CATA PULTA

WINTER 2025

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EDITORS' NOTE

WELCOME ONE AND ALL TO THE WINTER 2025 ISSUE OF CATAPULTA!

AS THE WINTERY SEASON IS UPON US, SIT DOWN WITH A WARM BEVERAGE TO ENJOY THE ONE AND ONLY LATIN SCHOOL SCIENCE MAGAZINE. AMIDST THE FERVOR OF NEW AI MODELS, VIRAL INFECTIONS IN BIRDS, AND POLICIES THAT COULD CHANGE THE LANDSCAPE OF HEALTH, OUR EDITORS HAVE BEEN WORKING HARD, WITH 310 ABUZZ AFTER SCHOOL IN BETWEEN THE ILL-TIMED SNOW DAYS THAT NEVER SEEM TO FALL ON A WEEKDAY...

UNLIKE TIKTOK, CATAPULTA IS HERE TO STAY, PROVIDING YOU WITH INTERESTING SCIENTIFIC CONCEPTS AND PHENOMENA WRITTEN BY MEMBERS OF OUR VERY OWN COMMUNITY.

FLIP TO PAGE 7 TO LEARN ABOUT HOW THE BRAIN AND GUT ARE CONNECTED IN HUMAN DEVELOPMENT. INTERESTED IN THE RELICS OF RUINED CITIES? EXPLORE THE DECIPHERING OF HERCULANEUM SCROLLS ON PAGE 8! IF BIOLOGY IS YOUR CUP OF TEA, YOU'LL FIND WHAT YOU SEEK IN PAGES 9 THROUGH 14.
STAY CURIOUS, KEEP WARM, AND WE WILL SEE YOU FOR ONE LAST RODEO IN THE SPRING!

SINCERELY,

Emily and William

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

MR. GALEGO
MRS. BATEMAN

WINTER ISSUE STAFF

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COSMOLOGY

Have you ever wondered how the universe was really created? Through cosmology—the study of the history and evolution of the universe — there exists two explanations for how the universe was created: religious and scientific reasoning. Religious reasoning is based on creationism, which suggests that God or a higher power created the universe. Scientific reasoning tries to explain how the universe was created using science and physical evidence.

Historically, there have been two scientific explanations for the origins of the universe: the Steady State theory and the Big Bang.

The Steady State theory states that the universe has always been the same—no big eruptions, no changes in evolution. It was always just "there," making a couple new atoms at a time in the midst of emptiness. In contrast, the Big Bang suggests that the universe exploded from a "cosmic egg." This singularity point revealed simple forms of matter such as protons and electrons, which then fused to become the first atomic nuclei of mainly hydrogen and helium. For decades, scientists have debated these theories until evidence from the 1992 Cosmic Background Explorer (COBE) proved the measurements from the Big Bang theory true. In 2013, the Atacama Large Millimeter/submillimeter Array (ALMA) radio telescope found younger stars and galaxies light years away, further confirming the Big Bang theory as the standard model for cosmology.

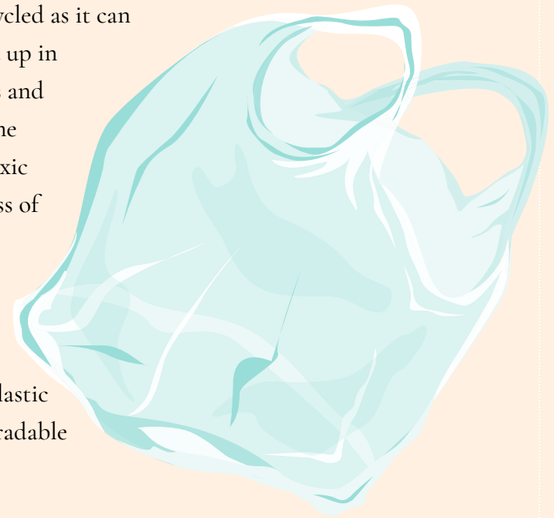
In 2021, NASA launched a new telescope into space: the James Webb Space Telescope. While it was sent to confirm our current findings, astounding evidence was sent back instead. It revealed that our galaxy might be expanding faster than we expected, which could refute the Hubble constant — the measurement of how quickly different galaxies are expanding away. These implications could throw off our whole understanding of the universe. Today, scientists are faced with a choice: make adjustments to the existing standard model or, the more daunting option: throw out everything we've found and start again.

Biodegradable Plastics

Currently, the world produces over 430 metric tons of plastic annually – more than the total weight of all the humans on Earth.

Only 9% of this waste is recycled, however. Reducing the production of plastics and other types of waste has remained at the forefront of the global effort to combat steadily increasing global warming.

In recent years, there has been a push to increase the usage of biodegradable plastics to curb the environmental impacts of regular plastics such as polyethylene. Biodegradable plastics such as polyhydroxyalkanoates (PHAs) and polylactic acid (PLAs) have become available in products such as packing peanuts and coffee cups, seeming to offer consumers a way to lower their carbon footprint. In reality, these alternatives don't have much of an effect. Though these currently available plastic alternatives contain natural materials like vegetable oil, food waste, and sawdust, they are still manufactured in the same way as conventional fossil-based plastics and, therefore, produce carbon emissions. Furthermore, many biodegradable plastics only break down under certain conditions. For example, polylactic acid only degrades in industrial compost settings; it cannot be conventionally recycled as it can contaminate other plastics in the bin. When bioplastics do end up in recycling bins, they often make their way eventually into rivers and oceans, as most landfills don't do industrial composting. In some cases, these plastics even end up being incinerated, releasing toxic chemicals and greenhouse gases into the environment regardless of how "environmentally-friendly" they may be advertised as.

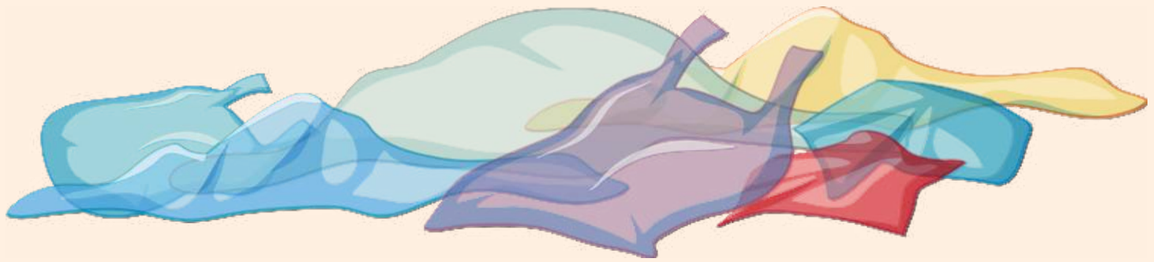


While this industry has not made sufficient progress yet, many are working towards better replacements. Researchers at the University of Wisconsin are developing a new biodegradable plastic based on corn cobs. This plastic would be more readily biodegradable and may be a suitable replacement for standard polyethylene.

At the University of California, Davis, another biodegradable alternative based on cheese waste byproducts is being developed. While these advances are working towards tackling the issue of creating degradable plastic, the cost remains a challenge in bringing such products to market. At Virginia Tech, researchers are working on a first-of-its-kind project to develop an affordable molecular bio-processing system to produce biodegradable plastics from food waste. This system will use microorganisms to convert food waste to fats, which will then be processed into bioplastics. As this process is similar to fermentation, it would ensure that the produced materials are easily compostable.

Even though bioplastics are still three to four times more expensive to produce than traditional plastics, the industry is expected to hit a value of $57 billion by 2032

This projection is primarily due to the pledges of various nations and large companies to shift away from single-use plastics. For instance, Starbucks announced in January 2024 its goal to make 100% of its cups compostable, recyclable, or reusable by 2030. Additionally, Coca-Cola, the current most significant known contributor to branded global plastic waste, signed the U.S. Plastics Pact in 2021, pledging to use 100% biodegradable, recyclable, and compostable packaging materials by 2030. These steps show signs of a promising future for biodegradable plastics and the environment.

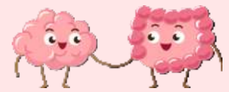


The Microbiota-Gut-Brain Axis

"All disease begins in the gut." – Hippocrates of Kos (c. 460–370 BCE)

These were the words hailed by Hippocrates — the "father of modern medicine" — 2,400 years ago. Regardless of the statement's dubious truth, Hippocrates's wisdom still rings true in the microbiota-gut-brain axis theory, where small disruptions in the symbiosis of gut bacteria and their hosts can negatively affect human health.

What is the Microbiota-Gut-Brain Axis?



20,000 genes. 3 billion base pairs. Numbers cannot fully depict the scope of the human genome: a centuries-long mystery only uncovered after over a decade of research and the efforts of scientists internationally in the Human Genome Project.

Now, compare that to the gut microbiota. Despite comprising a small section of the human body, the gut is inhabited by some of the body's most diverse microbial communities: bacteria, fungi, viruses, and archaea. Scientists estimate that the gut microbiota contains 150 times more genes than the human genome. This can be attributed to the myriad of tiny microbe species in the gut.

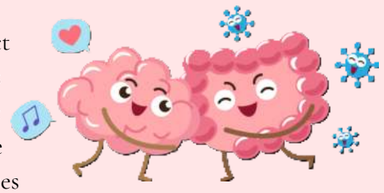
So what is the microbiota-gut-brain axis? It refers to the bilateral biochemical signaling between the gut microbiota and the human central nervous system. With the stresses of everyday life and constant pollutants and toxins from medications or food, the main factor that impacts the gut is our diet. This is problematic because gut microbiota contribute to forming the blood-brain barrier and brain cells themselves.

The microbiota-gut-brain axis serves as one of the most interesting regulators of the human body. For instance, small changes in the gut microbiota are associated with the development of neurodegenerative disorders such as anxiety, depression, and autism, and play a role in the development of preclinical Alzheimer's disease and Parkinson's disease.

Microbiota-Gut-Brain Axis in Research

During the past few years, the microbiota-gut-brain axis has become a hot area of research, and for good reason. For scientists, the axis's role as a key target in preventing the progression of neurodegenerative diseases emerges as an exciting area of research.

Additionally, the microbiota-gut-brain axis works as a critical regulator in glial functions, which helps form the blood-brain barrier and that support and connect neurons. Microglial activation and neuroinflammation are typical characteristics of neurodegenerative diseases. With new developments, only time will tell where this research leads. By understanding how the gut "talks" with the brain, we hope to gain insight into better treatment and prevention of neurodegenerative diseases through improving our diet. After all, "you are what you eat!"



A BREAKTHROUGH DISCOVERY: DECIPHERING HERCULANEUM SCROLLS USING AI

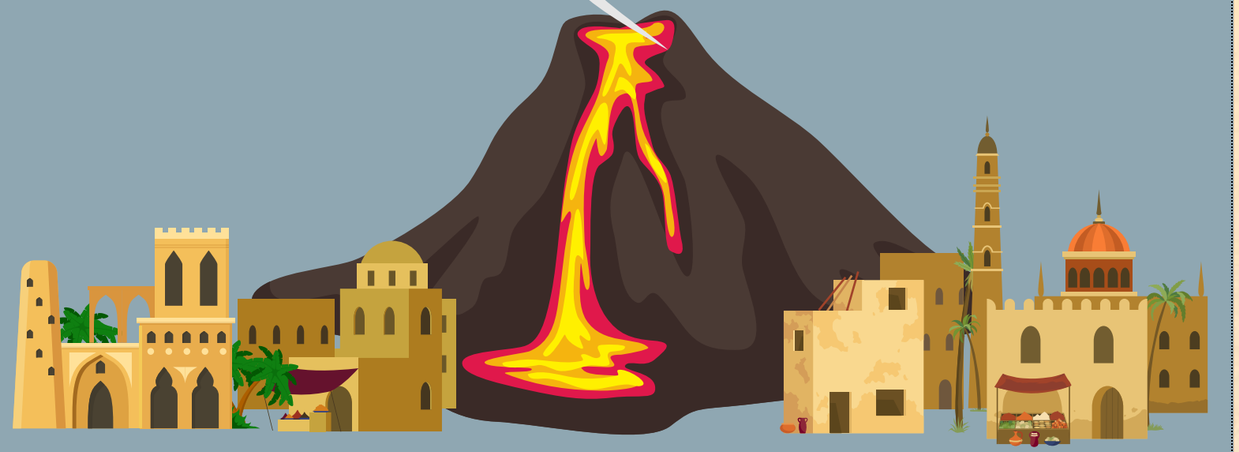
In 79 CE, after being dormant for centuries, Mount Vesuvius erupted, subjecting the city of Pompeii and surrounding Roman towns to a large cloud of toxic gas and volcanic ash, and eventually the flow of lava. While this disastrous event claimed thousands of lives, the remains of people and buildings preserved by hardened rock would contribute to the study of classical history; however, not everything has been fully explored.

In Hernaculeum, a town buried by the eruption, a building believed to have been owned by Julius Caesar's father-in-law held a collection of around 1,100 papyrus scrolls. These scrolls were carbonized due to the eruption, preventing archaeologists for hundreds of years from discovering the hints of ancient Roman history they could hold. The potential for these scrolls to contribute to modern knowledge of classical antiquity is what led researchers from the University of Kentucky to create the Vesuvius Challenge in early 2023, where participants are tasked with uncovering words on the papyrus for a monetary prize.

The first milestone was Casey Handmer's discovery of substantial evidence of ink on the scrolls, which he called "crackle patterns." This led to the first word being deciphered in August of 2023 by Luke Farritor, a computer science student at the University of Nebraska. Farritor used a method called "virtual unwrapping" which was created by Brian Seales — a cofounder of the Vesuvius Challenge — and has been in development for almost 20 years. This method entails using CT scan technology to take scans of each scroll, and the curved layers are then flattened digitally. Using Handmer's crackle patterns, Farritor developed a machine learning algorithm and fed it the scans. Miraculously, the algorithm identified ten letters on the papyrus. The majority of them formed one word: "πορφυρας" or "porphyras," which is Greek for purple.

Later in the year, Freie University Berlin student Youssef Nader independently found the same word, and the two split the "First Letters" prize, with Nader getting $10,000 and Farritor getting $40,000. These findings shocked the archaeological world, and many researchers are hopeful that this new technology will help them study a world previously unknown to modern society.

There is still a long way to go, with the Vesuvius Challenge's $700,000 grand prize still unclaimed, but this achievement sparks a promising future for deciphering the Hernaculeum Scrolls and uncovering the secrets of classical civilization.



SOFT CELLS:

REIMAGINING HUMANITY'S GRASP OF THE 3 DIMENSIONS

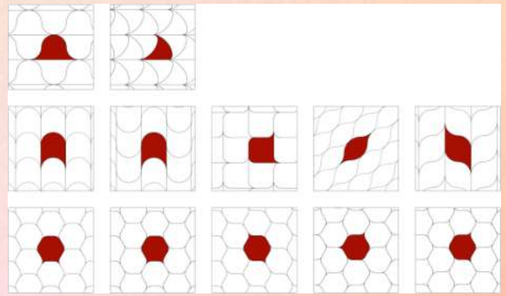
Tessellations, the specific arrangement of shapes so that they fill a surface with no overlaps or gaps, have intrigued humans since ancient Mesopotamia. Even though it is prominently featured in architecture and artwork throughout the ages, there seems to be a shortage of thinkers who have seriously pondered the various nuances revolving around tinkering with tiles. What is the least amount of vertices a shape could have and yet still tile a surface?

What is the least amount of vertices a shape could have and yet still tile a surface?

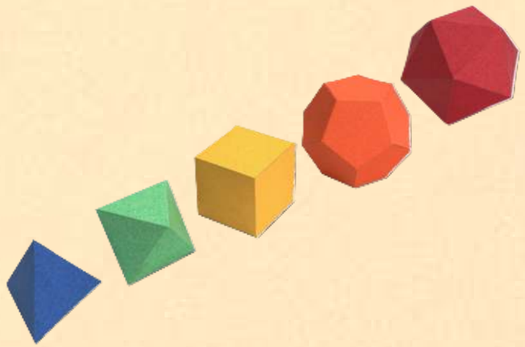
This thought has led a group of Hungarian mathematicians to uncover an entirely new set of shapes, sparking a discussion that can potentially revolutionize our perception of space-filling shapes and how they connect with the natural world.

"Soft cells," or shapes that can fill a space with no overlaps or gaps, serve to answer the question that has plagued Domokos, a Hungarian mathematician. The first step to finding how they work in three dimensions was to take a step back and observe them in the two dimensional world. Utilizing curves and observing the rules governing mosaics, Domokos found that it was impossible for the average number of vertices (sharp corners) in a tile to be lower than two. Using this observation, he concluded that a monohedral tessellation, or a tessellation made up of monotiles (which fill the plane with copies of itself), couldn't have fewer than two vertices either. In collaboration with Akos G. Horvath, they devised an algorithm that could successfully deform tilings of regular polygons like triangles, squares, or hexagons into monohedral tessellations made of two-vertex tiles.

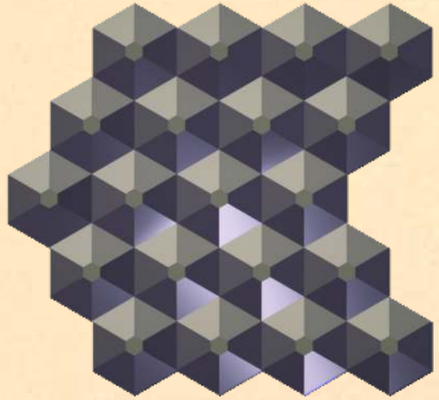
The spirals of the nautilus shell are an example of soft cells found in nature.



Source: Nature



Plato's five "Platonic Solids"



3D Tesselations

Plato

Aristotle

Then came the challenge: applying this newly discovered class of shapes to the three-dimensional space. 3D tessellations have been of interest since ancient Greece, when mathematicians such as Plato and Aristotle began imagining solids. Plato famously came up with the five "Platonic Solids" and centered his entire model of the universe around it. He was incorrect in his assumption that these five solids are able to form tessellations as monotiles, as only the cube meets the criteria. Later, in the 19th century, Russian mathematicians were able to catalog a new set of five shapes named "Parallelohedra" that also fit the standard for monotiles. However, all these shapes consisted of flat surfaces, with even the occasional proposed shapes bounded by curves having obvious sharp corners or vertices.

Eventually, Domokos and his team managed to identify a solid with just two corners, but soon realized that applying the assumption of the minimum number of vertices from 2D to 3D was completely false. He soon found an example that proved his point; it was possible to fill a space with solids that had no corners. "The shape itself was the proof," said Regos, a colleague of Domokos. This discovery sparked immense interest within the scientific community. Researchers wanted to know the conditions in which such a class of shapes could be made, just like the algorithm Domokos created earlier.

Regos attempted to convert the seemingly random warping of soft cells into mathematical language. She noticed that every polyhedron has a dual, that is, another polyhedron with corresponding faces and edges. If one were to find a path along the "mirrored" polyhedron that goes through all the vertices exactly once, it would also be possible to distort that shape into a soft cell. The phenomenon of locating a path that visits each of the corners on a dual polyhedron is called a Hamiltonian circuit. Horvath plans to use the established conditions to devise an algorithm to prove that there is a corresponding set of soft cells to the infinite category of polyhedrons.

As complicated as a soft cell may be, it may be a surprise that soft cells exist all over the world, from zebra stripes to river estuaries to heads to wheat to ammonite shell chambers.

As complicated as a soft cell may be, it may be a surprise that soft cells exist all over the world, from zebra stripes to river estuaries to heads to wheat to ammonite shell chambers. This formal classification of shapes, which humans have used unknowingly for centuries, may also serve a practical use. On top of minimizing sharp edges, a reliable understanding of "soft matter" for biologists would allow them to accurately model cellular material by utilizing nature's disdain for straight edges and corners. As for where soft cells may directly land in the scientific landscape, the answer only lies in the future.

Immune Warriors: CAR T Cells

Every single person has an immune system. Used for combating diseases and illnesses, these immune systems are crucial, helping maintain health and prevent illnesses. But how do our immune systems eliminate these diseases?

One of the most powerful forces in our body is the T cell. Constantly monitoring the body for abnormalities, these cells are good at finding and fighting diseases. The T cell has small receptors (simply named T cell receptors) used to detect unknown and potentially harmful substances or pathogens. After binding to one of those pathogens, it sends a signal through a stimulatory molecule. To work, the T cell requires another molecule produced by another costimulatory receptor to confirm that the body is actually under attack because any unnecessary activation could harm beneficial cells and lead to autoimmune diseases.

After it receives both signals, the T cell will activate and start producing more T cells. One type of T cell that it produces, called a killer T cell, looks for infected cells with its T cell receptors. Once found, it will force the cell to self-destruct and undergo cell death (apoptosis). Following the clearance of all of the antigens, the T cell will deactivate and remain dormant in your system for years, activating again when it spots the same pathogen. That ensures immunity against the pathogen.

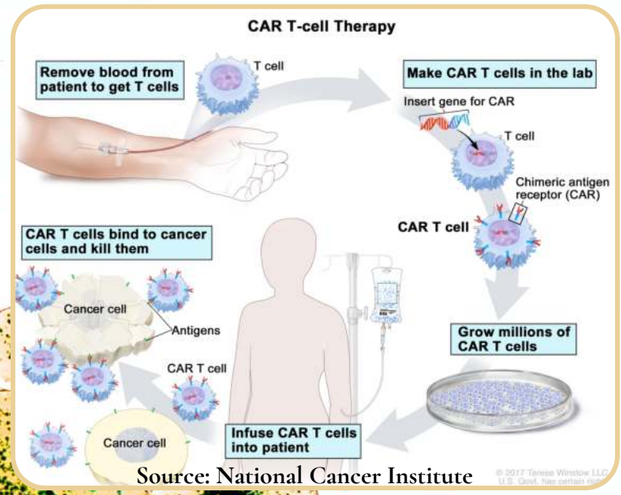
One of the biggest downsides to T cells is that T cell receptors can only detect antigens if they are held by a special receptor known as an MHC molecule, and so, it cannot recognize cancer-specific antigens not displayed on that receptor.

A therapy called "CAR (chimeric antigen receptor) T cells" resolves that issue. The treatment involves injecting DNA, usually through a deactivated virus, into a T cell. This DNA produces proteins that are a mix of T cell and B cell receptors—B cell receptors do not require the presentation of antigens on MHC—that are able to detect surface cancer proteins and act. This is why it's called chimeric, after the chimera in Greek mythology. The concept sounds simple, yet it is effective. As of 2023, there were 6 CAR T cell therapies for blood cancers, treating afflictions such as lymphoma or leukemia.

However, some issues arise with treatments involving CAR T cells. First, the whole treatment is incredibly expensive. Each type of CAR T cell is individualized, meaning that it has to be tailor-made for each patient using their own cells. That prevents massive scale-up of the treatment. Second, the logistics for sending out a personalized prescription are horrible. Sending an incorrect treatment would be horrible for the patient, and thus, the process of delivering and creating it takes time.

Lastly, research involving CAR T cells is incredibly slow: only a few research labs can make the therapies, limiting studies to small groups of participants at local hospitals. For those three reasons, the overall process takes around 1 month, during which a patient's cancer could worsen.

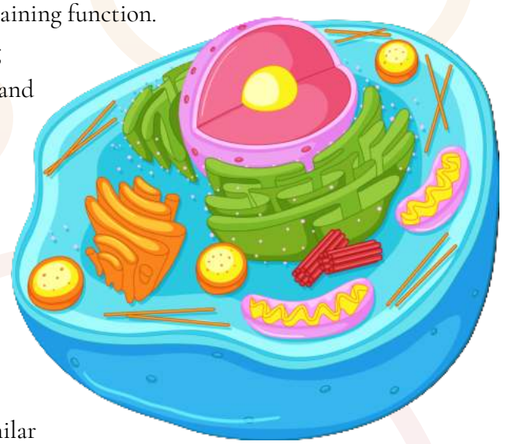
T cells are vital for immunity, and CAR T cell therapy offers a breakthrough in fighting cancer. However, its high cost hinders accessibility, emphasizing the need for cheaper, more convenient, and more effective therapies. Finding such therapies will, therefore, put us one step closer to the goal of eradicating cancer.



Source: National Cancer Institute

Cell Revival

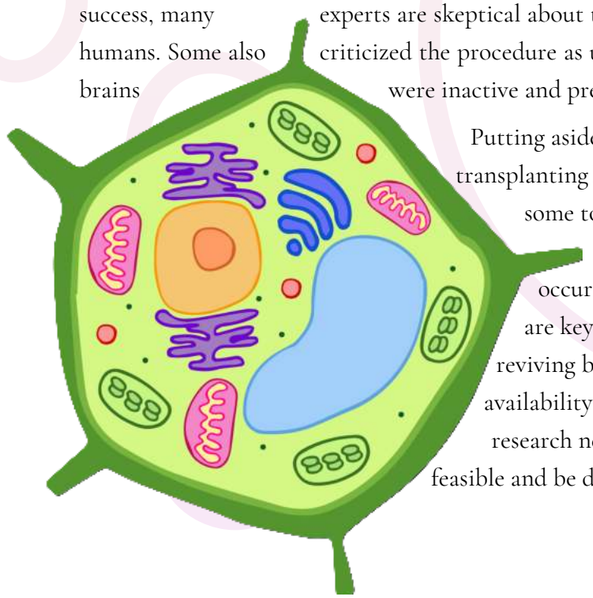
With cell revival, coming back from the dead may be less outrageous than previously thought. In 2022, scientists at Yale University attempted to bring the bodies of pigs back to life via OrganEx, a system that uses the circulation of nutrient-rich fluid to restore cell function. Although the pigs did not regain consciousness, cellular activity indicated that certain organs were indeed regaining function.



OrganEx could have several applications, including extending how long organs are available for transplantation after death and helping avert heart or brain damage after heart attacks or strokes.

Prior to this experiment, scientists completed a similar test using technology called BrainEx, which allowed them to run the liquid through the brains of dead pigs. Incredibly, some brain cells recovered activity. Nenad Sestan, who led both studies, explained their hypothesis: if they could restore certain cellular functions in regions of the dead brain most susceptible to ischemia, a lack of blood supply, something similar could be achieved in other vital, transplantable organs. This led to the creation of OrganEx.

One of the researchers, Zvonimir Vrselja, claimed that dead organs treated with OrganEx were nearly indistinguishable from healthy organs when viewed under a microscope. Despite the experiment's relative success, many experts are skeptical about the technology as the equipment may not be practical for humans. Some also criticized the procedure as unethical, even with nerve blockers that ensured the pigs' brains were inactive and prevented pain from being felt.



Putting aside the skepticism, this technology is a definite start toward transplanting human organs after death. The experiment is also causing some to reconsider the difference between a dead or alive brain, since the experiment made it clear that death does not occur at a certain moment. OrganEx and BrainEx technologies are key breakthroughs, and while BrainEx has shown promise in reviving brain cells, OrganEx is an even greater advancement in the availability of organs for transplantation after death. However, more research needs to be done before cell revival technology can become feasible and be deemed ethical for complete usage in animals, let alone for bringing humans back from the dead.

SCIENCE OF SLEEPING

Sleep is important. We've all heard it before. Health officials recommend at least 8 hours of sleep each night for teenagers. But did you know that the quality of your sleep is actually more important than the quantity of your sleep? Poor sleep quality can explain why you can still feel tired even after a long sleeping session. To improve the quality of sleep, you must learn the science of sleeping. Sleeping is composed of 4 stages: Awake, REM, Light, and Deep.

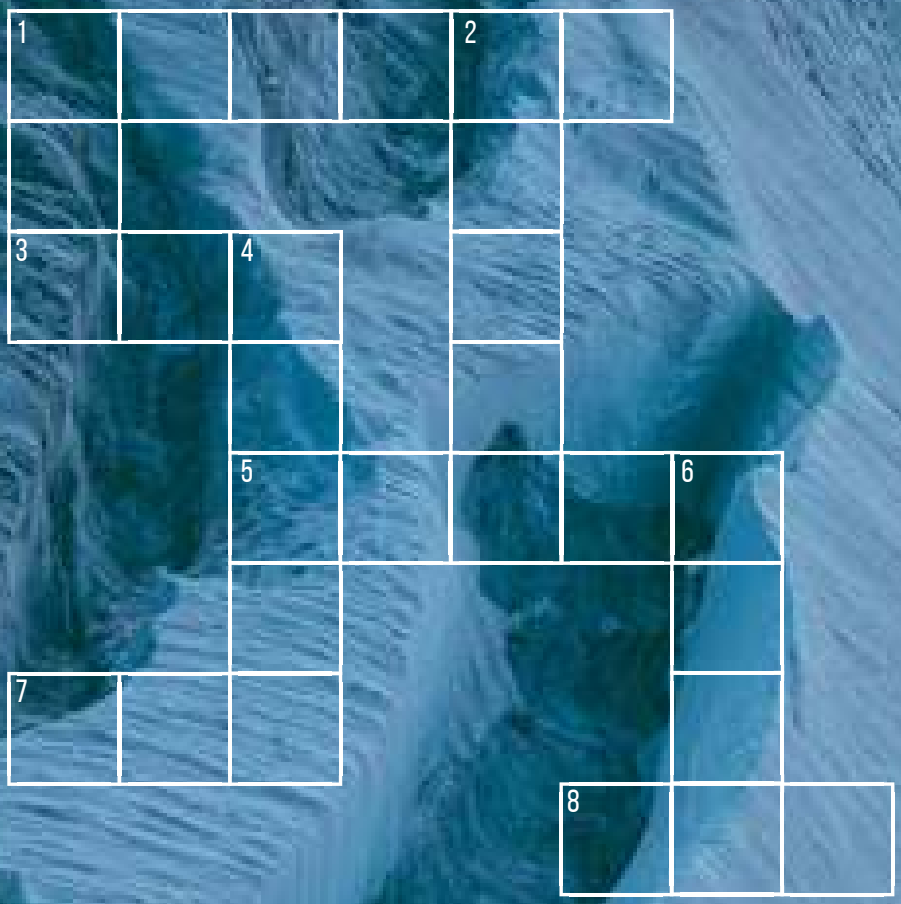
When you first fall asleep, the first phase you enter is the Awake Phase, which typically lasts 1-7 minutes. At this stage, your body begins to relax, but can still be easily disturbed. The next stage is the Light Sleep Stage, which lasts ten to twenty-five minutes. Your muscles relax and your brain activity slows down. This stage acts as a transition phrase to deeper sleep, and it is vital for consolidating memories. A person spends around fifty percent of their sleep time in the Light stage.

Then, you will enter Deep sleep, which lasts 20 to 40 minutes, though the duration shortens as you continue to sleep. This stage is critical to growing your muscles, tissues, and bone as the body releases growth hormones. It also regulates glucose metabolism, which resupplies and stores ATP in your body. At this stage, your body is most relaxed and most difficult to disturb. Fifteen to twenty percent of your sleep should be deep sleep. Another important stage of your sleep is REM (Rapid Eye Movement) sleep, which typically lasts longer as you continue to sleep. This stage is essential to "cognitive functions like memory, learning, and creativity." Brain activities rise to similar levels to when you are awake, and your eyes move rapidly. REM is also responsible for your vivid dreams. Twenty to twenty-five percent of your sleep should be in the REM stage.

All these stages combined last around 1.5 hours and go through 4-6 cycles in a typical sleep cycle. With that said, during poor quality sleep, you spend most of your time on the Awake and Light stages, which does not significantly improve your recovery. During high quality sleep, you spend forty to fifty percent in Deep Sleep and REM Sleep combined, which, on the other hand, does significantly improve and grow your cognitive and physical health.

There are many ways to increase Deep Sleep and REM Sleep. You can wear a sleep mask if your environment is too bright, wear ear plugs if your environment is too noisy, install blue light filters on your devices, or if you have a smartwatch, wear it to track your sleep stages.

PUZZLE



ACROSS

1. ____ = MC^2.
3. HAS A WAVELENGTH OF 700 NANOMETERS.
5. A SEQUENCE OF REACTIONS IS A REACTION ____.
7. CHILD WITH XY-CHROMOSOMES
8. ABBREVIATION OF "GRAVITATIONAL ENERGY".

DOWN

1. PINNA IS PART OF THE ____?
2. A KIND OF RADIOACTIVE DECAY?
4. DECOMPOSERS HELP WITH THE PROCESS OF ____.
6. AN OCEAN TIDE IN WHICH THE DIFFERENCE BETWEEN THE HIGH AND LOW TIDE IS THE LEAST IS THE ____.

EMAIL CATAPULTASCIENCEBLS@GMAIL.COM TO CHECK YOUR ANSWER!