

### Welcome to the September 2023 issue

SCIENCE NEWS *Monthly* is produced by the Science Department, St Benedict's Catholic Secondary School, Bury St Edmunds, Suffolk, UK.

# IS THERE ANYBODY OUT THERE? Essential building block for life found on a moon of Saturn – Enceladus.

Using data collected by NASA's Cassini mission, an international team of scientists has discovered **phosphorus** – an essential chemical element for life – locked inside salt-rich ice grains ejected into space from Enceladus. Furthermore, the small moon is known to possess a subsurface ocean. Water from that ocean erupts through cracks in Enceladus' icy crust as geysers at its South Pole, creating a plume. Subsequently, the plume then feeds Saturn's E ring (a faint ring outside of the brighter main rings) with icy particles.



During its mission at the gas giant from 2004 to 2017, Cassini flew through the plume and E ring numerous times. Phosphorus is the least abundant of the essential elements necessary for biological processes. And scientists hadn't detected it at Enceladus until now. Significantly, the element is a building block for DNA, which forms chromosomes and carries genetic information. Indeed, it's present in the bones of mammals, cell membranes and ocean-dwelling plankton. In addition, phosphorus is also a fundamental part of energy-carrying molecules present in all life on Earth. Life wouldn't be possible without it.

Frank Postberg is a planetary scientist at Freie Universität Berlin, Germany, who led the new study which has been published in the journal *Nature*. Postberg said: *"We previously found that Enceladus*" ocean is rich in a variety of organic compounds. But now, this new result reveals the clear chemical signature of substantial amounts of phosphorus salts inside icy particles ejected into space by the small moon's plume. It's the first time anyone has discovered this essential element in an ocean beyond Earth."

The authors focused on data collected by Cassini's **Cosmic Dust Analyzer**. This instrument sampled icy particles from Enceladus in Saturn's E ring. Cassini analysed many more ice particles when it flew through the E ring than when it went through just the plume. So the scientists were able to examine a much larger number of compositional signals there. By doing this, they discovered high concentrations of sodium phosphates – molecules of chemically bound sodium, oxygen, hydrogen and phosphorus – inside some of those grains.



The phosphorous is bound inside different water-soluble forms of phosphate, in concentrations of at least 100 times that of Earth's oceans. In addition, the team's geochemical modelling demonstrated that an abundance of phosphate may also be possible in other icy ocean worlds in the outer solar system, especially, Jupiter's moon Europa. Co-investigator Christopher Glein, a planetary scientist and geochemist at Southwest Research Institute in San Antonio, Texas, said: *"High phosphate concentrations are a result of interactions between carbonate-rich liquid water and rocky minerals on Enceladus' ocean floor and may also occur on a number of other ocean worlds. This key ingredient could be abundant enough to* 

potentially support life in Enceladus' ocean; this is a stunning discovery for astrobiology."

Although the science team is excited that Enceladus has the building blocks for life, Glein stressed that scientists have not actually found life on the moon. Or, for that matter, anywhere else in the solar system beyond Earth. He said: *"Having the ingredients is necessary, but they may not be sufficient for an extraterrestrial environment to host life. Whether life could have originated in Enceladus' ocean remains an open question."* 

https://www.jpl.nasa.gov/news/nasa-cassini-data-reveals-building-block-for-life-in-enceladus-ocean

#### MATERIALS SCIENCE - A new fabric mimics polar bears' pelts for warmth

Polar bears have black skin covered by fur that looks white. But that fur isn't like normal hair, says Trisha Andrew, a materials engineer working at the University of Massachusetts Amherst in the US. In fact it has a very unique structure.

Polar bears' hollow hairs channel infrared light from the sun toward their skin. This light has wavelengths too long to see but can be felt as heat. A dark pigment in the bears' skin — similar to the melanin in human skin — absorbs the infrared light. It also absorbs visible light that passes through the fur. The layer of fur keeps the heat from absorbed light from escaping. That can keep a bear warm for a while after the sun goes down, Andrew says.

Andrew and her colleagues designed their material to work in the same way. Nylon, a common material in clothing, forms the bottom layer. It's coated with a polymer called PEDOT, whose molecular arrangement and dark colour makes it absorb light like polar bear skin does. On top of that, the team added a lightweight layer of fabric called Agribon AG-19. It's made of the polymer



polypropylene and has tiny fibres that carry light toward the "skin" layer like polar bear hair does.

Under light, the new fabric kept a surface beneath it 10 degrees Celsius (18 degrees Fahrenheit) warmer than cotton t-shirt fabric did. The new material also performed better than Omni-Heat fabric, a material currently used to make warm outdoor gear. The researchers shared their results in the journal ACS Applied Materials & Interfaces. "It's washable. It's breathable. You could sew with it," Andrew says of the new fabric. It would feel like a lighter version of fabrics used for curtains and to cover couches, she adds. Wesley Viola, a graduate student at the University of Massachusetts Amherst who works with Andrew, has sewn the fabric into a mitten and a tent. Products like these could keep people cozy in frigid places like the Arctic.

https://www.snexplores.org/article/analyze-this-a-new-fabric-mimics-polar-bears-pelts-for-warmth

#### THE SUN - Solar maximum could hit us harder and sooner than we thought.

The sun is quickly approaching a major peak in solar activity. Experts warn it could potentially begin by the end of 2023, years before initial predictions suggested. From a distance, the sun may seem calm and steady. But zoom in, and our home star is actually in a perpetual state of flux, transforming over time from a uniform sea of fire to a chaotic jumble of warped plasma and back again in a recurring cycle.

Every 11 years or so, the sun's magnetic field gets tangled up like a ball of tightly wound rubber bands until it eventually snaps and completely flips — turning the north pole into the south pole and vice versa. In the lead-up to this gargantuan reversal, the sun amps up its activity: belching out fiery blobs of plasma, growing dark planet-size spots and emitting streams of powerful radiation. This period of increased activity, known as



This image shows how the sun's appearance changes between solar maximum (on the left) and solar minimum (on the right). (Image credit: NASA/Solar Dynamics Observatory)

solar maximum, is also a potentially perilous time for Earth, which gets bombarded by solar storms that can disrupt communications, damage power infrastructure, harm some living creatures (including astronauts) and send satellites plummeting toward the planet.

Originally, scientists predicted that the current solar cycle would peak in 2025. But a bumper crop of sunspots, solar storms and rare solar phenomena suggest solar maximum could arrive by the end of this year at the earliest — and several experts believe that we may be poorly prepared. Humans can do little to shield ourselves from a direct solar storm hit, but we can prepare for them by altering satellite trajectories, grounding planes and identifying vulnerable infrastructure. As a result, more accurate solar weather forecasts are needed to help us prepare for the worst.

The largest solar storm ever recorded was back in 1859 and is known as the *Carrington Event*, after the British astronomer Richard Carrington. It was linked with extraordinary auroras — the Northern and Southern Lights — that were visible in the sky near both the poles and the equator, everywhere from Canada to Australia. The enormous solar outburst also caused electrical disruptions from Paris to Boston. While the Carrington Event may seem like history, there are many concerns about what might happen if an event as powerful as — or even more powerful than— the Carrington Event were to strike Earth today, now that humanity is far more dependent on electricity.

https://www.livescience.com/space/the-sun/solar-maximum-could-hit-us-harder-and-sooner-than-we-thoughthow-dangerous-will-the-suns-chaotic-peak-be

#### **ENVIRONMENT - Humans hundreds of times 'deadlier' than sharks**

Humans are well known as super predators but for the first time scientists have put a figure on it. We exploit around a third of all wild animals for food, medicines or to keep as pets, putting almost half at risk of extinction, they say. That makes us hundreds of times more dangerous than natural predators such as the great white shark.

"The size and scale of what we found surprised us," said Dr Rob Cooke of the UK Centre for Ecology and Hydrology in Wallingford, Oxfordshire. "Humans have a breath-taking diversity of uses of animals but we need to move towards sustainable human-nature relationships across the globe."

The researchers analysed data on almost 50,000 different wild mammals, birds, reptiles, amphibians and fish that humans



We are entering the Anthropocene, the period during which human activity has been the dominant influence on climate and the environment. Domesticated animals now make up the majority of animal species on land, shaping the natural world. The researchers warn that continued overexploitation of wild animals will have "profound consequences for biodiversity and ecosystem function".

Humans hundreds of times 'deadlier' than sharks - BBC News

#### ASTRONOMY - Milky Way: Icy observatory reveals 'ghost particles'

An astronomical detector buried in Antarctic ice has provided a view of our Galaxy that has never been seen before. The blurry, extraordinary image is of the Milky Way, but it is composed of the "ghostly" particles that are emitted by the reactions that power stars.

The particles are **neutrinos**, which are extremely difficult to detect on Earth. Neutrinos have no electrical charge and virtually no mass which means that, travelling at the speed of light, they can pass through matter without interacting with it at all. This makes their detection almost impossible...but not quite.

The detector that scientists and engineers designed is called IceCube. It is composed of thousands of sensors on long cables that are drilled and frozen into a 1km cubic block of ice. The whole array is buried close to the South Pole. Whenever a neutrino interacts with one of the billions of ice water molecules, that interaction is captured.



Essentially, by knowing which sensor is triggered and at what time, we can reconstruct the direction that neutrino came from. The scientists say the discovery, published in the journal *Science*, is an entirely new window on our Galaxy, as it enables us to 'see' our Milky Way galaxy in an entirely new way. *"This is the first time we're seeing our Galaxy using particles rather than photons [of light],"* Prof Subir Sarkar from the University of Oxford told BBC News. This, he explained, provides a view of *"high energy processes that shape our Galaxy"*. Neutrinos can be thought of as astronomical messengers that point to those fundamental processes. They are created when particles called cosmic rays - that are rattling around at near light speed - smash into other matter.

Prof Naoko Kurahashi Neilson, a physicist at Drexel University in Philadelphia, and another member of the IceCube team, said that humans had been studying it for millennia. "We've seen it in many wavelengths of light - like radio waves and gamma rays - but since the dawn of time it was always in electromagnetic radiation. In all wavelengths of light or photons. This is the first 'map' of our Galaxy in something [other than light], and it's in high-energy neutrinos," she told BBC News. "It will mean we can start understanding the physical processes in the Milky Way better."

Prof Kurahashi Neilson added that the team would spend the next 5-10 years trying to answer questions that "we can finally ask".



#### **MEDICINE - Transparent mouse could improve cancer drug tests**

New drugs are often tested first on mice in the laboratory; however, observing the effects are difficult and controversial. Now, a remarkable new scanning method involving a **see-through mouse** could improve how cancer drugs are tested, by picking up tumours previously too small to detect.

Prof Ali Ertürk of the Helmholtz Munich research centre worked out how to make a dead mouse transparent in 2018. His team have now used chemicals to highlight specific tissues so that they can be scanned in unprecedented detail. The researchers say the method reveals far greater detail than existing



scanning techniques. In one of the first applications the team has detected cancerous tumours in the first stages of formation.

Normally lab mice are given cancer and scanned with conventional scans to see how the tumour has progressed. They are then treated with the cancer drug being tested and then scanned again to see what if any difference the treatment has had. Prof Ertürk says this is important because cancer drugs have to be shown to eliminate tumours in mice before being tested on humans. "MRI and PET scans would show you only big tumours. Ours show tumours at the single cell, which they absolutely can't. Current drugs extend life by a few years and then the cancer comes back. This is because the development process never included eliminating those tiny tumours, which were never visible."

The cancer application, published in the journal *Nature Biotechnology*, is just one of hundreds if not thousands to which the new scanning technique can be used to improve medical studies. It can enable researchers to see things they have never seen before.

https://www.bbc.co.uk/news/science-environment-66119980

#### ART & SCIENCE - microscopic handbag 'smaller than grain of salt' sells for \$63,750!

Art collective MSCHF, based in Brooklyn (US), is known for its controversial designs. They include shoes that contain human blood, trainers with holy water in the soles, a cologne that smells like WD-40, and giant red rubber boots. This time, the collective decided to take the trend of small handbags to the extreme: A microscope is needed to view the bag's design, with the tiny object measuring 657 x 222 x 700 micrometres. The bag features luxury handbag designer Louis

Vuitton branding, but has no connection to the brand. It is made of photopolymer resin and was created using a 3D printing technology often



used to make tiny mechanical models and structures. While it was being created, some of the tiny bag samples sent to be reviewed by the brand were so small that they were lost by the MSCHF team, the Smithsonian magazine reports. But loss of the item should be less of a worry for the new bag's owner, as a microscope with a digital display was included in the purchase.



The auction site did not list the price of the microscope separately from the bag. Bids for the item started at \$15,000. Speaking about the use of Louis Vuitton branding on the bag, MSCHF's chief creative officer, Kevin Wiesner, told the New York Times earlier this month that the group had not sought permission from the brand to use it. "We are big in the 'ask forgiveness, not permission' school," he said.

MSCHF microscopic bag 'smaller than grain of salt' sells for \$63,750 - BBC News

#### EARTH SCENCE – Has a new geological epoch begun?

Earth's history, over 4.5 billion years, is divided into time periods along a **geological time scale**. Often the periods are determined by a major global event. For example, the division between the Cretaceous Period (145-66 million years ago) and the Palaeogene Period (66-23 million years ago) is defined by a meteor that struck the Earth 66 million years ago and led to a mass extinction event, notable for the dying out of the land-based dinosaurs.

Our present geological period is known as the **Quaternary** and is deemed to have begun 2.6 million years ago. The Quaternary Period is typically defined by the cyclic growth and decay of continental ice sheets and the associated climate and environmental changes that they caused. The Quaternary Period is divided into two epochs: the **Pleistocene** (2.58 million years ago to 11.7 thousand years ago) and the **Holocene** (11.7 thousand years ago to today). Now a third ongoing epoch, the **Anthropocene**, is being proposed.



Scientists suspected the new epoch started at some point in the

early 1950s. So they set about looking for some place that might mark its official beginning. They narrowed a candidate list to 12 sites around the world. In the end, they chose Crawford Lake in Milton, Ontario, Canada. The proposed new epoch is named because its start will be defined by the effect humans are having on the global climate and ecology, notably since the Industrial Revolution 200 years or so ago.

Mud on the bottom of Crawford Lake holds one of the most precise records of how our species has altered Earth. These changes include upticks in plutonium, a radioactive element, left by military tests of nuclear weapons. There's also ash from the burning of fossil fuels, as well as deposits of heavy metals (such as lead). More recently, microplastics have been showing up here and elsewhere across the planet.

Scientists first started describing an Anthropocene in the early 2000s. They wanted a term to note how human activities were now reshaping the planet on a global scale. Still, the term lacked a formal geologic definition. The Anthropocene isn't an official epoch yet. More committees must approve it before it can be added to the official geologic time scale. But doing so would end the nearly 12,000-year-long Holocene. Marking the end of the last ice age, that epoch covered the rise of humans as Earth's defining species.

https://www.snexplores.org/article/canada-crawford-lake-anthropocene-start

#### STRANGE LIFE – Frogs that glow in the dark

In the dim twilight hours, many frogs may be capable of emitting a faint green or orange glow. A survey of hundreds of frogs in South America shows that far more frogs are **biofluorescent** than previously thought, researchers report at *bioRxiv.org*. The ghostly colours may have a role in the frogs' communication with members of the same species, the scientists say.

Biofluorescence occurs in many types of creatures. It happens when an organism absorbs light at one wavelength, or colour, and reemits it at a different wavelength with lower energy. Over the past several years, researchers have recognized the trait in a growing diversity of species, from the fur of flying squirrels and platypuses to the nests of certain wasps.



To get a more detailed and cohesive picture of fluorescence in frogs, researchers tested frogs using five different light sources covering a range of wavelengths from green to UV. From March to May 2022, the team captured and shone lights on 528 individual frogs in Brazil, Colombia, Ecuador and Peru and measured any reemitted light. All 151 frog species they tested had some degree of fluorescence, ranging from 2 percent of the original light intensity to well over 90 percent. Prior to this study, less than two dozen of the 42 frog species that had been previously tested were considered fluorescent. The frogs' green and orange fluorescence was most intense under blue light that dominates at twilight. This is similar to how many salamander species fluorescen.

Many of the frogs' body parts that strongly fluoresced are also involved in signalling to other frogs. Much of the fluorescence seemed centred on the throat and underside of the frogs, which are commonly used in courtship rituals. The green glow is probably something other frogs can see, the researchers say. The team found that in the twilight hours — a time when frogs tend to court and mate — frog eyes are quite sensitive to the particular green light that's emitted from the frogs' skin. The orange fluorescence, on the other hand, may be intended for a different receiver, such as a predator.

# MORE BIOLOGY - Relatives of the 1st mitochondria may be living in geothermal hot springs today

Scientists say they've identified a potential living relative of the ancient microbe that gave rise to of the cell" the "powerhouse the \_ mitochondrion. More than a billion years ago. one simple cell ended up trapped inside another and never left, and its descendants went on to mitochondria. become the so-called powerhouses of cells. This process is called endosymbiosis. But even now, bacterial relatives of that first trapped cell – a protomitochondrion, as researchers call it - can be found floating in modern hot springs, a new study suggests.



Protomitochondria gave rise to the cellular energy centre of eukaryotes — all animals, plants, fungi and protists, whose cells contain structures called organelles that perform specific functions. Although mitochondria still have their own DNA that's available for analysis, researchers haven't definitively determined which species of modern bacteria may descend from protomitochondria.

In the new study, published in the journal *Science Advances*, researchers focused on genetic traits that enable bacteria to perform certain functions that are essential to protomitochondria, like making fats for mitochondrial membranes. Using these genetic criteria, the researchers pinpointed a type of bacteria that has not been previously suggested to descend from protomitochondria and that lives in conditions similar to those that would have supported life in Earth's ancient oceans.

The researchers sifted through a repository of 314 genomes of alphaproteobacteria — the class of bacteria that research suggests protomitochondria came from — looking for genes that coded for essential proteins. Some of the most important of these genes serve the same purpose as ones mitochondria use to produce energy using oxygen, as well as without oxygen. Other genes would be needed to create certain fats, including cardiolipins. These fats are found in prokaryotes — organisms whose cells lack organelles — and in the mitochondrial membranes and certain waxy molecules of eukaryotes.

Bacteria in the order *lodidimonadales* met the greatest number of these genetic criteria, leading the researchers to believe that these bacteria could be closely related to protomitochondria. These bacteria live in a variety of places, including freshwater and ocean geothermal springs, an extreme environment similar to some found in Earth's oceans nearly 2 billion years ago.

A better understanding of how mitochondria evolved could potentially help us understand diseases in which mitochondrial function gets disrupted, such as Parkinson's disease. Beyond medical applications, learning about the origins of mitochondria can help us understand how all complex life, including humans, came to be.

https://www.livescience.com/health/relatives-of-the-1st-mitochondria-may-be-living-in-geothermal-hot-springstoday

#### **CHEMISTRY - How a Chemical Reaction Used by Chefs Helped Create Life on Earth**

A chemical process used in the browning of food to give it its distinct smell and taste is likely occurring deep in the oceans, where it has helped create the conditions necessary for life.

The **Maillard reaction**, known for its role in food browning, is also likely happening on the ocean floor, contributing to life on Earth by preserving organic carbon. Researchers at the University of Leeds have found that this reaction has helped raise oxygen and reduce carbon dioxide levels in the atmosphere, creating



conditions for complex life. The findings may also have implications for managing climate change.

A research team led by Professor Caroline Peacock at the University of Leeds posits that on the sea floor, the Maillard reaction has played a fundamental role in preserving organic carbon – the basis for al life. It has also contributed to raising oxygen levels and reducing carbon dioxide levels in the atmosphere, thereby creating conditions for complex life forms to emerge and thrive on Earth.

Dr. James Bradley, an environmental scientist at Queen Mary University of London and one of the authors of the paper, said: "Understanding the complex processes affecting the fate of organic carbon that is deposited on the seafloor is crucial to pinpointing how Earth's climate changes in response to both natural processes and human activity, and helping humanity better manage climate change, since the application and long-term success of carbon capture technologies relies on carbon being locked away in stable forms rather than being transformed into carbon dioxide."

https://scitechdaily.com/cooking-up-life-how-a-chemical-reaction-used-by-chefs-helped-create-life-on-earth/

#### PHYSICS - How a cup of water can unlock the secrets of our Universe and Life itself!

Researchers from Queen Mary University of London have made a discovery that could change our understanding of the Universe and even Life itself. In their study published in the journal *Science Advances*, they reveal, for the first time, that there is a range in which fundamental constants can vary, allowing for the viscosity needed for life processes to occur within and between living cells. This is an important piece of the puzzle in determining where these constants come from and how they impact life as we know it.

**Fundamental physical constants** shape the fabric of the universe we live in. Physical constants are quantities with a value that is generally believed to be both universal in nature and to remain unchanged over time—for example the mass of the electron. They govern nuclear reactions and can lead to the formation of molecular structures essential to life, but their origin is unknown. This research might bring scientists one step closer to determining where these constants come from.

Understanding how water flows in a cup turns out to be closely related to the grand challenge to figure out fundamental constants. Life processes in and between living cells require motion and it is viscosity that sets the properties of this motion. If fundamental constants change, viscosity would change too impacting life as we know it. For example, if water was as viscous as tar life



would not exist in its current form or not exist at all. This applies beyond water, so all life forms using the liquid state to function would be affected.

Any change in fundamental constants including an increase or decrease would be equally bad news for flow and for liquid-based life. We expect the window to be quite narrow: for example, viscosity of our blood would become too thick or too thin for body functioning with only a few percent change of some fundamental constants such as the Planck constant or electron charge.

Surprisingly, the fundamental constants were thought to be tuned billions of years ago to produce heavy nuclei in stars and back then life as we know it today didn't exist. There was no need for these constants to be finetuned at that point to also enable cellular life billions of years later, and yet these constants turn out to be biofriendly to flow in and between living cells. An accompanying conjecture is that multiple tunings may have been involved and this then suggests a similarity to biological evolution where traits were acquired independently. Through evolutionary mechanisms, fundamental constants may be the result of nature arriving at sustainable physical structures. It remains to be seen how the principles of evolution can be helpful to understand the origin of fundamental constants.

## If, in due course, it is found that the sum of all the fundamental physical constants works out to be 42, we should not be surprised!

#### https://phys.org/news/2023-08-cup-secrets-universe.html

#### ARCHAEOLOGY - Humans faced a 'close call with extinction' nearly a million years ago

Early humans might have almost gone extinct nearly 1 million years ago, with the world population hovering at only about 1,300 for more than 100,000 years, a new study finds (published in the journal *Science*). This close call with extinction may have played a major role in the evolution of modern humans and their closest known extinct relatives, the thick-browed Neanderthals and the mysterious Denisovans, researchers added.

To learn more about the period near the evolution of modern humans, scientists investigated the genomes of more than 3,150 present-day modern humans from 10 African populations and 40 non-African ones. They developed a new analytical tool to deduce the size of the group making up the ancestors of modern humans by looking at the diversity of the genetic sequences seen in their descendants. The genetic data suggest that between 813,000 and 930,00 years ago, the ancestors of modern humans experienced a severe "bottleneck," losing about 98.7% of its breeding population.



The scientists noted this population crash coincided with severe cooling that resulted in the emergence of glaciers, a drop in ocean surface temperatures, and perhaps long droughts in Africa and Eurasia. Scientists still don't know how this climate change might have affected humans because human fossils and artifacts are relatively sparse during this time, perhaps because the population was so low.

https://www.livescience.com/archaeology/humans-faced-a-close-call-with-extinction-nearly-a-million-years-ago

### **ASTROPHYSICS – DARK MATTER: the unanswered questions**

In the 1930s, a Swiss astronomer named Fritz Zwicky noticed that galaxies in a distant cluster were orbiting one another much faster than they should have been given the amount of visible mass they had. He proposed than an unseen substance, which he called dark matter, might be tugging gravitationally on these galaxies. Since then, researchers have confirmed that this mysterious material can be found throughout the cosmos, and that it is six times more abundant than the normal matter that makes up ordinary things like stars and people. Yet despite seeing dark matter throughout the universe, scientists are mostly still scratching their heads over it. Here are some of the biggest unanswered questions about dark matter:

**WHAT IS IT?** First and perhaps most perplexingly, researchers remain unsure about what exactly dark matter is. Originally, some scientists conjectured that the missing mass in the universe was made up of small faint stars and black holes, though detailed observations have not turned up nearly enough such objects to account for dark matter's influence. The current leading contender for dark matter's mantle is a hypothetical particle called a **Weakly Interacting Massive Particle**, or **WIMP**, which would behave sort of like a neutron except would be between 10 and 100 times heavier than a proton.

**CAN WE DETECT IT?** If dark matter is made from WIMPs, they should be all around us, so why haven't we found any yet? While they wouldn't interact with ordinary matter very much, there is always some slight chance that a dark-matter particle could hit a normal particle like a proton or electron as it travels through space. So, researchers have built experiment after experiment to study huge numbers of ordinary particles deep underground, where they are shielded from interfering radiation that could mimic a dark-matter-particle collision. The problem? After decades of searching, not one of these detectors has made a credible discovery.

**DOES DARK MATTER CONSIST OF MORE THAN ONE PARTICLE?** Ordinary matter is made up of everyday particles like protons, neutrons and electrons, as well as a whole zoo of more exotic particles like neutrinos, muons and pions. So, some researchers have wondered if dark matter, which makes up 85 percent of the matter in the universe, might also be just as complicated. Dark protons could combine with dark electrons to form dark atoms, producing configurations as diverse and interesting as those found in the visible world. Such proposals have increasingly been imagined, but figuring out a way to confirm or deny them has so far eluded scientists.

**COULD DARK MATTER BE MADE OF AXIONS?** As physicists increasingly fall out of love with WIMPs, other dark-matter particles are starting to gain favour. One of the leading replacements is a hypothetical particle known as an **axion**, which would be extremely light, perhaps as little as 10 raised to the 31st power less massive than a proton. Axions are now being searched for in a few experiments.

WHAT ARE THE PROPERTIES OFDARK MATTER? Astronomers discovered dark matter through its gravitational interactions with ordinary matter. But when trying to understand the true nature of dark matter, researchers have remarkably little to go on. According to some theories, dark-matter particles should be their own antiparticles, meaning that two dark-matter particles would annihilate with one another when they meet. The Alpha Magnetic Spectrometer (AMS) experiment on the International Space Station has been searching for the telltale signs of this annihilation since 2011and has already detected hundreds of thousands of events. Scientists still aren't sure if these are coming from dark matter, and the signal has yet to help them pin down exactly what dark matter is.

**COULD DARK MATTER HAVE AN ELECTRICAL CHARGE?** Radiation with a wavelength of 21cm was emitted by stars in the universe's infancy, just 180 million years after the Big Bang. It was then absorbed by cold hydrogen that was around at the same time. When this radiation was detected in February of this year, its signature suggested that the hydrogen was much colder than scientists had predicted. There is a theory that dark matter with an electrical charge could have drawn heat away from the all-pervasive hydrogen, sort of like ice cubes floating in lemonade. But the conjecture has yet to be confirmed.

FINALLY, THE \$64,000 QUESTION: DOES DARK MATTER ACTUALLY EXIST? Given the difficulties that scientists have faced trying to detect and explain dark matter, a reasonable questioner might wonder if they're going about it all wrong. For many years, a vocal minority of physicists have pushed the idea that perhaps our theories of gravity are simply incorrect, and that the fundamental force works differently on large scales than we expect. Often known as "modified Newtonian dynamics," or MOND models, these suggestions posit that there is no dark matter and the ultrafast speeds at which stars and galaxies are seen to rotate around one another is a consequence of gravity behaving in surprising ways. However, this is currently a minority view. The majority reckon that all the data so far points to dark matter being real.

### WORD(S) OF THE MONTH: VALENCE ELECTRONS (noun, "VAY-lance Eel-EK-trons")

These far-out electrons explain how an atom does what it does. Valence electrons are the electrons in an atom farthest from the nucleus. An element's number of valence electrons helps predict how atoms of that element interact with other atoms – ie., what chemical reactions that element willtake part in.

Atoms consist of three types of particles: protons, neutrons and electrons. Protons and neutrons pack together into a tiny centre — the nucleus. Electrons whiz around the surrounding space. That surrounding space is organized into levels. Electrons fill these levels from the inside out. The level closest to the nucleus fills first, with two electrons. If the atom has more than two, these overflow electrons must go to the next level. Then the next and next, and so on, as each level fills up. Valence electrons are those that live in whichever level is outermost. To be stable, atoms need a complete set of valence electrons to fill their outermost levels. For most elements, that number is eight. Atoms with fewer than eight valence electrons are more likely to take, donate or share another atom's valence electrons.

Consider this example: A neutral chlorine atom has <u>seven</u> valence electrons. A neutral sodium atom has only <u>one</u> valence electron. Neither has a complete set of eight. Losing one electron is "easier" than stealing seven. So that's what sodium does — it donates one electron to chlorine. In doing so, the two atoms form a chemical bond — becoming sodium chloride, which you know as table salt.