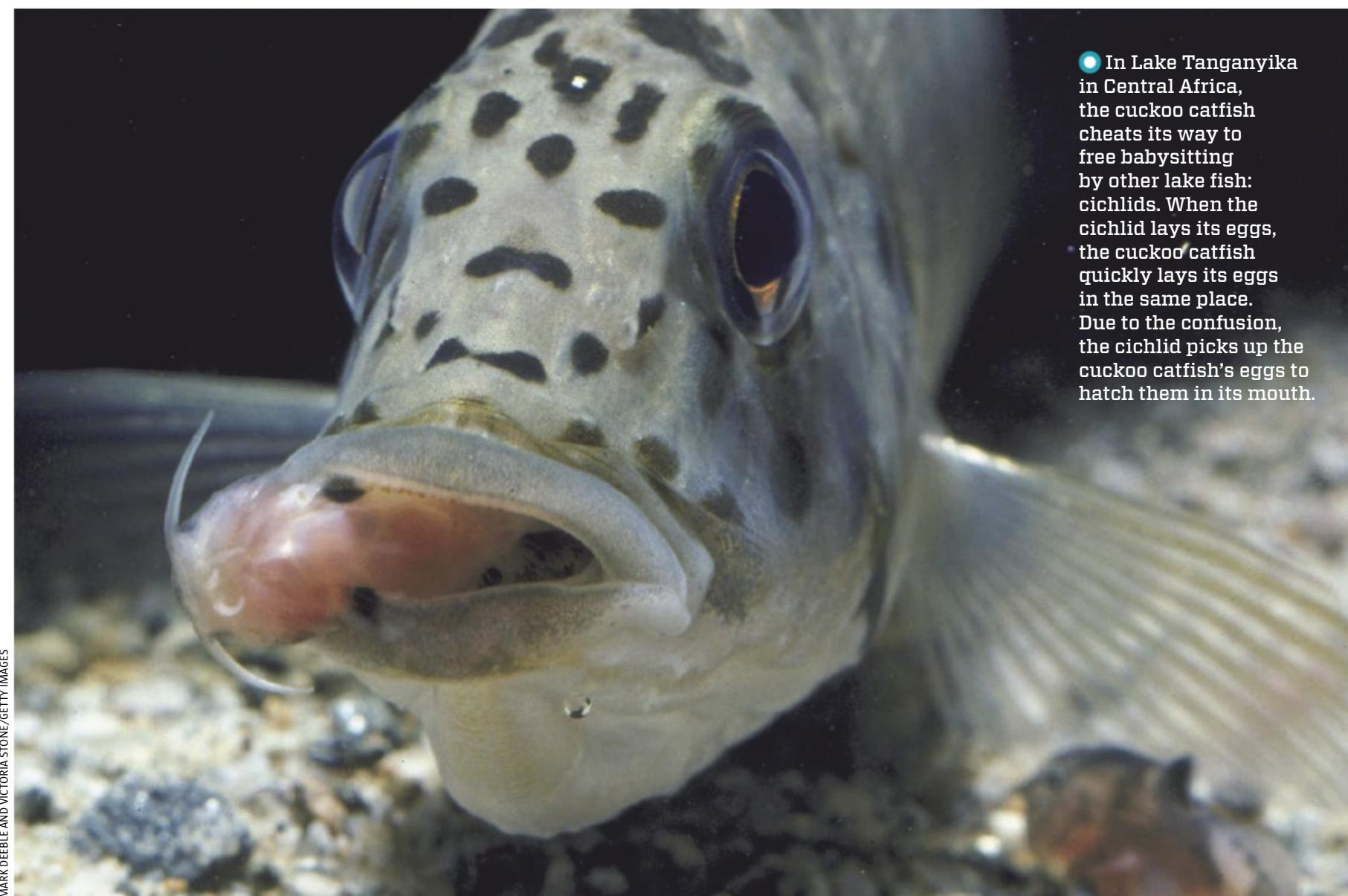


## Crime pays off

Ants kidnap, birds scare, and mussels are deceptive. The world is full of inventive animals that use unique methods to ensure their place in the food chain.

Emperor tamarins often have twins that combine to weigh half as much as their mothers. So females make sure to mate with 2-3 males over the same period of time, so they will help carrying the babies in confusion over who is the father.

**CHEATERS** | Female monkeys trick males to perform parental care.



MARK DEEBLE AND VICTORIA STONE/GETTY IMAGES

● In Lake Tanganyika in Central Africa, the cuckoo catfish cheats its way to free babysitting by other lake fish: cichlids. When the cichlid lays its eggs, the cuckoo catfish quickly lays its eggs in the same place. Due to the confusion, the cichlid picks up the cuckoo catfish's eggs to hatch them in its mouth.

**IMPOSTOR** | The cuckoo catfish makes other fish hatch its offspring.



MARK MOFFETT/GETTY IMAGES

● Some ant species use clever methods to expand their numbers: a queen conquers an alien nest, killing the ruling queen. Subsequently, the new queen waits for the eggs of the nest to hatch and the offspring to associate itself with her. On other occasions, she simply takes the eggs home.

**KIDNAPPERS** | Ants kidnap and assign the offspring of other species to slavery.



JEN GUYTON/NATUREPL

### TRICKSTERS | Passerines use false alarms to steal.

○ In the Kalahari Desert, passerines have found a way to steal food from the meerkats of the area. By means of false warning calls, the birds make the meerkats believe that predators are on their way. When the meerkats have escaped to their burrows, the birds steal their food.



○ A fresh water mussel species known as *lampsilis* produces tissue at the edge of the shell that looks and moves like a small carp. The tissue has both stripes and eyes that look like those of carps. But it's not a hunting lure: The idea of the bait is to make predatory fish bite holes in a bag of mussel larvae. Subsequently, the larvae flow into the fish's mouth and live in their gills.





JOEL SARTORE/NATIONAL GEOGRAPHIC

**IDENTITY THIEVES** | Mussel attracts predatory fish with fish-like tissue.

The myrmecophilous beetle is easily allowed to conquer otherwise well-protected ant colonies to consume the colony's offspring and lay its eggs. The beetle secretes droplets of a euphoriant from glands in its abdomen and the side of its body, which makes the ants relaxed and addicted.



BERT HÖLDLÖBLER, CHRISTINA L. KWADJIC, KEVIN L. HAIGHT

| **PUSHERS** | Beetle allowed to invade ant colonies to deliver drugs.



HARRY MARSHALL

Banded mongooses are extremely territorial animals that carry out surprisingly disciplined wars with each other. Typically, 20-30 of the small predatory mammals line up two fronts opposite each other, fighting their way back and forth, in bloody battles.

| **GANG MEMBERS** | Territorial power struggles trigger formidable clashes.

The black and white babbles live in small groups in South African savannahs in thick scrub. The offspring can often be observed on the ground, chattering and making themselves vulnerable to attacks. Studies have shown that the offspring exposes itself to predators to make the adults give it more food.



ALEX THOMPSON

| **BLACKMAILERS** | Birds force their parents to give them more food.

● In the Canadian part of the Rocky Mountains, bighorn sheep leave their group to get a special type of yellowish green lichen that grows on rock. The sheep scrape the lichen with their front teeth and horns to get a hallucinative effect. Some addicts continue, until their teeth are worn down.

## PhotoDoc

ANIMAL RISK  
THEIR LIVES TO GET  
INTOXICANTS AND  
FOOD.



| **JUNKIES** | Sheep leave the group to get drugs.



Crocodile relatives dominated  
the world more than  
200 million years ago.

JORGE GONZALES & SHUTTERSTOCK

CROCODILE RELATIVES

Crocodiles were pipped at the post:

# Rainy days ensured dinosaur dominance

▶ Huge carnivores, armoured herbivores, and two-legged sprinters – recent research reveals that a forgotten world of crocodiles dominated the dinosaurs for 50 million years. Not until massive rainfall and red-hot lava destroyed the dominant reptiles, could the dinosaurs take over Earth.

**T**he hammer hits the chisel, and the reddish brown rock in my hand splits, revealing the secret that it kept for more than 200 million years. Behind me, the mountain side slopes hundreds of m towards the ice-covered Carlsberg Fjord in East Greenland.

I have split many layers together with an international team of scientists in search of bones from the animals that lived here in the late Triassic, 207 million years ago. It was an important period in Earth's history, during which several groups of reptiles struggled to gain world dominance.

Since the Triassic began 50 million years earlier, a small army of crocodile relatives had ruled the world, but when the Triassic ended, they were almost all gone. Why they disappeared is one of the greatest mysteries of palaeontology, and the answer might be found

among the dinosaurs – a group of animals that lived in the shadow of the crocodiles for millions of years. They are the ones we are searching for.

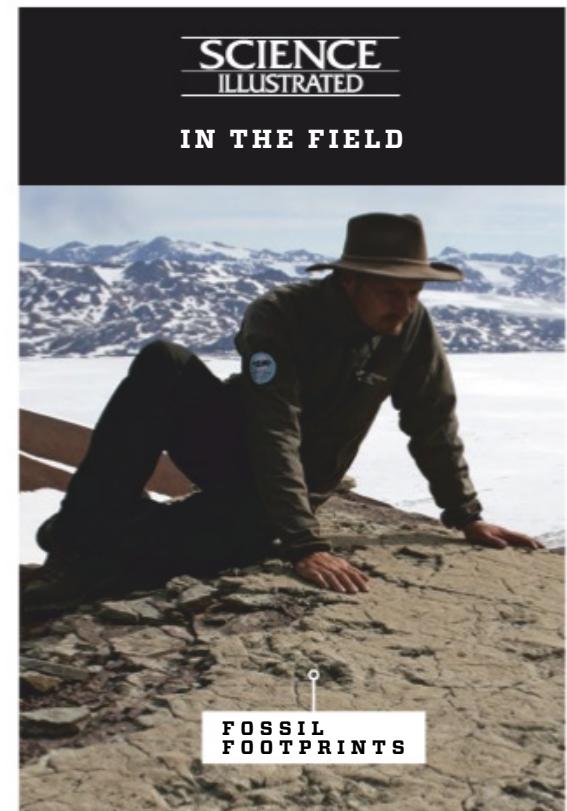
So far, our team has only discovered phytosaurs, i.e. crocodile relatives, but we are about to get lucky. The chisel has loosened another piece of rock, which lands in front of me. I carefully pick it up. Small, slender bones are embedded in the rock. One of them is fractured, and I can see that it is hollow inside.

"Those definitely do not resemble phytosaur bones," my colleague from Portugal says. He is sitting in the hole beside me. "They are from a predatory dinosaur!". We high five, and a dust cloud rises around us.

#### Disaster triggered race

252 million years ago, the Permian ended in the biggest mass extinction in Earth's history. ▶

EARLY DINOSAUR



#### Palaeontologist searches for the first dinosaurs

▶ Danish palaeontologist Jesper Milà has participated in three expeditions to Jameson Land in East Greenland – most recently in 2018. Together with scientists from Denmark, Portugal, etc., he is looking for evidence and bones in the Greenland rock, which can teach us more about a 200+ million-year-old ecosystem – and help us understand why the dinosaurs took over the world.

► 90% of all life was destroyed. When the Triassic began, the animals that had survived the disaster had free play. Perhaps that is why the Triassic became an unusually eventful period. Over the 50 million years it lasted, most of the major animal groups that we know today originated: frogs, lizards, crocodiles, dinosaurs, mammals, and many others.

The new groups did not divide the world equally between them. The struggle to dominate the ecosystems was a hard one, and the two strongest teams were crocodile relatives and dinosaurs. The two groups shared a common ancestor in the late Permian, but went their different ways in the early Triassic. When the Triassic ended, the dinosaurs had defeated the crocodiles, but according to new research, the victory had more to do with luck than with pure superiority.

In spite of the diversity of the Triassic, fossils of the animals of the period are relatively rare. Only in a few places of the world is it possible for us to get a glimpse of the struggle

that eventually led to the dinosaurs ruling Earth for about 135 million years. One of the places is Jameson Land in East Greenland. A series of expeditions in 1989-1995 revealed the remains of a some 207-million-year-old ecosystem full of huge amphibians, pterosaurs, turtles, mammals, and crocodile relatives. Only the bones of one single dinosaur species were discovered – the Plateosaurus herbivore.

We returned in 2012 and 2016, and now we are here again. I have brought a team of palaeontologists and geologists from Denmark, Portugal, and other places. In the reddish brown rock, we have just for the very first time found the bones of a herbivorous dinosaur in Greenland. They are not much to look at, but they are a key element of the history of the Triassic.

#### Dinosaurs were lagging behind

The dinosaurs and the crocodiles belong to the archosaurs – Latin for ruling reptiles. About 250 million years ago, the archosaurs divided in

two. One branch became the ancestors of crocodiles and their relatives. The other evolved into dinosaurs and pterosaurs. The first dinosaurs probably originated some 245 million years ago, but the oldest known dinosaur bones are 230 million years old. They belong to the small, omnivorous eoraptor from Argentina. With a length of only about 1 m, the eoraptor was not an impressive animal, and it did not by any means dominate its ecosystem.

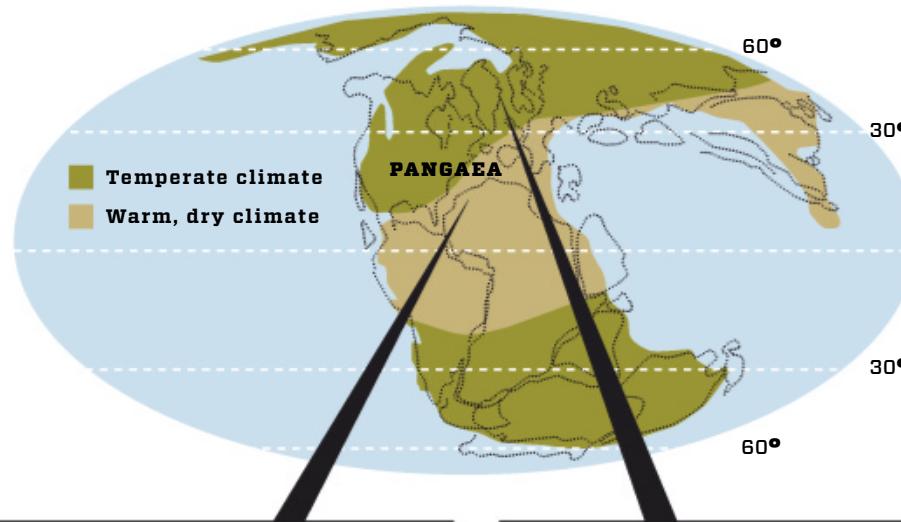
Over the next 30 million years, the dinosaurs became more common and more plentiful. Early relatives of the long-necked dinosaurs, the sauropods, began to grow bigger – some weighed more than seven tonnes – but they were still small as compared to their up to 70 tonne descendants of the Jurassic and Cretaceous. The herbivorous dinosaurs also grew bigger – but no more than a few hundred kg. A third group of dinosaurs, the ornithischians, were also present, but they were apparently extremely rare – their descendants later became successful

# Extreme climate divided supercontinent

Five times more carbon dioxide in the atmosphere than today. In the Triassic, 200+ million years ago, Earth's only continent was characterised by extreme drought and rain. But the dinosaurs kept their distance from the deadly weather phenomena.

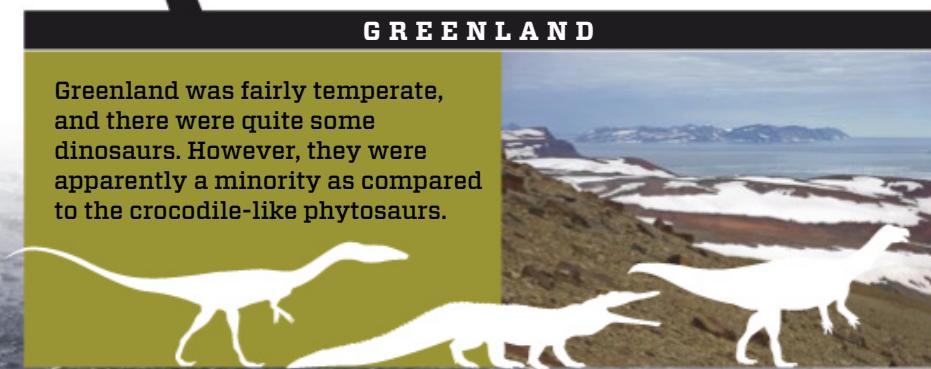
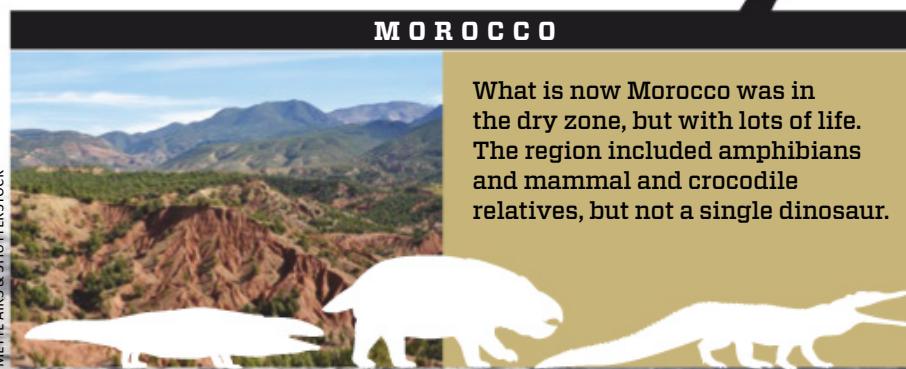
#### The Equator had drought and extreme rain

● The world of the Triassic only had one continent, Pangaea, which was often a hostile place to live. In a broad zone around the Equator, the climate was extremely dry with temperatures of up to 40-50 degrees. Close to the tropical coasts, the drought was interrupted once a year by a period of extreme rain, probably corresponding to the East Asian monsoon season.



#### The poles had a warm, moist climate

● The world was several degrees warmer than today, and the temperature difference between the Equator and the poles was slighter. ● There were no permanent ice sheets, and like the Equator, the northern and southern regions had a rainy and a dry season, but the difference between the seasons was smaller than by the Equator, and the climate was generally more temperate and moist.



herbivores such as duckbilled dinosaurs and horned and armoured dinos.

Our Greenlander predatory dinosaur undoubtedly formed part of a success story. The number of dinosaur species increased steadily in the Triassic, and the group developed a major arsenal of body types and sizes. That has made some people conclude that the dinosaurs were much more superior as compared to the other reptiles of the Triassic – that the dinosaurs were almost predestined to take over the world. But over the past decade, that image has faded. Studies carried out by American palaeontologist Steve Brusatte and his colleagues have revealed that the crocodile relatives were superior to the dinosaurs on hardly all counts towards the end of the Triassic. They were more diverse, they were often more numerous, and they were at the top of the food chain. The crocodile relatives had a firm grip on the world.

### Crocodiles dominated the world

A small head with a pointed snout and blunt teeth placed on a 4-m-long body densely covered in thick plates and with long, pointed spikes protruding from the neck – aetosaurs were the tanks of the crocodile genus, and they were among the most common herbivores of their time. The hefty armour served a key purpose: protection. In spite of their size, the aetosaurs were not in any way safe, as there were other, more frightening crocodile relatives everywhere.

On the water's edge, the aetosaurs – and the dinosaurs – had to look out for the phytosaurs, which in many ways looked like modern crocodiles, but their teeth were more knife-shaped, and their nostrils were located high up on the head, so they could hide all of their snout under the water. The largest phytosaurs grew 10 m long and could probably kill any type of prey.

On dry land, another crocodile relative ruled: rauisuchians, whose bodies were crocodile-like, but unlike modern crocodiles, their legs stood vertically under their bodies – like those of mammals and dinosaurs. That allowed the rauisuchians to move efficiently on dry land. Some of them even walked on their hind legs and were much like predatory dinosaurs. Like the phytosaurs, they grew up to 10 m long.

The crocodile genus was completely dominant, so it is almost incredible that only a few million years later, it was close to complete extinction. Only one single group survived into the Jurassic. They were small, slender, and agile animals that often walked on two legs ►



The Greenlandic rock is hard, and powerful equipment is sometimes required in order to access the fossils.

JESPER MILAN

Bones from phytosaurs, i.e. crocodile relatives, are common in Jameson Land. The animals were about 4 m long.

JESPER MILAN

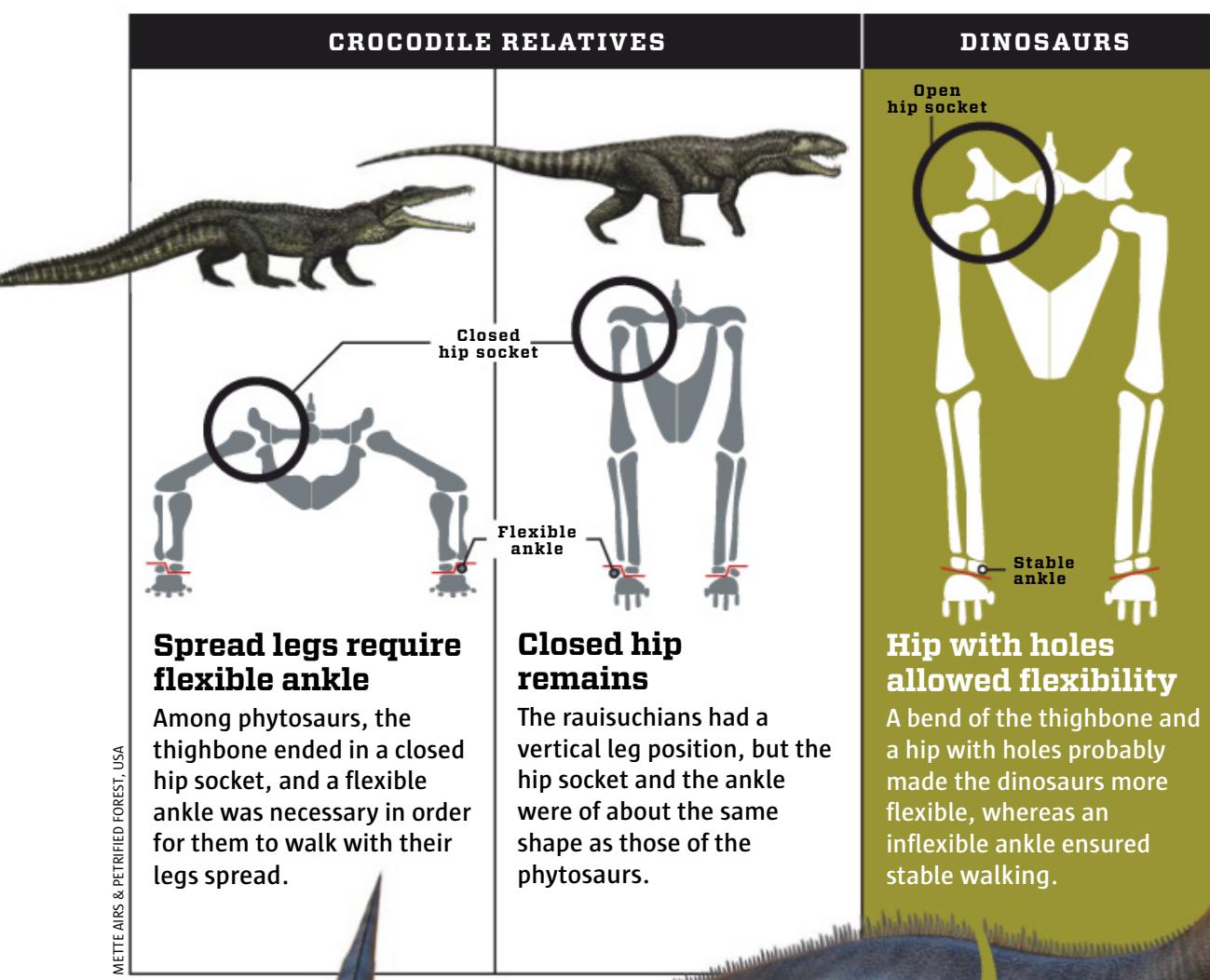


JESPER MILAN

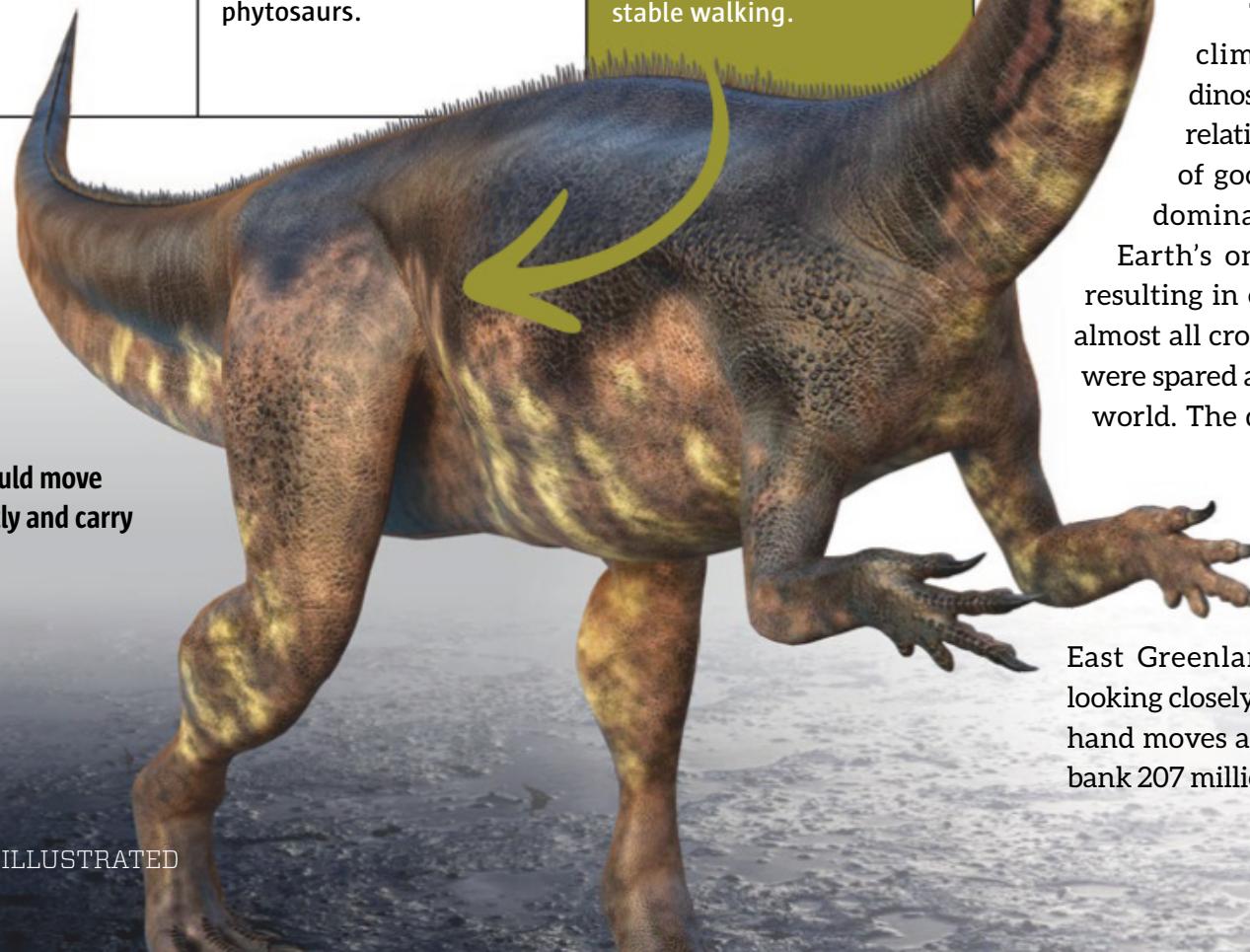
The 2018 expedition discovered the first known bones from a predatory dinosaur – such as this shoulder blade. The dinosaur was slight and probably about 1 m long.

# Inflexible ankles were dinosaurs' trump card

Flexible hips and stable ankles – a series of anatomical changes of the hind legs made the dinosaurs motion experts and helped them through the crises of the world.



SHUTTERSTOCK  
Dinosaur legs could move fast and efficiently and carry a lot of weight.



► or even climbed trees: the ancestors of modern crocodiles. On the other hand, the family tree of the dinosaurs exploded, and they became the kings of the ecosystems. Not until now, we have begun to understand what happened.

## Lucky with the weather

The dinosaurs did not like drought. In the first half of the Triassic, the climate was stable and dry – and the dinosaurs and their closest relatives were rare. 234 million years ago, a marked change occurred. The world suddenly received more rain. The wet period lasted for about two million years, and Italian scientists have just discovered one of the consequences.

In Northern Italy, they have found a series of fossil footprints from the period before, during, and after the rainy period. Before the rain came, at least 80 % of the evidence was from crocodile relatives. During the wet period, the quantity fell to 50 %, whereas the other half belonged to dinosaurs and their relatives. A few million years after the rain had stopped, the dinosaurs accounted for more than 90 % of the footprints. The rain boosted the dinosaurs, and they became the dominant herbivores in many, but not by far all ecosystems of the world. In a broad zone around the Equator, the climate continued to be extremely dry, and in spite of the region having a diverse fauna, there were apparently no dinosaurs. When the climate became slightly milder some 215 million years ago, the dinosaurs began to move closer to the Equator.

Two fortunate instances of climate change had helped the dinosaurs catch up with the crocodile relatives, but it took one more stroke of good luck to ensure them world dominance. 200 million years ago, Earth's only continent began to split, resulting in extreme volcanism that killed almost all crocodile relatives. The dinosaurs were spared and subsequently took over the world. The question is why the dinosaurs managed so well in spite of the ecological disaster.

## Back to Greenland

The low sunlight hits the East Greenland mountainsides, and I am looking closely at the reddish brown rock. My hand moves across what was a muddy river bank 207 million years ago, stopping at a small

indentation with a characteristic shape, which is unmistakable: a dinosaur footprint. In front of me, there are a series of prints – a snapshot of a small predatory dinosaur, which ran along the water a long time ago.

The Greenland rock is ripe with thousands of ancient footprints, and together with the bones, they tell an interesting story. While the dinosaur bones are in the minority as compared to bones from crocodile relatives, the dinosaurs are completely dominant, when it comes to footprints. Only one single, poorly preserved print is apparently from a crocodile relative. The rest are dinosaur prints. And the skewed distribution draws a clear picture: the dinosaurs were always on the move, and they covered much longer distances than their competitors did.

The more active life style was probably the result of a series of anatomical and physiological innovations. Like some crocodile relatives, the dinosaurs had their legs vertically under their bodies, but the dinosaurs

took the adaptation to a new level. The joint between the thighbone and the hip was more flexible in dinosaurs, and their ankles were more stable. Both allowed more efficient movement. The dinosaurs' metabolism was probably higher, allowing them to keep up their high level of activity, and many dinosaurs, including our Greenlander predatory dinosaur, had hollow bones: a part of a more efficient respiratory system.

The dinosaurs might not have taken over the world without the help offered by climate change and volcanoes, but they were undoubtedly experts on taking advantage of the new possibilities. Their ability to move fast and efficiently made them better at handling crises. As soon as the last disaster of the Triassic had loosened its grip on Earth, the dinosaurs were ready to take over the ecosystems. And they held on to their dominance for 135 million years – until their luck failed, and they suffered the same fate as the crocodiles. **SCI**



IESPER MILÀN

**Hundreds of 10-20-cm-long, three-toed footprints show that small predatory dinosaurs roamed Greenland's river plains.**

## Chain of disasters undermined crocodiles

New plant kingdom rulers combined with millions of km<sup>3</sup> of lava ended the reign of the most successful animals of the Triassic.

### Wet period put herbivores under pressure

**1** **234 million years ago:** A temperature rise of 3-4 degrees and much more precipitation caused major change for the world's vegetation, etc., which subsequently became dominated by coniferous trees. The changes had a severe influence on herbivores, including aetosaurs (crocodile relatives). The cause of the climate change might have been increased volcanic activity.

### Extreme climate zones are toned down

**2** **215 million years ago:** The sharp boundaries between the climate zones of the world softened, meaning that predatory dinosaurs came closer to the Equator to compete with the top predatory crocodiles: rauisuchians.

### Supercontinent split in half

**3** **201 million years ago:** The supercontinent of Pangaea began to split along western Africa, and the motion triggered huge volcanic eruptions. About 2-3 million km<sup>3</sup> of lava flowed across the continent, and the remains of the lava is now found in both North and South America, Europe, and Africa. All crocodile relatives went extinct, except one single group – the ancestors of modern crocodiles.



## FROM THE SCIENTIFIC ARCHIVES

### PRESENT STATUS

## THE PHONE MOVES INTO OUR POCKETS

Bell's and Gray's phones required a land line. Now, the old fixed-line phones are replaced by mobile phones, which communicate by means of radio waves relayed via towers. More than just voice calls, the mobile phone network can now transmit data at increasingly huge bandwidths. Today's mobiles routinely reach speeds of 100Mbps. The upcoming 5G network will multiply that by 10.



Mobile phones are slowly replacing fixed-line phones completely.

Alexander Graham Bell is credited with inventing the telephone, but his patent application shows that the idea for the phone was added in the margin at a later point in time.

SCANPIX/SCIENCE PHOTO LIBRARY



# The First Phone Wars

► Bribery and cheating. Slander and libel. The invention of the telephone deteriorates into a dirty war between the vigorous Alexander Graham Bell and the meek Elisha Gray. Gray reaches the patent office first - but Bell has the most unscrupulous lawyers...

In the US of the 1870s, the telegraph is the most popular way of sharing information across long distances. However, the technology involves several significant limitations: the cables can only handle one message at a time, and the procedure is very elaborate. The transmission of one single comma requires no fewer than six signals.

The telegraph companies install more cables, but that does not solve the problem, so Western Union, the biggest US telegraph company, offers a reward of US \$1 million to the inventor who can find out how to send several telegrams at the same time via one cable. The reward makes the inventors of the era think out of the box - with world-changing results.

## Bell cannot pay his assistant

One of the hopeful inventors is 29-year-old Alexander Graham Bell. He imagines that the problem can be solved with a "harmonic telegraph" with separate frequencies for separate signals.

Bell is only a hobby inventor. His real occupation is that of a teacher of deaf children. The job ensures him a modest income, but does not cover the rent of the inventor shop nor the salary of his assistant, Thomas A. Watson. Those expenses are paid by Bell's investors, the wealthy Thomas Sanders and Gardiner Greene Hubbard, who hope to share the income, if Bell's experiments succeed, allowing him to collect the million dollar prize.

## Success to ensure marriage

It is 1876. Bell is working hard, testing new designs. Not only out of ambition, rather to solve his personal problems. Bell has fallen in love with one of his students, Mabel, who is the daughter of a rich man, and the young inventor is painfully aware that his teaching job cannot provide for Mabel, who grew up in one of Boston's most wealthy families. Moreover, Bell's notes reveal that he is tormented by his permanent guilty conscience regarding his investors. The rich men have invested large sums in his

experiments and patent applications, and the young inventor feels ever more burdened by the expectation pressure.

So, Bell very much needs a success to ensure financial stability for himself and his investors.

## Gray transmits music

One of Bell's competitors is 41-year-old Elisha Gray. For two years, he has been working on a device that is to transmit sound via telegraph cables. Gray has already demonstrated a primitive version of his invention, which can transmit music via cables, but his goal is to enable the device to transmit understandable speech, so two people can have a dialogue across long distances.

On 11 February 1876, Gray asks his lawyer to file a provisional patent application. Gray's device is almost complete, and the inventor fears that one of his competitors will catch up with him.

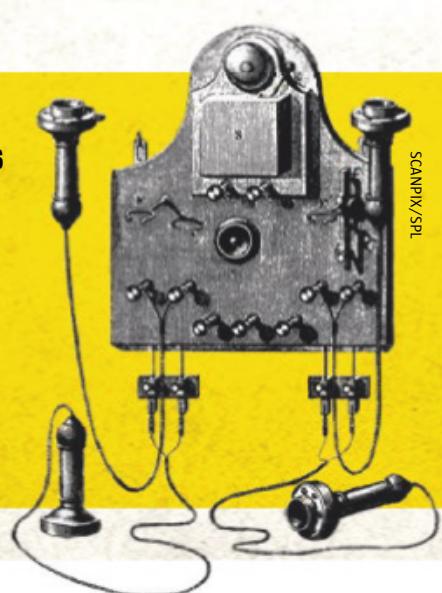
Three days later - on 14 February 1876 - Gray's lawyer files the application ►

## RING, RING...

Following Alexander Graham Bell's patent, the telephone conquers most of the world.

Hello?

**14 FEBRUARY 1876**  
► Bell and Gray both claim to have invented the telephone. Both inventions consist of two telephones which require a land line.



A Swedish copy

**1876**  
► Lars Magnus Ericsson opens an engineering shop in Stockholm. Soon, he takes an interest in the new telephones and begins to copy foreign models.





Throughout his life, Graham Bell was deeply in love with his wife Mabel. He strongly desired to give her a comfortable life, struggling for years to make a financially rewarding invention.

LIBRARY OF CONGRESS

► with the American patent office in Washington, DC.

### Lawyers exert pressure

On this day, Zenas Fisk Wilber, the chief examiner of the US patent office, is sitting at his desk in a remote corner of the room.

Around lunch time, two well-dressed men step in. They walk across the room – past the clerks, who are processing patent applications – to Wilber. The two men hand him a patent application from their client in Boston, Alexander Graham Bell. The lawyers pay the patent fee of \$250 and insist that Wilber register the application right away. The request violates the procedure of the office, where documents are normally submitted to a clerk to be registered at a later point in time. But as the

two lawyers are regular customers, Wilber agrees, registering the "telegraphy improvement" application.

The patent examiner also accepts to waive the requirement of the physical invention being submitted along with the application. Bell's patent application is the fifth one to be registered on 14 February 1876.

Later in the day, a clerk is working his way through the applications of the day. One of them is from Elisha Gray, who has filed for a patent on "instruments for the transmission and receipt of spoken sounds". Gray's application is registered as No. 39.

### Hungover employee

Five days later, Zenas Fisk Wilber makes an overwhelming discovery. Even though his head feels heavy after a long night visiting bars, he realises that Gray's application is very much like the one submitted by the lawyers on behalf of Bell.

The patent office has experienced two inventors working on similar ideas at the same time before, but it has never seen two such identical applications being submitted on the same day.

The customary practice of the office is that all applications from the same date are considered simultaneous. Wilber does not know what to do.

### Application suspended

Wilber seeks the advice of his superior, Ellis Spear, who establishes that the two applications must be considered as having been submitted at the same time. So, the patent office immediately suspends – according to its customary practice – Bell's application temporarily. The suspension is meant to allow the office to study the applications in detail and give Gray time to submit a full application, so the two inventors can compete on equal terms.

A written reply from Bell's lawyers arrives immediately:

"We request that you, before our application is suspended for three months, resolve whether it is true that our application was registered before the mentioned temporary patent."

By addressing Wilber directly and insisting on having the application registered immediately, the lawyers made sure that Bell's patent application is among the first to have been registered on that day. Also even though in practice, Gray's lawyer could have submitted his application first.

### The invention does not work

Six days later, Ellis Spear for unknown reasons chooses to violate the procedure and comply with the request of Bell's lawyers. The suspension is repealed, Gray is turned down, and on 7 March 1876, Bell patents the invention of the telephone.

Gray's bitterness would probably have intensified, if he had known that Bell's invention does actually not work in practice yet. Normally, an invention that is unfit for use would quickly be revealed by the patent office, as the inventor must submit a physical version along with the application. But Bell never submits a model of his telephone.

### Bell goes to Washington

What really happened in connection with Bell's application remains rather mysterious. The inventor usually records his progress in his lab journal, but during the period of 24 February-7 March – when the suspension is cancelled, and Bell gets his patent – the pages are blank, as Bell has gone to Washington. What he was doing in Washington also remains unknown.

On the other hand, Bell writes a lot

### Telephone exchange

1877

► Tivadar Puskás of Hungary, who worked for Bell, designs the first switchboard. At first, the technology can only handle two calls at a time.



### Now in Europe!

1878

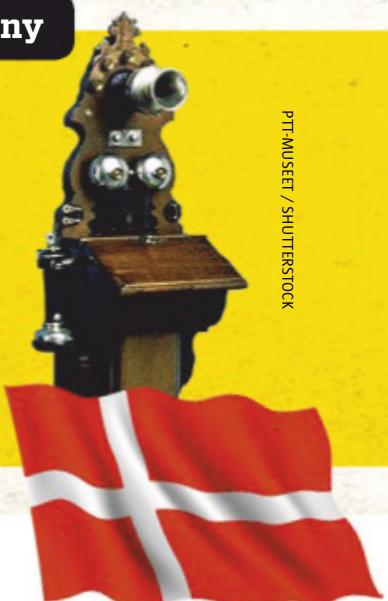
► The telephone comes to Europe, when the Telephone Company opens in London. The telephones are based on Bell's patents.

### Wireless telephony

1880

► Bell and engineer Charles Sumner Tainter design the photophone – the first cordless telephone in history – that transmits calls via a light beam.

PTT MUSEUM / SHUTTERSTOCK



about his new invention in the days following the approval of the patent. The notes are accompanied by a technical drawing that is suspiciously like the one Gray used in his patent application.

Bell's very patent application has also puzzled sceptics. The original document only concerns telegraphy improvements, and only a sloppy, rough note in the margin includes information about the fact that Bell's invention can also be used to transmit sound by means of an electrically conductive liquid.

Nobody knows why this very central and crucial description is added like a kind of reflection. The mystery is intensified by the fact that the addition is not included in any of the five other existing copies of the application.

A third remarkable detail is a letter that Bell sent to Gray a few days before his patent application was approved. The two inventors knew about each other and realised that they were both working on an invention concerning telegraphy, but they never met to discuss their inventions in person.

In the letter, Bell admits that he knows that Gray's invention has "something to do with vibrations of an electric conductor in a liquid". Bell writes, that this idea is remote from his own patent application. The acknowledgement is unusual, as according to the rules, Bell had no right to see Gray's application.

### "Send your congratulations"

The patent office's decision does of course not please Elisha Gray, who had been working hard on his invention for two years. In spite of the immense disappointment, Gray's lawyer advises him to accept his defeat instead of initiating a legal battle. According to the lawyer, ▶

## Did Bell copy Gray's invention?

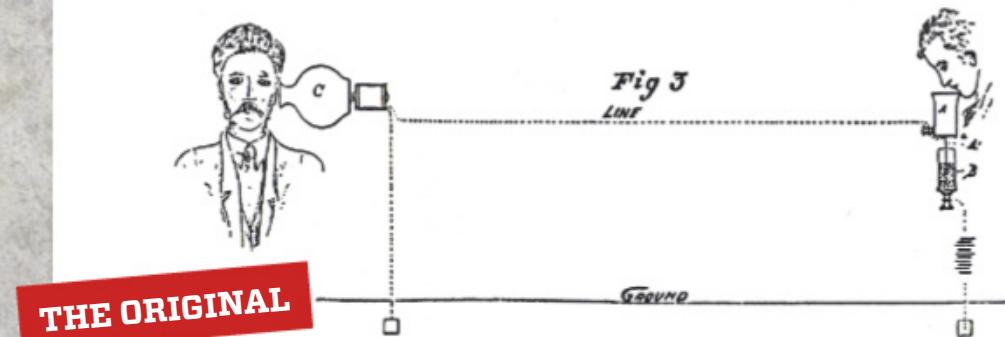
**In 1886, a patent office employee confessed to having been bribed to give Gray's patent application to Bell. A drawing in Bell's notebook supports the confession.**

History says Bell invented the telephone, but a drawing in his notebook reveals that the inventor probably copied Gray. The drawing is almost identical to an illustration in Gray's patent application.

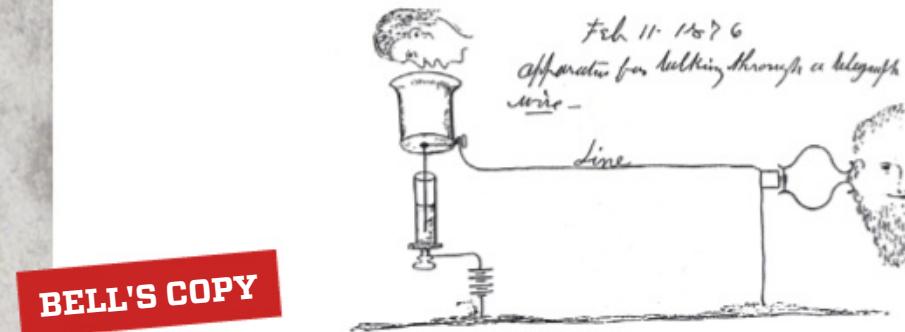
Bell denied to have seen Gray's documents, but in 1886, patent examiner Zenas Fisk Wilber admitted to have allowed Bell to study Gray's application. According to Wilber, he had

felt pressured to reveal the document, because he owed a great deal of money to one of Bell's lawyers.

The same lawyer was said to have made Wilber register Bell's application right away without requesting a model of the invention. Moreover, Zenas Fisk Wilber is suspected of having allowed Bell's lawyers to add a margin note to Bell's application, which describes technology from Gray's application.



**Gray's drawing** describes, how sound can be converted into electric impulses. A thin rod is attached to a membrane and immersed into a container with liquid. When a person speaks in the direction of the membrane, it is caused to oscillate, and the rod's motions make the intensity of the electric circuit vary with the sound. At the receiver's end, the voltage is converted into sound by means of an electromagnet and a membrane.



**Bell's drawing** comes from his notebook and is almost identical to Gray's technical drawing—only a bit more simple. Bell's illustration was made three weeks before Gray's and drawn after his trip to Washington, when Bell probably bribed his way to seeing Gray's patent application.

### KIRK's debut

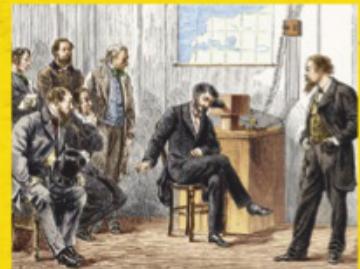
**1892**

Emil Møllers Telefon-fabrik opens in Horsens. Under the name of KIRK, the company becomes one of Denmark's major telephone makers.

### Long distance

**1915**

Bell makes the first call across the USA, from New York to San Francisco. His assistant Thomas Watson answers the call.



### The dial

**1919**

The first rotary dial telephones are installed in Norfolk, Virginia.

### Perfect receiver

**1919**

The American telecom company AT&T measures the heads of thousands of Americans in order to be able to design the perfect receiver.

► Gray even ought to send Bell a letter of congratulations and tell his opponent that he does not intend to demand to be credited with the invention. At this point, Gray does not know that apart from being his advisor in patent cases, the lawyer is also on Bell's payroll. According to historians, he could have given Bell information about Gray's invention.

### Western Union says no

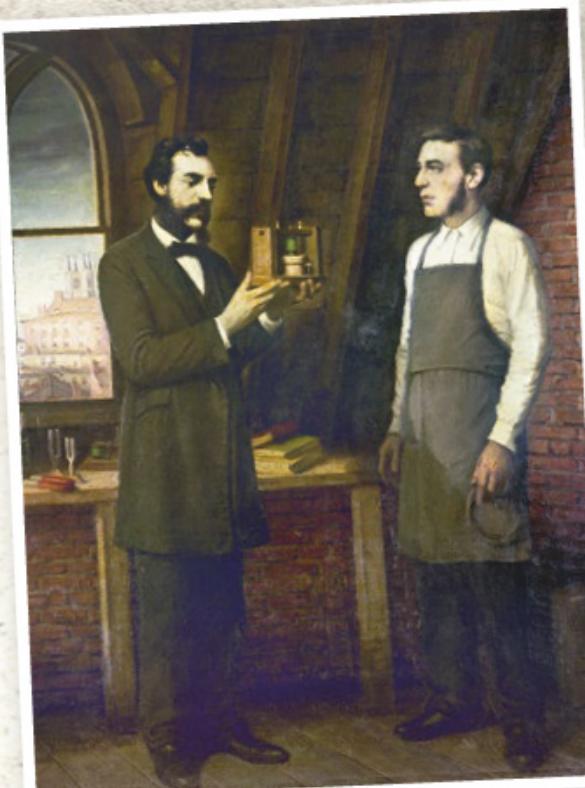
Bell, and not least his investors, had hoped that the telegraph companies would be thrilled to see the new invention, but the enthusiasm is difficult to find. In late 1876, the Western Union telegraph giant declines to acquire the patent rights at a price of \$100,000.

Perhaps because the company's president, William Orton, does not see the commercial opportunities involved in transmitting speech electrically. Or because one of Bell's rich investors previously made Orton his enemy by proposing a nationalisation of the entire telegraph industry.

Instead of selling the rights for his invention, Bell earns a modest income from travelling the country to demonstrate his new apparatus to a paying audience. With the first \$149 that Bell earns from his invention, he buys a silver brooch for his beloved Mabel. When the couple is married in July 1877, he gives his wife an unusual wedding gift - 1,487 shares of the new Bell Telephone Company, corresponding to 30% of the company. Bell only keeps 10 shares - or 0.02%. The other 70% of the shares go to the investors.

### Bell is tired of the telephone

After three years, Alexander Graham Bell's invention has still not become the expected



**The first phone call was made on 10 March 1876, when Bell called his assistant with the words: "Mr. Watson, come here. I want to see you."**

POLPHOTO/GRANGER

financial success. Bell is sick and tired of the controversial telephone. For \$5,000 in cash, he sells the rights to use the invention in England, spending the money on a 1.5 year honeymoon to Europe for him and Mabel, starting in August 1877.

During the honeymoon, Bell distances himself ever more from his own telephone company. Not even in 1879, when the Bell Telephone Company is challenged by Western Union, which has established its own telephone company based on Elisha Gray's ideas, does Bell want to have anything to do with the matter.

Bell's investors wish to sue the competitor for breach of patent, but in order to be able to sue Western Union, all the company's founders must agree. The investors eagerly try to make Bell return to

the US, but the inventor refuses to take the witness stand.

"What does it matter, who invented the telephone, as long as the world does not get to benefit from it? And why would I care what the world says, when I have achieved what I was working for: my darling, beloved wife," Bell said.

Of course, as soon as Mabel supports the investors, Bell agrees to participate in the legal proceedings.

### Gray challenges Bell

Bell spends nine days on the witness stand, where he is asked to explain how he knew about the details of Gray's application.

"I did not know anything about them. I asked the examiner (Wilber), who explained that it was a confidential document. I did not get to see the application, but he explained in general terms which part of my patent application conflicted with Gray's," Bell states. Zenas Fisk Wilber from the patent office supports Bell's statement.

### Gray: Bell is a copycat

The court case is the only time that Graham Bell and Elisha Gray ever meet. The case ends in a historic settlement, in which Gray and Western Union agree to state that Bell is the inventor of the telephone. The statement is announced far and wide in newspapers, but personally, Gray is not convinced. The two inventions are very much alike, and not least the microphone that converts speech into electric oscillations makes him suspicious.

"Based on Bell's own testimony in court, I am convinced that I showed him how to make the telephone that gave him the first results," Gray writes in his journal. The inventor's theory is confirmed a few days after the court proceedings, when he accidentally meets patent examiner Wilber

### Under the Atlantic

**7 MARCH 1926**

► The first transatlantic phone call between New York and London is made.

### Train telephony

**1926**

► First class train passengers travelling between Hamburg and Berlin can make phone calls from the train.

### Car phone

**1946**

► Motorola introduces the first car telephones.



### Area codes

**1946**

► All US cities get area codes, which are to make it easier to organise the rapidly growing list of phone numbers.

### Direct calls

**1951**

► The first American telephone subscribers are allowed to make direct calls without using a central telephone exchange.

on the street.

"Gray, you invented the telephone, and if your damn lawyer had done his job, you would have gotten the patent. But I did not know you very well back then. And you had never brought me cigars nor invited me out for drinks," Wilber said, which was his way of reminding Gray that Bell's lawyers had done those things.

### Telephone becomes a success

The settlement means that Western Union must cease its telephone activities. In return for this admission, Bell's company agrees to pay one fifth of the income generated by its patent to Western Union in the 18 years of the patent's life.

During the following years, Bell's telephone company grows steadily, and in 1881, it takes over Gray's company. When the controversial patent runs out after 18 years, the telegraph companies have long since lost the battle of communication to the telephone. Bell's successful company is the dominant market player and is beyond reach, when it comes to clients and cables.

The telephone's commercial success allows Graham Bell and Mabel to live in wealth for the rest of their lives.

### The truth died

The credit for the telephone officially goes to Alexander Graham Bell alone, but it is impossible for Elisha Gray to hide his frustration and bitterness forever. After Gray's death, his family discovers the following note among his documents: "The full story about the telephone will never be written. It is buried in the 20-30,000 pages of witness statements. And it is buried in the hearts of a few people, whose lips are either sealed in death or sealed with a golden fastener whose strength is even more intense." SCI

## The model lasted for 100 years

**Bell's first phone was not practical. It did not become so, until Edison supplied it with an efficient microphone.**

At the same time as Bell and Gray, another inventor, Edison, was working on a telephone. He did not make the invention in time, but developed the carbon microphone, which was much more sensitive than Bell's. In 1877,

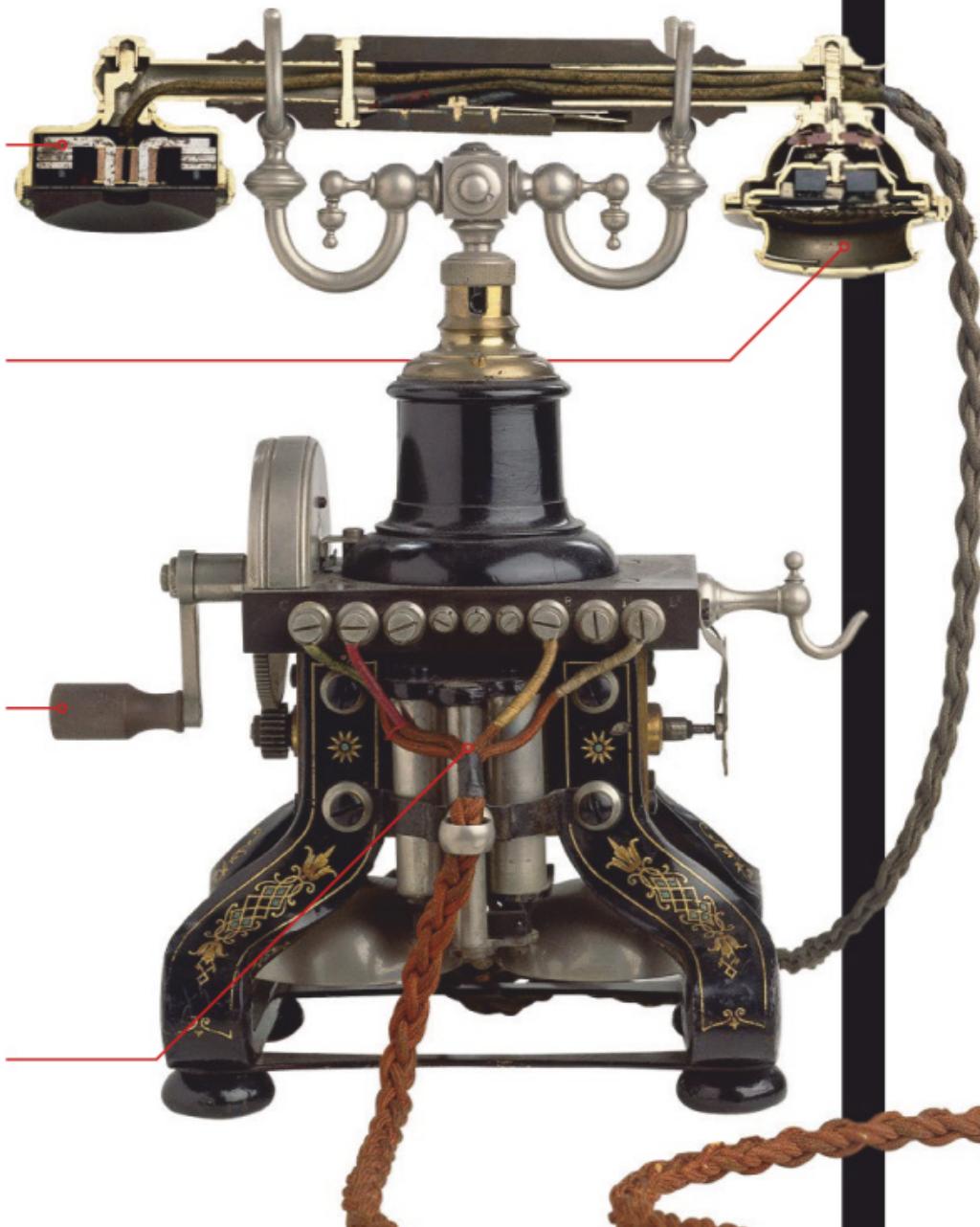
Edison introduced his phone, in breach of Bell's patent. After two years, they agreed to equip Bell's telephone with Edison's microphone. With improvements, the model lasted for many years.

**The speaker** consists of an electromagnet, which sets a membrane in motion to produce waves.

**Microphone:** The sound waves from the voice strike a membrane, which compresses the carbon granules, converting sound into electric impulses.

**Before a call,** the handle must be rotated, producing an electric current, which signals the telephone exchange via a special cable. The signal tells the operator that the subscriber wishes to be connected.

**Four cables:** Of the thick bundle of cables, two go to the receiver and two to the handle.



### Push buttons

1963

► The first push-button telephone is introduced.

### Nokia is born

1967

► Paper maker Nokia Company, rubber maker Finnish Rubber Works, and cable maker Finnish Cable Works merge, and over the next 30 years, Nokia becomes the world's leading mobile phone maker. Then it loses it all to Apple and Google.

### Automated

1987

► At 10.42am on February 23, 1987, the then Minister for Communications, Michael Duffy, makes the first official Australian mobile phone call using an analogue mobile phone weighing 1.5kg.



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## VISUAL INTELLIGENCE



**1** Which two socks make up a pair?

**2**  $4 \times 4 \times 4$  small cubes make up one large cube, whose vertical sides, top, and bottom are decorated with blue colour. How many of the 64 small cubes have no blue colour?



### Scientist in Focus



**Name:**  
Jacques Cousteau  
**Life span:**  
1910-1997

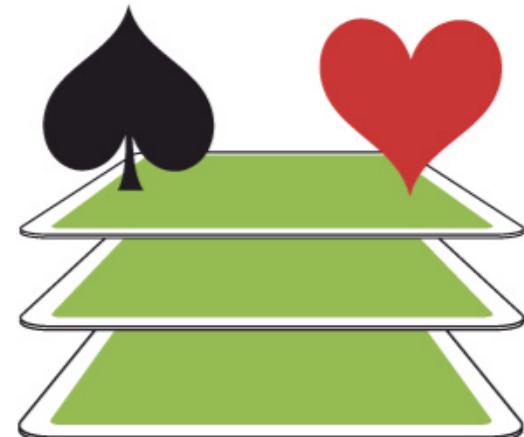
RIETZAU SCANPIX

### Adventurer made the ocean popular

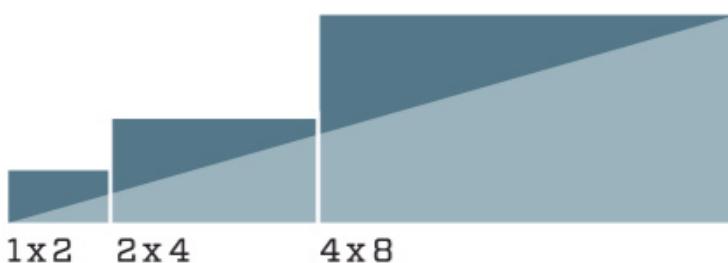
Scientist, writer, and film maker Jacques Cousteau loved the ocean and documented his exploration in books and films. Cousteau's enthusiasm allowed him to pass on his interest in oceans and environment to an entire generation.

## LOGIC

**3** Which three cards do you see? Right under a queen, you will find a jack. Right under a queen, you will find a queen. Right above a spade, you will find a heart. Right under a spade, you will find a heart.



**4** The three rectangles are intersected by a slanting line. What is the total area of the dark parts?



**1** Cousteau carried out most of his research from a customized ship named ...?

**A) Savannah**  
**B) Calypso**  
**C) Argo**  
**D) Potemkin**

**2** Which abbreviation is used about a type of diving, for which Cousteau developed gear?

**A) SNCF**  
**B) SMART**  
**C) SNAFU**  
**D) SCUBA**

**3** One of Cousteau's most popular books was published in English as ...?

**A) The Wet World**  
**B) The Silent World**  
**C) The Strange World**  
**D) The Magic World**

**4** In 2014, Cousteau's grandchild beat his underwater record of ...?

**A) 15 hours**  
**B) 1 day**  
**C) 1 week**  
**D) 30 days**

**PROBLEM 1:** **D and F** make up a pair.

**PROBLEM 2:** **24** cubes, 16 at the corners and 8 at the centre.

**PROBLEM 3:** Bottom card: jack of hearts, cen-

**PROBLEM 4:** **14**. The area of the rectangle that can embrace all three figures is  $4 \times 14 = 56$ . From half this area, you must deduct the two empty areas:  $28 - 2 \times 3 - 2 \times 4 = 14$ .

**PROBLEM 5:** **14**. The area of the rectangle that can embrace all three figures is  $4 \times 14 = 56$ . From half this area, you must deduct the two empty areas:  $28 - 2 \times 3 - 2 \times 4 = 14$ .

**PROBLEM 6:** Bottom card: queen of hearts, cen-

**PROBLEM 7:** **24** cubes, 16 at the corners and 8 at the centre.



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# REAL DRAGONS SWIM



**SPECIES:** Australian water dragon

**SCIENTIFIC NAME:** *Intellagama lesuerii*

**DISTRIBUTION:** Eastern Australia from Victoria to Queensland.

**IUCN CLASSIFICATION:**  
Least concern

The bearded dragon is a popular pet in the US, despite Australia's ban on the export of native animals. How does that work? Because enough *Pogona vitticeps* individuals had been shipped out before the ban came into effect in the 1960s. The result is an expatriate breeding population in the US pet trade that's going gangbusters - you can get beardies in all sorts of variant colours, with all sorts of congenital defects caused by inbreeding, such as bicephalism (two heads) and anophthalmia (no eyes).

The desire to breed fancier dragons is understandable: the standard *Pogona* sp. is, to the unsophisticated eye, just a grey lizard. But we don't need to bother messing with the poor beardie, because here in Australia we're spoilt for choice when it comes to spectacular dragons - and one is as close as the nearest creek.

The Australian water dragon is usually known by either of its two subspecies, and given how common they are in and around Sydney, most Australians probably think of them as the eastern water dragon. Or maybe "what was that noise, did you hear a splash?"

There's a pretty good reason why the mainstream lizard pet scene didn't go for *Intellagama* over *Pogona* - water dragons are on a whole different level to the good-

natured, relatively easy to catch and control beardie.

For a start, Australian water dragons can grow up to a metre long, while the biggest beardies top out at 60cm. *Intellagama* are extremely fast, and well-adapted to climbing trees: herpetologists categorise them as an arboreal species.

But the real kicker is that genus name. *Intellagama* means "smart dragon" and indeed these reptiles do seem far more switched on, alert, and ready to flee the scene, than the beardie. By a lot.

And that escape usually involves an almost certainly pre-planned dive into the nearest body of water, quick wriggle to the bottom, and then fast, powerful swimming using the vertically-flattened tail to the far bank. Then it's down a burrow that you can spend the next three hours trying to find, but never will.

Like the bearded dragon, the Australian water dragon is a member of the Agamidae - the agamid lizards. They might look a bit like iguanas, and indeed, they're in the Iguanidae supraorder with iguana and chameleons, but they're quite different from both.

In fact you could even see them as a bridge between the iguanas and chameleons. They can grow to iguana-like sizes, but some have a limited colour-



## COMMON LIZARD, RARE CATCH

Getting hands-on with an *Intellagama* is no trivial feat. This male, found in the Blue Mountains on a cool day, made the kind of mistake that gets a lizard eaten: he hid in small and shallow pool of chilly water. The cold made him sluggish, and the human brain's ability to spot the unexpected defeated his camouflage. The fast reflexes of a hot-blooded mammal were too good. His fate? A photoshoot, then release.

change ability, a tooth/jaw setup like a chameleon, and many use bright colours for courtship purposes.

Case in point: Australian water dragons are positively spectacular with their side-banding - and males with the brightest, reddest chests get the most ladies.

Of course, humanity's desire for exotic pets seems unquenchable, so you can get a license to keep an *Intellagama*, if you're really determined. But be aware, it's a long, long term commitment. In captivity, safe from predators and well fed, the Australian water dragon can live for 25 years. 

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