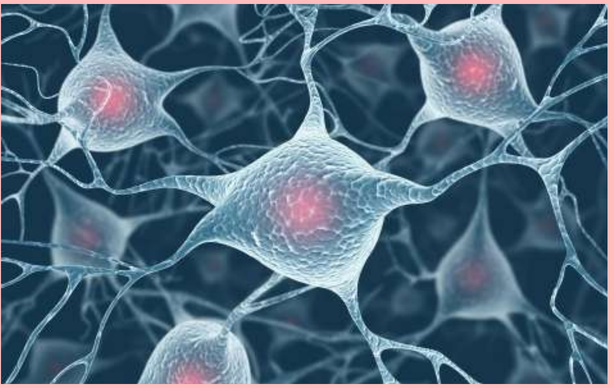
CATAPULTA

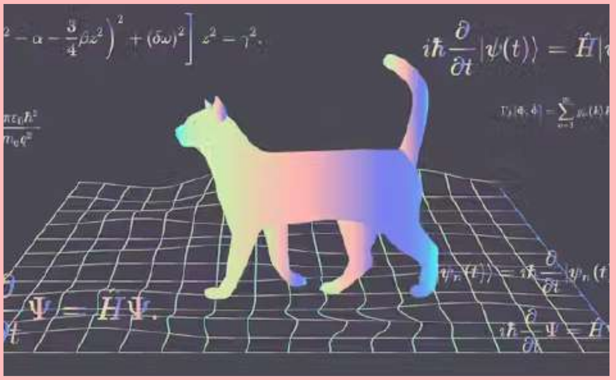
Spring 2025

The Transfermium Wars

Quantum Mechanics

Uncovering Neptune's Auroras





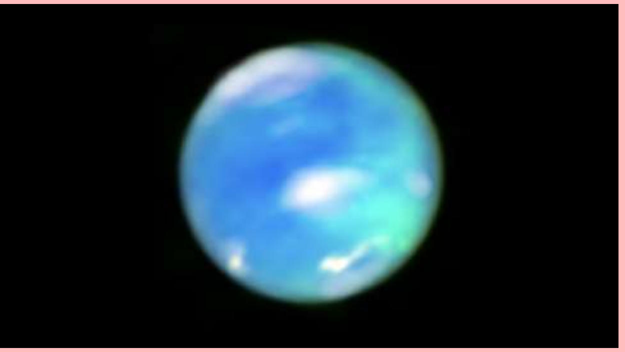


table of contents

EDITORS' NOTE

WELCOME TO THE 2025 SPRING ISSUE OF CATAPULTA!!!

FROM YOUR 2024-2025 EDITORS IN CHIEF — A TREMENDOUS THANK YOU TO OUR LOVELY EDITING BOARD FOR ALL THE AFTERNOONS SPENT TOGETHER WITH THE LIGHTS OFF IN MR. GALEGO'S ROOM. IT HAS BEEN AN ABSOLUTE PLEASURE. TO THE AWESOME WRITERS OF BLS WHO SUBMITTED ARTICLES, YOU TOO HELP KEEP SCIENTIFIC JOURNALISM ALIVE. KEEP THEM FLOWING :). ANGELINA AND EVAN, CONGRATULATIONS AND LOCK IN! WE ARE SO EXCITED TO SEE YOU TAKE CATAPULTA TO THE NEXT LEVEL. TRY TO BEAT OUR PI DAY FUNDRAISING RECORD, WE DARE YOU. FINALLY, TO THE EVER-LOVELY READER BASE OF CATAPULTA: BE LIKE A GAS AND EXPAND! MAY MORE STUDENTS AND FACULTY AT BLS PICK UP AND LEARN TO LOVE THIS MAGAZINE AS MUCH AS WE HAVE. ❤

ALL THE BEST,

Emily and William

FROM THE CURRENT TO FORMER EIC'S: PI-DAY CHALLENGE ACCEPTED! CATAPULTA WILL YET AGAIN BE BRINGING THE BLS COMMUNITY ANOTHER FIRE PUBLICATION! FROM READS ON THE INTERSECTION BETWEEN THE ENVIRONMENT AND GENETICS TO A DEEP DIVE INTO THE ABSTRACT FIELD OF QUANTUM MECHANICS, NO MATTER IF YOU ARE AN EMERGING READER OF SCIENTIFIC PUBLICATIONS OR A SEASONED VETERAN, WE BET THERE IS SOMETHING INSIDE FOR YOU! NEED A BREAK FROM READING? WE GOT YOU COVERED — JUGGLE YOUR NEURONS WITH THE PUZZLE ON THE BACK! WE HOPE YOU ENJOY THIS NEW ISSUE AS MUCH AS WE LOVED PUTTING IT TOGETHER.

ONWARD,

Evan and Angelina

SPRING ISSUE STAFF

THIS ISSUE OF CATAPULTA HAS BEEN MADE POSSIBLE BY THE BOSTON LATIN SCHOOL ASSOCIATION AND OUR FACULTY SPONSORS:

MR. GALEGO
MRS. BATEMAN

1635

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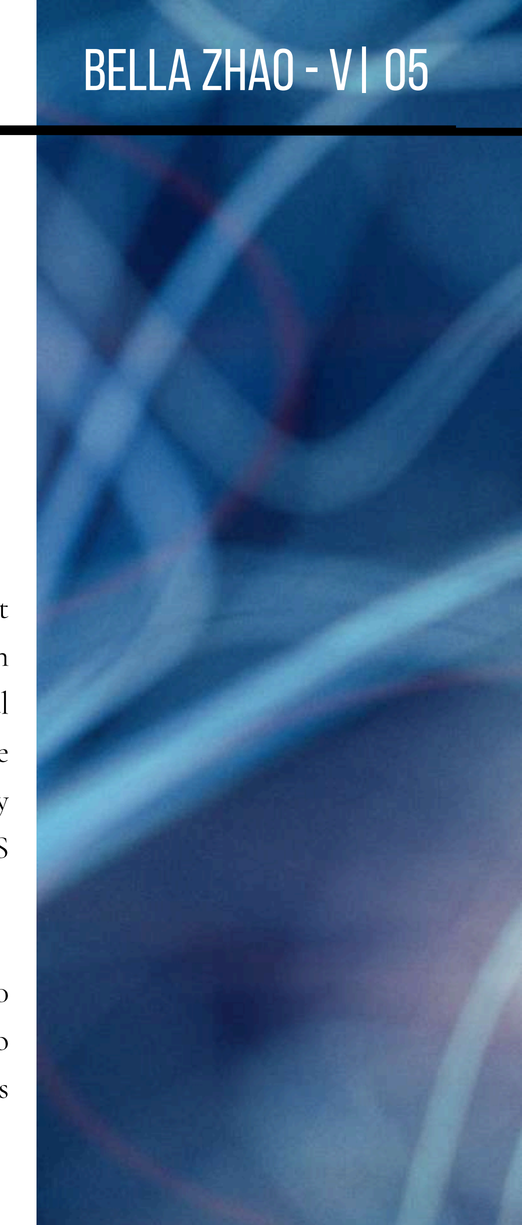
Nature vs Nurture

Have you ever wondered how you became you? Whether children are born with specific personalities or are shaped by their upbringing and experiences is an age-old question. Surprisingly, scientists tell us it's both nature and nurture. Nurture refers to how you were raised, while nature refers to one's biology. Thanks to advancements in psychology, experts in the field now stress that nature and nurture work together to shape humans, stating: "it's nearly always both".

In terms of nature, genes matter. Are you an extrovert? An introvert? Both? Modern studies at universities such as Yale, Vanderbilt, and Manchester have linked thousands of gene variants to the "Big Five traits." Almost all studies on this topic have pointed to the fact that most of our unique personalities consist of a major genetic component. However, it's important to keep in mind that genes do not always determine your personality. While genetic variation sets potential and limits for one's individual personality, life ultimately has the power to steer you one way or the other.

Of course, nurture, or the way you grow up, impacts almost every aspect of your personality. Studies have shown that one's family environment has a strong effect on their personality development. For example, warm and supportive parents often raise confident and socially skilled children, while strict parents can produce anxious or even withdrawn children. While parents are important, they do not dictate everything about you. In fact, many other factors like your school, friends, culture, or life events play a vital role in your development. Furthermore, have you ever noticed that you and your siblings act differently? Researchers call this the "non-shared environment," which is the idea that each child's unique experiences help explain why personalities diverge, even while growing up in close proximity.

Psychological sciences today tend to place more emphasis on interactions, as early life experiences can switch certain genes on and off. This is a fascinating topic known as epigenetics. Because of this, we can conclude that both genes and the environment shape personality. Nature sets the stage with genetic possibilities and potential, while nurture fills in the blanks. Understanding this complex mix is key to understanding why every person you meet is unique. The bottom line is that children are not simply born one way or made another—they become who they are through a lifetime of experiences and genes that are constantly working together.

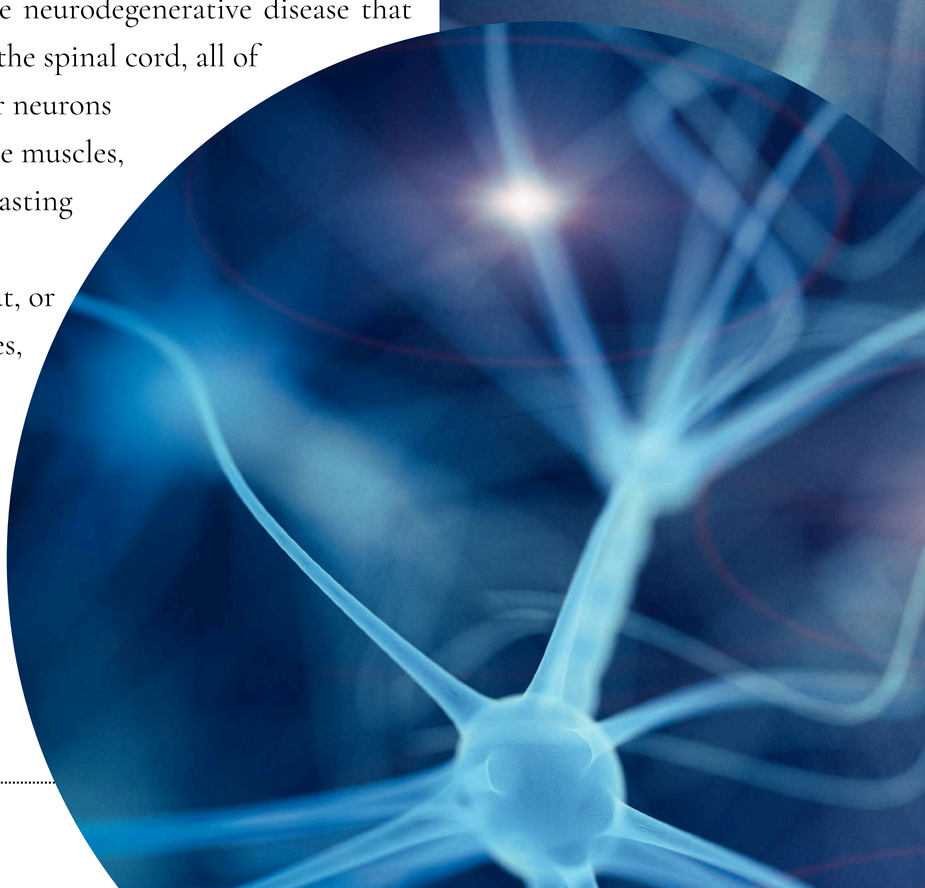


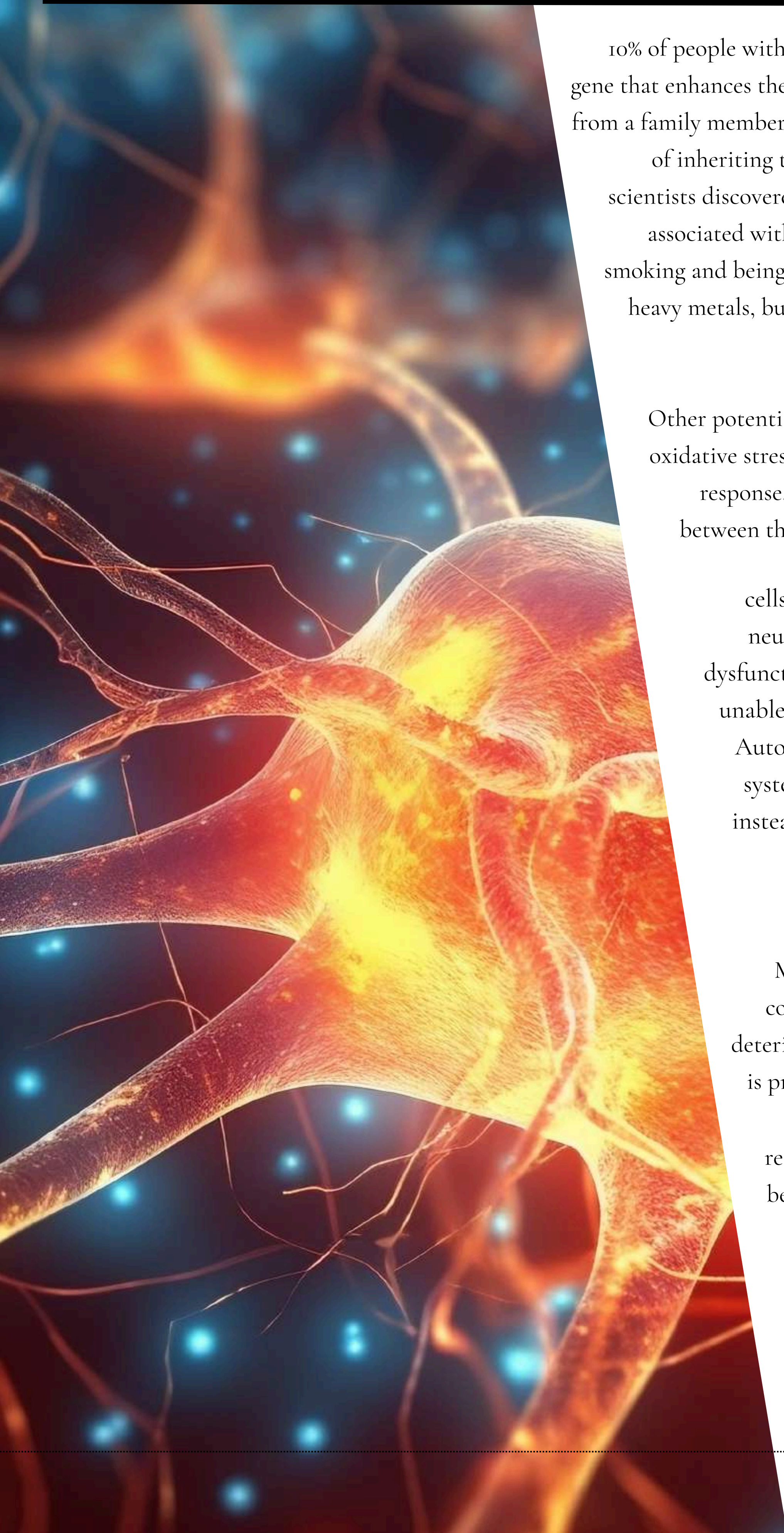
Amyotrophic Lateral Sclerosis (ALS)

"Hi, thank you for nominating me for the USC Speak Your Mind Ice Bucket Challenge. I would like to nominate..." Originating from the University of South Carolina, the Ice Bucket Challenge is a trend that has been blowing up all over social media platforms and aims to spread awareness for mental health. As a revival of the original ALS Ice Bucket Challenge, popular in 2014, this challenge dramatically increased public awareness of ALS and provided funding for the disease, fueling ALS research and leading to advancements in treatment.

Lou Gehrig is one of the most renowned faces in baseball history. He played 2,130 consecutive games for the Yankees, but his career was cut short by ALS. He died two years after his diagnosis, and the whole baseball world mourned for him. Due to his legacy, ALS is also known as Lou Gehrig's disease.

ALS, Amyotrophic Lateral Sclerosis, is a progressive neurodegenerative disease that impacts motor neurons, nerve cells in the brain, and the spinal cord, all of which control voluntary muscle movement. As motor neurons degenerate and die, they stop sending messages to the muscles, resulting in the muscles weakening, twitching, and wasting away. Eventually, the brain loses its ability to initiate movement, leaving the victim unable to walk, talk, eat, or even breathe. Early symptoms include muscle twitches, muscle weakness, slurred speech, clumsiness, untimely emotional reactions, and difficulty chewing or swallowing. As the disease grows, these symptoms get worse and worse, slowly eating away at the person until their death. Currently, scientists and doctors have created several drugs to slow down the disease, but there is unfortunately no treatment that completely eliminates it.





10% of people with ALS received the disease through a risk gene, a gene that enhances the likelihood of inheriting a disease, passed down from a family member. In hereditary ALS, children have a 50% chance of inheriting the gene. For others diagnosed with this disease, scientists discovered that certain environmental factors have been associated with an increased risk of ALS. Such factors include smoking and being exposed to lead or other toxins, chemicals, and heavy metals, but scientists are still trying to accurately narrow down which of them are risk factors.

Other potential factors that happen inside our bodies include oxidative stress, mitochondrial dysfunction, and autoimmune response. Oxidative stress is when there is an imbalance between the production of reactive oxygen species (ROS), which are unstable molecules that damage cells, proteins, and DNA, and the body's ability to neutralize them with antioxidants. Mitochondrial dysfunction occurs when the mitochondria in cells are unable to produce enough energy for the cells to use. Autoimmune response is where the body's immune system mistakenly attacks healthy tissues and cells instead of foreign substances. The exact causes and treatments of these conditions are currently unknown.

Many people who have been affected by ALS are completely unable to live on their own due to the deterioration of their essential bodily functions. ALS is practically a death sentence since there is no cure for it. Raising awareness, investing in scientific research, and supporting the ones whose lives have been robbed by this monstrous disease offers hope in finding ways to understand, halt, or even cure ALS.

AI ADVANCES IN PROTEIN CHEMISTRY

Artificial intelligence (AI) is stunningly transforming our daily lives through automating tasks and enhancing decision-making. Not only has it already disrupted various industries such as finance and healthcare, but it has also changed many aspects of scientific research, like protein chemistry. An example of this is demonstrated by the awarding of the Nobel Prize in Chemistry 2024 to scientists David Baker, Demis Hassabis, and John Jumper. Their pioneering work in cracking the code for predicting 3D protein structures helps scientists design entirely novel proteins with previously unseen functions through the development of AI technology and computing algorithms.

Most recently, Science, a peer-reviewed academic journal, reported two cases of advancements made in protein chemistry aided by AI technology. A group of researchers from the University of California and the University of Pittsburgh employed a De Novo approach, a method that solely relied on AI to design novel proteins as catalysts for chemical reactions from scratch. With further input from experienced chemists, two sets of the final products were able to facilitate a highly stereoselective process, which is when one stereoisomer —a 3D arrangement of a molecule—is preferred over another in a chemical reaction.

As a result, they were able to generate cyclopropanes and organic silanes. Protein catalysts are simpler and more stable than traditional enzymes. These processes have the potential to scale up for efficient and environmentally friendly production of cyclopropane and silicon-containing chemicals.

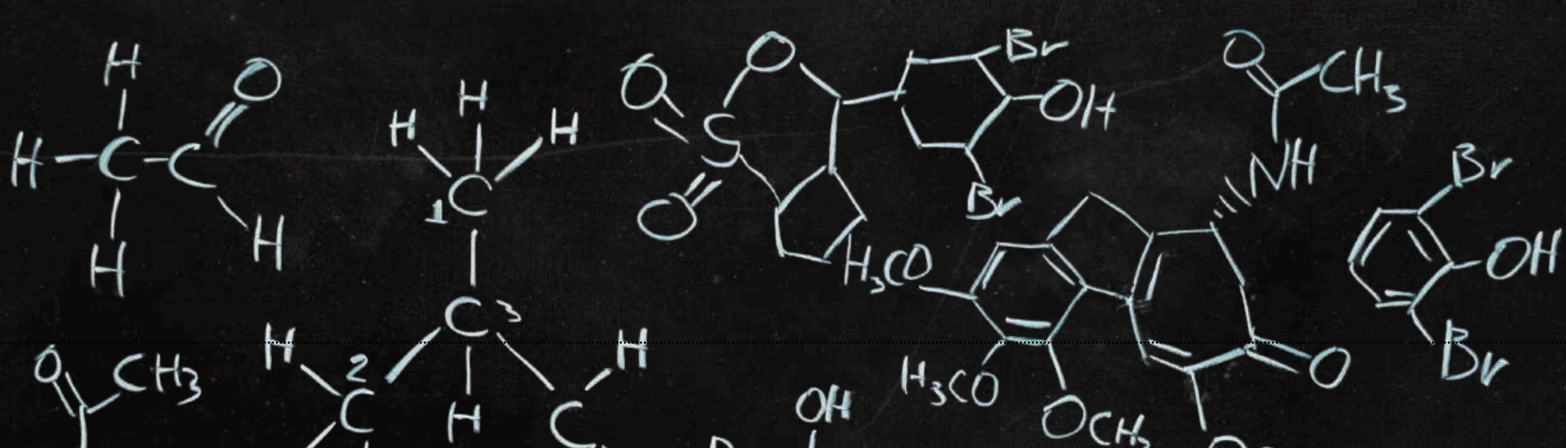
AI is also making strides in the pharmaceutical industry. Scientists in a Massachusetts-based biotech company recently reported that, in a matter of months, AI designed tens of thousands of antibodies (proteins involved in the body's immune system), producing dozens of potential disease-destroying molecules for clinical development. Designing antibodies is laborious with traditional approaches and can take years to select a candidate for development. AI presents a new way to speed up this process for development in both pharmaceuticals and the entire chemical industry.

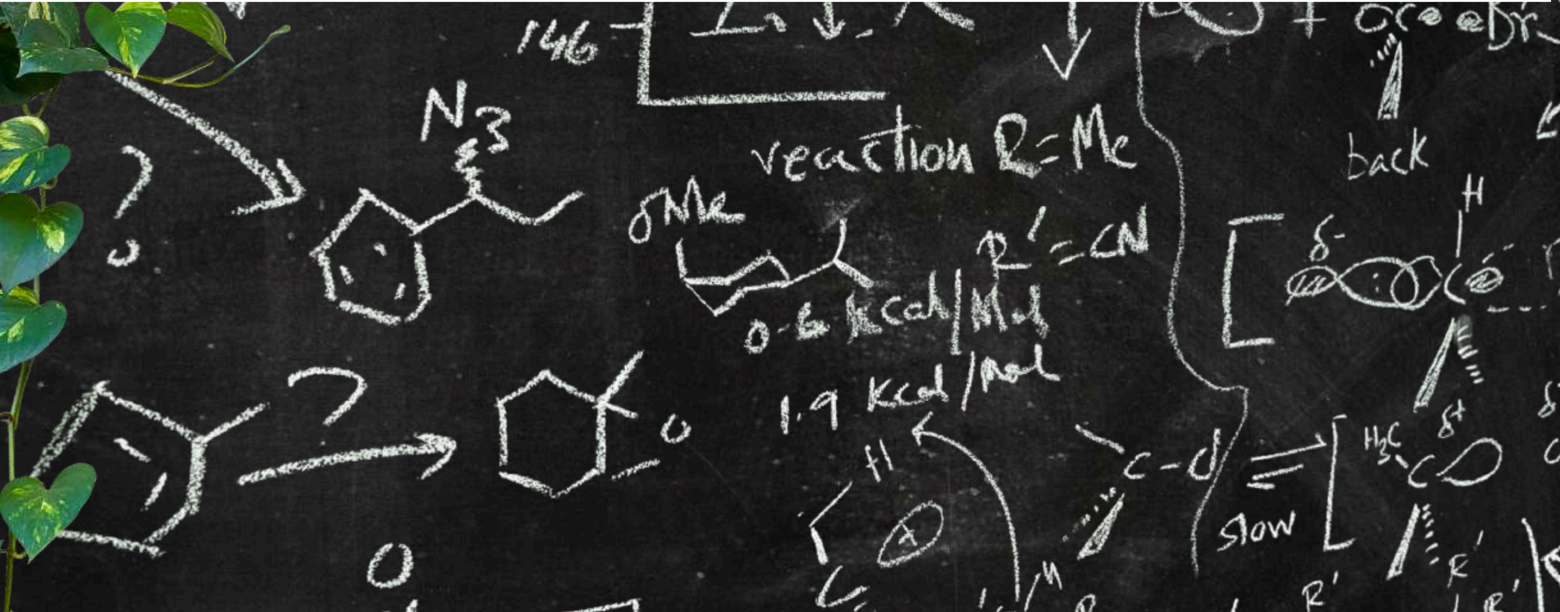
These advancements in protein chemistry demonstrate the enormous potential of AI in enabling new protein creation and in the development of ingenious tools for chemical and biological synthesis.

The Transfermium Wars: A Race To Discover New Elements

The Cold War was a period of fear and uncertainty, and the then-rising tensions between the United States and the Soviet Union would create a sense of competition that would change scientific history forever. Due to the drive to become more technologically advanced, the Cold War's proxy wars became a breeding ground for innovation that fueled not just the infamous nuclear arms race but also a race to expand the periodic table. The resulting series of clashes between two major labs, sparked by the desire to win the most prestige, would come to be known as the Transfermium Wars, with "transfermium" being the term referring to all the elements beyond fermium with atomic numbers greater than 100—these were all discovered during or after this era.

Fermium itself is named after Enrico Fermi, a physicist renowned for his work in nuclear fission and radioactivity. In the 1930s, Fermi and his team tried to find elements beyond uranium, also known as the transuranium elements. These elements were not naturally formed, but rather had to be synthesized in a lab. Specifically, Fermi's team fired neutrons at different elements in hopes that the nucleus of an atom would gain an extra neutron and transform into a new isotope. The trials on heavier elements led to beta decay, where an unstable nucleus of an atom releases an electron or positron, altering the number of neutrons and protons, transforming the element into a different one. When Fermi experimented on uranium, he found that beta decay altered the element, but falsely assumed that a transuranium element had been made. Although Fermi never found actual transuranium elements, his groundbreaking research nonetheless paved the way for later scientists to discover new elements.





In fact, it was Fermi's method that a lab at the University of California, Berkeley employed, combining it with their particle accelerator to find the first transuranium elements in 1940: neptunium and plutonium. Berkeley later discovered elements 95 through 101, numbered according to their atomic number. However, it would not be long after element number 101, mendelevium, when controversy would start to boil. A collaboration between three research institutes led to the announcement of element 102. Researchers at both Berkeley and the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, tried to replicate the results to confirm the discovery, but with each new transfermium element, the nuclei of the atoms became increasingly unstable, shortening the half-lives to mere seconds before the atom decayed into something lighter. Both teams were therefore unable to replicate element 102 with the original method, but each team did manage to recreate it using their own procedures. The issue was that Berkeley and JINR both claimed to have discovered the controversial element, lighting the fuse of controversy that launched the Transfermium Wars. Berkeley won in the battle over naming rights, and now "Nobelium" is element 102's recognized name today. However, conflicts over what to name newly created elements ensued over time.

One of the goals of element discovery is to reach the hypothesized "island of stability," where elements would be more stable and have longer half-lives. The search for this island, coupled with the desire for scientists to put their labs' name on the map, was what drove the race, but the island of stability has not been physically confirmed as of yet. Even without it, however, by the end of this period in world history, the periodic table had gained a whole new row of elements.

Today, there are still efforts to expand the periodic table. Recently, RIKEN in Japan has been leading the efforts to create elements 119 and 120, approaching the mystical island of stability. These efforts are joined by JINR, Berkeley, and other labs around the world. As time passes and technology advances, the list of known elements will continue to get longer as the human race unlocks more of the physical world.

Introduction to Quantum Mechanics and Schrödinger's Thought Experiment

While the mathematics of quantum mechanics is notoriously difficult, it is the philosophical element that is more mentally incomprehensible. In fact, even the greatest scientists in history have argued amongst themselves over their ideas. Albert Einstein famously said, "God doesn't play dice," referring to how the behavior of subatomic particles entirely contradicts the deterministic manner of the universe. Other figures such as Niels Bohr and Werner Heisenberg defended the uncertainty of quantum principles, and supported the Copenhagen Interpretation, a theory about the quantum world. Erwin Schrödinger offered potentially the most valuable explanation of quantum mechanics, the Schrödinger's Cat experiment, a philosophical interpretation of this field.

In this experiment, Schrodinger placed a cat in a closed box with a device that, by coin flip, may or may not release poison. Until the box is opened, the cat is considered both alive and dead – a glaring contradiction. This experiment was intended to explain quantum superposition, where a particle can be in two places at once, until observed in an experiment. In addition, elementary particles like electrons also exhibit wave-particle duality, experiencing characteristics of both a particle and a wave function. This phenomenon is postulated by Louis de Broglie, a major French scientist, who made numerous contributions to quantum mechanics.

The application of these properties in space describes the motion of a particle. Niels Bohr suggested that the wave function can be used to interpret a particle's probability of being at a certain point in space and time. This interpretation is called normalization, and it is foundational to understanding quantum mechanics.

The equation for it is: $$\int |\Psi(x,t)|^2 \, dx = 1$$

As confusing as it looks, this equation expresses an extremely simple idea: (x,t) represents a solution in real space. Quantum mechanics can only tell you the probability that a particular result will occur, not what will occur; a whole array of possibilities can happen. The sum of all of these possibilities, of course, has to equal one, which leads to the equation.

Quantum superposition explains why we can only find this probability. A particle can be in two different places at once, and only when observed do we know where it is. An electron can be in one orbital and another at the same time, just as the cat could theoretically be alive and dead. While this is difficult to comprehend, when Schrödinger's equation is used like Newton's law to determine position for all future time, the equation is accurate. Even in a world that is predictable, at the fundamental level of everything lies a beautiful, elegant level of uncertainty.

LANGUAGE REVIVAL: FROM SPEECH TO SCRIBE

516 LANGUAGES HAVE BEEN CLASSIFIED AS NEARLY EXTINCT WITHIN THE PAST DECADE. AS MORE PEOPLE ARE CONDENSED INTO CITIES, LANGUAGES BECOME MORE ASSIMILATED; OLD LANGUAGES ARE LOST, WHILE NEW, COMBINED DIALECTS ARE FORMED. LANGUAGE DEATH HAS OCCURRED AT AN ACCELERATED RATE – YET REVITALIZATION EFFORTS HAVE NEVER BEEN MORE ORGANIZED AND SUCCESSFUL.

The basic revitalization of a language takes years. To fully revive a language takes decades. The only successful revival of a language has been Hebrew – now, widely spoken and written with thousands of native speakers. Accomplished through sheer will and determination along with creation of language institutions, it has been dubbed "the most dramatic revival" in modern history. But, why did this succeed, while others failed?

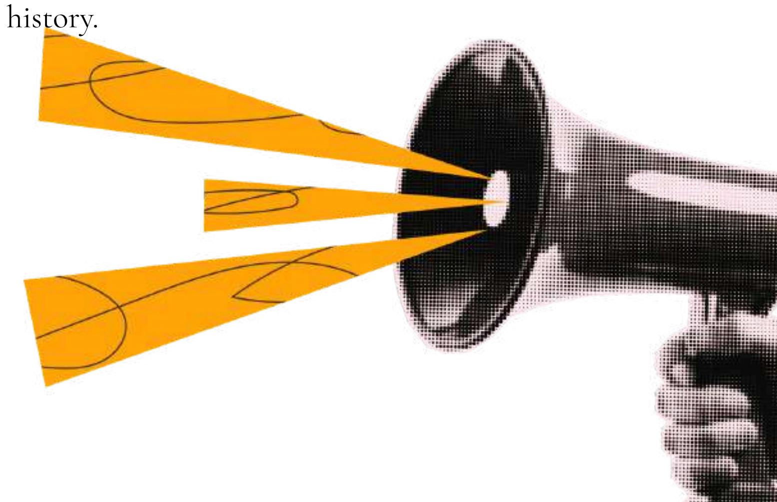
During a person's childhood, there is a critical period when the brain can most effectively create neuro-linguistic connections. All language learning starts in the left hemisphere. It contains two important areas: Broca's area, which controls the contractions and motor functions required to produce words, and Wernicke's area, which controls the comprehension and understanding of written and spoken language— the connection of meanings to words. These are the building blocks of language acquisition, which the right hemisphere uses. The right hemisphere is involved in the tone, voice, phrasing, and emotion conveyed through speaking. To revive a language, successful efforts must appeal to these parts of the brain.

There are many ways to revive a language. The best way to do so is to expose it to the general public. One of the most recent language revitalizations - that of Livonian, a language in Latvia declared extinct in 2013 - was facilitated by a heritage speaker couple and their creation of a Livonian children's book in 2020. The book has both a Livonian and Latvian version, allowing for all Latvian children to attempt to understand a language they have never heard. Considered the only surviving native speaker of Livonian in the world, their child was only exposed to Livonian during their first and second years. As of now, there are more than 300 speakers of Livonian in Latvia.

Some languages never truly die, but rather shift from their roots into dialects. The most well-known is Latin, shifting into the prototypes of the modern-day romance languages. A few language revivals have employed this strategy of language adaptation. Wôpanâak, the language of the native people living in inner Massachusetts and eastern Rhode Island, was revitalized in 1993 with the foundation of the Wôpanâak Language Reclamation Project led by Jessie Little Doe Baird. It consisted of the creation of a new dialect, filling in missing Wôpanâak rules and words with loan words from other related languages.

Manx, the heritage language of people living on the Isle of Man, was considered "extinct" in 1974 when the last native speaker died. Due to the abundance of written texts and a full translation of the Bible, their revitalization efforts were considered much easier than others. Formed in 1992, The Manx Language Unit was one of the main contributors to the language's survival, and through its revitalization efforts, formed an elementary school teaching exclusively Manx, as well as a museum showcasing its history.

Currently, about 43% of the world's languages are considered endangered. Take, for example, the Sámi languages, with the Ter Sámi dialect only having two alive native speakers. However, based on previous revitalization efforts and the growth of linguistic technology, the future looks bright for endangered languages coming back from the dead.



The Future of Aviation Through SAFs

Hundreds of thousands of flights take off each day, transporting millions of people to their destinations. Each trip, however, has a price tag—a mark on our planet that further aggravates climate change. The major role that the aviation industry has had in contributing to global carbon emissions has been a heavily discussed issue, even during the initial rise of commercial aircraft in the early 1900s. Only recently, in the 21st century, however, has it been addressed with a viable solution—sustainable aviation fuel.

First tested for commercial usage in 2011, sustainable aviation fuel (SAF) has been a rising alternative fuel for the global industry. SAFs are separated into two main classifications: bio-SAF and electronic SAF (e-SAF), both of which are produced by utilizing carbon capture methods that are far more environmentally friendly than traditional jet fuel production methods. Bio-SAF is sourced from biological renewables, like plants and waste products, while e-SAF is sourced from electricity.

SAF works by utilizing carbon directly out of the carbon cycle, therefore producing a net-zero carbon output. When bio-SAF, for example, is made through plants that take in carbon through photosynthesis, no additional carbon is released into the atmosphere. E-SAF, on the other hand, takes carbon from the atmosphere and turns it into fuel.

Today, the increase in research, investment, and public interest in SAFs is out of necessity, as global warming has forced researchers to focus on developing cleaner and more sustainable transportation. The issue lies in the immense carbon output of the widely used jet fuel in aviation. A 2022 report from the International Air Transport Association found that 3.16 kilograms of carbon dioxide are released into the atmosphere from the combustion of one kilogram of jet fuel. With worldwide carbon dioxide emissions rising, however, further exploration into alternatives is crucial to combat the damage pollution has on the environment.

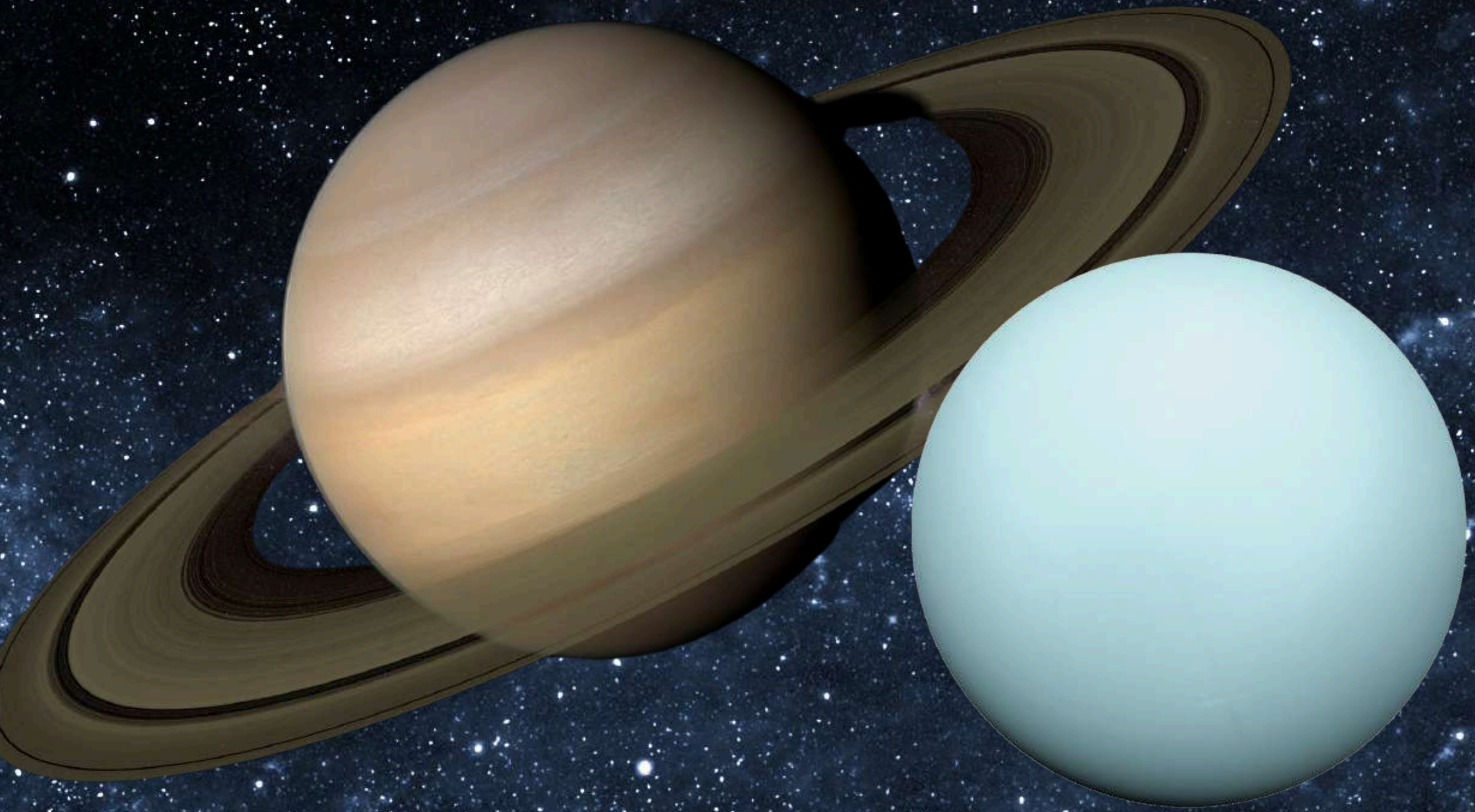
The simplicity of SAF-replacement for jet fuel is key, with the structure of aircraft not needing to be modified to swap them out. Thus, emissions can still be reduced without the hassle of the technicalities of aircraft adjustment.

Other concerns about SAF usage, like feasibility, can arise while discussing widespread SAF implementation. Despite this, nations worldwide have made an effort to set goals for the adoption of SAF in aircraft within the next decade. While it may not be tomorrow, it is certainly possible that your future flights could be carbon-neutral.

UNCOVERING NEPTUNE'S AURORAS

While the Northern Lights (or Aurora Borealis) are best spotted in the auroral zone between 60 and 75 degrees latitude, Boston, at a latitude of 43 degrees, was graced with this nighttime light show in April.

Auroras come from magnetic storms triggered by solar activity like solar flares—essentially explosions on the sun's surface—and coronal mass ejections—plasma gas bubbles ejected from the sun. Earth, Mercury, Jupiter, Saturn, Uranus, and Neptune have magnetic fields that help protect the planets from solar particles. These fields are a series of curves originating at one pole and ending at the other; solar particles such as protons and electrons flow through these magnetic field lines and funnel into the planet at its magnetic poles. As solar particles encounter the magnetic field protecting the planet, the field is stretched and dragged. These particles are launched toward the the planet when the field snaps back into place. As they come in contact with atmospheric gases, they transfer energy, which is released as flashes of light known as photons. As millions of photons are emitted simultaneously, the aurora becomes visible



TOP LEFT: SATURN
BOTTOM RIGHT: URANUS

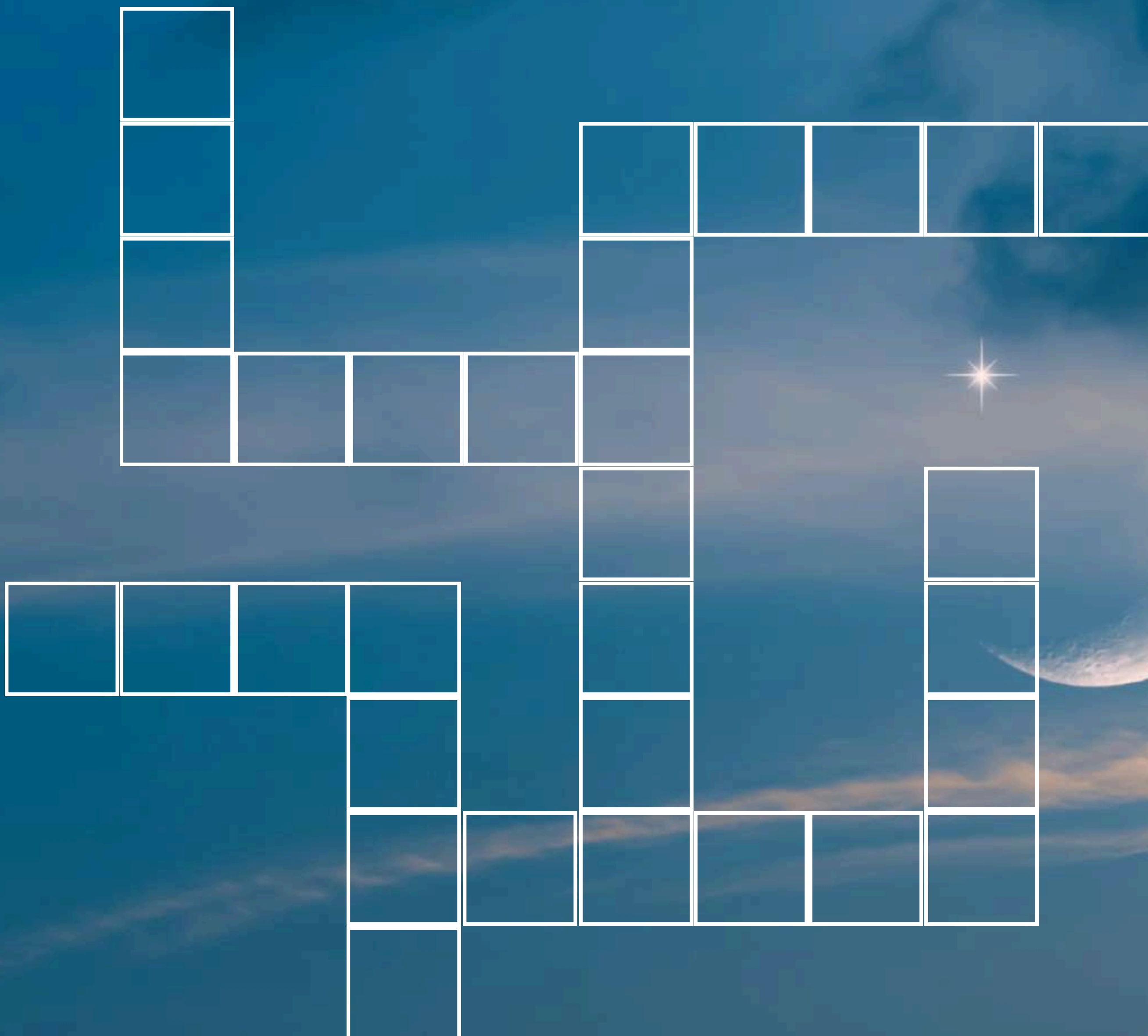
As Earth isn't the only planet with a magnetic field, it isn't the only planet where auroras occur. Scientists have successfully photographed auroras on Jupiter, Saturn, and Uranus. Photographs of Neptune's auroras, however, have been a long time coming. The Voyager 2 spacecraft, launched in 1977, is the only spacecraft to have visited Uranus and Neptune. It became the second spacecraft to enter interstellar space after its predecessor, Voyager 1. In 1989, Voyager 2 detected hints of auroral activity during a flyby of Neptune.

More than 30 years later, thanks to NASA's James Webb Space Telescope, Neptune's aurora has finally been photographed, with photos released in March 2025. The Webb telescope was able to capture these photographs due to its Near Infrared sensitivity Camera (NIRCam). This camera is capable of detecting light from the earliest stars, as well as galaxies in the process of forming. It is also equipped with coronagraphs, instruments that allow astronomers to take pictures of faint objects surrounded by bright objects. This works by blocking the brighter object's light to make it possible to see the dimmer object. This technology has previously been used to determine the characteristics of planets orbiting nearby stars.

The Webb telescope, in addition to simply photographing the aurora, also helps astronomers determine better photographing techniques. The Webb, besides an NIRCam, also has a Near Infrared Spectrograph (NIRSpec). A spectrograph disperses light from an object to form a chemical spectrum. Analyzing the spectrum can tell us about a celestial object's temperature, mass, and chemical composition, among other properties. Astronomers can use the obtained spectrum to determine the temperature of Neptune's upper atmosphere, which is how they measured it for the first time since Voyager 2. The temperature had dropped to almost half of what it was in 1989. This may explain why it took so long to photograph an aurora—drastically colder temperatures correlate to drastically fainter auroras. Astronomers also discovered the presence of trihydrogen cations (H_3^+), which are created during Neptune's auroras. This gas was a clear sign of auroral activity on the other gas giants. Auroral activity on Neptune differs from that of other gas giants as it is not confined to the north and south poles, but instead occurs throughout mid-range latitudes. This is due to Neptune's magnetic field being tilted 47 degrees from the planet's rotational axis; since auroras are based on magnetic poles, they appear in the sky far from Neptune's rotational poles.

On Earth, auroras glow in visible light ranges; meanwhile, on planets with hydrogen-based atmospheres like the gas giants, auroras tend to glow in the infrared or ultraviolet range, hence why Webb's infrared capabilities were pivotal in producing these images. Now, after 30+ years in the making, Neptune's aurora has been photographed and confined, and the Webb Telescope is turning to other tasks. Astronomers hope to utilize these photographs to study Neptune over its complete solar cycle of 11 Earth years to provide further insight into the origin of the planet's magnetic field and why it is so strangely tilted from its rotational axis.

PUZZLE



Across

2. Small Star
3. Absorption of Light
4. Type of Friction
6. Fish Parasite

Down

1. Fungus
3. American Keystone Species
5. Electrcity/Power
7. pH below 7

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