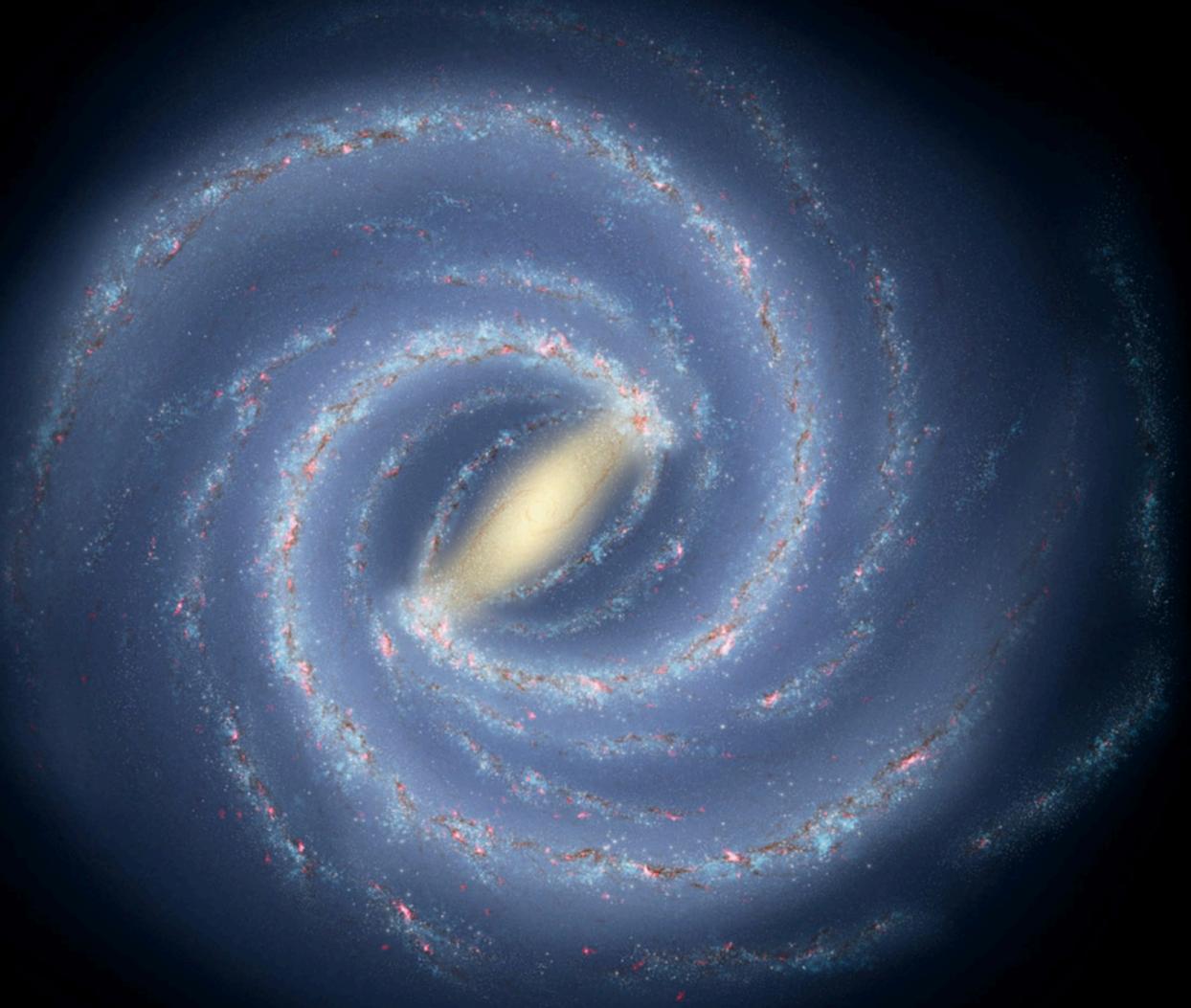


# HBSCIENTIST

## 2024-25



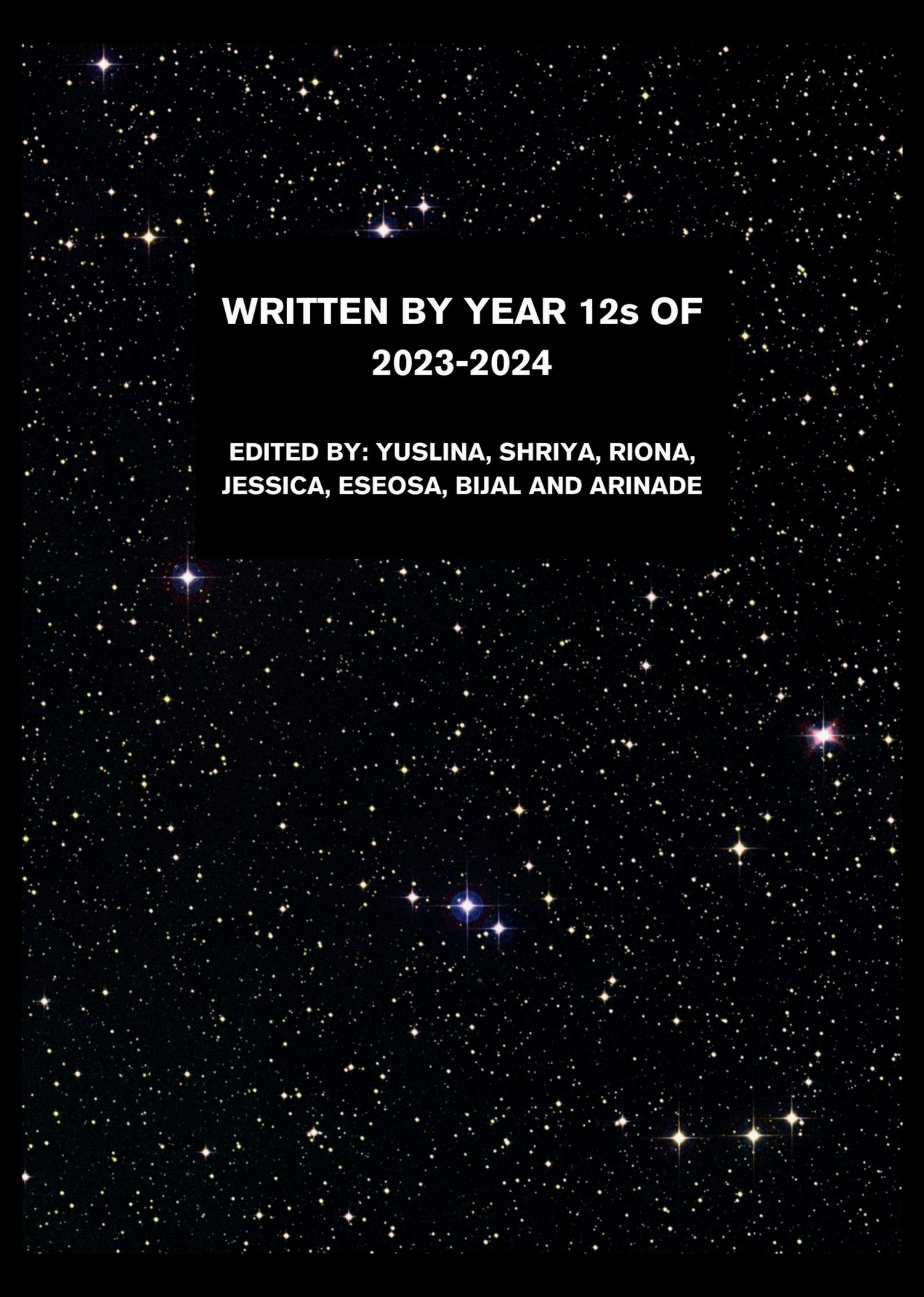
FEATURING:

**Exploring the  
World of  
Hallucinogens**

**Superfluids -  
Properties and  
Potential**

**A Mathematical  
Excursion  
Through Chess**

**'Injury and Brain  
Cancer' - Two  
Sides of The  
Same Coin**



**WRITTEN BY YEAR 12s OF  
2023-2024**

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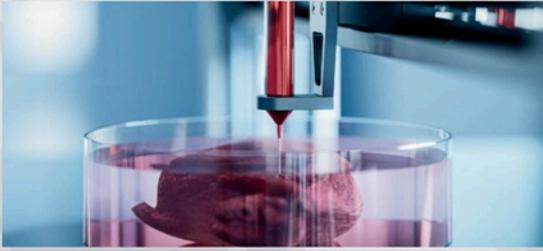
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## Printing the Future of Healthcare: 3D Bioprinting for Organ Transplants



Imagine a futuristic 3D printer, not one that crafts plastic toys, but instead creates human organs. Welcome to the world of 3D bioprinting, a groundbreaking twist on the familiar 3D printing technology.

To form these, substances called bioinks are processed in the same way as plastics, by being extruded through a fine nozzle. Bioinks are a liquid mixture of cells, with additional materials like matrices (binding substances) or biopolymers, which when they are printed, can form functional tissues and organs.

This technology has the power to revolutionise healthcare systems, especially here in the UK. NHS organ donation waiting lists have reached record levels, with around 7000 people currently waiting for a transplant, and average waiting time standing at 233 days. Finding a donor match is also incredibly tough, with even the slightest difference in organs causing rejection by the body. But using 3D bioprinted organs for this could waive nearly all these problems. These organs can be printed incredibly fast, with effective tissue having been printed in just 60 minutes. They would also have the same cell properties as the patient's own organs, meaning fewer complications, faster recoveries and most importantly, a dramatic drop in the seemingly endless waiting lists.

However, the technology is still in testing and trials, so while we might dream of a world where printers churn out organs on demand, it will be a while before this science fiction becomes an everyday reality.

-- Jahnvi

## Tuberculosis and why it should have been eradicated long ago

Tuberculosis. A disease that has caused over 44 million deaths since 2000, when there should have been none. A disease that has been treatable since the 1950s, and yet 1.3 million people still died from it in 2022. But what is tuberculosis and why is the oldest contagious disease known to affect humans still going around?

Tuberculosis, also referred to as TB and consumption in the past, is an infectious disease caused by the mycobacterium tuberculosis bacteria, which is transmitted through respiratory droplets and originally evolved from cattle bacteria. Common symptoms of the disease include, but are not limited to: progressive fatigue; weight loss, from a loss of appetite; fever and a cough, which often becomes bloody as symptoms persist.

While our immune system try its best to fight off the disease, the thick waxy coating of the bacterium makes it difficult for our infection fighting macrophages to penetrate and kill the bacteria, but they do manage to slow its growth by surrounding it, forming a tubercle and causing the disease to go into the latent stage in your body. However, if the immune system gets compromised in the future due to old age, another disease, malnourishment etc., the latent bacteria can activate and become infective once again. This is especially a problem in low and middle income countries, where tuberculosis worsens due to poverty and the lack of access to healthcare

Despite there being many methods of diagnosis and treatment, most are too expensive for poorer countries, where there are the most instances of disease.

However, many companies that provide tests and treatments have begun to decrease their own profits in order to help the many around the world who need it. For example, in September 2023, Johnson & Johnson decided not to enforce secondary patents on bedaquiline (a drug used to treat active tuberculosis) in the 134 low and middle income countries around the world, saving many lives. Additionally, Danaher, which owns the company with the main method of tuberculosis diagnosis and testing for drug resistance, GeneXpert, has decided to reduce their prices, making them zero profit. As more and more companies realise the impact they can make on the world by reducing their own profit, millions of lives can be saved every year, not just those suffering from tuberculosis, but also many other diseases that many low and middle income countries may not be able to afford diagnosis and treatment for. There is a positive outlook as more and more people realise this and campaign for this, which will hopefully lead to a decrease in mortality rate for many countries.

--Aarchi



## Bionic Humans

The 'Bionic Human' is not just science fiction - recent developments in technology indicate that this transhumanist concept could soon become a reality.

Today, more than a billion people worldwide are already dependent on assistive technologies, such as pacemakers, hearing aids, and prosthetics limbs. In these cases, their purpose is to aid the disabled in carrying out normal human functions, by enhancing their body's capabilities. Recently, there has been deeper research into enhancing human abilities using technology for more unconventional uses.

Professor Michael McAlpine and students of mechanical engineering at the University of Minnesota conducted

research into 'tattooing' a smartwatch onto a hand. They engineered 3D printers which used functional materials rather than hard plastics, and studied the topography of the hand to adjust their measurements. This allowed them to 3D print a wireless LED onto a hand, using a mechanism similar to a tattoo gun.

Further experimenting with these ideas are 'cyborg artists' who have developed the creation of new senses by applying technology to the human body.

Manel Muñoz, Spanish cyborg artist, developed and installed weather sensory fins in his head. The implants allow him to hear and detect changes in temperature, humidity and atmospheric pressure.

Another very famous example is Neil Harbisson, the world's first legally recognised cyborg. Harbisson is a cyborg activist who overcame his colour blindness by attaching an electrical antenna, called an 'eyeborg' to his skull.

Through this antenna, he is able to perceive visible and invisible colour as sound. This occurs via audible vibrations in his skull. Together with artist Moon Ribas - the world's first cyborg woman - he created the Cyborg Foundation, an international non-profit organisation promoting research and development into cyborg humans.

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Head of Engineering at Apple, Ray Kurzweil, says that gradual enhancement of humans is inevitable.

"That's the nature of being human - we transcend our limitations."

-- Ananya



# Immortality

When somebody mentions the idea of immortality, what comes to mind?

Whilst scientists argue that the human lifespan could range from a maximum of 120-150 years with the combination of a good diet and exercise habits, others still hold hope that true immortality is within our reach. Cryonic preservation is one of the methods aiming to overcome death, with some cryobiologists predicting that around 2040 the first person will be brought back to life.

Cryonic preservation is a deeply controversial topic, criticised due to both ethical and scientific concerns. Once somebody is pronounced “legally dead” their body is immediately transported to a cryonics facility where the “freezing” process begins. Any water from their cells is removed, ensuring that when frozen, they do not shatter and is then replaced with a cryoprotectant, a type of human antifreeze. The body is then cooled further using dry ice and placed in a metal tank filled with liquid nitrogen, with the hopes that eventually, one can be brought back to life. However, as of yet, this has not happened.



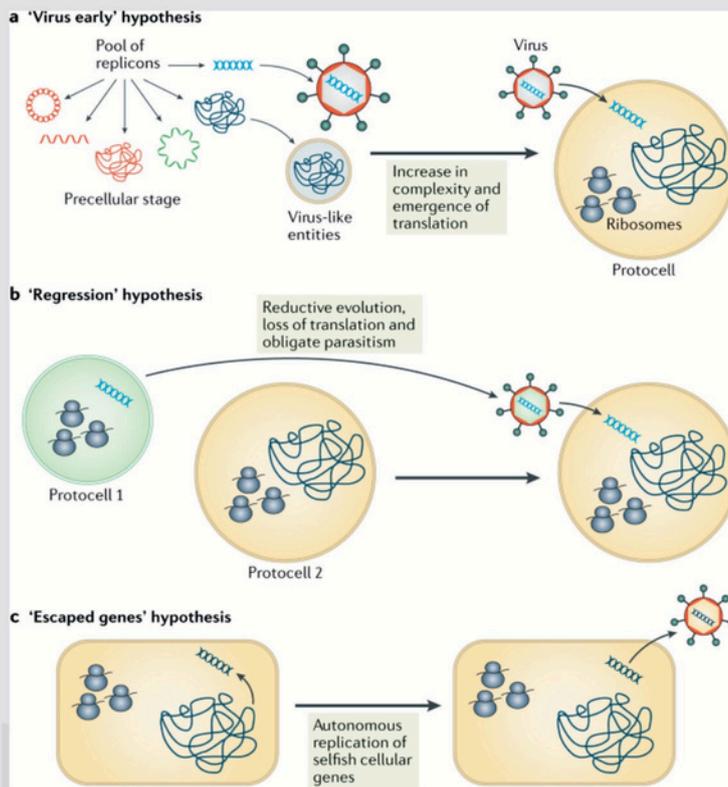
If we could achieve true immortality, should this be considered a “good thing”? With a lifespan no longer limited by the confines of death, we could spend more time with family, learn a new language, or travel the world; the possibilities seem endless. But with living forever may also come boredom and inevitably, an even greater ageing population, ultimately putting more pressure on the NHS and reducing the increased quality of life we set out to achieve. One could also argue that with curable and preventable diseases such as tuberculosis and malaria, killing over 1.9 million people in 2022, it would be more just to give money to regions most affected by these diseases.

Modern medicine is here to relieve us of suffering, and although it cannot prevent death altogether, it can delay it, allowing us to live out our final moments peacefully. As of today immortality seems to remain only a part of science fiction novels, however, if presented with the opportunity, would you choose to live forever?

--Amelia



# The Origin of Viruses



Viruses were brought into greater focus by the global pandemic and despite many of us being familiar with the impact viruses can have, their history is still a topic of uncertainty

Where do new strains of viruses come from? Despite not classifying as living organisms, viruses are able to evolve and these different strains cause difficulties when developing vaccines. Evolution in viruses can happen due to a number of reasons such as mutation, recombination and reassortment of genetic material. High genetic mutation rates occur due to a lack of proofreading enzymes that in most cells would proofread the RNA and DNA sequences to prevent errors in replicating genetic information but allows viruses to develop mutated strains that require different vaccines. Recombination of genetic information occurs when genetic material is mixed between viruses infecting the same cell; this can be caused by large genomes, discontinuous transcription and an increased amount of template and strand switching. Reassortment of viral genetic information happens when segmented viruses (viruses with multiple segmented genomes) infect the same cell and the ‘progeny virus’ has a genome derived from multiple viruses.

Where did viruses originate?

As viruses are too small and delicate to leave behind fossils in rock, tracking extinct viruses and their evolution through time is done through the fossils viruses have left behind in our genetics.

When viruses infect germ cells (those that develop into gametes) they can pass their genetic material onto the host’s offspring and integrate with the host species’ genome. The study of these ‘viral fossils’ is paleovirology which can track viruses back millions of years.

There are three main hypotheses that aim to explain the origin of viruses. The regressive hypothesis suggests that viruses were originally small cells that parasitised larger cells and lost their genes which were not required by parasitism (e.g. those needed to reproduce outside of the host cell). The escape hypothesis proposes that viruses have developed from escaped DNA or RNA, most likely mobile genetic elements such as plasmids and bacteriophages. The co-evolution hypothesis suggests that viruses had evolved from nucleic acid at the same time as cells that had developed on earth and have always been dependent on cellular structures. Evidence supporting this includes the genomes of eukaroviruses, archaeal viruses and bacteriophages all containing virus specific genes that have not been found to have statistically significant similarity to any cellular genomes.

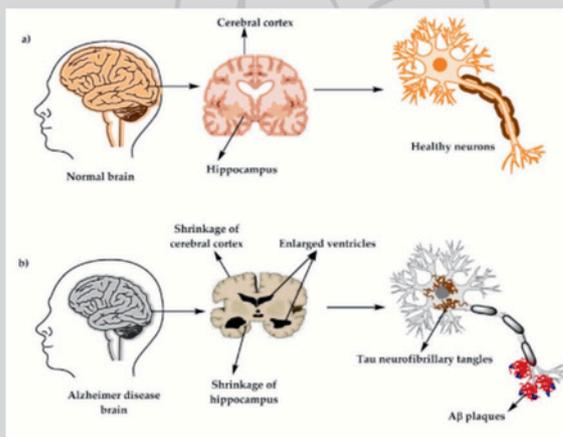
In summary there is a lot of information about viruses that can be interpreted to support different hypotheses but also a lot of information still to be found. The fast mutation rates of viruses make mapping the evolution of viruses an unfathomable task, meanwhile we are still tackling the effects they have on public health and the economy.

--Elizabeth

# 'Remember me': uncovering the illness in Disney's 'Coco'

Imagine being unable to remember what you did yesterday, or what you ate this morning, or what happened five minutes ago. This is what over 55 million people living with Alzheimer's disease go through every day. Alzheimer's is a degenerative brain disorder where beta-amyloid protein builds up into plaque, disrupting communication and destroying neurons (shown on the right).

The damage starts in the hippocampus, which controls short-term memory and memory formation, meaning that the patient may not remember the specifics of an event earlier that day. However, the amygdala (which processes emotions) is still intact, so they may recall the emotional aspects of it instead. It then affects the cerebral cortex, which controls language, memory and intelligence; it becomes thinner, making long-term memories harder to retrieve and shrinking the brain. In severe Alzheimer's, other lobes are affected, including the visual system in the temporal lobe, making it difficult to recognise what should be familiar faces, and the right parietal lobe, which controls balance and therefore makes it hard to move independently. Despite all this, learned skills, such as singing, are procedural memories; these are stored deep in the cerebellum, and so remain unharmed for a long time.



Moving on to Disney's 'Coco'...! Although it's never specified, it's likely that Mama Coco has severe Alzheimer's. She cannot walk (right parietal lobe damage), remember her daughter (temporal lobe damage), or talk (Broca's area damage). But, when Coco sings 'Remember Me', she miraculously joins in (preservation of procedural memory), and recounts Hector's story, getting her memory back. However, although it'd be incredible for music to heal the disease, the worst thing about Alzheimer's is that nothing can - there's currently no cure.

The brain is extraordinarily complex and the skull makes it difficult to access, so instead, scientists have been working on slowing the disease, using immunotherapies to target and break down the beta-amyloid plaques. The monoclonal antibody, Lecanemab, is our most advanced example, slowing disease progression by 27%, and decline in quality of life by 56%. It was approved for treatment in the US in July 2023, and we are awaiting a decision for its use in the UK. So, who knows? Even though it's not music or a cure, there may be some way to combat the disease after all.

--Zara

# The Crisis of Cryogenic Pathogens



In 2016, thousands of reindeer were found to have dropped dead in Western Siberia. The silent killer - a bacillus Anthracis outbreak. But what triggered it?

Rising global temperatures severely affect polar regions, warming 4x faster than the average rate. This causes the cryosphere to melt, releasing 4 sextillion anabiotic\* microorganisms into the world every year. To put this into perspective, that's the same number of stars in the universe. As the permafrost thawed, the frozen anthrax within the permafrost was released into the air, soil, and water. The released spores infected the reindeer, at a fatality rate of 86%. The anthrax outbreak spread to humans via zoonotic pathways\*\*, and infected 72 locals, causing the death of a child.

Scientists are studying pathogens released from the ice, in an effort to gauge the risk of mass extinction events. At Michigan State University, a software program called Avida was used to model the spread of pathogens to determine whether they would be able to adapt to current climates and infect organisms. 1% of the pathogens were tested, and found that in 3% of the simulations the pathogens became dominant in new environments. These invasions could cause up to a 30% loss of life in the host community. And this is only with 1% of the pathogens being tested, imagine the impact on ecosystems of millions of new pathogens.



Professor Jean Michele Claverie of Marseille University believes there is a large risk of strains of smallpox being released from the ice, a previously thought to be extinct disease. Vaccinations for smallpox are no longer carried out, and so infections would be catastrophic. The last smallpox pandemic caused 350 million deaths, and was the 2nd largest pandemic in human history.

Furthermore, rapid spread of pathogens is no longer a fantasy due to unprecedented levels of globalisation and interconnectivity, as we've witnessed during the COVID-19 pandemic. However, almost nothing is known concerning the consequences of invasions of communities by glacial microbes due to the complex and unknown epidemiology of ancient pathogens.

\*anabiotic - microorganism currently not multiplying but will do when introduced into friendlier environments

\*\*zoonotic pathways - ways that microbes travel from animals to humans, for example eating infected meat, or direct contact (e.g. animal bites)

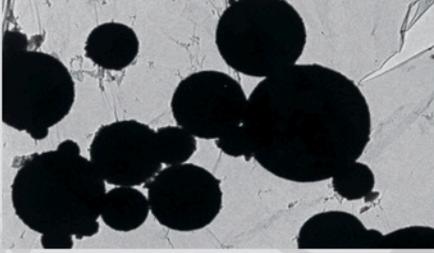
\*\*\*epidemiology - the incidence, distribution, and possible control of diseases and other factors relating to health

--Reina

## We Are Turning Ourselves Into Magnets

Within our brains are naturally-occurring crystals of magnetite - Earth's most magnetic material. While the exact reason for its presence remains unknown, up until now, it was thought to simply be an interesting, natural phenomenon.

However, when a team of scientists looked at samples of 37 human brains, they found something much more concerning. While biological magnetite usually forms in tetrahedral or octahedral shapes, the majority of magnetite particles found in these samples were instead round nanospheres. This was not natural.



Their origin? Air pollution.

The unfamiliar shape of magnetite particles discovered in the brain samples were in fact very familiar after all - they matched 'precisely' with the magnetite particles produced by combustion in industrial processes and released into the air.

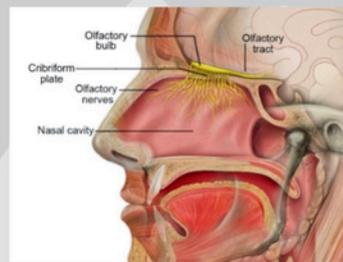
As magnetite nanoparticles are less than 150 nanometres in diameter, it is believed that these particles are small enough to be inhaled through the nose and enter the brain through the olfactory bulb (the brain section that relays information between the nose and the brain) (1). These particles are combustion byproducts, breathed in by people living in urban areas where there are high levels of air pollution.

For each biologically formed magnetite particle in the brain samples, researchers found at least 100 pollution-derived magnetite particles. In total, millions of magnetite particles per gram of brain matter were found. This could be devastating to human health.

These magnetite particles lead to the formation of very reactive oxygen species, causing cell damage and eventually cell death. In one study, subjects exposed to polluted air showed a deterioration in brain function equal to two years of ageing - which creates a huge concern for an increased risk of early-onset Alzheimer's in polluted cities. However, although airborne magnetite particles have been suggested as an environmental risk factor for Alzheimer's and other neurodegenerative diseases, more studies must be done to understand the exact nature of their risk.

Nonetheless, the disturbing nature of these nanoparticles show that policymakers must review their environmental regulations, else we risk the levels of these 'nanomagnets' in our brains rising to detrimental levels.

--Orbit



## Exploring the World of Hallucinogens

Hallucinogenic drugs also known as psychedelics are drugs that change how people see, hear, smell, feel and think. At high doses, it can cause both sensory and visual hallucinations. Some of the most common hallucinogens, such as Mescaline, Psilocybin, Cannabis, and Salvia come from natural sources like mushrooms, cacti and plants, but others are manufactured chemically, including LSD, Ecstasy, and Ketamine. Around 3.1 million people aged 16 to 59 years living in England and Wales reported that they had used a drug in 2022, with 180, 600 more people using hallucinogens in that year alone.

Different types of psychedelic drugs cause different effects, including delusions. For example, LSD produces a kaleidoscope of visual patterns and changes perception whereas Ecstasy boosts mood, which allows people to have more feelings of empathy and intimacy. Ketamine, on the other hand, creates out-of-body experiences, Salvia causes short effects such as being able to smell sounds or hear colours and Psilocybin causes euphoric feelings that make you excited, energised and awe-full. Consuming an excessive amount of these drugs can have serious side effects, not limited to muscle spasms, loss of coordination, convulsions, unconsciousness, aggressive behaviour, psychosis and more.



Psilocybin, more commonly known as Magic Mushrooms, is one of the most fascinating hallucinogens, as, despite the nausea, dizziness, diarrhoea, and stomach pains, Psilocybin is shown to be able to help treat addiction, anxiety, depressive disorders, PTSD, and end-of-life care. Robin von Rotz did a double-blind clinical trial with patients who were diagnosed with major depressive disorder, where half received a single dose of Psilocybin and the other half received a placebo. Administration of the drug showed a significant decrease in symptom severity of -13.0 points compared to the baseline, with one dose being able to cause long-lasting effects. Overall, one can see the harmful addictive effects of hallucinogens, but if harnessed correctly can they shapeshift the world of pharmacology.

--Ashori

## Zoonotic Diseases: Science Fact or Science Fiction?

On Monday the 27th of November 2023 the UK Health Security Agency reported that it had detected a human case of influenza A(H1N2)v, a swine-origin influenza virus, and an example of interspecies transmission of an influenza virus. This is the most recent example of sporadic reports since the late 1950s of human infections with swine influenza viruses, mainly in people who had direct contact with infected pigs and through a contaminated environment (due to the viruses often being found in the pigs' respiratory tracts, but not in their meat). Therefore, influenza A(H1N2)v is considered to be a zoonotic pathogen as it is naturally transmissible from vertebrate animals to humans, and the swine flu it causes is classed as a zoonotic disease.

Influenza A viruses are divided into subtypes based on two proteins on the surface of the virus: hemagglutinin (H) and neuraminidase (N), and are numbered based on the 18 different hemagglutinin subtypes and 11 different neuraminidase subtypes.

While there are more than 130 influenza A subtype combinations identified in nature, all of which follow this nomenclature, there are only three subtypes of swine influenza A virus that have been detected in pigs: A(H1N1) (which caused a pandemic in 2009 with 284,000 deaths globally), A(H1N2) and A(H3N2). There are potentially many more influenza A subtype combinations given the propensity for virus reassortment. Virus reassortment is a process in which influenza viruses swap gene segments, which happens when two influenza viruses infect a host at the same time and swap genetic information.

However, it is the combination of the close proximity between pigs and humans or birds, and that pigs have both human-adapted and avian-adapted receptor types in their upper respiratory tract that is unique. For this reason, pigs infected with swine influenza virus can be dually infected with avian or human influenza A viruses allowing virus reassortment to happen.

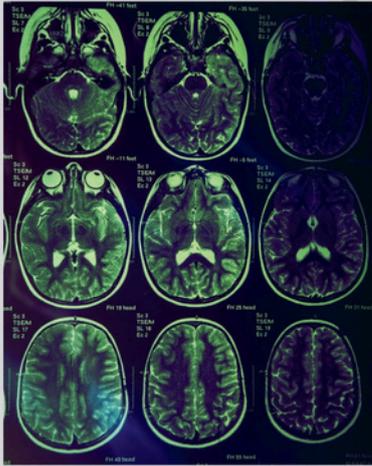
Therefore most swine influenza viruses are reassortments with mixtures of human, avian and swine virus segments, leading to the "mixing vessel" theory in pigs.

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--Eliana

## Using deep brain stimulation to cure Alzheimer's

Alzheimer's disease is a progressive condition that disrupts the communications in neurons which results in loss of function and cell death. It was also discovered that many abnormal clumps, known as amyloid plaques, and an abnormal accumulation of protein called tau that collect inside neurons, known as neurofibrillary tangles, were present in the brains of those with Alzheimer's. These changes to the brain caused patients to display symptoms such as loss of memory, language problems, difficulty with spatial awareness and many more.



As of now, there are no cures to Alzheimer's. However, scientists at Imperial College are developing a new form of deep brain stimulation that could work as a treatment for Alzheimer's without the need for surgery. This method is known as temporal interference (TI) which works by placing electrodes on the patient's scalp and delivering electrical fields to the brain.

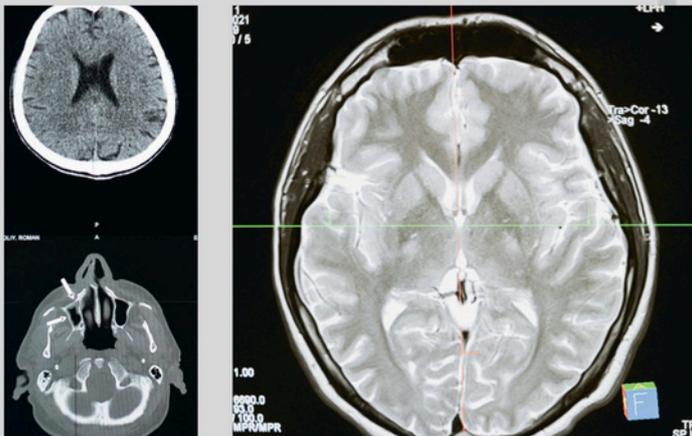
Researchers then target the overlapping sections in the electrical fields in order to stimulate the hippocampus without affecting the surrounding areas. The hippocampus has a major role in learning and memory and so by stimulating this area, researchers believe that patients might regain their memory.

The researchers tested the effects of TI by conducting a trial with 20 healthy volunteers. They used post-mortem brain measurements to validate that the electric fields could in fact be focused on the hippocampus.

They got the volunteers to memorize faces and names, an activity that relies heavily on the hippocampus. By using functional magnetic resonance imaging, they found that TI does solely affect the hippocampal activity induced by this task and that TI stimulation actually improved memory accuracy.

Researchers are now testing TI stimulation on patients with the early stages of Alzheimer's. Hopefully with future research, this method of stimulation will progress and will someday act as a cure for the memory loss caused by Alzheimer's.

--Asmita



## "You are what you eat" – is healthy eating the sole key to being "fit"?

"Tell me what you eat, and I'll tell you what you are" are the famous words spoken by French lawyer, Brillat-Savarin. These words were part of a philosophy that prevailed in civilisation for centuries – the food consumed has an influence on one's health.



In many ways this rings true, as diet is a risk factor for many conditions. According to the CDC, constant increased glucose intake is a known cause of type 2 diabetes due to the body being desensitized to insulin. An unhealthy diet is even a risk factor for heart disease, the biggest cause of death in the US in 2019.

While it may be true that nutritious eating is the key to being "fit", people still struggle with maintaining a healthy lifestyle. Regardless of the endless messages of the importance of a "balanced diet", the obesity rates in the UK are rising. However according to Dr Giles Yeo, this may not be a choice as "the inheritability of weight is similar to that of height."

A common example is found in the MC4R gene, this gene plays an important role in appetite regulation and weight control. Mutations in this gene have a significant impact on weight gain or loss by extension. Furthermore, studies have shown that 60% of the subjects' body-fat distribution can be attributed to genetics.

This is significant as fatty deposits around the organs (visceral fat) are much more dangerous than subcutaneous fat as it triggers inflammation which can damage the arteries. The cocktail of mutations within you are in the words of Dr. Yeo "a 2 hand of poker", depending on the cards you get; keeping a balanced diet may be an uphill climb for some.

So is diet the sole determiner of health? Clearly there are other factors that come into play of equal importance. Genetics is a risk factor for many conditions, even obesity, which is why holistic treatment for chronic conditions is necessary and often absent especially in conditions such as obesity which are often overlooked as being caused by diet alone.

-- Shamrutha



# Are ICDs actually our best bet in treating amyloid cardiomyopathic health conditions?

The use of pacemakers and implantable cardioverter defibrillators (ICDs) for the treatment of cardiac arrhythmia and amyloidosis has remained vastly unquestioned as the main and most widely utilised administration following its invention (dating as far back as the 1950's in the uk). However, as incredible of a discovery as it is, the drawbacks of placing an artificially designed product into the most vital organ of the cardiovascular system for the long term (in most cases) haven't been criticised nearly enough in comparison to how heavily reliant a person's life becomes when placed under the dependency of an automation and how potentially risky this could become.



In general, both ICDS and pacemakers are deemed safe and reliable, when even the implantation of them can be fatal, let alone the internal function. According to a study conducted by nih.gov, The mortality rate at two years among patients who accepted an ICD was 12.2% after ICD implantation, however among patients who declined ICD implantation, the two-year mortality rate was 5.3%. Now a difference of 6.9% may not seem too significant initially, however, considering the 7 decade long usage and research that the treatment has undergone, pharmaceutical alternatives evidently offer much lower chances of surgical death, by using drugs like immunomodulatory suppressants.

This isn't however to say that ICDs should be discarded: rather, they should be worked and improved on to ensure that they don't create further unnecessary issues for the patient.



The best example of this in relevance to cardiac amyloidosis specifically would be involuntary shock. This occurs when the electrical impulses sent out by an ICD or pacemaker are involuntary/ have been caused by a malfunction of the device, meaning that the electrical shock delivered wasn't needed and instead of restoring cardiac rhythm, could cause severe and even fatal conditions like ventricular fibrillation. It is uncommon, yet still concerningly possible for issues like this to occur, which could be detrimental to a patient's life. Where it is true that immunosuppressants will not work in many cases and organ transplants are extremely inaccessible, the wonderful invention of ICDS has saved thousands of lives respectively, which leads to many people overlooking the downsides of them. Hopefully At some point in the future, advancements in modern biotechnology and medicine will develop an even better alternative, or allow patients to eventually trust this machinery as a true life saver, and not a potential threat.

-- Mishika



# The Purpose of Sleep

Only three things are certain in life; death, taxes and sleep. Every couple of hours, we have to log off of our consciousness and we do this so much it accounts for a quarter to a third of a human life span. But why do we sleep?

To first answer this question, we need to know what happens when you sleep. Every night, we go through a sleep cycle composed of two different types of sleep: the non-REM (rapid eye movement) sleep and the REM sleep. Non-REM sleep accounts for the stages when you fall asleep (N1), are in light sleep (N2) and are in deep sleep (N3). Your heart rate, breathing and brain wave activity all slow down. As you cycle into REM sleep, your eyes move rapidly back and forth behind your eyelids. Your brainwaves become similar to those during wakefulness and your breathing and heart rate increase.

The cycle then repeats itself and during this time, your body undergoes many different processes such as memory consolidation and metabolism regulation to help you be ready for the next day, but arguably the most important purpose of sleep is to remove the build-up of toxic waste in the brain.



Research has shown that there is a network of fluid-filled channels which removes toxins in the brain, named the "glymphatic system". It flushes out the metabolic byproducts by mixing Cerebrospinal fluid (CSF) and Interstitial fluid (ISF) that holds both nutrients and waste products through the system, similar to the lymphatic system in the rest of the body. This includes beta-amyloid, which is the main component of the amyloid plaques found on the brains' of patients with Alzheimer's. The flow of the CSF is controlled by the glia, which are cells found in the brain that are non-neuronal, hence the name "glymphatic system". This process requires a lot of energy, meaning that there is no way the process can simultaneously occur when the brain is active, so the glymphatic system is more active when we're asleep.

Sleep affects almost all of the tissues and organs within the body and without it, we're left cranky, forgetful and barely functioning. So please, if you're ever thinking about pulling another all-nighter just to try and cram in something last minute, just go to bed.

-- Xinyue

## Sports Dentistry: A Growing Essential for Athlete Health

With the growing popularity of sports among younger generations, the demand for sports dentistry is rapidly increasing. Sports dentistry focuses on the prevention and management of orofacial injuries and related oral diseases associated with athletic activity. It is estimated that 11-40% of all sports injuries involve the face, often caused by direct impacts from balls or collisions between players. In addition to tooth and bone fractures resulting from such incidents, athletes frequently experience dry mouth due to heavy breathing during intense physical exertion. This reduction in saliva flow impairs the mouth's natural ability to neutralize acids and remove food particles, increasing the risk of cavities and gum disease.



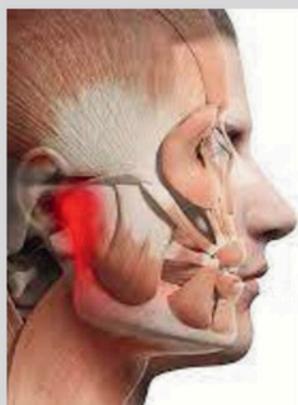
The competitive nature of many sports can also lead to stress-induced bruxism (teeth grinding), which can wear down teeth, cause jaw pain, and contribute to temporomandibular joint (TMJ) disorders. Diet plays a significant role in the oral health of athletes as well. While sports drinks, energy bars, gels, high-protein diets, and acidic fruits are often consumed to boost energy levels during training and competition, these products are high in sugars and carbohydrates. When not managed properly, they can contribute to enamel erosion, tooth decay, and cavities. Over time, these issues can escalate to more serious conditions, such as pulp infection, gum disease, and even systemic health complications, all of which can adversely affect an athlete's career and quality of life.

In response to these risks, current research is advancing technologies like "smart" mouthguards equipped with embedded sensors capable of monitoring and detecting injuries from impact forces, including concussions. These devices provide real-time data to coaches and medical personnel, enhancing player safety and helping to prevent long-term injuries. Additionally, innovations in materials and manufacturing methods, such as 3D printing, are being explored to produce mouthguards that offer improved comfort, protection, flexibility, durability, and shock absorption.

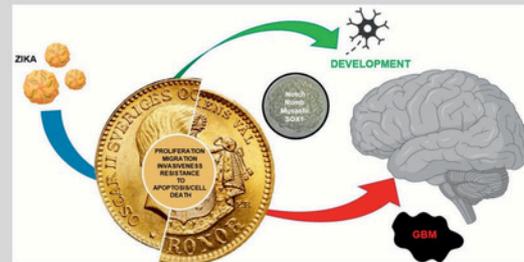


Looking ahead, the future of sports dentistry may include genetic testing to assess an athlete's predisposition to certain oral health issues, such as enamel erosion or gum disease. Personalized prevention and treatment strategies based on genetic insights could help athletes maintain optimal oral health throughout their careers, ensuring both their performance and long-term well-being.

--Shriya



## "Injury and Brain Cancer - Two Sides of The Same Coin"



Glioblastoma is the most common type of brain tumour in adults – current treatments extend survival, but they are not curative. Prof. Parrinello, a professor of neuro-oncology at the UCL Cancer Institute, explored the connections between injury and brain cancer to develop more effective therapies. To understand how these are similar, she first broke down the basics; neuro stem cells.

In the brain, neural stem cells specialise to form 3 types of cells:

1. Neurons – used for communication in neural circuits
2. Astrocytes – for regulating blood flow to the brain
3. Oligodendrocytes – protective layer that wrap around the axons of neurons to form the myelin sheath

Neural stem cells divide to generate new cells, and new neurones migrate to the site of injury to replace dead ones.

This process proves both useful and detrimental, as although they may go onto specialise into neurones; mutations may cause them to form tumour cells from their neuro stem-like state.

Mutations to the neuro stem cells give rise to glioblastomas. Here there is a synergy between mutations and brain injury as one can lead to the other: An injury to the brain earlier in life (e.g. a stroke) may cause mutations to astrocytes. This is then worsened by inflammation that comes with ageing, which can cause the development of a tumour later as astrocytes from tumour cells rather than neurones.

This process of neurones going back to their neural stem-like states becomes useful as glioblastoma are then able to mimic brain repair by:

Until the 1990s, neurologists were practising their profession under the doctrine established in the late 19th to early 20th century by the prominent histologist Ramon y Cajal:

Until the 1990s, neurologists were practising their profession under the doctrine established in the late 19th to early 20th century by the prominent histologist Ramon y Cajal:

"Once the development was ended, the founts of growth and regeneration of the axons and dendrites dried up irrevocably. In the adult centres, the nerve paths are something fixed, ended, and immutable. Everything may die, nothing may be regenerated. It is for the science of the future to change, if possible, this harsh decree."

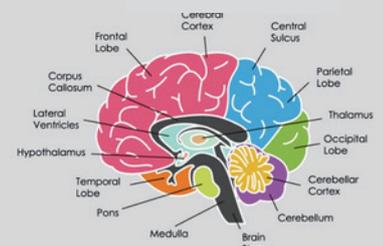
In other words, the harsh decree states that there are a set number of neural stem cells that cannot be regenerated once they die. However, modern day science has revealed that in the striatum, a structure in the brain, mutations can cause astrocytes to go back in development to a neural stem-like state to replicate themselves.

1. Tumour infiltrates the brain as cancer cells spread through the white matter
2. Tumour cells begin to behave like oligodendrocytes as they invade the white matter of the brain
3. Tumour cells retain info to cause oligodendrocytes-like maturation

What this shows is that the brain has specialised cell types and processes to repair itself. Whilst beneficial following an injury, these processes make the brain vulnerable to tumour development. Normal injury responses can be hijacked during the early stages of tumour development (astrocyte to neural stem cell conversion). However, these injury responses are also able to be re-activated during the growth of an established tumour (oligodendrocyte-like specialisation) to delay tumour growth.

Professor Simona Parrinello concluded that by harnessing these responses that are present in tumour cell, improved treatments could be discovered.

-- Arinade



# 'Superfluids - Properties and Potential

Superfluidity is a characteristic property of some liquids, which means that they have zero viscosity and flow without any kinetic energy loss. Therefore, a superfluid flows without any resistance or friction. This is a quantum phenomenon, which occurs at very low temperatures, so a key feature that is necessary for a liquid to transition into a superfluid, is the ability to remain in the liquid state, even at very low temperatures.

Superfluidity was first discovered in 1937 by Pyotr Kapitsa, John Allen and Don Misener. They discovered this property in the isotope Helium-4 and it was also later discovered in Helium-3. They remain liquids even at almost absolute zero (-273°C), however superfluidity in He-4 occurs at much higher temperatures than He-3.



Superfluids, such as liquid helium, have very interesting properties, which are due to the lack of friction between particles during their movement. One example of this is their ability to reside in constant motion - a persistent circular current will keep flowing forever. For example, when vortices are created in ordinary fluids, they would eventually be slowed down by the viscosity of the liquid. However, in a superfluid, there is no resistance so they can spin indefinitely. Furthermore, unlike the particles in a normal fluid, which move together as a unit due to the viscosity and friction between the particles, in a superfluid, this absence of friction means that each particle can move independently. This allows the fluid to even climb up the walls of a container and flow out over the top, seemingly defying gravity!

Currently, superfluids are being studied by physicists in the field, in order to find ways to apply their unique properties to aid advancements in engineering, technology, energy production and many more areas of research. Although their use seems limited at present, potential applications in fluid-dynamics, scientific instruments, and heat transfer/cooling systems suggest that they could be a real game-changer in a wide range of areas.

--Shreya

# Quasicrystals and their Impossible Structures

In 1982, whilst Dan Shechtman was looking over electron diffraction patterns of an aluminium-manganese alloy, he saw the impossible: A ten-fold symmetry.



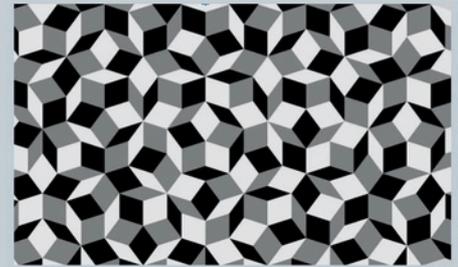
Hitherto unseen in crystallography, such symmetries were deemed forbidden, and with subsequent findings of fivefold and twelvefold symmetries, the world of chemistry was facing upheaval. But what do these 'symmetries' tell chemists anyways?

Crystallography was a revolutionary experimental tool that allowed chemists to reverse engineer a crystal structure by observing the way that waves reflecting off different layers of a crystal interfered to form a diffraction pattern. A key piece of information was the symmetry of the diffraction pattern: it was the crystal's rotational symmetry. Therefore a threefold symmetry meant the crystal structure would look identical after a rotation by 120 degrees. By intuition the shape of the unit cell would hence be a triangle, the unit cell being the smallest subsection of the crystal seen to repeat across it. This deduction causes no problems, as equilateral triangles tessellate perfectly.



However a five-fold symmetry suggests a pentagonal unit cell; when these are arranged on a surface there are gaps, but this is not strictly a problem. The real issue is that no 'gap' will ever be found to repeat anywhere in the structure, there is no periodicity: our crystal is not a crystal...

However it is hardly a lump of coal either. There is no perfect symmetry in the diffraction patterns of amorphous solids. So what Dan Schetman was faced with in 1982 was a quasicrystal.

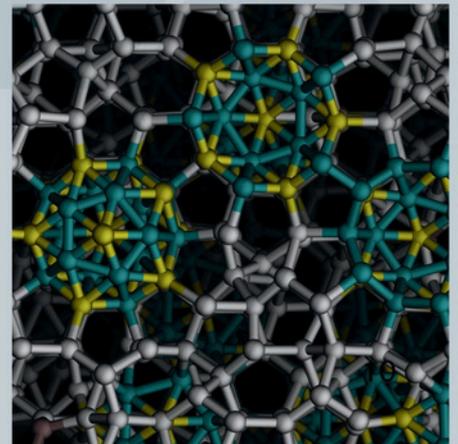


A good geometrical description of quasicrystals seemed lacking, however the answer lay in a curious hybrid of maths and art: Penrose tilings (above).

These tilings were made from 'fat' and 'thin' rhombi, which could cleverly be fit together to have these 'forbidden' symmetries while maintaining aperiodicity. Curiously, over large enough tilings the ratio of fat to thin rhombi approaches the golden ratio, a widely known irrational number. But with some chemical knowledge applied to these mathematical patterns, a structure could be deduced entirely in line with the diffraction patterns. At long last these mysterious materials had been explained.

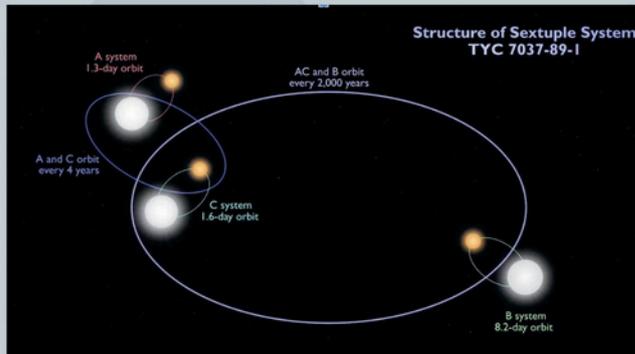
Except there is so much more unknown about quasicrystal properties. From unexpectedly low electrical conductivity to elastic deformations that involve completely novel particles called phasons, there are many promising discoveries yet to be made in this field, as we strive towards a full understanding.

--Siyona



## Introducing Binary Star Systems

A binary star system is a system where two stars orbit each other. Though this sounds unusual to us, it's thought to be common among stars. Some sources state that up to one third of stars in the galaxy may be in binary systems, while others estimate up to 85% of stars. Though estimates vary, these systems are not particularly rare. Star systems can contain more than two stars up to an observed maximum of seven (such as AR Cassiopeiae and Nu Scorpii) or a theoretical maximum of eight stars; a system of any more simply could not be sustained.



Binary star systems were first noticed around the 1600s, after the invention of the telescope. Some of the first to be observed were Acrux in the Southern Cross (which is actually a triple star formation in which one of the three stars is a binary system) and the Mizar Alcor System in Ursa Major (in which Alcor is a binary system itself and Mizar is actually a pair of binary systems in a binary system, forming in total a six-star system!)

Binary star systems are classified in different ways, including by how they are observed (visual, spectroscopic, eclipsing and astronomic) and more interestingly, by the structure of the system (detached, semi-detached and contact binaries.) These terms refer to the Roche lobe of the stars.

The Roche lobe is an area around a star within a binary system within which the pull of that star is bigger than the other's, and material is bound to that star. When both stars are fully within their Roche lobes, this is a detached system and the stars generally evolve separately and do not have a strong effect on each other. When one star exceeds its Roche lobe, gas transfer occurs from this to the other star, which affects the evolution of both stars. When both stars exceed their Roche lobes, however, this is called a contact binary and the gases that form the outer region of each star overlap and surround both stars together. Over time, friction caused by this gas envelope slows the orbit of the stars, which may result in them merging.



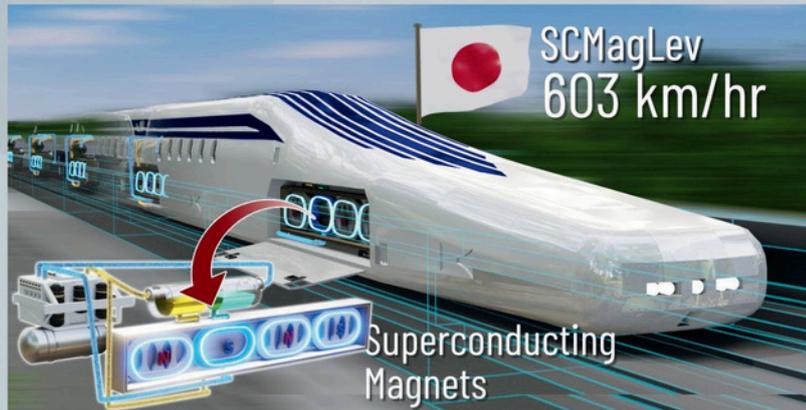
Even within these categories there is a lot of variation. For example, star systems may contain compact objects such as black holes, neutron stars or white dwarves, which further complicate their structure.

-- Anna

## Superconducting the Future: The Quest for Room-Temperature Magic

Levitating trains, energy generated by nuclear fusion, and effective quantum computers powering scientific research - these ideas may sound like the start of a bad film about a utopian future, but they might be closer than you think. Many scientists believe that the key to these technologies is superconductors, with hundreds racing to be the first to discover the mythical room-temperature superconductor.

Although they may seem incredible, superconductors aren't magic - just physics. They are characterised by two key properties: zero resistance (current can circulate without energy dissipation) and the Meissner effect (external magnetic fields cannot penetrate the material, only remaining at the surface). These properties can be observed in materials such as mercury, below a critical temperature and pressure, and they are key to revolutionising future technologies. For example, zero resistance would allow us to build extremely strong magnets, which could be used in transport or even nuclear fusion.



The microscopic theory of superconductivity, or the BCS theory, is the best, thus far, to explain superconductivity. It harnesses two quasi-particles ('fake' particles, which don't actually exist, but can be used to simplify complicated phenomena): the phonon and the Cooper pair. Phonons are the 'particles of sound and heat'—quanta of vibrational mechanical energy. For example, heat in a lattice structure can be modelled as the transfer of phonons between the ions. When the lattice is sufficiently cooled, the ions vibrate less (fewer phonons are transferred), and the interaction between electrons and ions becomes noticeable. Each electron attracts the positive ions around it, creating a positive charge, which attracts another electron. This effect carries on as the electrons move through the lattice; hence, we can model the two electrons as a single particle: a 'Cooper pair'—bound together by the interactions of phonons (as the ions vibrate). These Cooper pairs can then flow without resistance (as the two electrons are fermions, hence the Cooper pairs are bosons, forming a condensate at these low temperatures), creating a superconductor—a material with zero resistance.

However, this theory is incomplete: we still have no explanation for why superconductors can form at higher temperatures, where the thermal energy should be enough to break up the Cooper pairs. Experimentally, the search for a low-cost room-temperature superconductor is ongoing and would be revolutionary. So, whether you're a budding theoretical or experimental physicist, the race to discover, and understand room-temperature superconductors is just beginning, offering a thrilling journey into one of the most transformative scientific pursuits of our time.

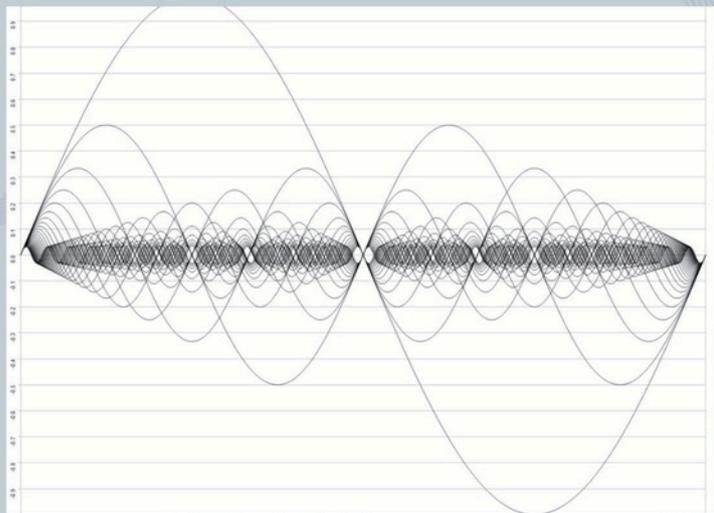
-- Jessica



# Harmonics and harmonic series - a link with mathematics and music

From a surface perspective, maths and music present themselves as very independent fields of study from each other. However, although they seemingly sharing no direct link, they are concepts which see themselves cross over in many different ways. A particular field of crossover involves harmonics and its series.

Take string instruments; when played, they produce standing waves - two progressive waves moving in opposite directions while having the same frequency and amplitude, on strings stretched between two nodes, points with 0 displacement. Take a violin for example - by changing the placement of your finger, you are changing the position of one of the nodes, shortening distance, changing pitch. As you play, what you mainly hear is the fundamental frequency - the lowest resonant frequency in a vibrating object, and the predominant frequency in a complex waveform.



However, aside from hearing the pitch you intend to play, there are many other sounds emitted - these are overtones (or partials) and harmonics, where harmonics are overtones that are whole number multiples of the fundamental. It is actually the combination of harmonics, overtones and the fundamental that you hear collectively, and is what makes each sound distinct from each other, otherwise known as timbre, due to variance in strength between overtones in different instruments.

The harmonic series itself occurs naturally with every instrument. The harmonic series is an arithmetic series ( $n, 2n, 3n, \dots$ ) where  $n$  = the fundamental. As humans perceive sound nonlinearly, higher harmonics sound closer together in pitch. Some of the harmonic series are not exactly in tune with the 12-tone equal temperament (12TET) tuning system, the tuning system used in Western music, specifically the 7th, 11th and 13th; they all have cent deviations\*  $\pm 30$  from the 12TET, where 12TET is an octave divided into 12 parts, evenly spaced on a logarithmic scale by a ratio of a 12<sup>th</sup> root of 2 between each semitone.

So, next time you decide to tinker with an instrument, listen carefully; you might just hear a little more than the music.

A piece worth listening to: *Partiels - Grisey*, a piece composed using the harmonic series.

--Katie

0 0 +2 0 -14 +2 -31 0 +4 -14 -49 +2 +41 -31 -12 0

C2 C3 G3 C4 E4 G4 B4 C5 D5 E5 F#5 G5 A5 B5 B5 C6  
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Figure 1.20 from [Müller, FMP, Springer 2015]

# A Mathematical Excursion Through Chess

"A chess problem is simply an exercise in pure mathematics." Thomas Hardy

The abstract strategy game, which we know as chess, was born in India during the Gupta dynasty in the 6th century and its structure and nature are related to several branches of mathematics such as combinatorics and topology. In this article I will be exploring knights' tours and its connection to graph theory and magic squares.

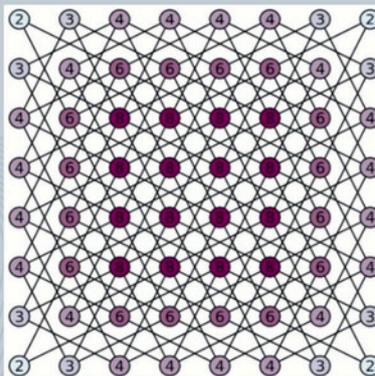


FIGURE 1  
Knight's Graph showing all possible paths - numbers on each node indicate the number of possible moves that can be made from that position.

There are two types of Knight Tours: 'closed' - where the Knight ends on a square that is one Knight's move from the beginning square (so that it could tour the board again immediately, following the same path), and 'open' - when the Knight cannot move back to the beginning square after the tour ends.

Referring to Figure 1, you can see that a knight's tour can be visualized through graph theory and the knight's tour itself is an example of a Hamiltonian cycle problem as the knight must visit each square exactly once.

Despite the knight's tour being confined to an 8x8 chessboard, there are in fact 26,534,728,821,064 different ways of performing a closed tour, including reversals, rotations and reflections. The number of open tours is still undetermined.

Furthermore, Leonard Euler, a renowned Swiss mathematician, created the semi-magical square. This can be demonstrated using a knight's tour where each row and column sums to 260, each quadrant sums to 520 and each half row, half column and each quadrant within the 4 main quadrants sum to 130. However, this is only a semi-magic square because the diagonals, unfortunately, do not sum to 260. Through the computation of these tours, we have found 140 different semi-magic tours such as the one demonstrated below.

260	1	48	31	50	33	16	63	18	130	1	48	31	50	33	16	63	18	1	48	31	50	33	16	63	18	
260	30	51	46	3	62	19	14	35	130	30	51	46	3	62	19	14	35	47	2	49	32	15	34	17	64	
260	47	2	49	32	15	34	17	64	130	47	2	49	32	15	34	17	64	52	29	4	45	20	61	36	13	
260	52	29	4	45	20	61	36	13	130	52	29	4	45	20	61	36	13	5	44	25	56	9	40	21	60	
260	5	44	25	56	9	40	21	60	130	5	44	25	56	9	40	21	60	28	53	8	41	24	57	12	37	
260	28	53	8	41	24	57	12	37	130	28	53	8	41	24	57	12	37	260	43	6	55	26	39	10	59	22
260	43	6	55	26	39	10	59	22	130	43	6	55	26	39	10	59	22	54	27	42	7	58	23	38	11	
260	54	27	42	7	58	23	38	11	130	54	27	42	7	58	23	38	11									

The knight's tour is just one of the many ties between mathematics and chess and another famous problem is the Eight Queens Problem which is a combinatorics problem published by Max Bezzel in 1848. The knight can take many other forms of tours such as Octonarian tours, Symmetric tours and Vandermondian tours and there has been research into other pieces and their tours, however I strongly believe that the knight's proves to be by far the most intriguing.



In fact, I think it is safe to say that the knight is by far the best piece and Bobby Fischer's octopus knight is the perfect example of its impregnability and strength when used with great insight and shrewdness.

--Gaayathiri

# An illusion of intelligence: the surprising case for Artificial Intelligence in Video Games

You might be surprised to hear that “Artificial Intelligence” has been used in video games since the 1950s; the term itself is an overstatement ...and perhaps a little too flashy. Rather, game AI, distinct from academic AI, aims solely to enhance the gameplay experience, allowing entities in a game appear “alive”, yet through techniques often unexpectedly heuristic and simple - “an illusion of intelligence”.

The surprising simplicity of game AI is evident in its most recognisable application: the Non-Playable Character (NPC). NPC behaviour is essentially defined by a Finite State Machine (FSM) - an abstract computational model that exist in only one state at a time, and switches states depending on certain input. Certainly the most famous example is *Pacman* (1980). Its trademark “ghosts” have three states: roam, chase and flee. An in-game event (player eats a pill) triggers a change in state (flee!) [Figure 1]. The result is a simple yet incredibly elegant model that requires minimal computational power. (In fact, FSM is used in the operation of vending machines and traffic lights.)

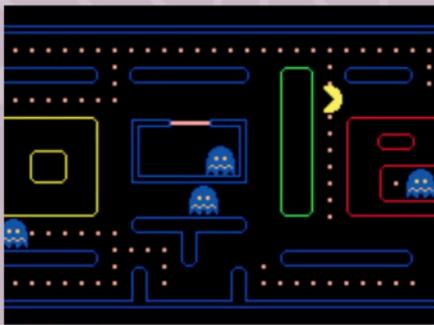


Figure 1: Flee!!! A screenshot of myself playing Google's PACMAN doodle

Modern games use FSM-based AI combined with fuzzy logic (a many-valued logic form where the value lies anywhere between 0 and 1, as opposed to the absolute 0 or 1 in Boolean Logic) to introduce unpredictability and “human” inconsistency to NPCs. This is essential for stealth-based games like *Assassin's Creed* (~2023), where AI possesses the ability to “hunt”. When the “hunting” AI detects a player, it will transition from an idle to alert state, then look for realistic markers (such as sounds or footprints) and decide whether to pursue, the path it takes, the weapon it wields, all dependent on player behaviour. This allows for stunningly complex gameplay - FSM at its arguable finest.

With the growing popularity of first-person shooter games and the rise of the real-time strategy genre, emerged the need for AI opponents which were well-trained enough to rival human players in combat and strategy. Here we introduce the “Cheating AI”, the ultimate illusion of intelligence.

AI opponents are programmed to have inherent advantage over the player: perfect shot accuracy in first-person shooters, higher speeds in racing games, physics-defying “cheats” in sports games to secure goals. In the real-time strategy game *Starcraft II* (2010), the AI opponent is simply given extra resources and vision of the whole map, unavailable to the player.



These so-called “intelligent” programs, in reality, operate on a set of predefined rules while taking crude shortcuts by accessing information in the game engine and when programmed badly, affects the gameplay massively. It seems, perhaps, a cold case for AI.

But recent development offers hope for AI in the video game industry. DeepMind's breakthrough program AlphaStar, unveiled in 2019, learns by imitating the best human players in *StarCraft II* and has beaten professional E-sports players at the game. The emergence of generative AI has led to research such as in Rikkyo University, Tokyo, exploring the creation of “human-like” NPCs with dynamic speech and movement patterns. Near-infinite open-world games such as *No Man's Sky* (2016), which can generate 18 quintillion unique variations of planets, open the doors for generative AI to reshape the non-linear storyline, open-world video game genre. From its humble arcade-game roots, game AI has come a long way, yet the future promises us even more immersive and dynamic gameplay. In this ever-shifting landscape of innovation, what awaits us within those virtual worlds of tomorrow?

--Lindsey

# The Healing Touch of AI

In the ever-changing landscape of healthcare, Artificial Intelligence has emerged as a game-changer, transforming the industry. AI's far-reaching influence spans across healthcare with particular emphasis on precision, efficiency and a patient-centric approach.

Utilising machine learning models developed by AI have proven to be significantly beneficial as they tirelessly monitor vital signs of patients in critical care and notify healthcare professionals of heightened risk factors. While conventional medical devices like heart monitors focus on tracking basic vitals, AI has gone a step further by being able to identify complex conditions, like sepsis. An IBM client developed a predictive AI model, tailored for premature infants, with a 75% accuracy rate in detecting severe sepsis. It enables doctors to be informed of potential complications at an earlier stage, allowing them to intervene promptly. This clearly shows how the integration of AI into the healthcare industry helps to make early detection more possible.



Medical imaging and diagnostics represent another domain where AI has showcased its impact. Advanced image recognition algorithms, developed by machine learning models have drastically aided healthcare professionals in analysing and identifying complicated medical images with subtle abnormalities. This ensures more precise analysis, treatment strategies as well as optimising patient outcomes and enhancing overall wellbeing.

Behind these technological breakthroughs stand entities like Google Health and IBM Watson Health who have played pivotal roles in revolutionising the capabilities of AI and its implementation into healthcare. In the future, AI guarantees advancements in clinical workflows and reducing administrative burdens as the next step. Undoubtedly, it will improve the efficiency of healthcare, especially in the NHS.

To conclude, AI has woven itself into the fabric of healthcare and paved the way for a future where treatments are more accurate, personalised and efficient. The healing touch of AI is reshaping the healthcare industry, promising a new era of health and well-being, powered by technology.

--Ipshita



## What human problems will computers solve in the near future?

A computer is designed to solve what a human cannot easily. Challenges present themselves ubiquitously to the human population. Computers and its associated technologies continue to rapidly evolve every day due to providing solutions and alleviating these pressing issues.

An example is how our current transport model is deficient. In light of this, it is a promising prospect that AI and computer models can be used to develop more effective traffic management systems, both by harnessing real-time data of traffic flow and changing weather patterns; and by the advent of autonomous vehicles to offer route and traffic optimisation.



Another example is how machine learning's ability to process mammoth data sets will allow for precision healthcare. To elucidate, cutting-edge software will optimise diagnostics and develop personalised and versatile treatment plans. Aside from patient care, quantum computers will be able to offer a far more superior understanding of molecular structures to aid drug development, and their predictive power can improve foresight into how drugs will evolve and interact over time. In effect, computers will be able to direct resources to more accurate healthcare solutions, exponentially augmenting our ability to cure diseases and reduce human suffering.

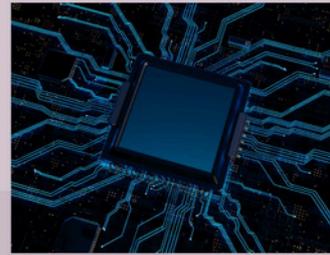
The worsening ramifications of climate change are wide-reaching. Cities consume two thirds of the world's energy, yet average consumption can drop by 15% due to smart city governance as a means for sustainable development. It promises to aggregate one hundred times more data than conventional city governance. Moreover, computer models and AI systems can parse through tremendous amounts of data, transforming predictive analytics for extreme weather events and natural disasters, and consequently strengthening communities' resilience.



The brilliance of a computer stems from its limitless potential, power, and applications. With the emergence of each new challenge, there is a solution, waiting to be designed by a keen or inspired computer scientist.

--Adeena

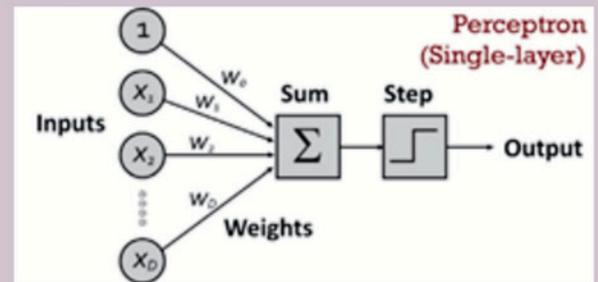
## How Computers Classify Through Machine Learning



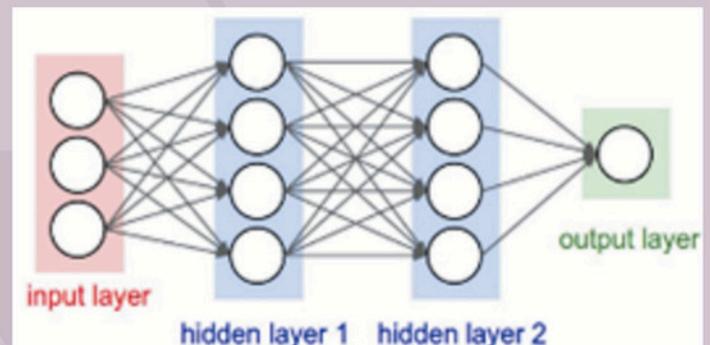
Machine learning is part of artificial intelligence, and it is the capability of a machine to act similarly to humans. It gives computers the ability to learn without being explicitly programmed. Machine learning is what lies behind chatbots, language translation apps, and medical diagnosis machines.

Two of the subcategories of machine learning are: supervised machine learning and unsupervised machine learning. Supervised machine learning is when machine learning models are trained using data sets which are already labelled (for example a labelled collection of images of cars). The machine would then learn to identify pictures of cars on its own. Unsupervised machine learning is when a program searches for patterns in data which is unlabelled (for example an unlabelled collection of images of flowers), therefore it can find patterns or trends within this data.

As for the mathematics that lies behind supervised machine learning, consider the example of a machine learning model which classifies images of numbers into 7s and 8s. Initially, the machine is supplied with an extensive labelled dataset of images of 7s and 8s. The computer autonomously discerns the key features characterising 7s and those characterising 8s.



Upon identifying these features, the machine undergoes training to recognise the digits using a perceptron. The inputs to the perceptron are the principal features of the 7s and the 8s, and these inputs are combined with weights, which signify the importance of each feature. The inputs are summed together, and a step function is applied to deduce the digit; the determination of the digit depends on whether the resultant value surpasses a predefined threshold or not.



Extensive amounts of data can be processed with a machine learning model by linking many of these perceptrons together, and this would form a neural network - which is an attempt to reproduce some of the ways it was perceived that neurons in the brain work.

In essence, machine learning and neural networks empower machines to grasp intricate patterns and features, revolutionising tasks from image recognition to language processing. The realm of artificial intelligence is constantly expanding, reshaping the way we interact with technology.

--Riya

## Should Robots Build Our Bridges?

Henry Wigmore was a police officer in the late 1800s when he began noticing a strange pattern amongst bridges toppling, stream trains crashing and foundations failing.

Humans.

When messy human emotions drive an engineering project, there's a 78% chance of failure. Take the Hindenburg; the largest airship crash to date. Built by the German Zeppelin Company and billed as the largest and safest airship constructed, the Hindenburg burst into flame and was destroyed on May 6 1937. This disaster, claiming 35 lives, marked the end of the era for giant rigid airships.



But what allowed the Hindenburg to burn its way into the history books? Was it the poor choice of "incendiary paint" on its exterior that gave way due to a build up of static charge? Or was it the two, hard left turns near landing that could have snapped a steering cable creating sparks and flame?

Whilst the Hindenburg was a major disaster in aerostatic flight rooted in human error, the Titanic is much more infamous. Boldly claimed to be "practically unsinkable" and the largest object to ever move on the water at the time, the RMS Titanic was felled on its maiden voyage.

In conjunction with this, high speeds, a fatal wrong turn, weather conditions, a dismissed iceberg warning, and brittle failure all contributed to one of the worst maritime tragedies. Several of these were attributable to human actions and let's not forget, there was enough room for Jack.

But nowhere can we observe the impacts of messy human drama than in the Cold War. Challenger and Chernobyl were both Cold War catastrophes, where the world's superpowers were each rocked by disasters occurring just three months apart.



Halfway across the globe, on January 28, 1986, at 11:38 a.m. EST, the Space Shuttle Challenger took off from Cape Canaveral, Florida. Christa McAuliffe is set to become the first ordinary U.S. civilian in space. However, 73 seconds later, the world witnesses a tragedy as the shuttle explodes due to a malfunction in an O-ring seal on the right solid-rocket booster.

In all of these case studies covered so far, there is an observable causal link; Humans. Although the error occurs at the operational level, improper designs, poor procedures and poor process safety are often the underlying causes of error. Henry Wigmore noticed this at an early age and became the foundation of what is now known as Forensic Engineering; combining engineering principles and investigative techniques to analyze to determine the causes of structural failures.

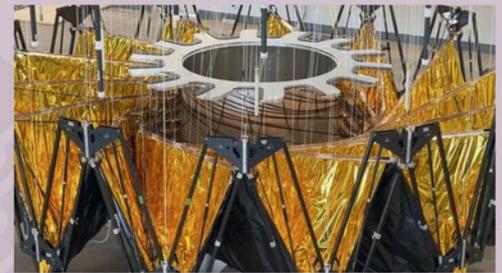
But however much we try to guard against human error, it is impossible to remove it completely. Unless we use robots. Which then begs the question...Should robots build our bridges?

--Manasvi

## Unfolding Potential: The Art of Origami in Aerospace Engineering

Origami, the ancient Japanese art of paper folding, has fascinated artists, mathematicians, and engineers for decades with its intricate designs and mathematical principles. Aerospace engineers have embraced origami's inherent properties - flexibility, scalability, and efficiency - to revolutionise the design and deployment of structures within the field, including solar panels, telescopes, and satellites.

Solar panel arrays, vital for spacecraft, face limitations due to space constraints. Origami principles offer a solution by enabling engineers to craft solar arrays that fold tightly for launch and unfold precisely in space, ensuring cost-effective launches. Origami techniques also facilitate adaptable solar arrays crucial for missions with varying orientations relative to the sun. Flexible hinges and strategic folding patterns allow panels to adjust angles, ensuring optimal sunlight exposure and enhancing energy generation efficiency.



Origami's influence extends to the creation of lightweight, high-resolution telescopes like the James Webb Space Telescope (JWST), a large space-based observatory, which showcases a primary mirror composed of 18 hexagonal mirror segments. While its mirror segments don't directly use origami, a complex deployment system involving precise folding and unfolding achieves the desired alignment and shape of the mirror. Various other components of the telescope highlight origami's evolution into a cutting-edge methodology for designing lightweight, deployable structures in space exploration.

Implementing origami in practical applications faces challenges during the shift from paper models to functional systems. Factors such as weight, forces, and dynamics vastly differ from traditional origami on paper, where strength, reliability, and robustness are paramount for engineering projects. However, advancements in materials, simulation, and manufacturing offer solutions, such as multi-material composites mimicking paper folds, ensuring strength and reliability in engineering projects.

By harnessing the creativity of origami, aerospace engineers drive innovative solutions shaping the future of space exploration deepening our understanding of the universe through compact, efficient, and adaptable structures.

--Vedhika

# Reusable rockets: The future of space exploration

The recent initiation of reusable rockets has completely revolutionized the way space exploration will work in the future by making launches more sustainable, cost effective and efficient.



The main concept of reusable rockets works on the use of a multistage vehicle. The first stage at the bottom is the heaviest as it contains the main engines for launch. The second stage is lighter and is used to take the payload into space/orbit. The main function of the reusable rocket currently is to bring the first stage of the rocket back to earth in a controlled way, as it's the most expensive and important piece of the rocket. In fact, since the Falcon 9 rocket completed this feat in 2015, some rockets have been reused up to 15 times. While launches of these rockets had cost about \$62 million in the past, the invention has already brought the cost down to 30 million and SpaceX's new reusable rocket, Starship, could bring down launch costs to about 2 million. While we also currently see launches happening once or twice a month, this could very well become multiple rocket launches a day.



How does the launch and landing of these reusable rockets work?

The first stage ignites and the rocket takes off and continues to burn until the engines are exhausted. At this point stage separation happens, the payload and the second stage continue their launch upwards, while the first stage begins its descent. The logistics of this maneuver is very important. The Falcon 9, SpaceX did this very impressively in 2015: The first stage does a 180 degree rotation and uses back burns from the engine to get into a proper trajectory for landing. Continuous burns of the engine in the opposite direction using supersonic retropropulsion reduce the velocity greatly. The Falcon 9 achieved great accuracy when landing, with a 10m position accuracy. This was greatly due to the invention of grid fins. Grid fins are aerodynamic control surfaces and change their angle to change the position and trajectory of the rocket. They are effective in super/subsonic speeds and greatly reduce aerodynamic drag. Finally the landing stage of the rocket is able to land safely and precisely using landing legs on top of either a land pad or drone ship. Wow! What a process!

This process of re-landing reusable rockets will only continue to become more efficient and exciting, with companies such as SpaceX and Blue Origin leading this feat and building amazing reusable rockets such as Starship (2023), that will revolutionize space travel in the future.

--Riona

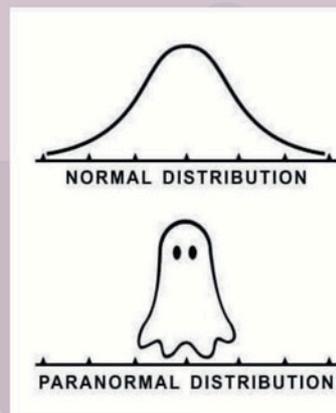
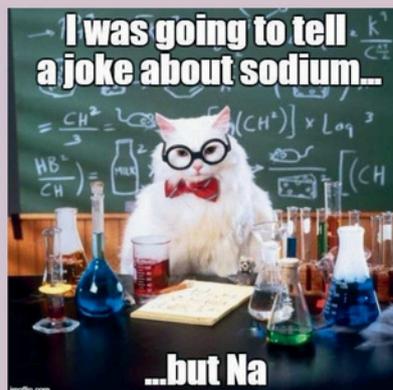
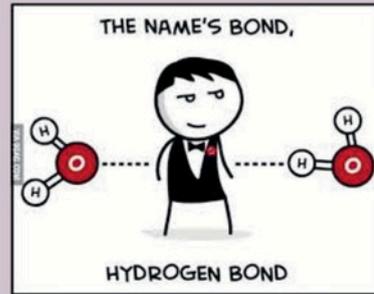
# Science Bants:

WHAT DO YOU CALL AN ACID WITH AN ATTITUDE?

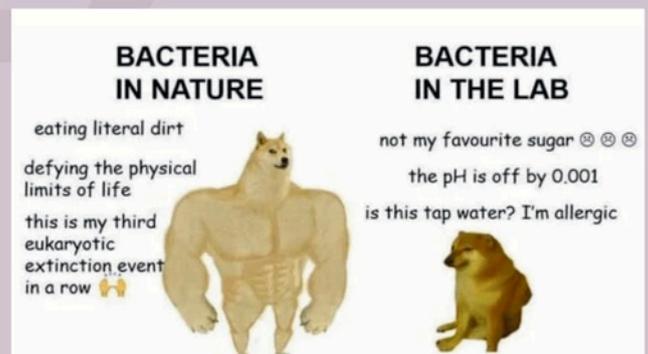
gimme ur lunch



A-mean-oh acid.



science teachers when you mix water and food coloring without wearing safety goggles



# HBSCIENTIST WORDSEARCH

M F R T U B E R C U L O S I S C H I D S  
W S L A T S Y R C I S A U Q Y I G D T D  
Z Y S X S Q P E E L S A J C L N V E H I  
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C V S T D O J H T Z N O I R L J V O M D  
O T A E O N O A H T G N I M A G I R O S  
R Z R R G I B C I T O N O O Z W H P L Q  
R Z J Z K C H S C F S P J R N T L G H E  
F F Z A G Q T N O I T A L U M I T S J K

HBSCIENTIST

BIONIC

MAGNETS

SLEEP

SUPERCONDUCTING

COMPUTER

CRYOGENIC

ZOONOTIC

QUASICRYSTALS

ORIGAMI

ORGAN

IMMORTALITY

STIMULATION

DENTISTRY

CHESS

AI

HALLUCINOGENS

CARDIOMYOPATHIC

BINARY

ROBOTS

TUBERCULOSIS

ALZHEIMER

DIET

BRAIN

GAME

MACHINE

VIRUS

SUPERFLUIDS

HARMONICS

ROCKET

# SCIENCE PHOTOS OF 2024



GROUPS OF BACTERIOPHAGES — VIRUSES THAT INFECT BACTERIA



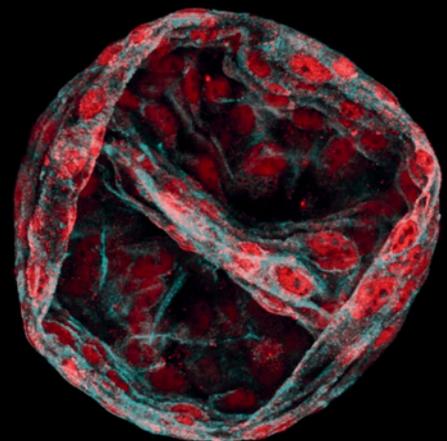
RARE VOLCANIC VORTEX RINGS - SMOKE RINGS PRODUCED BY ITALY'S MOUNT ETNA



43 METEORS, THE MILKY WAY AND STONEHENGE PHOTOGRAPHED DURING A METEOR SHOWER



TAKEN BY PHOTOGRAPHER ENRIC GENER IN THE MEDITERRANEAN SEA



AN ORGANOID MADE OF HUMAN PLURIPOTENT COLON CELLS, WITH THE METABOLIC ENZYME MTHFD2 STAINED IN RED

