#700STEMChallenge

FINALISTS
MAGAZINE 2021

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INTRODUCTION

Congratulations to the finalists of the fourth Sydenham #700STEMChallenge.

There were over 70 entries, all of an extremely high standard. After much deliberation, the following articles were selected as the top three entries for each category.

UNDER 14 RESULTS

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2nd - What link is there between pregnancy and oral health?
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1st - Quantum computers
T Mitchell, South Hampstead High School

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Eva Helly-Osborne, Royal High School Bath

3rd - How one letter could be changing the future
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3rd - The Grumman F-14 Tomcat: A Cinematic and Aviation Marvel
Sienna Jacobs, Wimbledon High School

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J Sanitt, South Hampstead High School

3rd - A platonic journey through the dimensions
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Maya Shah, Notting Hill and Ealing High School

3rd - How has artificial intelligence influenced organic chemistry?
F Braganza, South Hampstead High School

Technology/ Engineering:

1st - Could bringing back the mammoths help solve climate change?
Sophia Harley, Wimbledon High School

2nd - Volumetric Displays: From Science-Fiction to Science
Vedagiri, Wilson's School

3rd - What is a heat recovery ventilation system, and how can it improve energy-efficiency in the home?
Danielle Senanu, Oxford High School

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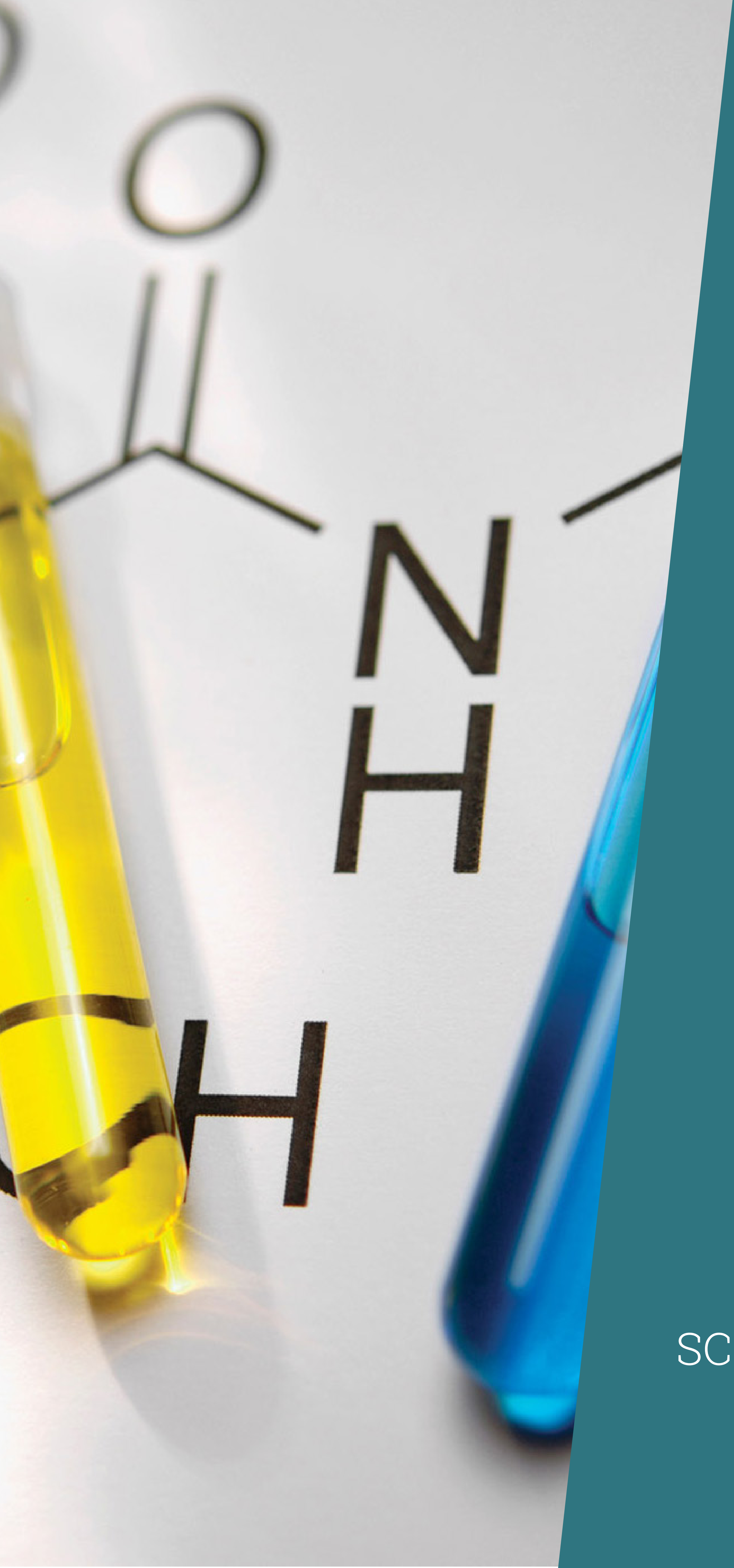
Amy King, Oxford High School

2nd - The Unsung Hero of Renewables
E Roberts, South Hampstead High School

3rd - Antibodies against HIV: Immunology gone viral
Julia Grzywacz, Wimbledon High School



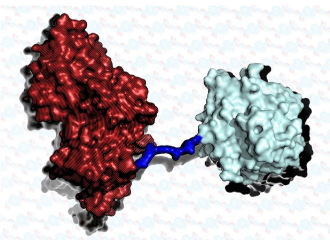
UNDER 14
SCIENCE ESSAYS

Can the bacterium Ideonella sakaiensis 201-F6 solve our plastic crisis?
- Noa Murphy-Morris, Sydenham High School

We are all aware that we are living in a plastic crisis of our own making. National geographic states that "a whopping 91% of plastic in the world is not recycled" ending up in landfill where it can take 500 to 1,000 years to degrade (Parker 2019). Plastic is polluting rivers, beaches, lakes and oceans across the world not to mention the precious sea animals that are dying after ingesting our plastic rubbish. Banning single-use plastic is not a long term solution as this would increase food waste resulting in increased carbon dioxide emissions, contributing to global warming, and burning it would also be environmentally damaging (UCL 2020). It is therefore essential that we find inventive new ways to overcome plastic pollution. So, could biology be the solution to this plastic epidemic? Is Ideonella sakaiensis our answer?

In 2016, scientists at the Kyoto Institute of Technology in Japan made a surprising discovery! They tested different bacteria from a polyethylene terephthalate (PET) bottle recycling plant and found Ideonella sakaiensis, a bacterium from the genus Ideonella and family Comamonadaceae. They found that Ideonella sakaiensis was capable of digesting plastic that was formerly thought to be imperishable in nature. It works by secreting an enzyme (a type of protein that can speed up chemical reactions) known as PETase. This splits certain chemical bonds called esters in PET, leaving smaller molecules of MHET that the bacteria can absorb, using the carbon in them as a food source (Flashman 2018).

As incredible as this discovery was, in 2018 Professor John McGeehan, director of the Centre for Enzyme Innovation (CEI) at the University of Portsmouth took this discovery a significant step further. He and his team created an engineered version of PETase that was able to break down plastic in a matter of days! They mixed PETase with a second enzyme, MHETase, and found "the digestion of the plastic bottles literally doubled" (Rigby, 2020). The MHETase breaks down the compound further into its separate monomers ethylene glycol and terephthalic acid. This then again allows enzymes to eat the carbon in these monomers. The researchers connected the two enzymes together in the lab, using genetic engineering as shown in this diagram.



The super enzyme, which is two proteins joined together © Aaron McGeehan/Knott et al (Rigby 2020)
Therefore a 'super-enzyme' able to break down PET six times faster than the original PETase enzyme alone had been created (Rigby 2020).

Yet how can the recycling industry make use of this knowledge to solve our plastic crisis? We know that Ideonella sakaiensis breaks down PET, however the process is still too slow to be useful in the recycling industry. It takes a certain amount of time before the bacteria have established themselves and reach a volume that really makes a difference. The question is how do we speed the process up so that it can keep up with our speed of plastic consumption? Scientists need to understand how they can make Ideonella sakaiensis work faster by changing conditions such as heat and ph. However by manipulating certain conditions, unforeseen issues can occur where the microorganisms are not thriving. There is also the risk of encountering 'denaturation', the process whereby the enzyme can no longer function due to extreme changes, when trying to manipulate enzymes (Meyer 2019).

Scientists have also been looking at ways to make use of the broken down components; ethylene glycol and terephthalic acid; ethylene glycol can be used directly in antifreeze, or to replace the plastic carrier bags that are on the way to being banned in many countries.

Looking to the future, scientists have battled with the limitations of PET hydrolase enzymes in terms of their limited productivity. There are new ideas to skip the bacteria itself and instead focus on imitating the enzyme's processes (Meyer 2019).Tournier et al (2020) report on exciting new developments in working with hydrolase enzymes which appear, in the early stages, to outperform Ideonella sakaiensis in laboratory trials. This is an exciting new development that could eventually lead to improved results in plastic recycling.

Nature has shown us how enzymes can be used to solve our plastic crisis. Thanks to the discovery of Ideonella sakaiensis, nature has indeed outperformed humans.

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Science in my day
- MMK Schröder, Wilson's School

Science and everyday life cannot and should not be separated – Rosalind Franklin

My day seems boring. Wake up, eat, read, walk, sleep. But Science, Technology, Engineering and Mathematics is everywhere – from waking up to falling asleep. In the morning, optic nerves in my eyes sense the sunlight, triggering a release of cortisol to wake me up, where the brain is the body's control centre and sends messages through nerves which control my muscles. Then I get out of bed and move around. Nerve cells communicate with each other by sending chemical and electrical signals. [1]

I throw back my bedding so moisture from body sweat during the night might evaporate and air can kill the 1.5 million dust mites[2] that are everyone's sleep buddies (icky!) Nature calls and I open the bathroom door by applying torque (a force that causes an object to rotate). I spread fluoridated toothpaste on my toothbrush and brush. Two minutes of this tricky manoeuvre is all it takes for my pearly whites – long may it last! Fluoride can help prevent tooth decay caused by too much sugary food and drink.[3]

I have a simple breakfast of toast. Once eaten, a *slightly* more complex process continues inside me. Chewing my food mixes it with saliva to turn it into a wet lump - the bolus (ew!) and the oesophagus propels it into the stomach through peristalsis. Here my food is pounded and broken down with acid, before entering the small intestine where nutrients are absorbed through the villi, small projections in the intestine walls. Onwards through the large intestine, water is extracted, leaving a dry-ish lump that eventually leaves the anus. Clean the toilet, open the windows and wash your hands!

Back to my gripping novel. Reading works around our knowledge of the spoken language. First and last letters are surrounded by spaces to make them more visible and distinctive. For example, when we read the word 'duck', our brain first processes 'd' and 'k' and then identifies the other letters, allowing us to distinguish this word from others like 'deck'.[4]

I get dragged out for a brisk walk. More than my leg muscles, my heart, abdominals, arms and back also get a workout. We try to avoid main roads because petrol and diesel exhaust fumes[5] contain noxious gases and particles that irritate the eyes and respiratory tract. Long-term exposure to fumes could increase my risk to lung cancer or deadly seizures.[6]

We are especially careful crossing quieter roads because the technological marvel that is the electric car can silently creep up on you. I observe the slight push back when my neighbour's car starts. This is inertia, when an object resists a change in its motion. My parents remind me of my own inertia to certain activities. I am out of breath when we get home after working my muscles hard and respiring more.

At home I watch squirrels trying to break into our bird feeder. Light bounces off the squirrel and into my eyes, where a convex lens, the cornea, focusses images onto my retina upside-down. Optical nerves take the image to my brain that flips it and voila!

After lunch I watch television from the sofa. Food I ate is stored as energy measured in joules. Typically, a 13-year-old needs around 10 million joules each day [7]. The television I watch works by shining three beams of light through every pixel; each beam in a different primary colour. When these colours are blended on the screen, I see a delicious cake topped with slashes of icing and meringue (yum!)

I practise my drum grade pieces. People who regularly play drums start to develop thicker fibres in the main tract connecting the two halves of the brain.[6] Through the day I drink water to stay hydrated and help my body function properly, like carrying nutrients and oxygen to my cells and flushing out waste chemicals.

After dinner, I start to flag. When the sun goes down, the pineal gland in my brain produces a hormone called melatonin and makes me tired and sleepy. Melatonin is produced a few hours later in teenagers than it is in adults, wanting me to go to bed and wake up later.

You may not think you are into STEM, but *we are* STEM.

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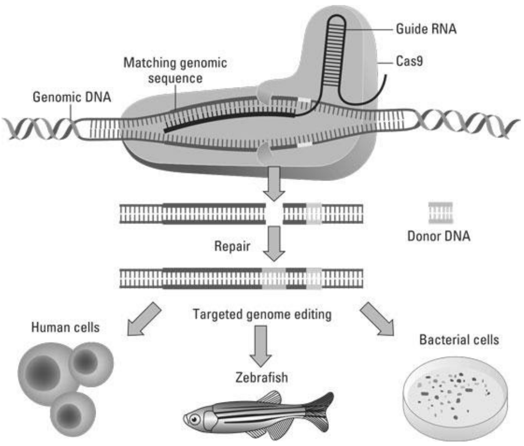
Genetic Engineering into the Future…
- Dia Nair, South Hampstead High School

Imagine a world where scientists can modify genes to achieve eagle-like vision, substantially expand human brain capacity, or even lengthen one's lifespan. A world where diseases like cancer becomes a threat of the past; where mankind achieves super-human capabilities, which if handled carelessly, could even lead to the annihilation of humanity. Seem like an unreal, crazy, and sci-fi place? What if all these scenarios could potentially become the future of our planet within years? How? Simple: Genetic Engineering.

CRISPR – The Innovative Panacea

Over the last few decades, genetic engineering has evolved from being a matter in the realm of probability, to life-changing technology saving millions of lives. Initially, it was a process of extracting genes from an organism and transferring it onward to another organism, so that the latter can develop that trait. However, this method had achieved little success because the gene would have to be added to every cell in the body, a process which on its own is quite difficult.

However, in 2012, two female molecular biologists invented a new method which does just that: it's named CRISPR. CRISPR (or CRISPR-Cas9) is the world's most successful technology when it comes to editing genomes. It has two components: CRISPRs, which are specialised extensions of DNA; and Cas9 enzyme proteins, which act like molecular scissors to cut the DNA.



The CRISPR-Cas9 system works by using short RNA sequences that have the correct genetic code needed in the cell. They are also connected to the Cas9 protein. Firstly, they are added to a cell with the defected gene. The RNA then connects to the target sequence and the Cas9 cuts off the DNA. The cell then automatically replaces any faulty genes. This would mean the cells within the body have not only successfully eradicated all the defective genes but added healthy ones too.

Genetic Diseases - A Worry of the Past

The new gene editing method using CRISPR helps cure many genetic diseases. Let's take the example of Creed Pettit, a boy suffering from leber congenital amaurosis (LCA): a genetic syndrome occurring when genes allowing sight have not been passed

down from either the mother or father's side. This meant that Creed would turn fully blind as he approached adulthood.

However, six years after being diagnosed, Creed and his family got to experience genetic engineering first-hand. There had been a remedy discovered for LCA called Luxturna, a harmless virus which would replicate healthy copies of the missing gene within the retina. Creed was the youngest person to go through this gene therapy and the improvement in his eyesight was evident within days. Genetic engineering clearly seem to create cures for diseases which doctors once believed as non-treatable. Going by Creed's example, it could become the ray of hope for many.

The Ethical Argument – Promising or Perilous?

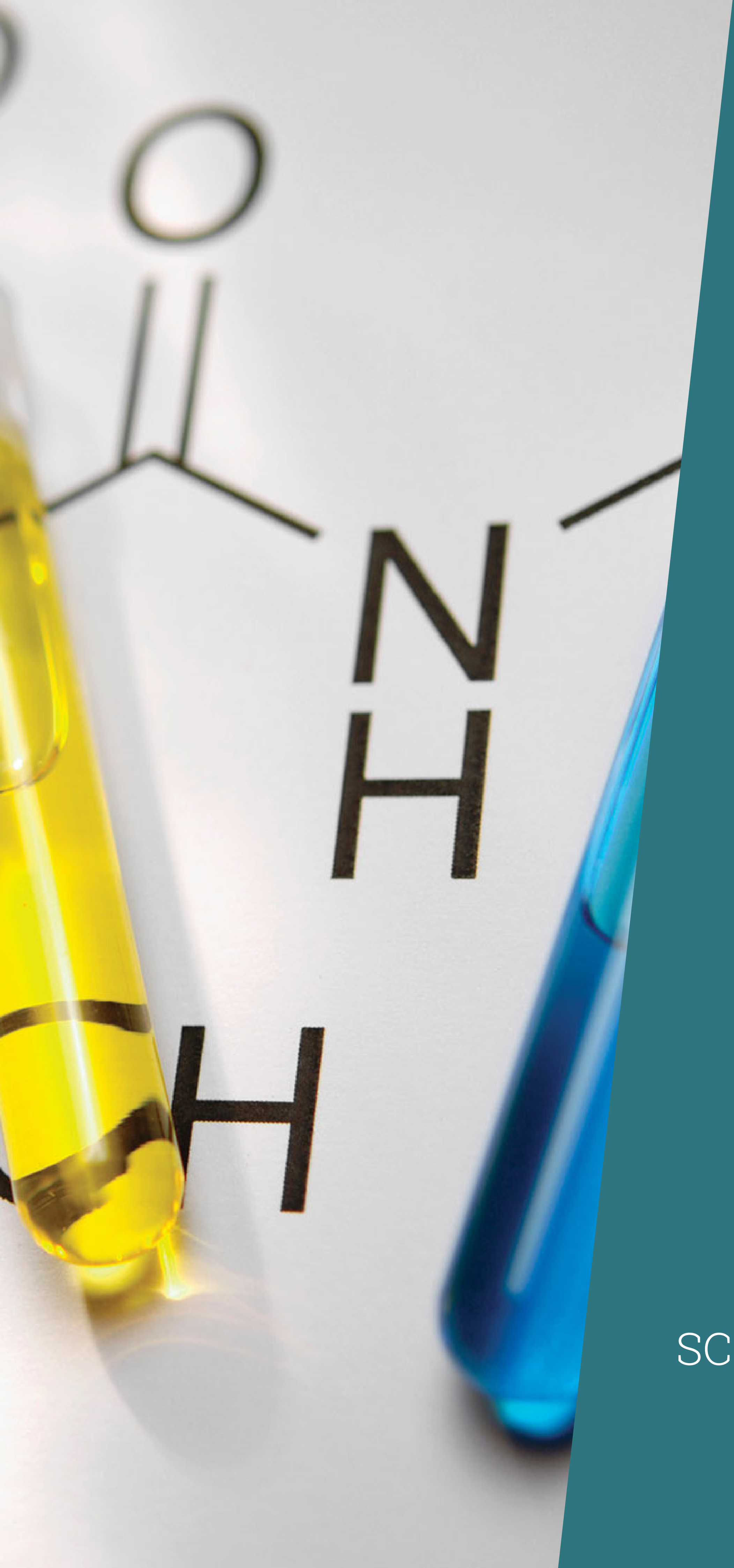
Genetic engineering, as mentioned above, holds immense potential for curing various diseases. If applied on a child, the modified gene will not advance through the offspring. That said, it can also repair faulty DNA within an embryo, which would cause the new gene to be passed to future generations. This process could change the DNA structure of humans, in possibly volatile ways.

While it seems as one of the finest victories of Science and Technology, there is an equally powerful argument against genetic engineering. Such school of thought

believe that the decision to improve a human genome should not rest with a select few. The argument questions who get to decide the improvement on the gene structure of humans going into the future. Should the human genome, which has evolved over billions of years, be allowed to be tampered by a few scientists - a process which could potentially end in unintended consequences.

Conclusion

In today's day and age, genetic engineering holds life-changing possibilities for millions; it has great value in human evolution and advancement. As seen above, CRISPR-Cas9 holds immense promise to cure many genetic ailments. However, the route has hidden risks too. Gene editing has the potential to alter the course of human evolution, for the good or the bad. So, the trillion-dollar question: which path will mankind take as we march towards our future?



UNDER 16
SCIENCE ESSAYS

Stem Cells: Can they help to get people back on their feet?
- Tehya Beighton, Oxford High School

Einstein once said that “Life is like riding a bicycle. To keep your balance, you must keep moving”. Movement is essential to life. Through aerobic exercise, it helps us manage stress and anxiety by reducing levels of cortisol and adrenaline, the hormones responsible for the ‘fight or flight’ response. In addition, it increases the production of endorphins, which elevate our mood. Without movement, it is almost impossible to function properly. For the 156 million people worldwide who are wheelchair bound, it’s a way of life that they have either been living with (if born with a spinal deformity), or have developed later in life, either gradually as a degenerative disease or suddenly after spinal trauma. However, solutions to these problems are becoming much less of a fantasy with the recently emerging area of using stem cells for regenerative medicine. So, can we use them to help these people live functional lives?

A stem cell is an undifferentiated cell, which means it’s final cell type has not been determined. The potential of stem cells can vary. A true stem cell is totipotent, meaning that it can develop into any different kind of specialised cell, as happens during embryonic development. A pluripotent stem cell is similar, but has slightly restricted abilities. It is this feature that makes them so valuable to us in medicine and such cells can be referred to as embryonic stem cells. Other stem cells stay partly undifferentiated and are stored in bone marrow until we need to use them to heal structures such as bones; however, these are only multipotent as they are partly differentiated, so can only form a limited number of tissue types. We can still use these to create specific cells in a controlled environment by harvesting different kinds of stem cells from parts of the body and injecting them into the site of damage. By controlling the conditions they are grown in, we can encourage them to become specific cells. These cells are called Mesenchymal stem cells.

When the spinal cord is damaged, myelinating cells and neurons die. It is known that the spinal cord attempts to repair itself by other myelinating cells migrating from the peripheral nervous system to remyelinate the damaged axons and by adult stem cells migrating to the site of injury to attempt to replace the damaged neurons, but the dead cells at the site form scar tissue that thwarts the productivity of the stem cells, so the attempt is often incomplete or unsuccessful. Scientists use both Mesenchymal and Embryonic stem cells to address this issue. Mesenchymal stem cells can be harvested from bone marrow, and are able to differentiate into macrophages, which can clear the damaged site of debris and scar tissue by ingestion. This process can encourage the productivity of myelinating cells to start repairing the axons of damaged neurons. Pluripotent embryonic stem cells can be harvested (controversially) from the centre of an undeveloped human embryo. Injected into a damaged spinal cord, they can specialise to become neural cells to make up the severed nerve, myelinating cells for rebuilding the myelin or astrocytes for supporting the neurons and playing a part in the immune response.

Being able to get people back on their feet after spinal injury would be a huge metaphorical leap forward in modern medicine. There are, however, ethical challenges to achieve this goal, none more so than the harvest of pluripotent stem cells from human embryos. In terms of practicality, there have been anecdotal cases of tetraplegic patients making full or partial recoveries with stem cell based therapies. As we learn more about this pioneering research, the possibilities become endless and cures for not only spinal cord injury but other degenerative conditions such as Parkinson’s and Huntington’s disease become a realistic hope for the future.

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What link is there between pregnancy and oral health?
- Naini Sindiyo-Bennike, Streatham & Clapham High School

Did you know that gingivitis affects 60% to 75% of all pregnant women? Usually, when women are pregnant, dental checks and oral health does not jump to mind, but it is extremely important. This is what I am going to be exploring.

Throughout pregnancy, hormonal fluctuations occur and these can lead to gum disease and tooth decay, or dental caries. This is mainly due to various changes in the salivary composition. Saliva is typically composed of sodium, potassium, calcium, magnesium, bicarbonate, and phosphates. During pregnancy, there is a gradual decrease in calcium and glucose levels and an increase in phosphate levels. Owing to these acidic changes, teeth become liable to dental caries and erosion. Another reason why the saliva becomes more acidic is because of the decrease in salivary pH and buffer capacity. A buffer is most commonly a solution that can resist a pH change when there are more acidic components added. So, with reduced levels of phosphate and bicarbonate (which account for the buffer), it allows the saliva to become more acidic. It is very well known that while women are pregnant, some crave certain foods and these are frequently cariogenic (cause decay), this is known to be because of hormonal changes. Consequently, the mixture between a decrease in saliva pH and certain food cravings, makes the teeth of pregnant women significantly more prone to dental cavities and erosion.

Not only does the increasingly acidic saliva affect teeth, but also the surrounding gum (typically the gingival tissue). This can aggravate pre-existing gingivitis. This is when your gums bleed quite easily, but this is fairly treatable. In a study conducted by Doctor Rola Al Habashneh in 2008, they found that 81% of physicians agreed that pregnancy increases the inclination of gingival inflammation. This inflammation is usually more present in the second or third month of pregnancy, this may increase or carry on in the next 3 months and then eventually start to decrease in the last month. If gingivitis is left untreated it can develop into periodontitis, which is a relatively severe case of gum disease as it affects the surrounding tissues that support teeth. In extremely severe cases, it can start to affect the bone that also supports teeth.

How do these oral changes affect the pregnancy itself in return? If the gingivitis develops into periodontitis, it can unfortunately have unfavourable consequences for the foetus and/or the child. Some studies and research have found a connection between severe gum disease, including periodontitis, in pregnant women and preterm labour and low birth weight (LBW). This is because the bacteria from the inflammation in the gums can get into the bloodstream and target the foetus. It gets worse, only less than half of physicians (32%) conducted by the same study by Doctor Rola Al Habashneh, felt that periodontal disease can be treated safely using scaling and root planning during the pregnancy. This means that many doctors would not perform the treatment on pregnant women.

In conclusion, oral health and dental care during pregnancy should not be underestimated. In my opinion, for every ultrasound, a dental/oral health care check-up should be performed to ensure that the baby can be carried healthy to the end of term. In addition, the importance of oral care at home should be highlighted.

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The Role of Hydrogen in Meeting the World's Climate Goals
- Astha Sinha; James Allen's Girls' School

Texas freezes. Ice caps melt. The dolphin population dwindles. We are constantly swarmed by articles describing the detrimental effects of climate change but, how are we actually tackling it? The 2020 Paris agreement set out the climate goal of stabilizing global temperature rise at 1.5°C and whilst we have made progress with the ever increasing use of electric cars and renewable energy- which now accounts for c. 40% of total electricity generation in the UK- this alone will not be enough to successfully meet the target.

There are still many hard to decarbonise sectors where it is proving difficult to considerably reduce CO2 emissions. Take for example the EU, where the energy it uses in sectors such as transport, industry and heating is currently responsible for 75% of its greenhouse gas emissions. This is because these sectors face certain constraints in electrification and cannot solely rely on variable renewable energy flows. Here, hydrogen has the capability to play a vital role in reducing greenhouse emissions.

One of the main uses of hydrogen will be for transport. Whilst many experts believe that electric vehicles are the future for passenger cars, the use of hydrogen fuel cells (a cell which produces electricity when supplied with hydrogen and oxygen with the only product being water due to the oxidisation of hydrogen) for other, larger means of transport such as lorries, trains and aeroplanes is likely. This is due to the fact that hydrogen has a high energy per unit mass which would result in a smaller and lighter battery needed to power the vehicle. Many transport companies have already invested in building hydrogen powered vehicles, an example being the firm Alstom which launched the world's first passenger train powered by hydrogen back in 2018.

Furthermore, hydrogen can be used as a substitute for coking coal in the steel industry- one of the world's largest carbon emitters. Traditionally, coking coal is used to reduce the iron ore which releases 1.9 tonnes of CO2 for every tonne of steel produced. Instead by using hydrogen, which produces water instead of carbon dioxide, it will greatly reduce the overall carbon emissions from the industry.

However, despite the wealth of benefits it brings, hydrogen does come with a few challenges. Firstly, hydrogen has a low volumetric density which means that it needs to be compressed in a high pressure container. What is more, hydrogen has a low ignition energy and high flame speed which increases the probability of it igniting in an unplanned manner with unstable flames. Both these factors create significant problems when it comes to the transportation of hydrogen which could prove to be expensive. Moreover, there is a slight concern over the social acceptability of hydrogen as confidence for switching to hydrogen from fossil fuels still needs to grow. Finally, an important consideration to take is the production of hydrogen. Depending on the method used to produce it, we can split hydrogen into 3 main categories: grey, blue and green. Grey hydrogen is made from fossil fuels which undergoes a process called steam reformation. Blue hydrogen is also made using fossil fuels but includes carbon capture and storage technology which removes the majority of the CO2 released. Lastly, we have green hydrogen which is produced by electrolysis using renewable energy. Humans already produce around 70 million tonnes of hydrogen each year, mainly for making ammonia fertilisers and methanol to use in oil refining, however, the vast majority of this is grey hydrogen. In order for hydrogen to make a difference when it comes to carbon emissions this needs to change so that all of the hydrogen produced is blue or potentially even green. Fortunately, due to the rapidly decreasing price of power from wind and solar farms, production of hydrogen using clean electricity is looking increasingly likely.

Overall, despite all its challenges, hydrogen has a crucial part to play when it comes to reducing carbon emissions and meeting our climate change goals; especially when used in combination with renewable energy generation it could present a viable long term solution. As scientists continue to make breakthroughs when it comes to providing energy form hydrogen, the once distant utopia of a carbon neutral world is slowly forming into an affordable reality.

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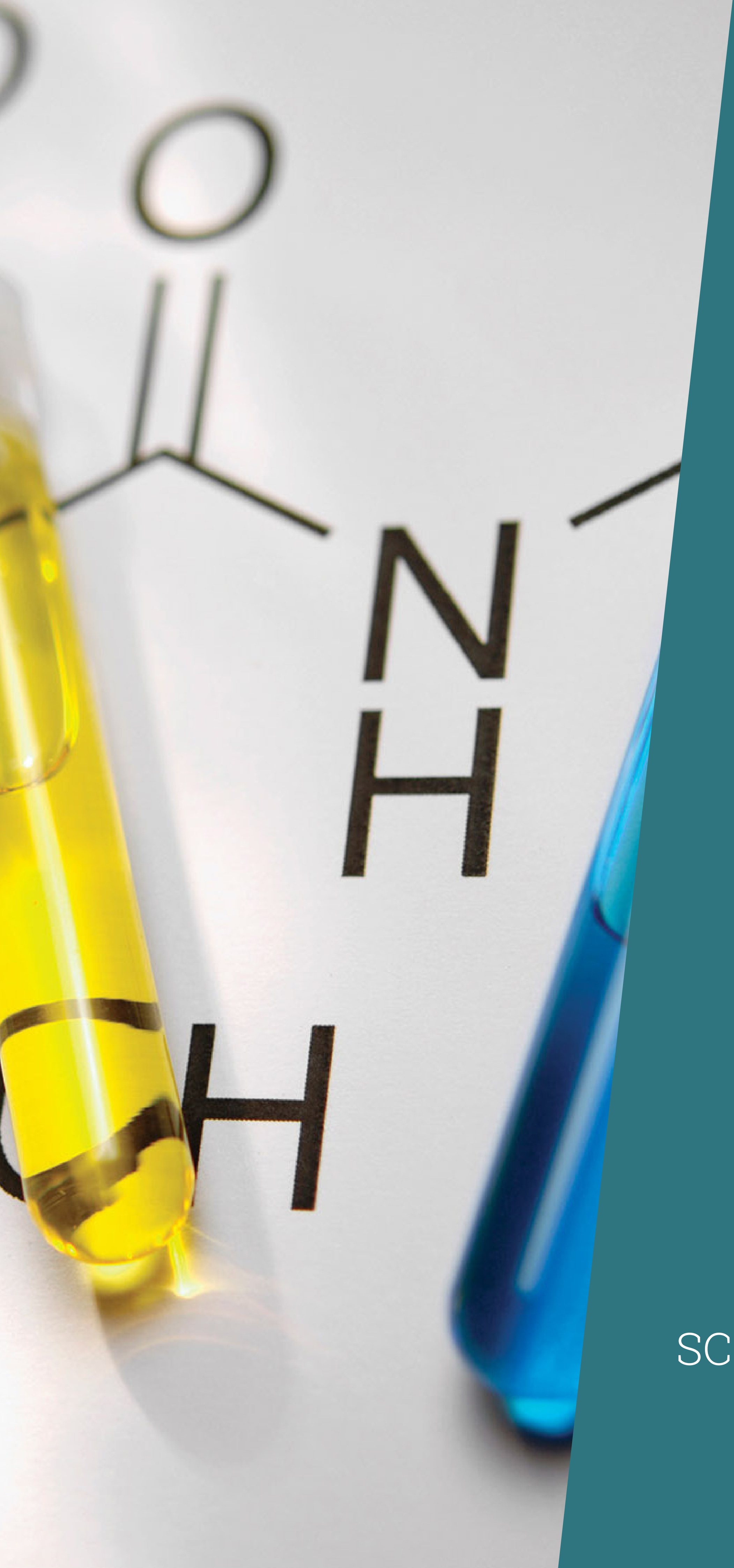


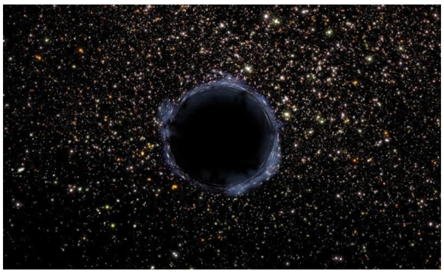
UNDER 18
SCIENCE ESSAYS

What are and how do black holes arise
- Magdalena Freund, Royal High School Bath

Humanity has always been fascinated by the infinite expanses of space. We want to know what's out there; whether there are other forms of life besides us; when space was created and how everything is linked together. Today we can say much more about the different planets, galaxies and phenomena, which usually occur several thousand light-years away from us, than about the depths of the world's oceans.

One of these phenomena are the "black holes". There is no complete definition of these yet. However, we know that they can devour not only matter (planets, space ships, stars, etc.) `not even light, can escape´ (Nasa Science). They are not normal holes, but a kind of funnel. At the end of the funnel is the singularity. There, the entire mass is concentrated on an extremely small volume (density is infinite), creating such a huge gravitational force that not even light can escape from there. The outermost boundary of black holes is called the event horizon. Anything that crosses this horizon will never escape from the funnel again because it need to be faster than the speed of light (300,000 km/sec). Comparatively, the escape speed to leave the Earth is 11.2km/sec.

The `spaghettification´ (Maya Wei-Haas) became known by Stephen Hawking´s after he published his book "A brief history of time" (1988). Due to the already mentioned high gravitational force, which emanates from the singularity of the black hole, everything is pulled into length like spaghetti. As the gravitational force increases with less distance, this process is accelerated until nothing is visible to the human eye. Thus, the journeys through black holes shown in science fiction movies would only become feasible if there was no more singularity.


computer animated black hole

When we hear the term "black holes", we usually think of the theory of relativity established by Albert Einstein. He `first predicted the existence of black holes in 1916, with his general theory of relativity´ (Taylor Redd, 2019). This states that apparently, space-time can be stretched and compressed by gravity. This means that black holes have such a large gravitational force that they can bend space-time (time and space become unimportant and have no longer any influence). Einstein and Nathan Rosen explain this theory in an experiment also known as the Einstein-Rosen-Bridge.

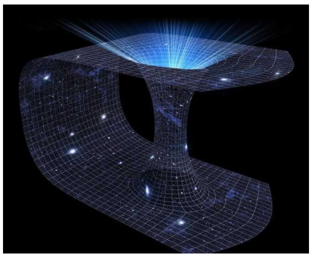


illustration black/white hole + wormholes (2)

You have to fold a piece of paper in the middle and set it up to create a kind of hemisphere. Then you stick a pen into the middle of one side of the sheet and come out on the other side. One hole represents the "black hole". There, the matter is "devoured". On the other side, the matter comes out again. This is also known as the "white hole". The path has the name "wormhole" – so the theory.

But how do the black monsters of the universe come into being? Two forces act on a star: the gravitational force (gravity) that holds the star together (to the center) and the radiation pressure (from the center). The latter is produced by burning the "fuel" inside the star. Due to these two countermeasures, the star remains stable. The star who becoming a black hole, must be `three times the mass of the Sun´ (Nasa Science). `For smaller stars, the new core will become a neutron star or a white dwarf´ (Taylor Redd, 2019). As soon as this star no longer has any fuel inside and thus no more radiation pressure, the remaining gravitational force causes the star to collapse in just a fraction of a few seconds. This collapse produces a colorful explosion called a supernova. How big and how strong the attraction of the black hole will be, depends on the former size of the star.

There is a difference between small and large black holes. The origin of the small stellar black holes is known. However, we cannot yet comprehend the origin of the large massive black holes. For their formation, it would need stars that are several million times heavier than the sun, and this cannot exist, because if a star becomes too heavy (300 solar masses), it is torn apart by its own radiation. Nor can they be grown, because the universe is far too young to do so. Besides, an "intermediate size" has never been found that would confirm this theory.

`Scientists have found proof that every large galaxy contains a supermassive black hole at its center´ (Flint Wild, 2018), but also `as many as ten million to a billion such (smaller) black holes in the Milky Way alone´ (Nasa Science). These stabilize the entire Galaxy and are therefore very necessary. `The supermassive black hole at the center of the Milky Way galaxy is called Sagittarius A(*). It has a mass equal to about 4 million suns´ (Flint Wild, 2018). The black hole named A0620-00 in the constellation Unicorn is the next black hole to Earth. However, it is several thousand light-years away from us and therefore cannot be dangerous to us.

Many scientists are researching about this matters. Only a few months ago, the Nobel Prize in Physics was handed over to three European scientists who have made important findings.

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Why There Is Mistrust of Medical Professionals and Healthcare in Black Communities
- *Maya Shah, Notting Hill & Ealing High School*

Black communities have suffered years of enslavement, racial segregation, and structural racism in every aspect of their lives; whether in the criminal justice system, or at their local GP. This history of persecution has led many Black people to feel as if they cannot trust state bodies to care for them: healthcare is no exception. There is a particular mistrust of healthcare, established through centuries of unequal, inadequate medical care and exploitation under the guise of medical research.

Systemic racism permeates every societal institution, including healthcare, resulting in the sometimes fatal mistreatment of Black patients, which causes wariness of medical professionals. In 2021, Black women are still four times more likely to die in childbirth than White women in the UK. Although socio-economic factors could explain this disparity, a report using data from the United States Department of Health and Human Services concluded that Black, middle-class women were more likely to die in childbirth than White, working-class women. This undermines explanations based on socio-economic inequalities.

Much of the inadequate care Black people receive is due to centuries-old, racist fallacies about the Black body, still believed by many medical professionals. In a 2016 Princeton University study of 222 White medical students and residents, about 50% reported that at least one of the fallacies was possibly, probably, or definitely true. These included: nerve-endings are less sensitive in Black people than in White people; White people, on average, have larger brains than Black people; Black skin is thicker than White skin. These widespread beliefs are the result of bigoted doctors, who, in the 1800s, performed heinous, non-consensual experiments on Black slaves to substantiate the racist belief that the Black body is intrinsically different from the White body. Their beliefs were presented as fact and published in medical journals, and as the 2016 study showed, are still perceived as truth by many. This racist pseudoscience has had serious, adverse consequences on the treatment that Black people receive, as well as deepening Black communities' distrust of healthcare.

Whilst structural racism is a significant cause of disparities in healthcare, racist ideology and violations of Black people have formed the foundation of modern medical and anatomical understanding. Intergenerational trauma, a result of medical exploitation, has led to a fear of public health services and officials. Throughout the 1800s, the bodies of Black slaves were utilized as 'anatomical material' in medical schools, and their dissected bodies were exhibited without consent across America. The lauded 'father of gynaecology', J. Marion Sims, performed extensive and painful operations on Black female slaves without anesthesia; he also believed the Black people were impervious to pain. Even after the abolition of slavery, Black people were dehumanised and reduced to objects of medical research, as depicted by the notorious 'Tuskegee Study of Untreated Syphilis in the Negro Male'. The study, conducted by the US Public Health Service, ran from 1932 to 1972. It consisted of 600 African American men, 399 of whom had syphilis, instead told they were being treated for 'bad blood', a term used to refer to a variety of ailments. To trace syphilis' progression, the researchers provided no care, despite penicillin being the recommended treatment for syphilis in 1947; they watched as the men went blind, developed mental disorders or died, due to their untreated syphilis. 128 participants died from syphilis or related complications. Taking into account this history of exploitation, Black communities' lingering suspicions about healthcare and health officials are understandable.

When discussing this mistrust of medical professionals, it is important to acknowledge the events and inequalities that have led to its establishment, instead of regarding it as paranoia or a lack of education. Recently, this is reflected in research that showed that 72% of Black Britons are hesitant to get the Covid-19 vaccine, despite the Black community being one of the hardest hit by the pandemic. Ultimately, until medical bodies accept the existence of structural racism in healthcare and act to overcome these disparities, Black communities will continue to feel that the government does not have their wellbeing and health in their best interests and this entrenched mistrust will not lessen.

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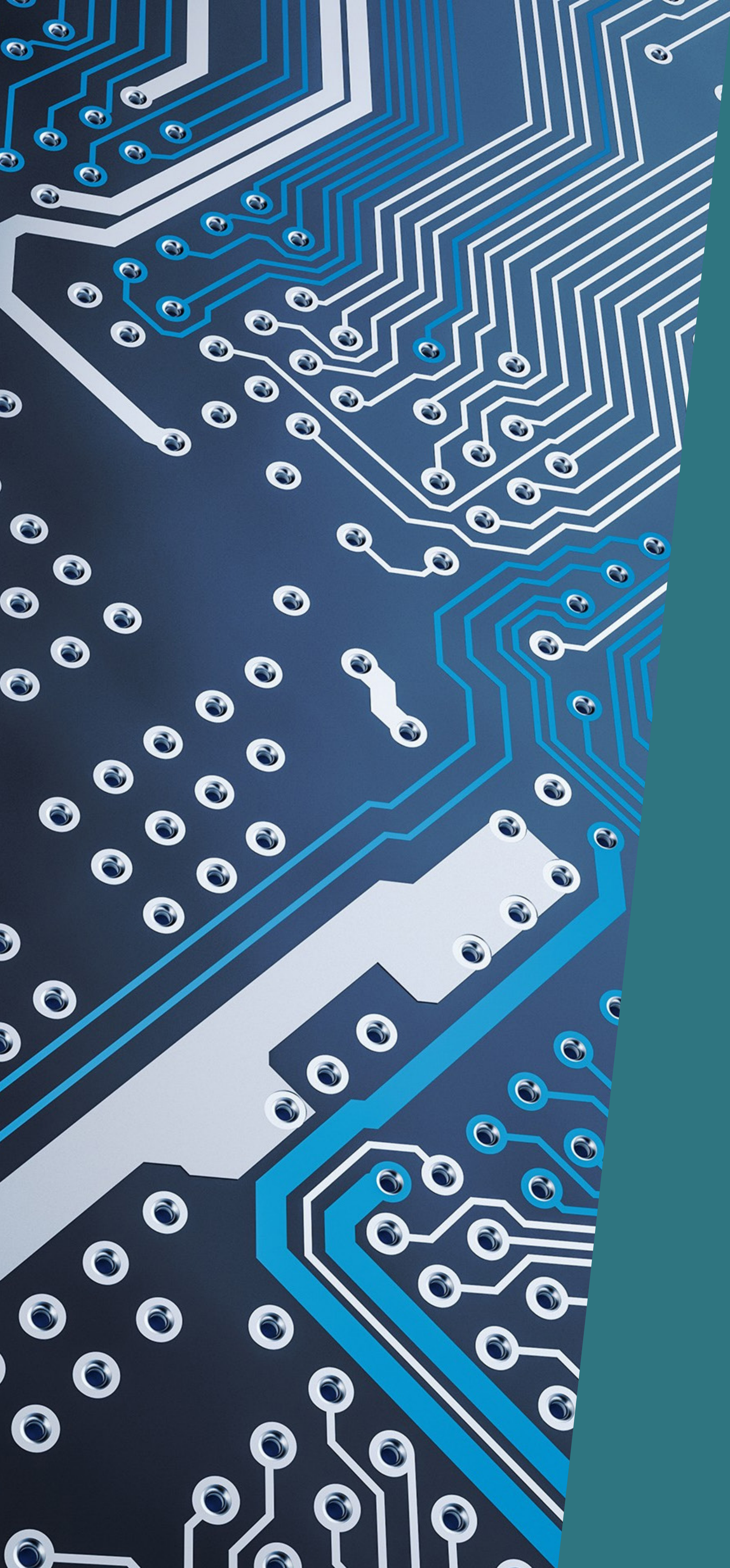
How has artificial intelligence influenced organic chemistry
- F Braganza, South Hampstead High School

Artificial intelligence is the future of humanity and almost every job industry ; it is changing the world as we speak. From marketing to healthcare, finance to transportation it has modified and will continue to modify the way in which businesses function on a daily basis. It is the future and as said by Doctor Kai-Fu Lee 'AI is going to change the world more than anything in mankind. More than electricity.' One area of science which has greatly benefited from the development and use of artificial intelligence is organic chemistry. Whether it is studying the formation of molecules or doing physical experiments, artificial intelligence has helped chemists massively when it comes to getting results from a reaction, analysing the composition of molecules or developing reliable vaccinations / medicines.

The coronavirus pandemic has taken us all by surprise and has sent us into an extremely abnormal life. Fortunately multiple vaccinations have been made available to us after a year's wait, however this eager wait would have been remarkably longer had artificial intelligence not been something broadly used. Artificial intelligence is able to speed up the process of drug-making and due to this a variety of vaccinations were designed, reviewed and distributed at an immensely quick pace. Artificial intelligence has been trained, over the years, to form chemical compounds that have never been discovered before meaning instead of taking a long period of time to produce an effective vaccination there has been an inexpensive, rapid discovery of many drugs which are able to prevent the development of many viruses. Machine learning within AI has given organic chemists the opportunity to get a detailed look at the arrangement of specific molecules and how the virus evolves once in our system. Given that chemists are able to see how the virus emerges they can from that information develop an immune response to it (vaccine) which is possibly the point at which if passed signifies that a medicine works the way it should.

The pandemic is not the only aspect that has made the most out of artificial intelligence, without AI the synthesis of organic molecules would not be where it is today. Synthesising organic molecules is one of the hardest tasks a chemist will have to do given that they have to design a possible molecule and have to develop chemical reactions in which these possible organic molecules proceed through. This means that chemists have to progress through retrosynthesis, an arduous process in which new molecules are analysed and multiple reactions are used to produce them. The term 'computational chemist' is not new in the field of organic chemistry however it has improved a lot over the years widening its ability of tasks it can complete. Nowadays synthesis of molecules on a computer can now be provided through the use of an artificial intelligence, this demonstrates an enormous breakthrough in the field of chemistry and will make a huge difference in human's capacity of generating new molecules. While artificial intelligence is changing the world of chemistry, a human's input is still very much needed for example in the drug-design algorithm of an RNN. In the past technology for speech recognition has been used to identify molecules however again this chemical approach still requires a human to ensure the algorithm knows where to start and what type of molecule to analyse.

The spark in interest of artificial intelligence is transforming the restricted success chemists can have in the section of organic synthesis. The synthesis of molecules as previously stated is an extensive process that is a lot more difficult without the aid of machine learning and 'computational chemists'. Artificial intelligence is becoming more and more advanced however it will still be a long time until technology is able to replace synthetic chemists. Almost every chemist uses computational systems to synthesise accurate molecules and to generate solutions for problems in healthcare at a fast pace. Artificial intelligence is an extremely developed area of computer science that will impact our world and will completely change the way we think as human beings, it has made and will continue to make colossal discoveries in drug-discovery and the synthesis of organic molecules allowing our world to grow exponentially.



UNDER 14 TECHNOLOGY ESSAYS

Green Transport: Red Light to Global Warming?

- Zahra Cheema, Oxford High School

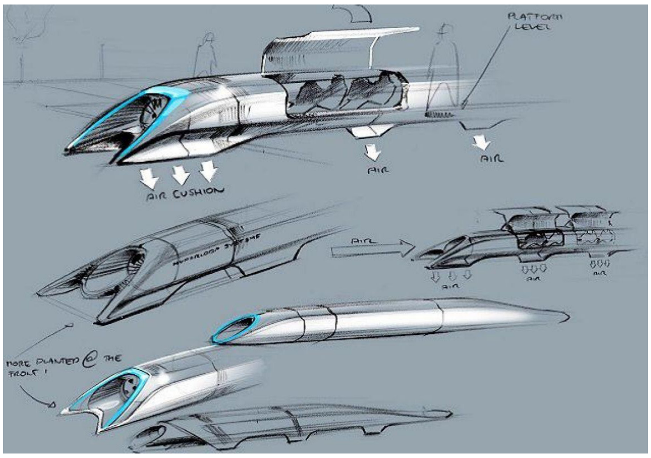
We are living in a world where technology is constantly evolving. This can be seen across all areas of engineering from modes of transport to Artificial Intelligence, Robotics and even Biomechanics. Since global warming is the most immediate threat to our planet, engineers are constantly working to reduce carbon emissions in all areas, but especially transport. Despite this being a time of ingenuity in this sector, it is also an era fraught with difficulty.

Autonomous Vehicles

Research shows that 19% of jobs in the United Kingdom require their applicants to be able to drive (RAC Foundation, 2021). These figures could be irrelevant in the future because of the development of autonomous vehicles. Unfortunately, progress is sluggish. Many companies such as Honda, Tesla, Toyota and Waymo declared in the late 2010s that they would be releasing self-driving cars by 2020, but this is still yet to happen. This is due to the fact that these cars need to be exposed to an exceptionally large amount of data, in order to be able to handle the many different situations a driver faces today. Also, it is incredibly expensive to supply each car with simulations of less frequent scenarios and time-consuming to test drive them numerous times (Vox Recode, 2020).

The Hyperloop

Another futuristic mode of transport being developed is the Hyperloop. This idea was first proposed in 2013 by Elon Musk, CEO of Tesla and SpaceX. He open-sourced the project and hosted an event at SpaceX headquarters in California in 2017 to further explain this. He also organised a competition in Los Angeles, which invited budding engineers to try and make his idea a reality. The Hyperloop comprises of two sections, a Partial Vacuum Tube and a pod. The pod uses magnetic levitation and electric propulsion to travel through the tube. The Partial Vacuum Tube minimises air resistance and the magnetic levitation and electric propulsion reduce friction. This results in minimal resistance and allows the Hyperloop to travel faster (Insane Curiosity 2020; Futurology 2020; ritm1 2019; Red Herring 2018).



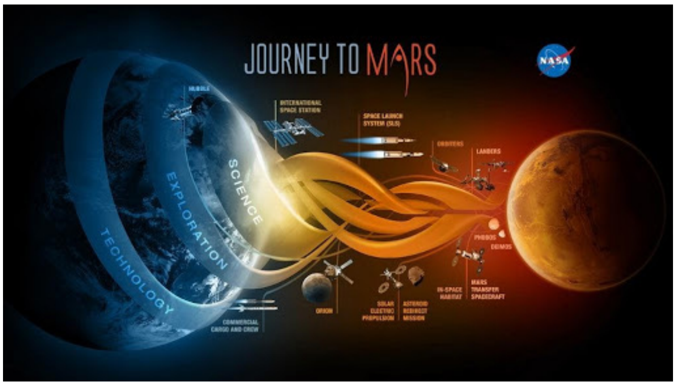
Musk has stated that he wants the Hyperloop to be fully solar-powered. This would suggest that it wouldn’t contribute to climate change. The Hyperloop is also adaptable to go underground, leaving it both unaffected by the weather and much safer than driven public transport, decreasing the risk of accidents. Assuming its popularity, this would also lessen congestion on motorways and consequently reduce 75% of emissions (TED, 2017).

The Hyperloop offers potential economic benefits, as well. The tickets would be cheaper than high-speed train tickets because the tube diameter could be shortened vastly. The vacuum would eliminate the need for extra space, thereby making construction much cheaper. Furthermore, it probably would be incredibly popular, due to the travel time it could save: engineers are aiming for the Hyperloop to break the sound barrier. Hyperloops should be able to function 2-3 times faster than standard high-speed trains and be 2-3 times more energy efficient. This would enable travel from Washington DC to New York to decrease from 3 hours to just 30 minutes, creating new job opportunities for people, which may have otherwise been inaccessible to them. It is incredibly expensive to construct, but it should only take about a decade to recoup the money invested through ticket fares (The Economist 2017; TED 2017; The B1m 2020; Top Quick Peek 2020).

Pathway to Our Downfall?

On the other hand, advancements in technology could be our undoing. On the 8th March 2018, the first human fatality due to an autonomous vehicle occurred (Forbes, 2019). This shocking incident awakened us to the dangers of Artificial Intelligence and resulted in anxious questions as to what had happened, whose fault it was and what could be done to ensure it wouldn’t happen in the future. Governments could also be granted access to control these modern vehicles, which could result in both criminals and innocent people being tracked, monitored and captured. The more our lives ‘upgrade’, the greater the risk we will face from people with power, possibly breaching human rights.

Pathway to Success?



In conclusion, we are witnessing an era of huge leaps in technology and engineering. We are on the cusp of breaking the sound barrier on Earth with the Hyperloop, whilst in space we have landed the Rover "Perseverance" on Mars- yet another advancement in engineering. Musk plans to go even further and establish a city on Mars. On 3rd March 2021, SpaceX managed to land one of its Starship prototypes, the first step towards this goal (BBC News, 2021). All modes of transport have been developed significantly over time. This century will be the first to combat climate change through 100% renewable-powered vehicles, a feat that was unimaginable in the last (Insane Curiosity, 2020).

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What Does the Future Hold for Aerospace Engineering?
- Clara Simpson, Oxford High School

The global aerospace industry has an estimated worth of $685.6 billion and with climate change rapidly becoming a more concerning problem, knowing what the future holds for the industry has never been more important. Aerospace engineering is the second most in demand type of engineering for jobs in the future and will continue to grow due to the higher demand for 40,000 new commercial helicopters and 27,000 new passenger aircrafts between 2013 and 2031 just to name a few. Aerospace engineering is split into two sectors: aeronautical and astronautical engineering. Aeronautical dealing with vehicles that'll go in the air and astronautical dealing with them that'll go into space. Aerospace engineers build everything from mobile phones to Mars rovers and are having to tackle emissions, cyber security and data management along with a wealth of other puzzling problems making this a truly interesting field.

On the 30th of July 2020, NASA's Perseverance rover was launched with a lot of well thought through aerospace engineering gone into it. The rover has some of NASA's most innovative and exciting technology on board along with some complex systems like the landing apparatus that has a total of six stages that take place over "The Seven Minutes of Terror" in which NASA has no control over the rover and can only sit and watch. Perseverance, however, isn't the only exciting new development from NASA, they are planning some huge missions in space exploration over the next few years which is very compelling for aerospace. One of their most ambitious projects is SPHEREx, launching in 2024, SPHEREx is going to do research into the origins of the universe for two years. This is a thrilling mission in terms of aerospace because it will include lots of rousing new pieces of technology like the radioactive telescope that will cool to less than -193.15 .

Aerospace engineering is not only making incredible technological advancements but it's also shaping the future of construction, making it more ecological and economical. There are many ways that the construction industry can improve by paying attention to aerospace including taking on disruptive technology, this saves huge amounts of money - and there's proof. SpaceX has already lowered their costs by using reusable rockets that are about half the price of the more conventional options. Aerospace can also help improve the construction sector (and other similar areas) by teaching them that one of the main keys to success is having high aspirations. This is why aerospace is thriving so much because quite literally the sky's the limit. Other industries can learn from this because thinking up innovative ideas is just as important as being able to achieve the slightly less large-scale ones.

As technology advances, it is no surprise that the materials the aerospace industry uses get more and more contemporary. Orbex, a small aerospace company, is developing a 3D printed rocket made from a combination of aluminum and titanium alongside others to make it lighter and more temperature resistant. The blend of these two metals is similar to a metal that has been used in the aerospace industry for a long time, nickel. Nickel is very heat resistant but is more recently being pushed aside as new alloys begin to make their way into the industry. These rockets will also be reusable and fueled by bio-propane. The industry is beginning to use more composite materials as well, due to their efficiency and cost effectiveness. They are starting to be used for more than just cabin components, instead they are becoming part of the landing gear, fuselage skins and even the engines.

It is clear now that the industry of aerospace is not just a side sitting unimportant branch of engineering but a predominant and influential area of maths and science. In the next few years, we will see this sector becoming even more dominant in the world of engineering and construction as the demand grows for more economical and ecological solutions. The future of aerospace and aviation technology is only going to get more exciting because when invested in, this province will prove itself irreplaceable by allowing the world of engineering to reap the financial, scientific and global benefits.

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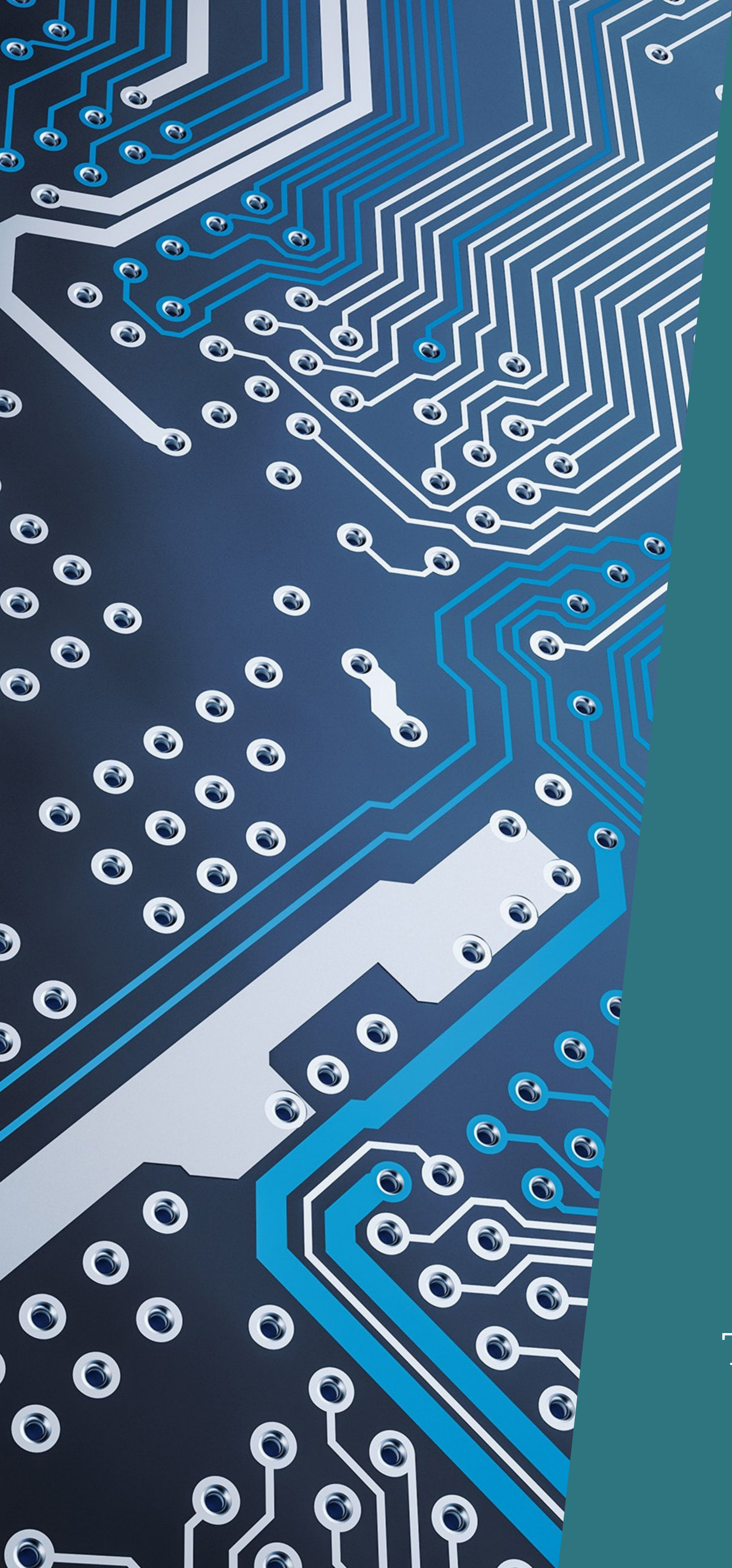

UNDER 16 TECHNOLOGY/ ENGINEERING ESSAYS

Quantum computers
- *T Mitchell, South Hampstead High School*

The purpose of quantum computers is that they can be used as a different tool to replace classical computers.

A classical computer performs operations using classical bits, which can either be one or zero. In contrast, a quantum computer uses quantum bits, and they can be both zero and 1 simultaneously. This is what gives a quantum computer superiority over computing power.

Quantum Computing is the use of quantum phenomena such as superposition and entanglement to perform computation. Seems like a genuinely complex sentence but in an essence it's simple!

Quantum Bits can be a single photon, a nucleus or an electron. For example, with electrons, all electrons have a magnetic field, so they are basically like tiny magnets. This property allows them to spin, if you place them in a magnetic field, they will Aline with that field, just like an ordinary compass. Now, this is the lowest energy state so you could call it the zero states or (for the electron) Spin down. Now you can put it in one state or spin up but that takes energy. Right now, we have created something similar to the classical bit, spin up or spin down or 1 and 0. But the funny thing about quantum objects is that they can be in both states at the same time. When you measure the spin, it will be either up or down but before you measure it the electron can exist in what's called a quantum superposition. This is where (in a quantum system) it exists in several separate quantum states at the same time. For example, a coin facing up has definite values; heads up or tails down. Without looking at the coin you can believe it's head or tails. In quantum experience material properties of things do not exist until they are measured. Until you "look" (measure the particular property) at the coin, Asia the coin is on its side, it's neither up nor down.

Quantum entanglement is where the quantum states of two or more objects are contrasted even though the individual objects may be spatially separated. In this quantum mechanical phenomenon, it is possible to have two particles in a single quantum state so that when one is observed to be spin-up, the other one will be observed to be spin-down and vice versa indefinitely, even though it is impossible to predict, in accordance to quantum mechanics, this set of measurements will be observed.

As a result, measurements performed on one directly influence the other systems entangled with it. However, quantum entanglement does not enable the transmission of classical information faster than the speed of light. Quantum entanglement has been used in the emerging technologies of quantum computing and quantum cryptography, to explore quantum teleportation experimentally.

Quantum Computers can change the idea of data security with practically unbreakable encryption. Although quantum computers are able to crack many of today's encryption methods, predictions are that they would create hack-proof replacements, redefining data security!

Quantum computers are excellent at solving optimisation problems like figuring out the best way to schedule flights at an airport or configuring the best delivering routes for the FedEx truck. Quantum computers work faster than a classical computer, for example, google announced it has a quantum computer that is 100 million times faster than any classical computer in its lab. Quantum computers will make it possible to process the about of data we're generating in the age of big data.

In times of Climate Change and Global Warming, electricity consumption is extremely significant. Fortunately, quantum computers will reduce power consumption anywhere from 100 up to 1000 times as quantum computers use quantum tunnelling.

The quantum tunnelling effect arises when particles that move through a barrier that, disaccords to the theories of classical physics, hence should be impossible to move through. This quantum phenomenon would imply that there is a finite probability that some of the particles will tunnel through the barrier.

Once a stable quantum computer is created, machine learning will accelerate exponentially. reducing the time to solve problems from hundreds of thousands of years to mere seconds, accelerating the rate of growth of our economy exponentially!

What direction is progress taking us in?
- Eva Helly-Osborne, Royal High School Bath

YouTube, Netflix, Snapchat, even the word internet, are words that have become part of our everyday vocabulary. The way technology has advanced in the last decade has enhanced our way of living and created job
opportunities that people in the 1800s would have claimed to be science fiction. With the internet and our devices, our survival through the pandemic has seemed inevitable, our connections through news and culture have sustained us but they are also slowly contributing to the deterioration of our planet.

Our daily consumption of Amazon deliveries, electricity, driving and getting an aeroplane are what we would normally think about when we look at climate change and our carbon footprint. ([1]John A Paulson, Environmental impact of computation and the future of green computing) What if I told you that by 2025 it is estimated that 7% of those emissions would be caused by the increasing systematic smartphone development and usage every year, and that one day these emissions could maybe even surpass those of aviation? ([2]1:37, The Shift Project)

Every year 1.5 billion extra smartphones are made and at the moment iPhones have captured the world's attention with quickening development from one phone to the next. ([3]Sustainability Illustrated, 0:03) At the surface we see a faster sensory reaction, a thinner more maniable model, a camera with lenses that can mimic the photography of a professional camera and now waterproof features that enable your phone to capture your adventures in the most improbable places. But because of this the production of these phones increases and more unrenewable resources need to be quarrelled from the ground which results in hard cheap labour, becoming more significant in poorer countries, and landfills filling with old devices.

Technology is developing so fast that scientists only realise the sustainability issues once the products have sold world wide. Measures of recovering old phones to make new ones by disassembling each component, like the Apple robot Daisy, have been successful but many more will need to be produced for a large scale impact. ([4]Apple, A planet sized plan) By recovering these parts the waste of old phones is reducing and if we continue in this direction our progress will positively influence our planet.

We are still learning, as technology is advancing we are finding new ways to fix these sustainability problems we face and even Netflix were still trying to understand how they could minimise their carbon emissions and positively change it in 2019, by that time millions of families were already connected to their channel. ([5]Page 3, Environmental social governance, Netflix) The side effects of streaming and binge watching are only now being comprehended but by limiting your videos to an hour a day it could start having effect.

When watching your videos, a lot of energy is used to power the flow of the data through to your device. With a rise of videos being watched and music being listened to these carbon based fuel data centres are emitting a lot more carbon than initially expected. By watching one YouTube video you could be emitting 8.7g of carbon into the atmosphere.([6]2:21, The Shift Project) The systematic usage of about 58% of the world wide population means that some data centres are heating up so much that more energy is needed to cool everything down. ([7]Industry Today, The Growth of Technology)

Apple's plan has already put in place screen time and some people have already considered having the same sort of programme that could calculate our carbon dioxide emissions dependent on our overall screen time.

The production of these phones hasn't given us the opportunity to learn the damage our use can have on the behind the scenes mechanisms of such devices, so to progress in the right direction people and especially young adults need to be made aware of the impact their electronic consumption has on the world.

By raising awareness Greta Thurnberg was able to communicate to younger generations and influence them into coming together and taking action. Globally millions of children collaborated across 150 different countries to strike for climate. ([8]Newsround, Global climate strikes : millions of children take part in protests to help protect the planet) It is impossible to turn back the clock of time but we can change our actions and like Ghandi said "Be the change you want to see in the world." Today's youth are the famous scientists, engineers and mathematicians of tomorrow and by making them aware now we are one step closer to the green technology our world needs to thrive.

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How one letter could be changing the future
- Ishaan Choudhary, Wilson's School

With the exponential improvement in technology that humanity has witnessed over the past 30 years, it has become ever more pertinent that already existing machinery is developed to become more refined and streamlined. Whilst new technologies are constantly being invented, the true progression (and even conservation) of man relies upon our ability to continually modernise and make more efficient our already existing technology. A prime example of this is the fairly recent conception and utilisation of the lithium iron phosphate battery.

For years, the conventional lithium ion battery has been used in a multitude of daily use equipment including mobile phones, laptops and electric vehicles due to their rechargeable capabilities. This list of examples is in no way exhaustive and it is clear that the lithium ion battery plays a crucial part in every single one of our lives despite, perhaps, its existence being lesser known to the wider public. Perhaps even lesser known are the extreme dangers that these batteries pose to the machinery they are used in and the great disadvantages that were endured when these batteries had no alternative.

One such problem that often occurred was self combustion should overheating occur in the traditional lithium ion battery. Essentially, inside the chemical cell, the liquid electrolyte could dry up and, following the failure of an insulating microporous separator layer, cause a short circuit between the electrodes leading to an explosion or fire1. Furthermore, the conventional cathode material of the lithium ion battery is lithium cobalt dioxide (LiCoO2) which is extremely susceptible to thermal runaway where the increased temperature increases current which causes a further rise in temperature in a somewhat uncontrolled positive feedback system which is clearly hazardous and can occur regardless of ambient temperature. This has led to multiple disastrous accidents in the past; the most devastating of which transpire on aircraft carrying high quantities of the battery. Several accidents are the result of this, with the rate of progression as it is today, now almost ancient technology: in September 2010 a UPS cargo plane with over 80,000 batteries on board caught fire and crashed, killing two pilots in the process[2]. Whilst safety is integral and obviously should be manufacturers' number one priority, socioeconomic factors of the lithium ion battery are similarly disheartening. The use of cobalt in the cathode of a lithium ion battery adds massively to the high cost of its manufacturing; its mining in conflict areas such as the Congo is also ethically questionable and obtaining it has become geopolitically complex and thus alternatives have been sought after[3].

The frontrunner in alternative technology is the development of the lithium iron battery. The addition of the letter 'R' in the battery's name is accompanied with a whole host of benefits, hence this article's name. More commonly known as LFP cells, the cathode used in these batteries are lithium-iron phosphate (LiFePO4). Low toxicity, low cost and long term stability are a few of the qualities that are increasing the battery's prominence in certain machinery[4]. LiFePO4 is intrinsically safer than its cobalt comprised counterpart as it omits its negative temperature coefficient that leaves the conventional lithium ion battery liable to and encouraging of thermal runaway. Additionally, LFP cells can withstand short circuit conditions and higher temperatures to a much greater extent which means that they are incombustible in the event of mishandling - differing completely to the traditional lithium ion batteries[5]. Even more surprisingly, the composition requires no cobalt and is revolutionarily cheap. It could be rightfully questioned why companies aren't making the switch to safer, more durable and cost effective batteries.

Well, simply put, they are. The embodiment of recent innovation, Tesla, confirmed that, in tandem with the Chinese government, a new version of the Model 3 will hit the market with cheaper lithium iron phosphate batteries[6]. Forbes deemed the inauguration of LFP "Tesla's most important move yet' with its capability to, by 2023, push past the $100 per kWh barrier that may conclude that electric vehicles finally become cheaper to buy than their internal combustion engine equivalents. The threshold may be further annihilated as the predicted price is just $61 per kWh in 2030[7] proving just how truly revolutionary this development is and its capacity to be a catalyst for a more sustainable future.

Whilst the intricacies of lithium battery technology are somewhat less important, the message that these evolutionary developments represent are paramount. It clearly demonstrates a humanitarian urge to guard against complacency and to never be fully satisfied, continuing to improve and enhance inventions as problems arise. This small improvement to a somewhat antiquated technology shows to us that simply being satisfactory is not enough and this must continue to be the case in all walks of life, should humanity continue to prosper.

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The Grumman F-14 Tomcat: A Cinematic and Aviation Marvel
- Sienna Jacobs, Wimbledon High School


Fig. 1

The Fighter Aircraft, Grumman F-14 Tomcat is probably most well known for its starring role in Tony Scott's iconic 1986 movie Top Gun, arguably one of the best aerial dogfighting movies and a timeless classic. The success of the movie is largely due to the engaging jet fighter sequences, both in training and the climactic fight at the end of the movie that sees the F-14 fight (and win) against MiG-28s over the Indian ocean (although these were actually Northrop F-5F and F-5E Tiger IIs spray painted black!) (Lindsey, 1986).

The movie-star Tomcat is an absolute beast of an aircraft with a top speed of Mach 2.34 (2485 km/h) and a long, 1000 mile combat range. (Wikipedia, 2021) It was operational from 1970 to 2006 for the US Navy and is still in use for the Iranian Airforce; it was also used during the Iran-Iraq war, where it was highly successful (although it was mainly designed for potential use in the Cold War) (Wikipedia, 2021). It used pioneering radar technology with the microprocessor-controlled AWG-9 (which could track 24 aircrafts 195 miles away), and the ALR-23 (an Infrared search and track sensor) (Hollings, 2019)- a formidable opponent indeed.

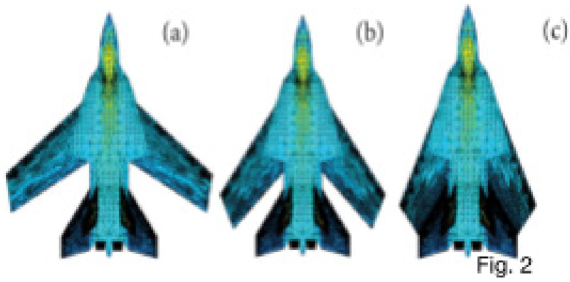

Fig. 2

The real engineering genius of the F-14 lies in its wings. It utilised variable-geometry in its variable-sweep wings that could range anywhere from 20º to 68º (see Fig. 2) and could be controlled automatically by the central air data computer in the flight control system or the pilot if needed (Wikipedia, 2021). The individual wings could also be swept to different, asymmetrical angles. Although it wasn't the first aircraft to experiment with this technology it was the first to use it to such a degree of success. The brilliance of this tech was that the plane could optimise its lift-to-drag ratio at the current indicated air speed. (Anderson, et al., 1988) During take off, on the carrier steam catapult, the wing speed angle would be smaller to maximise lift. Lift is generated due to the designed shape of the wings, so high pressure is created underneath, and low pressure is created on top, causing the plane to rise (Science Direct, 2021). However, the problem with this is that at high speeds, a small angle of wing sweep would increase drag which inhibits the aerodynamic potential of the plane for reaching high speeds and would induce transonic (equal to Mach 1 (the speed of sound)) air flow over an aerofoil sooner and hence create a sonic boom and supersonic airflow sooner too. (Urdis, 2014) The problem with this is that wing flutter could ensue (as seen in the Junkers Ju-87 Stuka during WW2 dive bombing manoeuvres (Dwyer, 2014)), making the plane extremely hard to control - a real issue during dogfighting and aerial combat where accuracy is essential. With variable wing speed though, at these high speeds wings would be fully swept back, almost to a delta wing shape (Day, 2013) (see Fig. 2c), to postpone the onset of Mach 1 speed over the wing, by increasing span wise air flow (air flow parallel to the wing's leading edge) over the wing and ergo delaying the sonic boom (which would create airflow separation wave drag behind the boom) (Urdis, 2014). Due to movement of air over an airfoil, where air first accelerates, then decelerates due to the pressure gradient, (Learn Engineering, 2016) transonic air speed can be reached over the wings, before the aircraft itself is flying at or above Mach 1, so delaying this is key for high speed aircrafts.

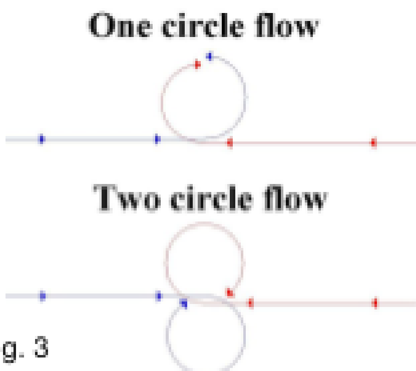

Fig. 3

The swept wings also help with one and two circle dogfighting (see Fig. 3) - methods of aerial combat taught at places such as Top Gun, where the swept back delta wing shape is more desirable, as it gives the plane a faster turn rate (Naval Air Training Command, 2018). This is because the plane can be rolled and then use its lift vector (the force perpendicular to and created by the wings) (Nakamura, 1999), to help the plane turn faster and fly a smaller radius circle (Archive Today, 2013). Because of the large surface area and shape of delta wings (which create vortices - areas of low pressure that generate more lift on top of the wing (Wikipedia , 2021)), lots of lift is produced at this angle which makes the plane turn very fast (Muir, et al., 2017); this is a big advantage for catching enemy planes and avoiding missiles.

In conclusion the aerodynamic prowess of the F-14 Tomcat makes it a formidable presence from both an aerospace engineering standpoint and a cinematic one, where, despite certain 'silver screen' liabilities being taken, it's dominance as a military aircraft, including its incredibly high speeds, impressive turn rate, and combat accuracy, has helped make Top Gun such a thrilling and successful movie.

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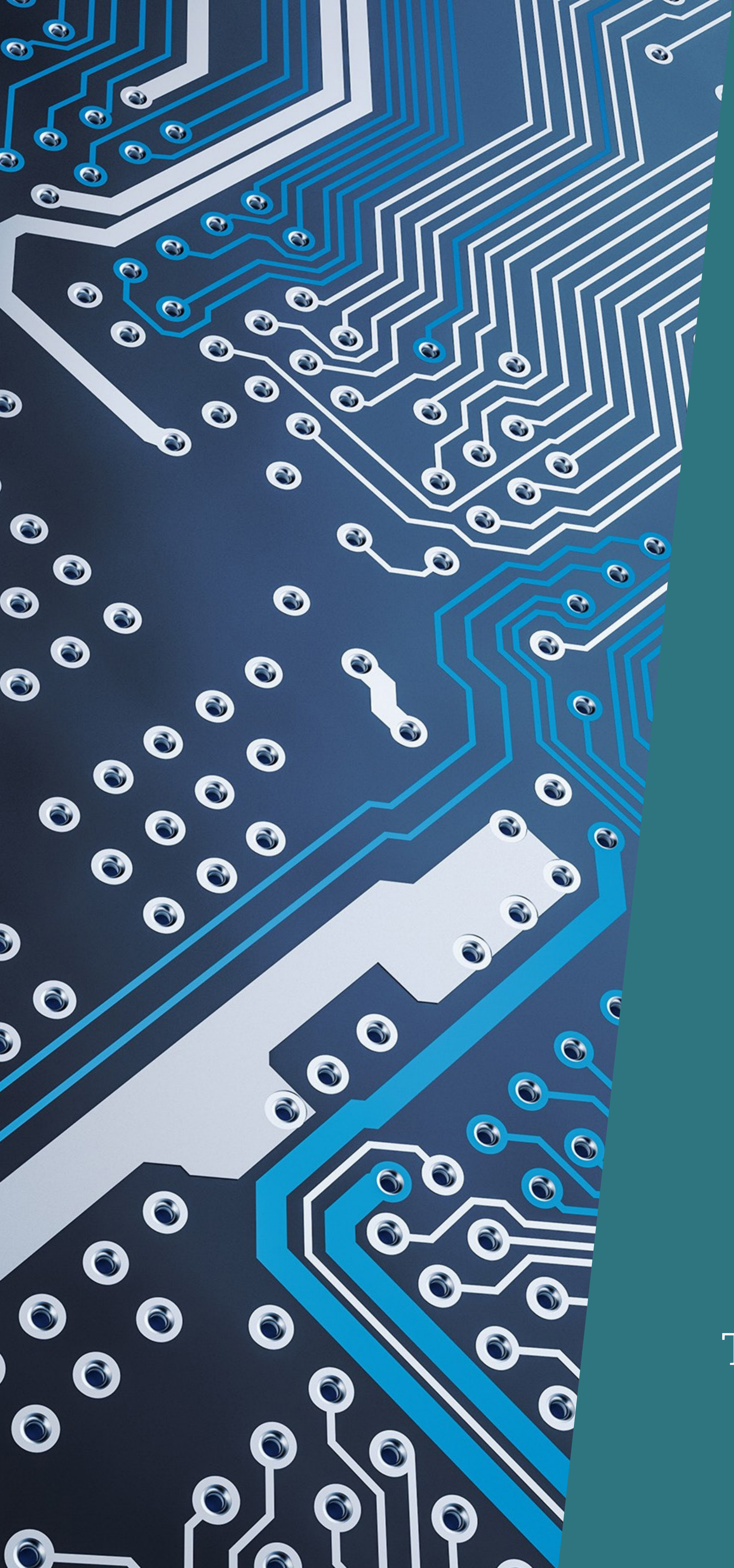

UNDER 18 TECHNOLOGY/ ENGINEERING ESSAYS

Could bringing back the mammoths help solve climate change?
- *Sophia Harley, Wimbledon High School*

Since Jurassic Park, de-extinction, the process of generating an organism that is either an extinct species or resembles an extinct species, has been an intriguing prospect. The concept of reintroducing the woolly mammoth, for example, has been a well-mooted topic for decades. But many scientists claim it is balderdash – any investment, they say, risks diverting valuable conservation efforts away from still-living species with little to gain. The business case doesn't stack up, until now…

Pleistocene park covers 160km^2 of perilous tundra in northeast Siberia and forms the basis of Russian scientist Sergei Zimov's unconventional plan to slow the thawing of the permafrost. Frozen earth, or "Russian Sphinx", contains over 1600 billion tonnes of carbon, twice the carbon currently in the atmosphere and three times the carbon sequestered in the world's forests (Schuur, 2019).

As the soil thaws, these carbon-rich vestiges of ancient life, including plant roots and animal carcasses, are released and converted into carbon dioxide and methane by hungry microbes. Scientists predict that at current rates, the thawing of the permafrost will use up to ¼ of our carbon budget set at the Paris Accord (Anon., 2020). This is a slug of the budget we can ill-afford to lose.

Zimov believes he has the answer to averting this potential climate catastrophe; he says, "there is only one [way] to prevent [this] from happening. We must restore the Ice Age." By reintroducing heavy grazing animals, a feature of the "Pleistocene epoch", the blanket of metre-thick insulating snow, is trampled, making it dense and more able to allow extreme winter cold to penetrate the soil (Wernick, 2017). Zimov's early trials are promising: the temperature of the permafrost in Pleistocene park is now 2.2°C lower than before (Anon., 2020). But trampling the snow isn't the only benefit grazers offer. They also generate a nutrient cycle that favours grasslands over the current tundra flora, a landscape peppered by coniferous trees.

Whilst nurturing grasslands at the expense of trees may seem counter-intuitive in the fight against climate change, the environmental benefits heavily outweigh the costs. Trees may well be good carbon sinks, but they also absorb heat which ultimately warms the permafrost beneath them. Grass on the other hand, reflects more light and thus reduces the amount of heat absorbed by the soil, whilst also capturing more carbon in its roots than current vegetation. In turn, the grasses can feed huge armies of herbivores – a beautifully harmonious ecosystem.

The question is: how do we thin out the trees to help the transition towards this environmental utopia? Rather than a fleet of gas-guzzling bulldozers, perhaps a battalion of climate-friendly, tree-felling mammoths may provide the answer. The problem, of course, is that they are long since extinct. But this might be about to change. George Church, head geneticist on the Harvard Mammoth project thinks so too.

South of Chersky, Siberia, in an area called Duvanny Yar, relics of ancient life lie exposed along the riverbank, including mammoth bones preserved for millions of years by the now-thawed permafrost. Crucially, the sub-zero temperatures largely prevented decomposition of organic material (Mezrich, 2017). Whilst DNA degrades over time, therefore hampering efforts to sequence the entire genome of a mammoth, various fragments of DNA can be stitched together to form a near-complete genomic model. Without the entire genome, cloning is off the table. But there is an alternative: CRISPR technology enables precise editing of DNA within a living organism (Rich, 2020), or, in this context, a close living relative.

99% of a mammoth's genome is very similar to that of the Asian elephant (Worrall, 2019), and Church is in the process of comparing the Asian elephant's genome against the model mammoth's, to identify the genes that need synthesising. The goal is to reintroduce the traits that make a woolly mammoth unique and able to thrive in the sub-Arctic tundra; subcutaneous fat, small ears, a shaggy coat and, importantly, haemoglobin to maintain their high metabolism (Knapton, 2015). Once synthesised, the next step is to place the modified genes into the embryo of its Asian cousin.

According to WWF, in the last 50 years, 60% of the world's species have disappeared (Grooten, 2018) at the hands of humans, and there is growing evidence that we are also responsible for the demise of mammoths. At the point at which humanity's existence on Earth is itself under threat, isn't it ironic we turn to a species we helped eradicate to protect the largest carbon reservoir on the planet?

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Volumetric Displays: From Science-Fiction to Science
- *Vedagiri, Wilson's School*

Chances are you've never even heard of volumetric displays before – let alone know what they are. But it's likely that you have actually seen one already – maybe not in real life, but at least in movies. Volumetric displays are nothing more than what the layman refers to as a "hologram". A "hologram" such as the ones in Iron Man – or, more famously, the "hologram" of Princess Leia, projected in Star Wars. I say "hologram" with quotation marks because, in fact, holograms aren't the same as volumetric displays. While volumetric displays create real 3D images of 3D shapes, holograms merely appear 3D – they're virtual images, scattering light at a 2D surface.[1][2][3]

Although holography was discovered all the way back in 1948, by a Hungarian scientist named Dennis Gabor, the first volumetric displays were only created in 2006 – almost a whole century after they were first postulated in science fiction novels.[4] A team from the Japanese National Institute of Advanced Industrial Science and Technology (AIST) collaborated with Keio University and Burton Inc. to create the first "real 3D images". While this first volumetric display was primitive, to say the least, with no useful application – apart from creating a pattern of dots in the air, they showed one thing: there is indeed a solution to the "lightsaber challenge". The "lightsaber challenge" is the question posed by scientists: "how do you simply stop light from traveling in
mid-air?" (As phrased by Dr Ricardo Figueroa, Rochester Institute of Technology).[2][5][6]

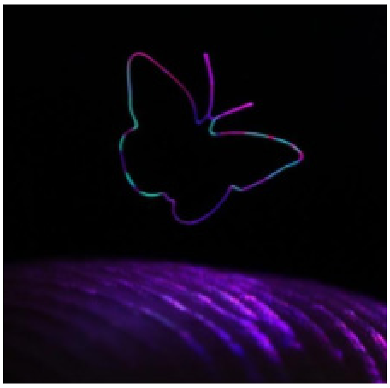

Figure 1: Volumetric display of a butterfly from Brigham Young University

Just as the team from AIST managed to break down air molecules into glowing plasma, to emit visible light, back in 2006, a team from Brigham Young University similarly managed to overcome the lightsaber challenge. They successfully created a high definition display in 2018 by "trapping" and "steering" a cellulose particle with a laser beam (known as an optical-trap display). While the display was merely a few centimetres in size, it demonstrates yet another advancement in volumetric display technology - the creation of high-resolution images even in a free-space display (can project the display in air) (Figure 1). However, in reality, this display is only an illusion caused by the rapid movement of the particle. As David Smalley, PhD, from BYU says, "a good way to think about it is like a firefly or a sparkler". What he refers to is the human persistence of vision, where images seem to fuse together as the human eye cannot process the images fast enough.[2][7][8][9][10]

At this point, one is obliged to express their concerns for the viability of volumetric displays – if it took 12 years to get this far, surely at this rate competitors such as Microsoft's HoloLens are much more likely to succeed. Right? Wrong. Arguably, the most revolutionary development of volumetric displays came with the Voxon VX1 display table. At US$9800 per unit, it offers much better value than Microsoft's HoloLens 2 which, although only US$4950, doesn't allow multiple people to use a single device simultaneously.[11][12]

Voxon Photonics' VX1 is a swept-volume display (it operates by rotating emissive or reflective screens), with a resolution of 500 million voxels (essentially 3D pixels) per second. But it has more than just good graphics. The real commotion about the Voxon VX1 comes from its wide range of applications. The Australian start-up has already listed 37 use cases for the VX1 despite the novelty of the technology – and more is to follow.[9][12][13] Some of these uses, like playing games at over 4000 FPS, are simply for entertainment purposes. Others, however, have much more practical applications, such as 3D representation of molecules or instant 3D imaging using Blender, the CAD software. And demonstrations of volumetric displays for medical imaging and training have already taken place. They can even be used for 3D mathematical modelling, military visualisation, and, of course, video communications (Figure 2).[12][13]

Despite all these existing uses for volumetric displays, there are still limitless possibilities for them. There is still the possibility of making volumetric displays responsive to touch – or the possibility to infuse AI to explore more applications – or the possibility to make the technology small enough to fit in a phone, or a watch. Actually, it seems I can hardly claim the development in volumetric display technology has even begun. And maybe it still is science fiction, and not quite science. But what I can say, is that the future looks bright.

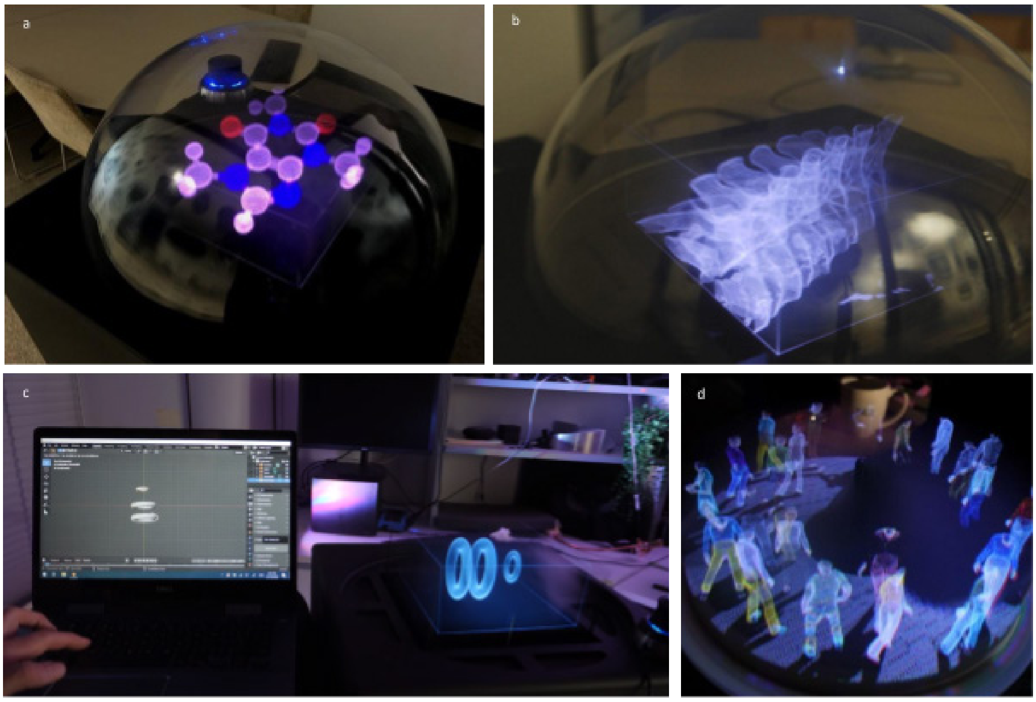

Figure 2: Some of the many uses of VX1: (a) molecular modelling (b) medical imaging (c) use in CAD (d) live broadcasting

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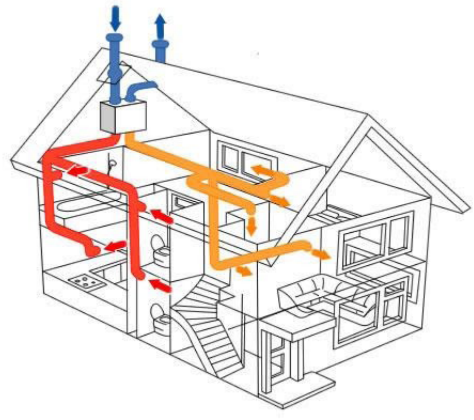
What is a heat recovery ventilation system, and how can it improve energy-efficiency in the home?

- ***Danielle Senanu, Oxford High School***

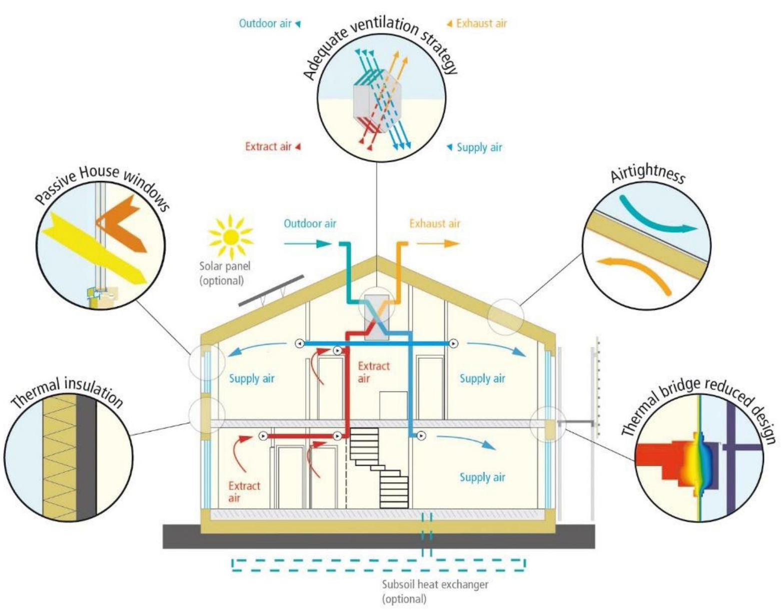
Sustainable construction is "The creation and management of healthy buildings based upon resource efficient and ecological principles," according to BSRIA, Centre for Construction Ecology (1996). Within the field of architecture and construction, one of the most important aspects of building design is the heating, ventilation, and air conditioning (HVAC)[1]. The way we heat and insulate our homes has a big impact on the efficiency of the building itself, as well as the wider environment. In this article, I will explain what a heat recovery ventilation system is and describe how such a device can improve energy-efficiency in the home.



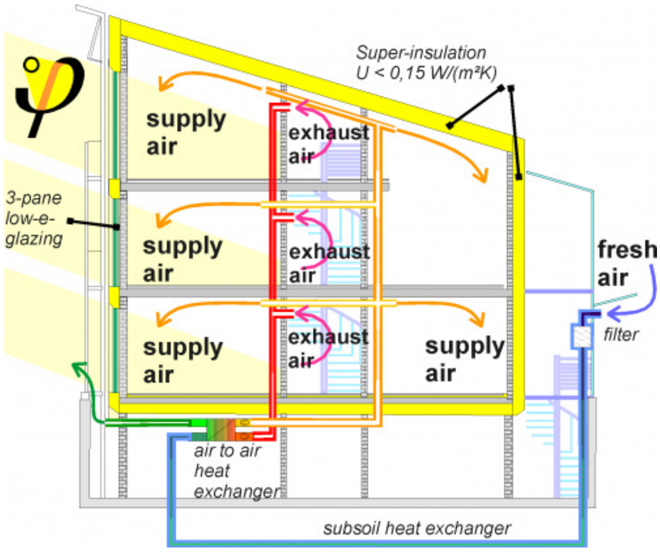
A heat recovery ventilation system (HRV), also known as a mechanical ventilation heat recovery (MVHR), is an energy recovery ventilation system that uses an air-to-air heat exchanger to recover heat that would normally be lost and wasted, while simultaneously supplying fresh, quality filtered air[2], therefore greatly improving the indoor environment. Often, they are located in the attic, loft, or plant room of a building. Instead of just simply extracting the stale air and substituting it with outside air, a HRV system draws the heat from the extracted air and passes it to the air which is being filtered in from outside, thus providing heat to the other parts of the house (Figure 1)[3]. The extracted air and the supply air do not flow within the same pipes, so that no cross contamination of the air flows can take place, which would otherwise defeat the purpose of the system.

The heat recovery unit is connected to each room by air valves, through a network of ducting that runs throughout the building. HRV systems work by using the valuable warm air or water in a property and recycling it. In recent years, HRV technology has been significantly enhanced, so that there are now systems available that are able to extract up to 90% of the heat from stale air (particularly present in humid rooms like the kitchen and bathroom) and return it to the fresh air that is circulated back into the system[4]. It is important to note that such a system only works well in a well-insulated environment. Due to poor insulation, thermal bridges are often allowed to exist, primarily across windows and thin walls, whereby heat is able to escape from our homes. As a result, we increase the central heating instead of investing in quality insulation, which increases our heating bill and carbon footprint dramatically[5].

The following example demonstrates the benefits of a HRV system in the home. In 1996, Dr Wolfgang Feist founded the Passivhaus Institut in Germany, an independent research institute dedicated to "research on and development of construction concepts, building components, planning tools and quality assurance for especially energy efficient buildings."[6] In 1991, Dr Feist successfully completed the construction of the world's first ever passive house, located in Darmstadt-Kranichstein, Germany. An important and useful feature of the Darmstadt residence is the heat recovery ventilation system[7] (Figure 2). As a result of rigorous testing and in-depth research, what remains today is a highly efficient residential housing unit that continues to perform excellently in terms of energy efficiency and function 20 years later.



In the building report, Dr Feist wrote that "This continuously operating comfort ventilation system provides a constant supply of fresh air to each accommodation unit." These ventilators operated perfectly for almost 15 years, until they were replaced, owing to standard renovation work[8].



Energy-efficient technology is not just about utilizing external natural sources, like the sun or the wind, and using it in our buildings; instead, by making the most of what already exists in our immediate environment, we can reduce the effect we have on the environment, including the amount of heat that we allow to escape from our homes all the time.

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3. (BPC Ventilation LTD., 2017)
4. (The Renewable Energy Hub UK, 2018)
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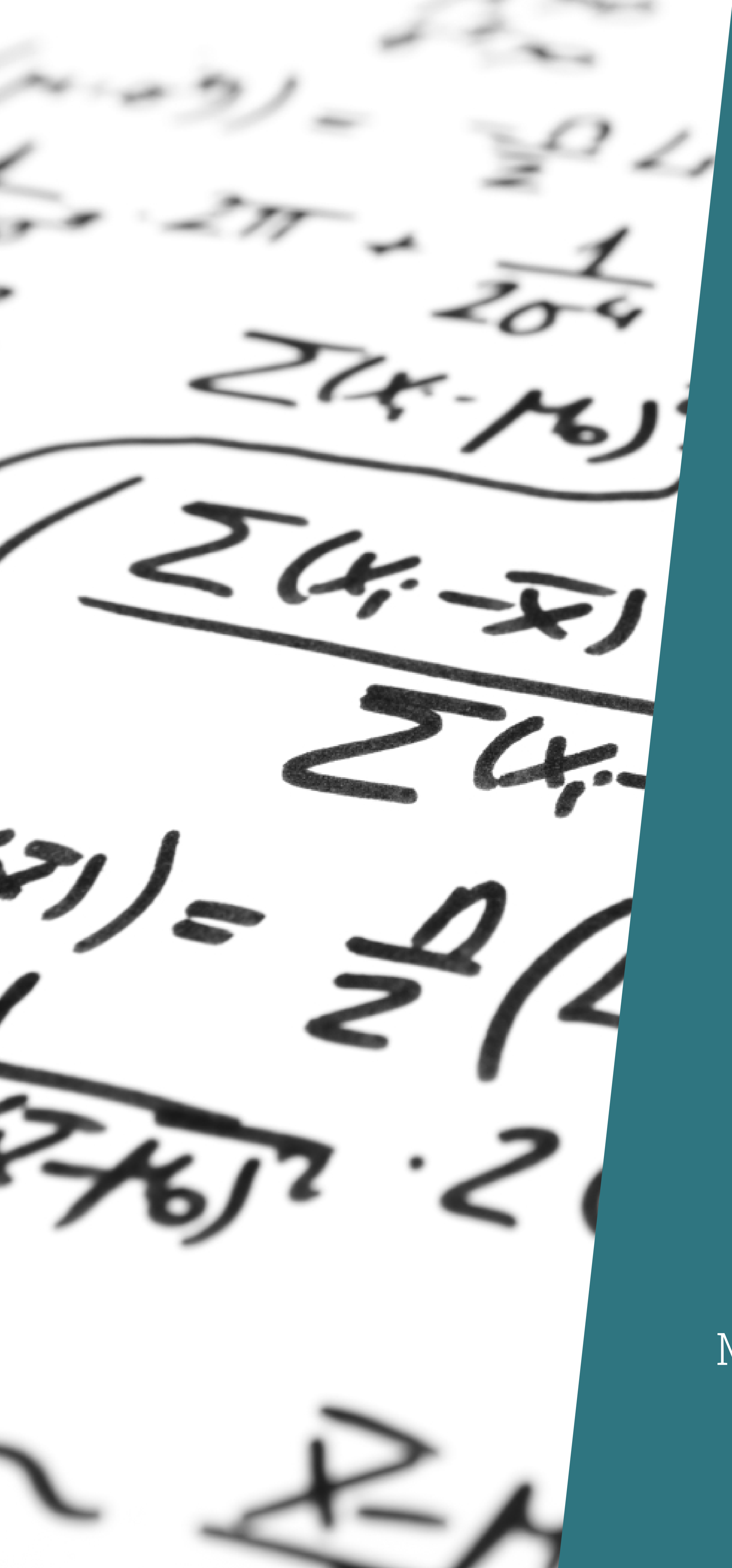

UNDER 14 MATHEMATICS ESSAYS

The Magical World of Vedic Mathematics

- Rohan Banerjee, Wilson's School

Some believe that the world of Mathematics is magical. Discovering the joy of Vedic Mathematics has convinced me about the same.

All of us know that Mathematics has origins that span many centuries. However, few are aware that more than 3000 years ago, India used an ancient system of calculations which is now known as Vedic Mathematics. The term 'Vedic' comes from the Sanskrit word 'Vedas' meaning knowledge. Vedas are sacred Indian scriptures which cover a range of topics including Science and Mathematics. In early 20th century, the knowledge of the ancient Vedas was retrieved by Indian monk scholar Swami Tirthaji. His pioneering work Vedic Mathematics is now deemed to be the basis for all further studies on this subject. (Das, n.d.) (1).

Vedic Mathematics comprises sixteen mathematical formulae and 13 sub-formulae which deal with different branches of Mathematics. These formulae can solve problems ranging from Arithmetic to Algebra to Plane Geometry and even Calculus with just a few simple steps. Once the formulae (which are called 'sutras' in Vedic Mathematics) are learnt, they can be applied to problems like multiplication, division, fraction, etc. Vedic Mathematics was also used to develop concepts of right-angled triangles, fractions, and irrational numbers (Dutta, 2002) (2). Peter Gobets, member of ZerOrigIndia or Project Zero, said, "Really, the first place where zero was used as an equation was in India with the ancient Vedic mathematicians," (Szalay, 2017)(3). Furthermore, Marcus du Sautoy, Professor of Mathematics at the University of Oxford, stated, "We now know that it was as early as the 3rd century that mathematicians in India planted the seed of the idea that would later become so fundamental to the modern world.' (4) (Car17, 2017)

Vedic Mathematics has gained popularity for teaching young children as it helps improve speed and accuracy, while developing a good foundation for mathematical thinking. It eases basic mathematical operations by providing quicker ways for calculation. For some children, realising that they can now do mental multiplication of any large numbers as long as they know their times tables up to 9 is a relief. Children enjoy this foray into the magical world where numbers don't seem daunting. Indeed, with each calculation I did using Vedic Maths, I felt I was opening doors to a land where magic was real. The techniques of Vedic calculation made large numbers less fearful and easily manageable. In fact, I realised that the larger the number, the more noticeable was the magic of Vedic Mathematics.

One interesting application is in multiplying numbers by seeing how close they are to the base of 10, 100, 1000, etc. For example, to multiply 996 and 998, we see that they are 4 and 2 away from 1000. We first get the number 994 (which is 996-2 or 998-4) and then add 008 at the end (8=4x2) to get the answer 994008. Similarly, when we want to subtract a number from a multiple of 100 (like 1000, 10,000 or 100,000) we can use this Vedic method to reach our answer quickly. If we want to calculate 1000 – 234, we can subtract each figure in 234 from 9, giving us 765. Adding one gives 766 which is the right answer. Vedic Mathematics has many such methods to help in calculations that would normally have taken much longer!

There have been great mathematicians who have used Vedic Mathematics to build their concepts of advanced Mathematics, such as Aryabhata who gave us the value of pi in the 5th century. In recent times, Shakuntala Devi used Vedic Mathematics to help solve complex mathematical problems. By the age of five, Shakuntala Devi was recognised as a child prodigy in intricate mental arithmetic. Later, the speed at which she could do calculations including cube roots, earned her the name of 'Human Computer' (5) (Pandya, 2013). After she could multiply two 13-digit numbers randomly picked by the Department of Computing at Imperial College, London in 28 seconds, she featured in the 1982 Guinness Book of World Records. Shakuntala Devi has dedicated a lot of time teaching techniques of Vedic Mathematics in mathematical institutes and writing books for children to inculcate love for the subject. (Devi, 2005)(6)

From simple fun activities like challenging friends with maths problems to complex applications like astronomy, Vedic Mathematics has something for everyone!

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Mathematics
- Zakiyah Nasar Ali, James Allen's Girls' School

Maths helps us understand the world- and we use the world to understand maths. [1] But do you know the origin of maths? Or why some things are the way they are? Maths didn't just exist, so how did it come to be how it is today? We have been studying it from such a young age but most of us don't ask ourselves any of these questions.

First, what is maths? If you look up a definition, it will come up with something like: "a science of quantity, structure, space and patterns" [2] or something along those lines. But there is so much more to maths than numbers; it is a language of logic and opens up many possibilities and connections around the world.
So, who started it? The answer to that is complex. No one person invented maths; it was built up by different people around the world at different times. Think of it as a meal- its ingredients have been grown in different parts of the world at different times, to make a final product.

Let's rephrase the question- how did it start? Well, we start maths by counting. Our prehistoric ancestors would have known about amounts and could instinctively tell the difference between one and two people, for instance. They needed to mark/name these quantities. Archaeologists have found the earliest signs of counting about 30,000 years ago on bones with engraved dashes. We also know that people used pebbles to count since the word calculus comes from Latin, meaning pebbles. [3]

Soon after, in Iraq, somebody realised that there are quantities, and they should be named. [3] And just like that, after being named, it became possible to count and write. This was great, but immediately it became limited. How would you count, for example, people in a village? So, the next step was combining digits. [3] When combining digits, you can create many numbers. Now, it was possible to count big. This was the invention of numbers.

Several number systems were designed and developed all around the world, such as the Roman numerals. It has seven digits and could be combined to make any number. [3] But these number systems were not perfect as it would not make sense to add. For example, you couldn't add II (2) and VIII (8) as it was not possible to do: VIII + II. Centuries later, people from East India and the Middle East had the idea of the number 0. A digit to qualify something that doesn't exist. It took time for it to be accepted across the world, but when it was, there was a clear number system. [3]

But what about topics in maths? Well, now that we have numbers, there were mathematicians around the world who invented formulas, ideas etc. Let's look at algebra. How was algebra invented?

To start, algebra was invented to help with real-life problems, such as farming. To calculate the amount of water needed for x number of crops is an algebra problem and people worked these out without the notations we have today. The first recorded word problem was in 2000 BC, in Ancient Babylon where a farmer worked out a similar problem. [3] However, there were no mathematical inventions just yet.

At 400 AD, Diophantus from Alexandria (North of Egypt), introduced symbols and accepted fractions as numbers. At 800 AD, Brahma Gupta from India introduced rules for negative numbers and 0. At 820 AD, in Baghdad, Al-Khwarizmi wrote a book called "The compendious book on calculation by completion and balancing." [3] He used the rules from Diophantus and Brahma Gupta, along with his thoughts to write this book. In the title, there was a word - "al-jabr," meaning restoration of broken parts. This word is what's known as algebra today. [3]
When these texts and ideas travelled across Europe i.e., Spain, they had to be translated by Spanish scholars. The word unknown in Arabic was called "al-shay'un." In Spanish, there is no 'sh' sound so the letter 'chi' from Greek was used to make the sound 'ck'. When this was translated into Latin, they simply replaced the letter "chi" with the letter x. That's why we refer to x so much when we talk about the unknown. [4]

So, there you have it! We can see that maths has taken a long, interesting journey to be where it is today and it is the work of many great people.

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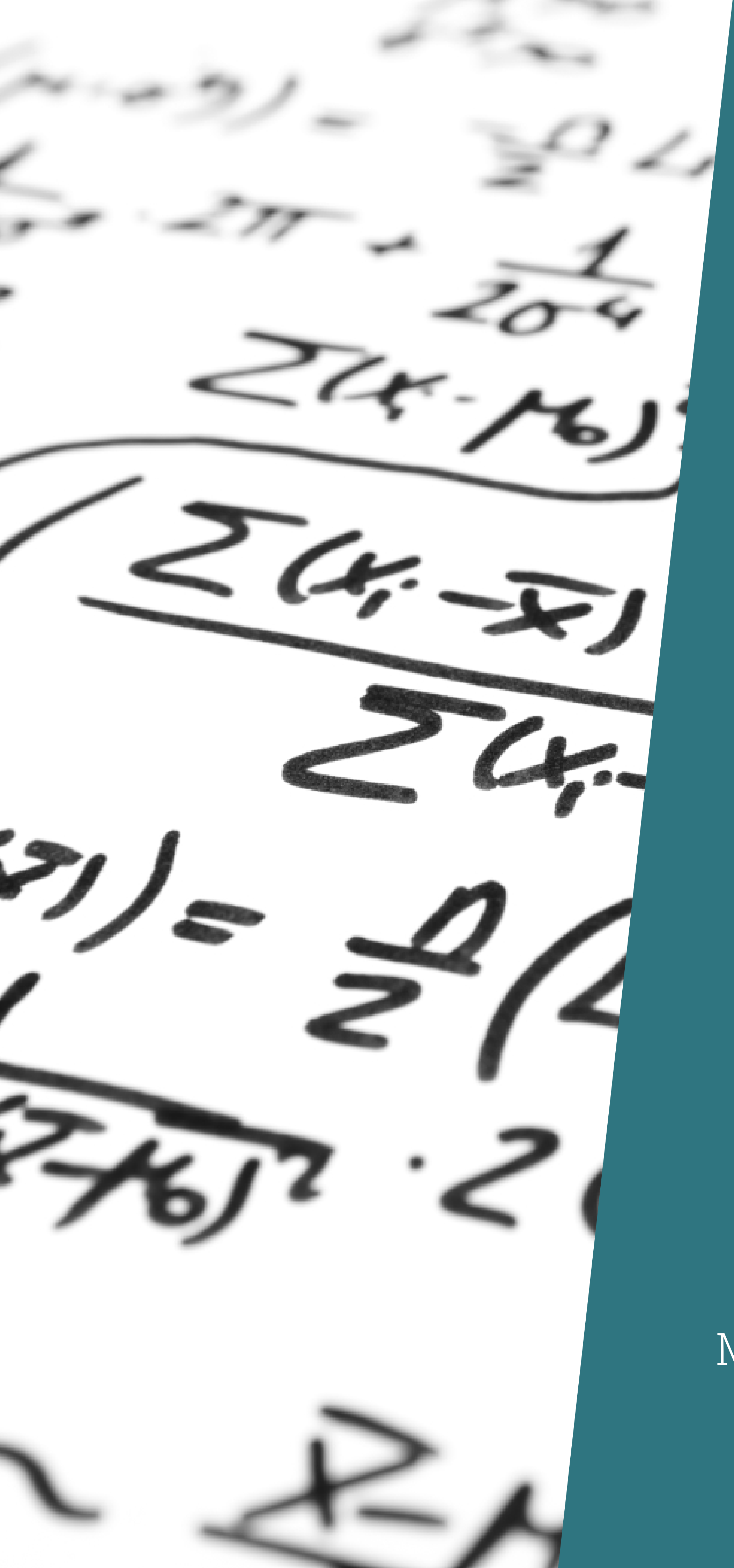

UNDER 16
MATHEMATICS
ESSAYS

The Journey of Nothing - Zero as a number
- Trisha Thakkar, Oxford High School

Numbers are a part of every aspect of our lives. In the previous sentence alone, there are 38 letters out of which 16 are vowels out of which 6 are solely the letter 'e'. Granted, such information is not very conspicuous to most but it goes to show that everything is made up of something. But is that really the truth? If we take a look back at the first sentence, we can see that there are gaps in between the words. Spaces of nothing that yet somehow make everything around them more comprehensible. Without them, the sentence would simply be an incoherent string of letters. The first sentence also hints at another such phenomenon. Before all those words and spaces existed, there was simply nothing. A blank white page that gives everything that is to take form upon it a start to build up from. We as humans have trouble identifying these principles of nothing and yet have still managed to incorporate them into our numerical system. Zero. A word with four letters and two vowels. A round elliptical shape. An amount signifying absolutely nothing.

The origins of the number zero are greatly obscure. Some propose that it was first used by the Sumerians while others argue in favour of the Babylonians. The names of the cultures who were first to use it have been greatly debated though what they used it for remains the same. Zero, in its ancient beginnings, was not a number but instead a place holder. A way to differentiate between numbers such as 32 and 302. By using a place holder between 3 and 2 we have established that a tens place exists but is empty therefore moving 3 to the hundreds place. For this use, zero did not have a numerical figure, it was instead notated using two wedge symbols. Wedges were not the only notation used. Relics found in archeological sites of other ancient cultures such as Mesopotamia showed different markings used for the same purpose. This first use of zero did not utilize it as a number. It was instead treated more like a punctuation mark or decimal point. It was used only to ensure that the numbers around it in a figure are read in their correct numerical place[(2)].

The transition of zero into a number began in India[(1)]. In around 650 A.D., the mathematician Brahmagupta was the first to use arithmetic operations using zero. Though he used dots to represent zero rather than a numerical figure, the purpose it served was that of a number. Through Arab voyages, the Indian interpretation of zero reached the Middle East. Arabian mathematicians began basing their numbers on the Indian system. Later in the ninth century, an Arabian mathematician called Mohammed ibn-Musa al-Khowarizmi would be the first to start using equations equal to zero forming the basis of what is now known as algebra. By his time, zero was now notated as a circle-like figure similar to its modern-day counterpart but smaller than the other numbers[(3)]. The Italian mathematician Fibonacci would later introduce this Indo-Arabic number system to the rest of Europe through his book Liber Abaci. Though, he would not treat zero the same as the other numbers[(2)]. Fibonacci's efforts later caused other European merchants, bankers, and mathematicians to start using zero in their calculations. By the time Descartes used (0,0) as the origin for his Cartesian coordinate system, zero was now a more common part of the numerical system. Finally, through Newton and Leibniz working with numbers as they approached zero, calculus was created and zero was cemented as a recognized number[(3)].

Numbers truly are a part of every aspect of our lives but none have gone through as great of a change as zero. Its journey from being merely a punctuation mark to having a permanent place in our number system has been a long one. It has been through everything to represent nothing.

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Modelling the evolution of viruses
- Jacqui Sanitt, South Hampstead High School

After reading countless news articles discussing mutations of COVID-19, I decided to create a program that simulated the effect of an evolving virus on a susceptible population.

In this program, I designed a population where each individual has a specific immune defence rating ranging from 1 to 9, distributed on a bell curve. Then I created two viruses, with the characteristics immune infiltration (ability to infect the immune system) and transmissibility. A virus was only able to infect a person if its immune infiltration was higher than the person's immune defence. The number of people who would be exposed to each virus per round was the number currently infectious multiplied by that virus's transmissibility. Once a virus had infected someone, there was a one in thirty chance the virus would mutate, thus creating a new strand. The infected person's immune defence would immediately turn to 10, meaning they were unable to become re-infected. This mirrors how the human body produces antibodies in order to prevent the person catching the same illness multiple times. After contracting the illness, the person stays infectious for three weeks/rounds of the program, and when the time has elapsed there is a one in ten chance that person will die. The program shows how many people each virus strain has infected, as well as calculating the total infections and the number of deaths.

Here are the three main points I have learnt from my program:

The viruses that were most successful in infecting people were the first ones to hit the population. This is because at the beginning the population had no immunity, meaning they were susceptible to the virus. In some ways this is surprising, as a virus with higher transmissibility and greater immune infiltration had infected far fewer people than a virus that had lower ratings, simply because it was introduced to the population first. Interestingly, this mirrors what is happening with some COVID-19 strains, where even though the new mutation is more infectious, it is infecting fewer people than the original strain, largely due to the population's increased immunity and therefore decreased susceptibility.

The first people in the population to contract the virus were the ones most susceptible. Whilst analysing the population, which was set to 20000 throughout, I noticed the people who were infected were the ones with the lowest immune defence ratings. In some ways this is predictable as the virus can only infect someone if the virus's own immune infiltration is higher than the person's immune defence. However the extent of this was staggering: everybody with an immune defence less than average (five) had been infected, along with a significant proportion of the fives and sixes.

The virus peaked at round 10 with an average of just fewer than 10000 people (half the population) infectious. However the viruses continued infecting as late as round 40, resulting in over ¾ of the population having been infected. Most of the virus strands had died out preceding this point, though often a new virus mutation, which enabled this virus strain to be able to further infiltrate the person's immune system, as well as becoming more transmissible, was still infecting new people. I observed one 'super' virus that had significantly mutated meaning it was able to infect everyone, except the previously infected. Luckily, in real life this is almost impossible, though this program does demonstrate the risk of mutations of viruses.

Overall, this program simulates how a virus interacts with a population, as well as showing how different strains of a virus mutate. This program shows how models of viruses can be used to explain how viruses behave in the real world. This is because the program enables finding and protecting the people most likely to become infected first, as well as estimating the peak of infections caused by a virus, thus allowing restrictions to be most effective as they are brought in at the right time. Lastly, the program demonstrates how a mutation of a virus can cause more infections even in a previously exposed population, showing the dangers of virus mutations.

The code is in Appendix One and here is an online version: https://trinket.io/library/trinkets/02b16d9be8. Excerpts from the sample output is in Appendix Two.

Appendix One

```
#evolution of viruses

#viruses
#transmissibility #immune infiltration #people infected
viruses=[[4,5,1],[5,6,1]]
#population

import random
population = []   #initialises array for population
for c in range(20000): #starts for loop, which creates the population. #change the range to alter the population size
  x = random.gauss(5,2)
  x = int(x + 0.5)
  x = max(x,1)
  x = min(x, 9)
  nextperson = [x,1,]
  population.append(nextperson)
person=0     #creating variables to use in the main for loop below
rannumber=0
ranmutation=0
rantransmissibility=0
infectedpeople =[[1,0,0,0],[1,0,0,0]]   #creates array of infected people. each row symbolises a week.Row one = week one. Once people have had the virus for three weeks, they're no longer infectious

def checkvirus(infectivity, immune):   #defines checkvirus in order to stop duplicates of the same virus
  for checkvirus in viruses:
    if checkvirus[0] == infectivity:
      if checkvirus[1] == immune:
        return False
  return True

for qqq in range(20):     #starts for loop
  loopcount = len(infectedpeople)-1
  for s in range(loopcount):
    print(infectedpeople[s][0],infectedpeople[s][1],infectedpeople[s][2])
    maxinfected = (infectedpeople[s][0]+infectedpeople[s][1]+infectedpeople[s][2])*viruses[s][0] #max infected calculates how many people will be exposed to the virus
    deathamount=(infectedpeople[s][2]//10)
    infectedpeople[s][2]=0
    infectedpeople[s][2]=infectedpeople[s][1]   #changing which week/round people were exposed to the virus, afer three weeks they are no longer infectious
    infectedpeople[s][1]=infectedpeople[s][0]
    infectedpeople[s][0]=0
    infectedpeople[s][3]=infectedpeople[s][3] + deathamount
    print(infectedpeople[s][3])
    print('maxinfected ' + str(maxinfected))
    for k in range(maxinfected):
      person=random.randint(0,len(population)-1)   #seeing who in the population will be exposed to the virus
      popperson=population[person][0]
      if popperson < viruses[s][1]:    #checking whether the virus will infect the person(if the virus' immune infiltration is stronger than the person's immune defense)
        if random.randint(1,20)==15:    #checking to see if there will be a virus mutation(1 in 20 chance for this program)
          ranmutation=random.randint(-1,1)
          newvirus=viruses[s][1]+ranmutation     #creating a new virus strand with this mutation, the mutation changes the virus' immune infiltration ability
          if ranmutation==-1:
            print('Mutation, -1!')
            if checkvirus(viruses[s][0], newvirus):    #checking to see if the same virus already exists, before adding a new virus strain to the array, in order to prevent duplicates
              viruses.append([viruses[s][0] , newvirus , 1 ]) #adding the new virus to the array
              infectedpeople.append([1,0,0,0])
              print('infected ' + str(infectedpeople)) #prints the new list of infected people
          if ranmutation==1:
            print('Mutation, +1!')
            if checkvirus(viruses[s][0], newvirus):
              viruses.append([viruses[s][0] , newvirus , 1 ])
              infectedpeople.append([1,0,0,0])

        if random.randint(1,30)==30:        #checking to see if there will be a virus mutation
          rantransmissibility=random.randint(-1,1)   #checking if virus will become more or less transmissable
          NEWVIRUS1=viruses[s][0]+rantransmissibility
          if checkvirus(NEWVIRUS1, viruses[s][1]):
            viruses.append([NEWVIRUS1, viruses[s][1], 1])
            infectedpeople.append([1,0,0,0])
            print('New virus alert!')
        population[person][0]=10   #switching this person's immune defense to 10, meaning they will not be able to get infected again.Mirrors human's immune system
        infectedpeople[s][0]=infectedpeople[s][0]+1
        viruses[s][2]=viruses[s][2]+1 #adding 1 to the total number of people who have been infected

print('The viruses ' + str(viruses) + '    ') #prints the virus array
print('This is the population:  ' + str(population)) #prints the population array
print('this is how many people at this time have each virus ' + str(infectedpeople))

total=0
for i in range(len(viruses)):
  total= total + int(viruses[i][2]) #for loop adding up the values in the array to calculate how many people in total have had the virus
print(str(total) + ' people have had a virus')
sum=0
for i in range(len(infectedpeople)-1):
  sum= sum + int(infectedpeople[i][0]) + int(infectedpeople[i][1]) + int(infectedpeople[i][2]) #for loop adding up the values in the array to see how many people are currently infcectious
print(str(sum) + ' people are currently infectious')
deathtotal=0
for i in range(len(infectedpeople)-1):   #using for loop to calculate how many people have died
  deathtotal=deathtotal + int(infectedpeople[i][3])
print(str(deathtotal) + ' people have die
```

Appendix Two

```
(1, 0, 0)
0
maxinfected 4
(1, 1, 0)
0
maxinfected 8
(2, 1, 1)
0
maxinfected 16
(7, 2, 1)
0
maxinfected 40
Mutation, +1!
New virus alert!
Mutation, -1!
infected [[5, 7, 2, 0], [1, 0, 0, 0], [1, 0, 0, 0], [1, 0, 0, 0], [1, 0, 0, 0]]
(18, 7, 2)
0
maxinfected 108
New virus alert!
(1, 0, 0)
0
maxinfected 5
(1, 0, 0)
0
maxinfected 4
(1, 0, 0)
0
maxinfected 3
(39, 18, 7)
0
maxinfected 256
Mutation, -1!
Mutation, -1!
Mutation, +1!
(2, 1, 0)
0

...

Mutation, +1!
Mutation, -1!
(0, 0, 0)
0
maxinfected 0
(37, 43, 49)
10
maxinfected 516
Mutation, -1!
```

A platonic journey through the dimensions
- *Tiffany Igharoro, Sydenham High School*

Here is a sequence:

1,1,∞, 5, 6, 3, 3, 3..

What do you think comes next in the sequence? Remember your answer and read on to find out if you were right.

Bon voyage!

We begin our journey on dimension-0 : a singular point.

Fig. 1.1
"point"

If we extend our point we get a line, and thus our new dimension.

Fig. 1.2
"line"

We can "extend" our line into a 2D plane to form a square. The simplest polygon we have on this dimension would be a **triangle.**

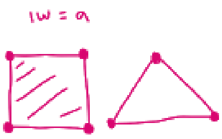
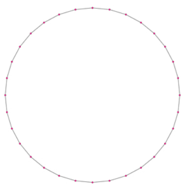


Fig. 1.3
"2 D"

We can create an infinite amount of 2D-polygons and eventually we get something with the likeness of a circle.

Fig 1.4



A triacontagon or a 30 sided shape

When we look at polygons we know that they are regular 2d shapes made from lines of equal length. A platonic solid is a convex 3d-polyhedron (shape) where all the faces are made from identical polygons and the same number of faces meet at each vertex.

Things to remember

For an object to be considered a regular polytope
1. minimum of 3 faces meet at each vertex (to form a corner)
2. sum of internal angles at vertex where they meet, must be less than 360 when the angels are above 360 degrees we end up with a "flat" shape.

Constructing our 3-dimensional “platonic solids”:

∠ = 60° for a equilateral-triangle . 4 triangles form a closed 3d shape(tetrahedron) whereby each vertex has 3 faces meeting. The sum of the angles at each vertex = 180°. 180° <360°. This means that there is space left to “bend” our shape into dimension-3.

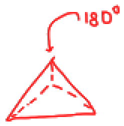


fig 1·6

4 triangles form an open shape (a square could be attached to the bottom to form a square based pyramid). If we take 2 of these open shapes and treat them as halves we can connect them to make one shape made of 8 triangles: the octahedron. 4 faces meet at each vertex and 4x60° = 240° , 240°<360

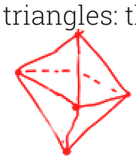


fig 1·7

Finally, we can create a shape called the icosahedron (20 triangles), where 5 triangles meet at a vertex and 5 x 60° = 300° , 300°<360°.

fig 1·8

The same works with 6 squares. We can make 3 faces meet at each vertex forming our corner & connect 2 corners to get a closed shape: cube. 3 x 90° = 270° , 270°<360°.

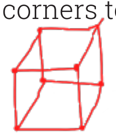
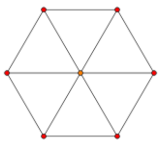
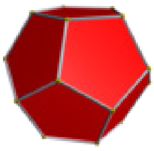


fig 1·9



The final platonic shape is created by using 12 pentagonal faces. 3 faces meet at each vertex. 3 x 108° = 324°, 324° < 360°.



There aren’t anymore because once we move past a pentagon the internal angles are too big & the shape flattens out. E.g Each internal angle of a hexagon = 120° . We need at least 3 to form a corner and 3 x 120° = 360° which is too large.

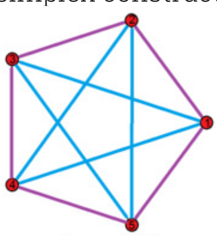
The 4th dimension

Since our brains are 3-dimensional it’s “impossible” to imagine the 4th dimension. Instead we use projections of the 4th dimension. (There’s a movie called flatland which demonstrates this idea)

The faces of the polytopes for dimension-4 and above, use the regular, convex shapes from the previous dimensions as faces.

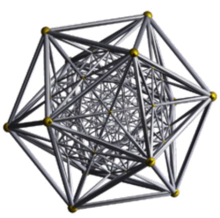
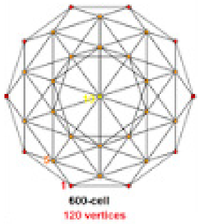
The dihedral angle of a tetrahedron is 70.5°. 70.5° x n < 360°. Where n = 3, 4 , 5 . We can fit these around a shared edge & have space to bend our shape into the dimension-4. We call each platonic solid that acts as a component in forming these 4d shapes a “cell”.

When n = 3 , we get a 4D simplex constructed of 5 cells; where 3 cells meet at each edge.

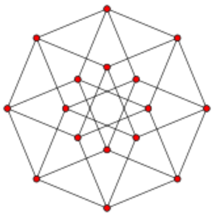
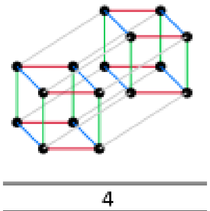


Orthogonal projection

When n = 4, we get a cross-polytope constructed of 16 cells; where 4 cells meet at each edge.
When n = 5, we get a cross-polytope constructed of an insane 600 cells; where 5 cells meet at each edge. (This is because we get a shallow angle of 7.3°)

Dihedral Angle of a cube = 90°. We can use 3 to form a corner and still have space resulting in the 8 cell/ Tesseract/4D-hypercube 4 x 90° = 360 so there is no space to bend in dimension-4.

Dihedral Angle of an octahedron = 109.5°. So we can have three meat at every edge to form a 24 cell.

Dihedral Angle of dodecahedron = 116.5°. We can have 3 meet at every edge, but the resulting angle is 10° which is very shallow so we end up with a 120 cell.

Higher Dimensions

Only 2 of the 4-gons(4d shapes) have dihedral angles < 120° : tesseract and 5-cell. All measure polytopes (n-dimensional hypercubes) have angles of 90°, so we can form a hypercube on every dimension. Three simplexes (triangles - tetrahedrons - 5 cell) can be used to form the simplex on the next dimension. Cross-polytopes (e.g our 600-cell) have angles of 120° so cannot be reused. However a new cross-polytope can be formed on every dimension from our simplexes. So for dimension > 4 we can make 3 regular-polytopes. And the sequence has been explained!

This is the simplest way to demonstrate these ideas however, this could also be explained by using a combination of Euler's formula, Schlafli Symbols {s,m} and topology.

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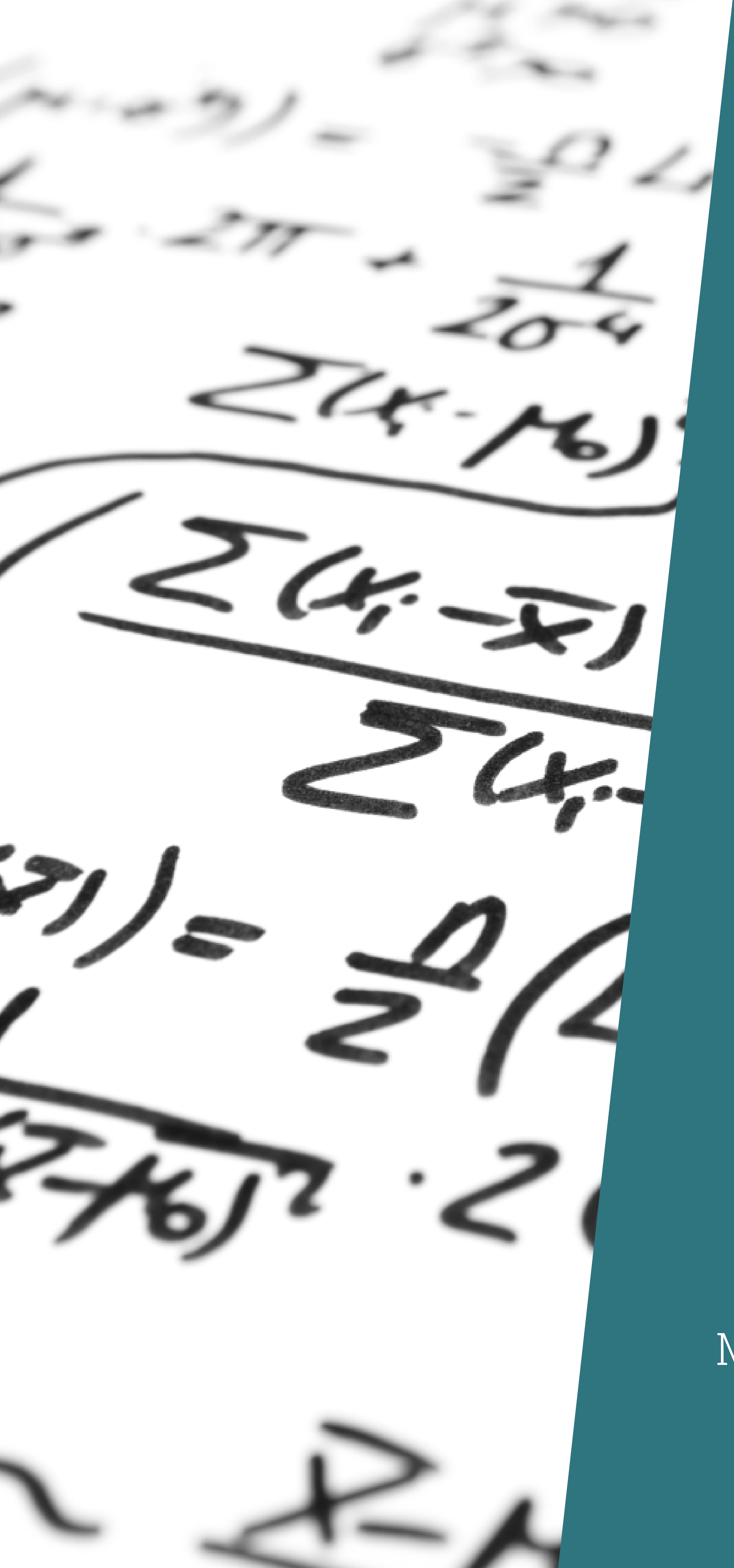
All diagrams are my own unless mentioned here:

Dodecahedron - Dodecahedron
5cell- 5-cell
600 cell- 600-cell
Hypercube and orthogonal projection of cube- Hypercube



UNDER 18
MATHEMATICS
ESSAYS

Do Plants Carry Protractors?

- Amy King, Oxford High School

This seemingly nonsensical question can be answered using Fibonacci's sequence. Fibonacci's sequence is a series of numbers (1,1,2,3,5,8,13...) in which each number in the sequence is derived from adding the two numbers before it. This sequence, often called Nature's Code, was first discovered by Indian mathematicians as early as 700AD. However, the phenomenon was introduced to the West in 1202AD by Leonardo of Pisa (more commonly known as Fibonacci).

Fibonacci numbers occur in places ranging from apple and banana cross-sections to the number of petals on a flower or swirls on a pinecone. For instance, an apple core has 3 petal shaped cut outs in the centre and petals are commonly in groups of 3,5 or 8. This adherence to the Fibonacci system is by no means accidental. Its purpose is to achieve maximum efficiency for growth.

The leaves on a plant must absorb enough photons from the sun for photosynthesis to work which then allows them to grow. By spreading out the plants' leaves in the most efficient way, they can catch the most sunlight and therefore grow the most.

Botanists have noticed that plants seem to be consistent when it comes to the angle between one leaf and the next. There are an infinite number of possibilities in which leaves can grow so how can this angle reliably be the same?

If leaves all grew at the same 90-degree angle off a stalk, they would be on top of each other and the highest leaf would block out the light for all the rest making photosynthesis less efficient. It is vital for plants to reduce overlap to maximise efficiency. Any fraction with a rational number would eventually have overlap, but an irrational fraction could prevent this. Number theorists have concluded that Phi (ϕ- approximately 1.618) is the most irrational number of all. Each pair of adjacent Fibonacci numbers creates a ratio (3/2, 5/3, 8/5...) that gets closer and closer to Phi as the numbers increase. The Greeks were the first to observe Phi, also known as the Golden Ratio, and believed that the objects in nature that obeyed this ratio were the most aesthetically pleasing. Whatever the direction of the first leaf, the next leaf will be $360/\phi$ away. This equates to roughly 137.5° clockwise or 222.5° anti-clockwise. These two leaves are adequately far enough apart that they can absorb sufficient photons. As more leaves are added, they tend to form in the spaces between the existing leaves but overlap in such a way (according to the Golden Ratio) that they manage to always leave room for the next leaf to have exposure to the sun as well as the ones below.

Back to the original question: do plants carry protractors? The obvious answer is no. However, without a protractor, how do they manage to get the 137.5° space right each time? The answer lies within the meristem, the part of the plant from which new leaves emerge. As the plant grows, the new leaves move further away from the meristem. The leaves are pushed away not only from the meristem but also from other leaves at an angle of $360/\phi$.

Hormones in the plant dictate where the leaves grow. When the hormone in the area closest to a leaf is used up, a new leaf will grow further away where there is growth signalling hormone remaining, using up the hormone in that area as well. New leaves continue to form in the spaces furthest away from the existing leaves because that is where there is the most hormone left. Once everything is locked into a pattern the plant cannot escape because there is no other empty space with adequate hormone to allow it to break the sequence.

Thus, the plant does not carry a protractor as it does not know the angle exists. However, the space that is one Phi away is the space with the most hormone left and hence, this self-perpetuating cycle based off the Fibonacci sequence is the most efficient way for plants to grow and why over 405 million years, they do so, having never once used a protractor.

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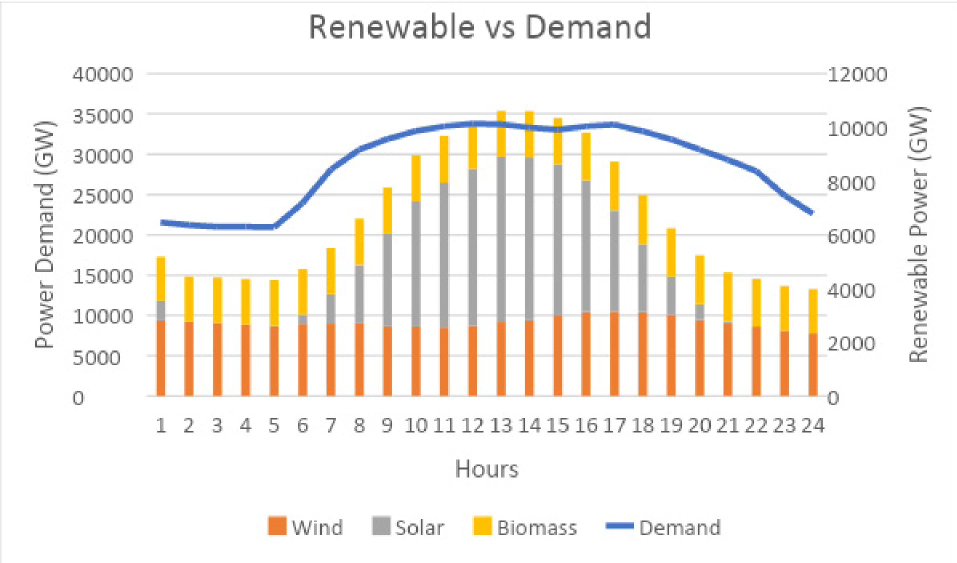
The Unsung Hero of Renewables
- E Roberts, South Hampstead High School

Countries all around the world are investing more and more in renewable energy, with many pledging to turn carbon neutral in the near future. However, moving to renewable energy isn't just dependent on increasing renewable energy generation, but on increasing energy storage as well.

Energy storage does what it says on the tin - it stores energy. But why is it so vital in order to achieve 100% renewable energy?

One key problem we will face is that the supply of renewables and demand for energy don't match. Renewables normally peak at midday (when the sun is highest), with a sharp drop off early and late in the day. This results in peak generation not matching peak consumption, which could result in blackouts during peak demand. This discrepancy can be seen in Figure 1. As renewables release their energy into the grid instantaneously, there is nothing stored as extra fuel for peak times. Whenever there is a mismatch, there is nothing the grid can do to increase supply.



A graph showing average UK renewable generation vs demand[1]

Another problem is the unreliability of renewables. If the sky becomes cloudy or wind speed falls, output can massively drop. These fluctuations are unpredictable, so even before we reach complete dependence on renewable, the polluting 'peak plants' we currently use to regulate dramatic falls in generation won't be able to respond quickly enough to counter the fluctuation. Without these plants at all, these fluctuations will majorly affect the reliability of supply for consumers. This is a problem that will only get bigger (and more expensive) with time if nothing is done.

We haven't needed to worry about this before as fossil fuels are both a store and source of energy. Energy is stored in the fuel until it is needed on the grid at which point it is burnt, ensuring stability. As renewable energy sources can't be stored like we can store coal, oil and gas, we need to provide this function separately. This is where energy storage comes in.

Pumped hydro, which makes up around 97% of global energy storage, works by building a pump system between two reservoirs of different heights. By pumping water to the top reservoir, electrical energy can be stored as gravitational potential, it can then be converted back by letting the water flow back down. Lithium-ion batteries are predominantly used for battery farms and they store energy in reversible reactions with the electrodes.

The way energy storage solves the two major problems while still being economically viable is it takes in energy when demand is low, supply is in excess and energy is cheap. It then releases energy during peak times to help even out the supply, when energy is more expensive, therefore making a profit. It also reduces the economic losses inflicted by blackouts (one 100MW battery farm in Australia has saved an approximate A$116 million in blackout prevention).

It solves supply and demand issues as it can store the excess renewable energy during the middle of the day, and releases it as supply drops before demand does. It is also more responsive than peaking plants. While it depends on the type of energy storage, both the current major energy storage solutions (pumped hydro and Lithium-ion battery farms) can respond in seconds to these fluctuations, allowing them to counteract the fluctuations effectively and smooth out supply.

However, expanding energy storage isn't going to be easy. Pumped hydro is extremely expensive to scale, with each project costing upwards of $3.5bn, and there are limited sites that they can be built on. Lithium-ion batteries are cheaper, but aren't designed for large scale static storage - they lose capacity with full charge/discharge cycles. Mining for the materials is also extremely harmful to the environment and shelf life is short (around 5-10 years). Any new storage technologies will be expensive to invest in, as they don't yet have the economy of scale.

This shows that renewable energy generation isn't the only area we need to invest in. It is vital for a zero carbon future that governments and private investors understand the importance of increasing storage capacity, and designing more efficient, cheaper ways of storing this energy.

1. https://gridwatch.co.uk/

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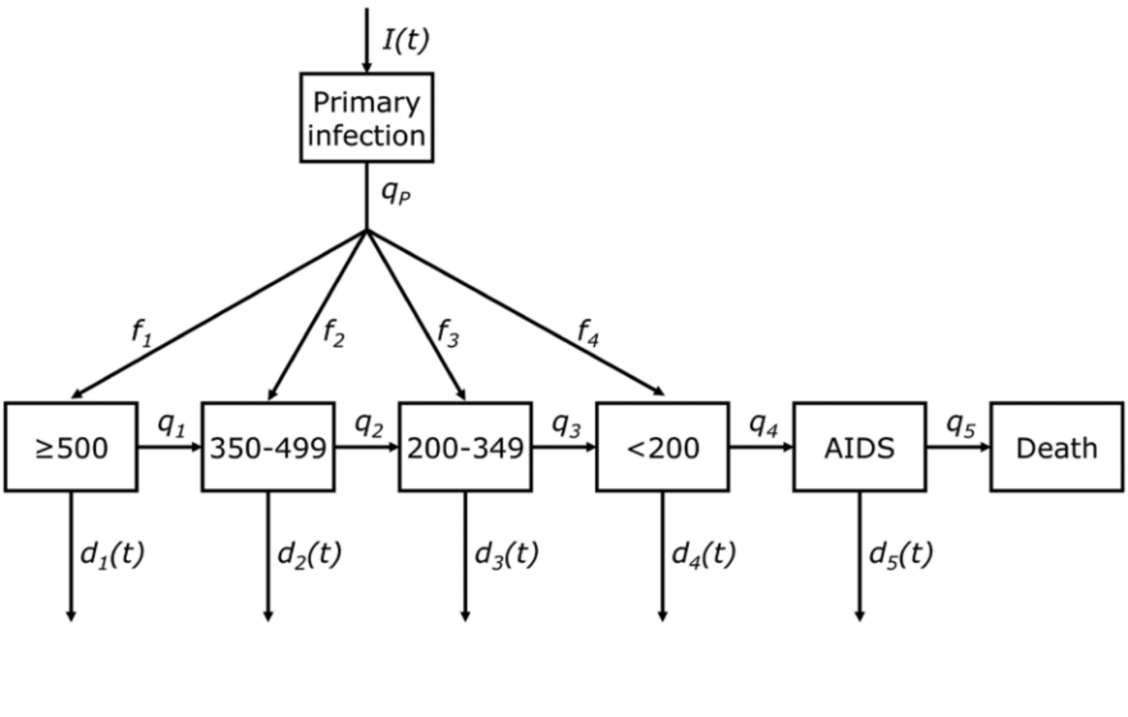
Antibodies against HIV: Immunology gone viral
- Julia Grzywacz, Wimbledon High School

At face value, society imposes ideas that perpetuate harmful beliefs, planted into our minds as young children. HIV/AIDS is no exception– many ill-informed people fear others with this 'invisible' disease, solely because their parents ingrained this notion into them. Would antibody HIV therapy be feasible in improving peoples' lives?

"Vaccines were developed in the twentieth century to address the needs of a society caused by infectious diseases," (Rappuoli, 2011) and can be used in the process of acquiring 'immunity.' The history of immunisation begins with practises of smallpox inoculation, "as early as 200 BCE," that included "scratching matter from a smallpox sore into the skin." (Philadelphia, n.d.) There have been accounts from the 1500's of the ancient Chinese and Indian civilisations also carrying out such practises. In 1796, the British scientist, Edward Jenner inoculated a boy with pus, formed from a cowpox lesion in 1796; thus creating a 'prototype' vaccine which eliminated smallpox. He made the immunisation practises widespread, therefore today hospitals continue to administer vaccines to babies. Over centuries, people have grappled with many global epidemics, more recently HIV/AIDS. HIV was "transmitted from non-human primates to humans and began to diversify4" (Hillis, 2000) as a result of hunting and the eating of chimps by the people of the current Democratic Republic of Congo. The retrovirus mainly affects those who acquire it via unprotected sex or people who inject narcotics and share the equipment. Currently, HIV affects "1.6 in 1000" (Kirwan PD, 2016) people of the UK population, however many people walk undiagnosed or asymptomatic. The treatments offered by the NHS for those who seek HIV-related care include PEP (post-exposure prophylaxis medicine) to prevent the infection of others, or antiretroviral drugs. Nonetheless, these generic treatments do interfere with the quality of the patient's life, and often the medication can lead to hepatotoxic side-effects.

After extensive research orchestrated by scientists, monoclonal antibodies were discovered to aid in HIV-1 therapy. They studied "antibodies against HIV-1 with broad neutralizing activity", which "defined some of the sites of HIV-1 vulnerability on the envelope spike." Experiments were conducted using antibody cloning techniques to then identify, "single B cells that express antibodies that bind to the HIV-1 envelope spike." (Florian Klein, 2013) These antibodies now recognised the "HIV-1 envelope glycoprotein by targeting defined vulnerable epitopes on its surface" and "antibodies targeting the CD4 binding site." (Gruell, 2018) The HIV virus attaches itself most commonly to the CD4 protein on the T-cells, and replicates, killing the T cells in the process and weakening any immune responses. The number of lymphocytes drops, and the body cannot fight with opportunistic infections anymore, which is the development of HIV into AIDS. This new generation of antibodies would prevent the further infection of more cells by the virus, and modifying the antibody binding sites would make them complementary to more different viral strains. A model used to "estimate HIV incidence and time to diagnosis is an extension of the model used by Sweeting and colleagues," which is "a unidirectional flow through different stages of infection that are characterised by CD4 counts or the presence of AIDS events… all individuals first enter a phase of primary HIV infection and then… progress to AIDS through up to four different CD4 strains," (Ard van Sighem, 2015) to help deduce the number of undiagnosed people.



Antibody therapies unfortunately do have limitations – ranging from their expense to the ethics of animal testing. Macaques can produce antibodies for HIV but carrying out animal trials do not equate to the safety in human trials. For example, the failed 'Theralizumab' 2006 drug trials. "In 2006, a phase 1 clinical study was conducted for a CD28 super antagonist antibody TGN1412 in six human volunteers. After very first infusion of a dose 500 times smaller than that found safe in animal studies, all six human volunteers faced life-threatening condition involving multi organ failure for which they were moved into an intensive care unit." (Attarwala, 2010) This could be the case with new HIV developments and the transfer of animal testing to people. However, this limitation is exceeded by the advantages, such as the safety and efficacy of administering antibody-based therapies. "A number of therapeutic antibodies have been approved by FDA for cancer therapies12," (Teow, n.d.)therefore previous antibody research for the viral infection was not futile. Scientists are particularly hopeful because after studies published in Nature, "a cocktail injection of multiple kinds of antibodies dramatically lowered blood concentrations of the virus in monkeys." Furthermore, "since the antibodies attack the virus differently than HIV drugs do, a combination of therapies might thwart the virus better than standard therapy does," (Seppa, 2013) which proves that this virus can be conquered.

Unfortunately, many people don't register the reality of HIV positive people – so as Princess Diana once said, 'HIV does not make people dangerous you know, so you can shake their hands and give them a hug: Heaven knows they need it.'

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