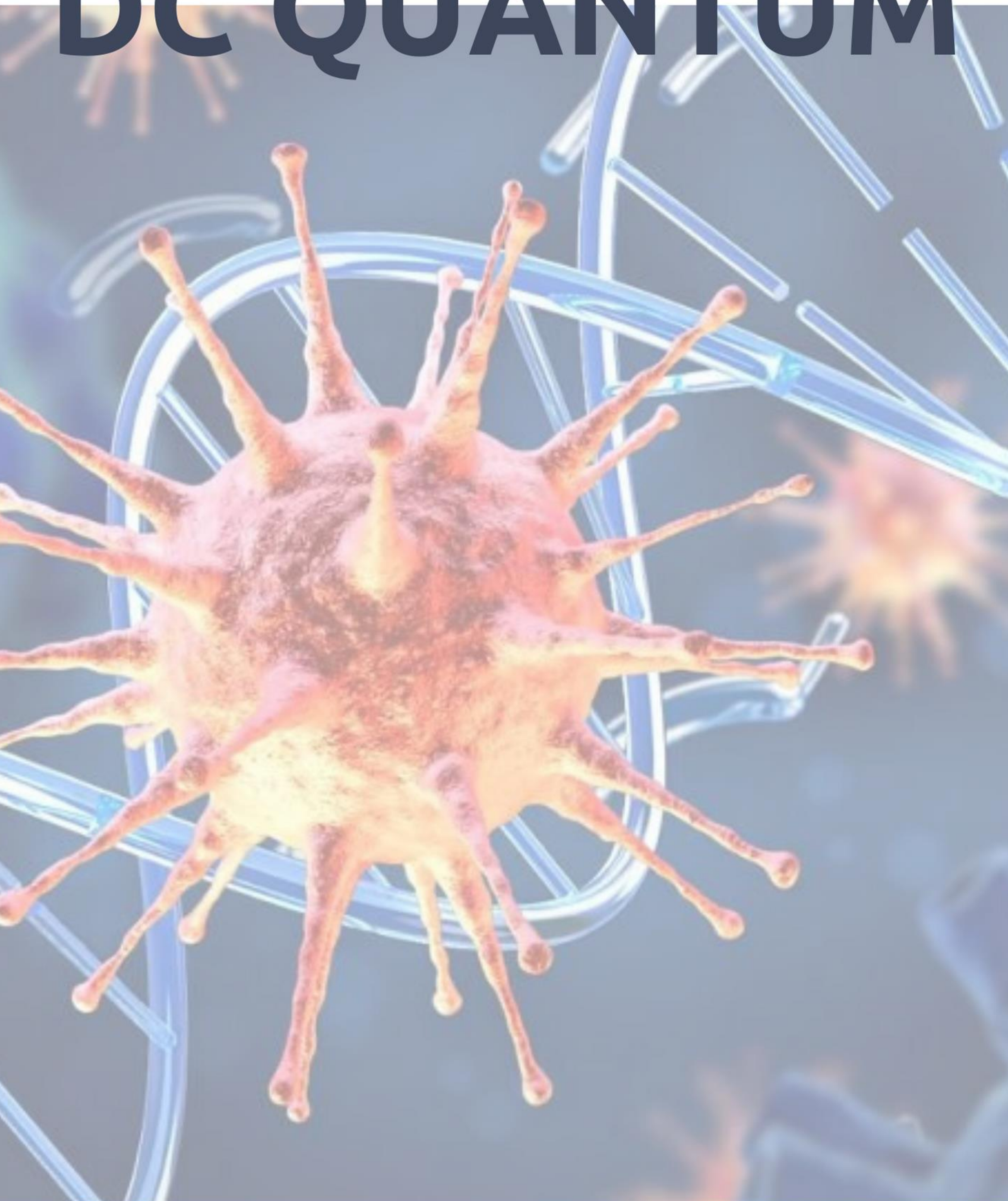
VOL. 02 | APRIL 2021

DC QUANTUM



CONTENTS

Editors:

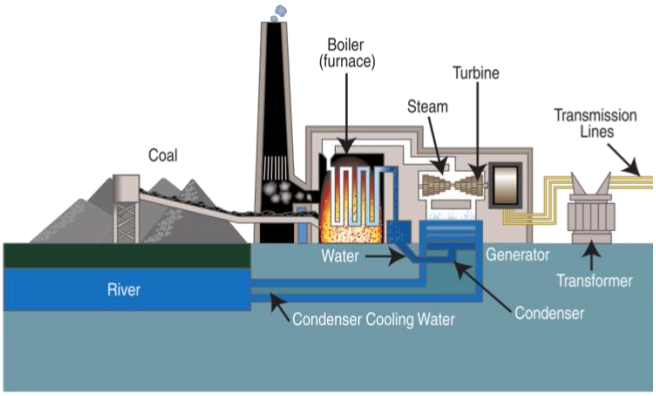
Editor in Chief - Abhay Nischal
Managing Editor - Shrish Janarthanan
Senior Editors - Ashrita Ganesh and Chiara Federico
Editors - Aakriti Singh and Aanya Tashfeen

Designers:

Head Designers - Shehara Amarasekara
and Chiara Federico
Designers - Abhay Nischal and Shrish Janarthanan

ENERGY FROM THIN AIR?

As we all know, energy from our main supply does not come from thin air. A great amount of it comes from fossil fuels (such as coal). So, what does the title mean: energy from thin air?
Just so that everybody is clear, this part should explain how fossil fuels are converted into energy. Fossil fuels are extracted from the ground and brought to energy stations. There, they are burnt in a fire. The heat is used to evaporate some water in a tank, which in turn spins a turbine. The water vapour then condenses back into water and the cycle begins anew. Back to the turbine, it turns a generator (dynamo) which produces electricity. The electricity can then be brought over power-lines and used in houses.



Just for reference on how commonly this cycle is used, in 2019, over eighty percent of energy produced was produced like this.

However, there are two issues with this system. First of all, an infinite amount of fossil fuels does not exist. Secondly, burning fossil fuels releases greenhouse gases, causing global warming.
So, it should now be evident that we need a different energy source, one which can be used forever and one which does not pollute the air. There are different types of renewable energy, but they generally all eventually switch off. For example, the sun is not in the sky all day, so solar energy is not perfect. Wind turbines only spin when there is wind, making them imperfect. Geothermal energy can even pollute the air slightly. So, we need a different solution.

Now this might sound crazy, but it is possible to create energy from thin air. How, you may ask. Developed at the University of Massachusetts Amherst, a device called Air-gen was created by electrical engineer Jun Yao and microbiologist Derek Lovely. It works by using electrically conductive protein nanowires (which are produced by a microbe called Geobacter) and are connected in such a way so that current is generated from the water vapour naturally in the air (humidity).
In more detail, the nanowires (which are around ten microns thick) are connected to electrodes. These electrodes rest on a film which absorbs water. This, along with fine pores in between the nanowires, creates conditions where electricity can be generated from the moisture in the air.
Air-gen can work day and night and can even work in places with very low humidity. But it is nowhere near perfect (yet!), as it is not the most effective way to generate clean energy. It only generates 17 microamperes per centimeter. This is equal to 0.017 milliamperes, which is pathetic compared to a solar-panel's 28-35 milliampere generation. This means that solar energy can generate around 2,000 times more energy. But hopefully, in the years to come, we can build onto this to make a design that is much more effective. Air-gen is likely to be commercially available soon.

^ [image of Air-gen]

Alexander Westerhof 7JKI

The Science behind Agrivoltaics and Floatovoltaics

Ashrita Ganesh
12CMM

According to the Center for Climate and Energy Solutions (C2ES), solar photovoltaics are the 'fastest growing electricity source' but only produce 'a fraction more than 2 percent of the world's electricity', which is confusing, to say the least. Whether it be on rooftops, installed in windows or in barren areas of land, solar panels are likely to become a major source of electricity in the coming years.

Although many would think that vast, arid deserts are the perfect place to install solar farms - after all, desert sunlight is intense and you don't usually have to worry about any cloud cover - this is not the case, as solar panels do not work as effectively in the heat.

Before we progress, we need to discuss how exactly solar panels function. Their main purpose is to convert light directly into electricity. When they absorb sunlight, the energy from the light, in the form of photons, is absorbed, knocking loose several free electrons, which then drift freely in the cell to create an electrical current, which can then be captured and transferred to a wire. According to manufacturing standards, a 25°C temperature indicates the peak optimum temperature of solar panels (this is when the photovoltaic cells can absorb sunlight with maximum efficiency). When solar panels absorb sunlight and get hot, the electrons pick up more energy from the environment, which causes them to reach a more excited state; even more, when they're already excited, they have less room to absorb energy from the Sun. Thus, solar panels work best in moderate climates, where unfortunately, due to population density and infrastructure, it can be hard to find the space to set up a large field of solar panels.

Since the 2000s, countries around the world have been implementing what seems to be a win-win solution: agrivoltaics. Agrivoltaics involves combining crops with photovoltaic panels, installed with enough height to allow farm machinery to pass underneath. Agrivoltaics is an eco-friendly solution as there is no need to clear up extra space just for the panels. Moreover, the plants, which are now protected from the worst of the midday sun's rays, become little evaporative coolers on the landscape. They take in carbon for photosynthesis while letting water escape from their leaves, creating a cooler microclimate.

The release of water works just like sweating: the evaporating water removes heat from the plant, which brings down the plant's temperature and cools the surrounding area. This helps solar panels be noticeably more efficient. According to researchers centred at the University of Arizona, solar panels over croplands were 3% more efficient than solar panels in the same region that were not over croplands. Although 3% sounds like a negligible amount, over time, these small gains add up.

Engineers have also extended a similar concept to a setup called floatovoltaics, in which floating solar panels are placed on bodies of water. As the water is typically cooler than the air, the solar panels can function efficiently. Research in 2017 discovered that the natural cooling effect of the water below solar panels can boost power production by up to 22%.

Both agrivoltaics and floatovoltaics offer benefits beyond more efficient power generation. Firstly, land or soil does not need to be cleared or treated. Secondly, they can be installed faster with less manpower. Thirdly, in the case of floatovoltaics, the panels improve the quality of water. This is because the shade from the panels reduce the amount of photosynthesis, which in turn restricts algae from growing.

Setups like these already exist in many parts of the world, most noticeable China and Japan, and are likely to become more popular and could produce a significant fraction of the world's energy in the future. Hopefully, small steps like these can effectively reduce our reliance on more conventional forms of producing electricity, while helping us meet SDG7 (One of the development goals established by the UN General Assembly in 2015. It aims to 'ensure access to affordable, reliable, sustainable and modern energy for all').

How is Nanotechnology changing Medicine?

Karma Bridgman
9BPH

Nanotechnology is becoming more popular in the technological world, by currently improving existing materials and processes and then scaling them down to the nanoscale. From being used in developing countries to help treat disease and prevent health issues to developing existing treatments in medical research, its potential in revolutionising modern medicine. The small size of nano tech allows it to integrate into several different fields. All of these technologies and ideas fall under the umbrella term *nanomedicine.*

Enhanced drug therapy

Nanotechnology has an increasingly large relevance in the future of medicine. For example, nanotechnology has the potential to be used as enhanced therapy for cancer due to the size being small enough to accumulate (with the treatment drugs) in the tumor site. This is a solution to the limitations of cancer treatment as being drug resistance and limited solubility. It is also being researched in medicinal imaging, particularly ultrasounds and MRI scans. An ongoing development is "nanodrugs" where nanoparticles are created and designed for targeted drug delivery towards specific damaged parts of the body. The use of these techniques improves the drug biodistribution, targeting active molecules to diseased tissues while protecting healthy tissue. These can also be implemented to increase iodine distribution for CT scans, allowing a better reading of the entire body.

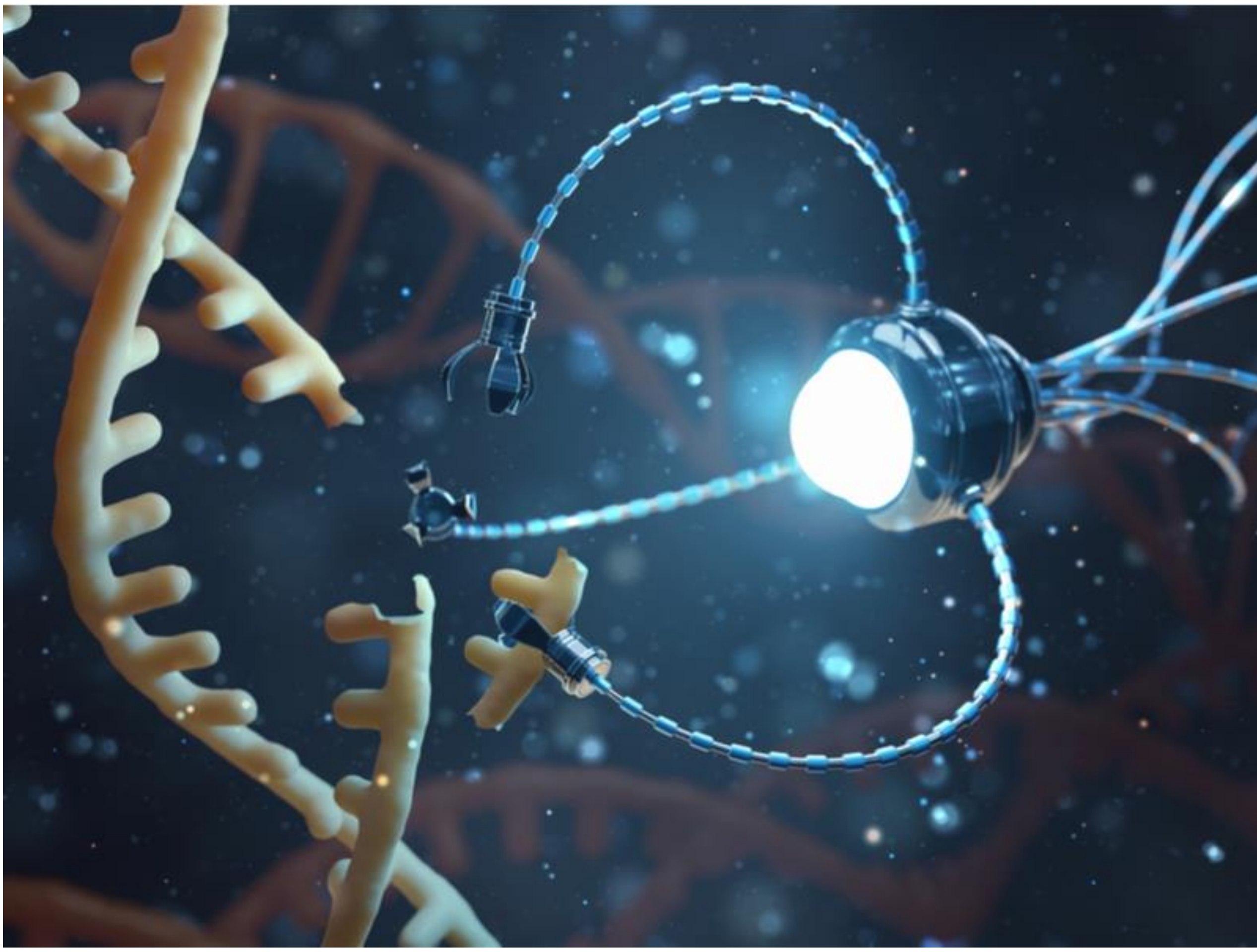
Cancer detection and treatment

There is currently lots of mysteries in the area of curing cancer, in which nanotechnology can be extremely beneficial. Nanoparticle contrast agents can also be used as opposed to regular contrast agents to be distributed through the body more and show more contract on the imaging screen, allowing for smaller or abnormally shaped tumors to be found easier. An example is a struggle of treating brain tumors since the body rejects the anti-cancer agents to the brain due to the brain blood barrier.

Nanoparticles of certain elements can also be used in cancer therapy to reduce tumor sizes. By using 27nm gold particles to target cancer cells, the nanoparticles become attached to tumor, which helps to destroy cancerous cells. The possible toxic effects that the injection of tumor necrosis factor (a protein used for) has on healthy cells is also reduced when coated with the nanoparticle surface. With the injection of the coated TNF, patients are able to tolerate 20 times the normal dose of TNF, whilst delivering anti-cancer agents that the body is more likely to accept.

Nanorobots

A specific kind of nanotechnology, called molecular nanotechnology is used to create cell repairing machines to extend a human's lifespan by injecting a nanorobot. As dystopian as that sounds, a machine (the size of a nanometer and undetectable by the human eye) is introduced to the body which would then detect and possibly even repair internal damage and infections. These programmable nanorobotic devices could be capable of reversing the effects of viruses and cardiovascular disease, assisting the immune system in combatting infections, destroying cancers, and rewriting genetic errors in cells. After developing research in the next century, a nanorobot that cures infections could be the future treatment for an epidemic, creating no need for vaccine research. This can greatly impact our world greatly, allowing for a more effective and faster response to future medical crises.



Non-invasive surgery

One of the best ways to minimise deaths from surgery is to make it completely non-invasive. This can be achieved using a lens with carbon nanotubes to convert light into sound waves, that can be used to blast tumors in patients with cancer. As recovery is faster when a less trauma is inflicted upon a patient, there is less scarring and there are usually fewer complications in the aftermath of the operation. Through nanotechnology, nano-sized biosensors are used to lessen these post-surgery scars through shortening a patients recovery period and saving hospitals money, reducing infection rates within the hospital, reducing the waiting lists for operation and allowing doctors to treat more patients in the same period of time. More radically, the potential of the applications of nanoscience within surgery is nanobots which are robots which would be miniaturised for entry into the body through cavities. A nanobot controlled by a surgeon using a computer could perform precise surgery within cells, which humans aren’t capable of, as scalpels are thousands of times larger than a nanorobot and as they are operated by a human instead of a computer, have a chance of slipping up.

Commercial health industry

Nanomaterials can also accelerate commercial health products. This can be accomplished through carbon nanotubes being key materials in the development of wearable electronics and fitness monitoring and through electronic devices being incorporated into clothing and 'smart skin' applications. Companies are currently working towards making their smart watches even more useful, durable and smaller using nanotechnology. For example, carbon nanotubes can be implemented to create a smart fabric since they’re compared on the nanoscale and have 400 times the tensile strength of steel. With this amazing durability, carbon nanotubes could be integrated to create an ultimately durable fabric for their apple watches or to make high-durability computing software for some of the world’s largest space companies such as NASA and SpaceX. A downside would be how carbon nanotubes are very good conductors, but there are other nano-scale fibers and that are able to substitute or be altered. This can lead the way in the durability of smart products and protection, creating the best mobile fitness and health monitoring devices yet.

Nanotechnology is already leading to dramatic improvements in health care. From improving drug transmission, to bettering quality of surgery and recovery, to revolutionising materials in health products. Nanotechnology is transforming modern medicine techniques. However, the question that comes up is: should hospitals pursue a path to more advanced and effective treatments? Or should governments focus their funds towards making healthcare that is economically available to everyone?

The Case for Canines in the Detection of Covid

Leo Allcorn 8SOR

Across the globe, canines are being utilised to detect Covid-19 through smell and they have shown outstanding results. Trainers around the world are claiming almost 100% accuracy in the identification of both positive and negative cases, and considering current studies suggest that PCR tests have an accuracy of only 85%. Almost 100% accuracy would be outstanding. Scientists involved in the efforts suggest that canines could help deal with the pandemic because of the ability to test hundreds of people an hour in busy places such as stadiums and airports. Another advantage is canines would also be cheaper than the traditional PCR test. In addition, canines only take 2 seconds to determine whether a human has covid or not, another outstanding factor considering it can take days to receive results from a PCR test.

Unfortunately, not enough research has been conducted for scientists to know if this would work on a large enough scale for it to be truly affective. Another disadvantage of canine testing is that they show extremely varied results in accuracy. For example, in Grandjean’s study, 2 out of three dogs got 68/68 correct, while the other dog got 10/57 cases correct.

The use of Canines in the detection of Covid-19 is showing huge potential and using more natural methods of detecting viruses helps us work towards a safer more sustainable future for the planet. Large scale studies are being carried out across many countries around the globe and with more peer reviewed studies likely in the future, the outlook is positive.

Quantum Computing

Parth Goel 9BST

Computers… The medium through which you are probably reading this article.

They have made many great strides in the past couple of decades, transforming from room-sized monoliths, to sleek and powerful devices of the future. But they are once again, approaching a turning point. A type of computer is being born that ties radical new breakthroughs in physics, with the latest that computer science has to offer. The Quantum Computer (QC).

They - as the name suggests - utilise the laws of quantum physics to propel the processing capabilities of computers, making them exponentially more powerful than our everyday machines.

Throughout this article, I will talk a bit about how modern computers function, and the problems they face, followed by how quantum computers aim to tackle these problems, while briefly covering some of the basic concepts in quantum physics. I will then proceed to talk about the future of quantum computing, if such a computer is even viable, and if they are, how they will affect our world.

THE PROBLEM WITH MODERN COMPUTERS

But before we can look into QCs, let's delve into the average one. A computer essentially is a large number of simple logic gates tied together in complex strings to produce a meaningful output. The processing power of said computer is determined by the number of said logic gates the machine has. Problem is, logic gates take space. The average modern computer can contain up to 100 Million Gates! So, to fit all of this into a portable 'laptop', scientists have been working on making the gates smaller and smaller, but at some point, the laws of physics simply will not allow it.

To explain, let us look at something called a transistor. It - much like a switch - can open and block a flow of electricity, or electrons. Think of it like a parking gate with a long stream of cars on one side. When the gate opens, cars are allowed to 'flow' through, but when closed, nothing much happens. Now, the smaller and smaller the transistor becomes, the smaller and smaller the 'gate' becomes, and here is where quantum physics messes things up. If the gate reaches a certain - unimaginably small - size, the cars will now be able to 'teleport' across the barrier, essentially making it useless. This process is called Quantum Tunnelling and is becoming a big problem in the development of computers. Current transistors are only about 14 NanoMeters in length, around 500 times smaller than the average red-blood cell! As transistors are shrinking smaller and smaller, some to the size of only a few atoms, quantum tunneling is rendering them useless by it's 'gate passing magic'.

QUANTUM COMPUTERS

Scientists are now working on computers that are not only able to deal with these problems, but use the properties of quantum mechanics to their advantage. And here, we have arrived back to Quantum Computers…

You may be familiar with Bits. A simple binary unit, representing a 1 or a 0. This can be done in multiple ways, but most commonly, they are represented as either a high or low. This means that if a computer has 4 bits of storage, they can represent one of 16 different values. This is sufficient for everyday tasks, but when they get very complex, such as modelling chemical reactions, this method is simply too inefficient.

Here is where we introduce the brilliance of the design of a quantum computer. Quantum particles have many absurd properties, and one of them is named: Quantum Superposition. This property allows quantum particles to be in multiple states at once. Think of quantum superstition as the state a coin is in when you toss it into the air. To the lay observer, there is no feasible way to predict the 'state' or side that the coin will land on. The only way we can know is by measuring the coin's state, or in other words, catching the coin mid-air. If you were to ask a quantum physicist what side the coin was on when it was in the air, they would reply with both. When there is no way to predict the state of a quantum particle, it, in essence, is in both states at once.

Quantum superposition allows quantum computers to perform calculations that can utilise all 16 possibilities of a 4-bit configuration compared to the single possibility that traditional computers use. This means, as you increase the number of bits in a quantum computer, the processing power of a quantum computer will increase exponentially compared to the growth in power for a regular computer. Paired with things like quantum entanglement, quantum computers can become powerful enough to do things in a couple of days that would take classical machines millennia.

THE FUTURE OF QUANTUM COMPUTING AND ITS APPLICATIONS

With the processing power that quantum computers promise, it is hard to think of things that could not be done magnitudes better with the use of QCs. However, here is where we need to talk about Quantum Supremacy. Quantum Supremacy is a sort of benchmark for quantum computers. It details a point of development of a QC that allows it to compute something that would take a classical computer an unfeasibly long time. And that is what quantum computers are all about.

When a quantum computer reaches supremacy, and maybe even before that, it would be able to do things so complex, that we probably don't have many things that would require its full potential, but one of the uses that many are ectatic about is that quantum computers should be able to accurately model chemical reactions, entropy and all!

Google's Quantum Computer has achieved something similar, successfully modeling a small – simple chemical reaction with their quantum Sycamore chip. Advancements like these may just mean that, in a couple of decades time, we will be operating on Quantum Computers.

SCIENTIFIC BREAKDOWN OF EMOTIONAL RESPONSES

Shehara Amarasekara 12MDH

Happiness, sadness, anger, fear – these are routine emotions for the average human being, so routine that we almost forget that there are millions of neurons zipping around in our brains to make us react in different ways. I have always been intrigued how individual moments in our life instinctively cause practically instantaneous reactions. What causes us to cry, or laugh, or jump from shock?

Crying is instigated by negative emotions – simple enough to understand – but when we delve a little deeper, the act of tears is a self-soothing behavioral response. When we cry, natural chemical messengers such as endorphins and oxytocin are released to mitigate the emotional distress our body is responding to [1]. These tears are known as emotional tears… In actuality, tears produced from crying as a reaction to emotional distress have a varied chemical composition to reflex tears, for example. Tears from an emotional response are also known as 'psychic tears' and have a different chemical response due to a higher concentration of protein-based hormones and neurotransmitters such as leucine enkephalin, which acts as a painkiller during the feeling of stress. Emotional tears hold a great quantity of leu-enkephalin hormone, prolactin hormone, adrenocorticotropic hormone, potassium and manganese. Tears are also composed of salts, water, antibodies, lysosomes with intention to relieve stress. Research suggests that crying for long periods of time releases oxytocin and endorphins – feel-good chemicals – which aid the easing of emotional pain. Psychic tears are natural painkillers so, if you're sad, let it all out and your endorphins will make you feel better!

The average person laughs at least 17 times a day! Laughing is synonymous with positive sensations and the action acts as a healthy way to overcome stress. More frequent laughter is psychologically proven to improve quality of life and is a non-pharmacological, alternative treatment to instill positive effects on the immune system and ones' mental health. The medical community acknowledges laughter as a beneficial form of therapy due to its ability to decrease the serum levels of epinephrine, cortisol and 3,4-dihydrophenylacetic acid [2]. This decrease in serum levels reverses the stress response. Laughter also has the capability to cause fluctuations in dopamine and serotonin levels in the brain, which creates a sense of well-being in the brain.

We've all seen people getting startled from jump-scares in horror films and this reaction is instigated by your 'fight-or-flight' hormone as your inner glands produce adrenaline in response to fear, stress, danger or excitement. Adrenaline increases your body reactivity as a defense response, triggering an increase in heart rate. Blood may be redirected towards your muscles, which is why you may feel your limbs shaking after a jump scare. This feeling is caused by a surge in energy which shallows you're breathing by providing more oxygen to your muscles.

Endorphins are our brain's happy hormone, and they are able to produce neuronal signals which transmit to your facial muscles, instigating a smile [3]. Smiling actually stimulates a reward system in our brains which increases the levels of endorphins, in somewhat of a happy loop! Frowning, on the other hand, is stimulated from stress which causes facial tension. Frowning does not have the same psychological and physical benefits that smiling does; it takes up more of your facial muscles and is caused by negative emotions.

The human brain is a fascinating and beautifully complex organ, particularly when it comes to generating emotions…

A variety of chemicals and hormones instigate the simplest of muscle movements that we do multiple times a day without acknowledging all the work that goes into making them happen!

Sources:
[1] https://www.healthline.com/health/why-do-we-cry#:~:text=Research%20suggests%20that%20when%20you,is%20a%20self%2Dsoothing%20behavior.
[2] https://pubmed.ncbi.nlm.nih.gov/[illegible]/
[3] https://www.britishcouncil.org/voices-magazine/famelab-whats-science-behind-smile#:~:text=When%20our%20brains%20feel%20happy,muscles%20to%20trigger%20a%20smile.&text=When%20our%20smiling%20muscles%20contract,of%20happy%20hormones%20%2C%20or%20endorphins.

The World's Largest Epidemic - Measles

Simra Yousaf 11MYA

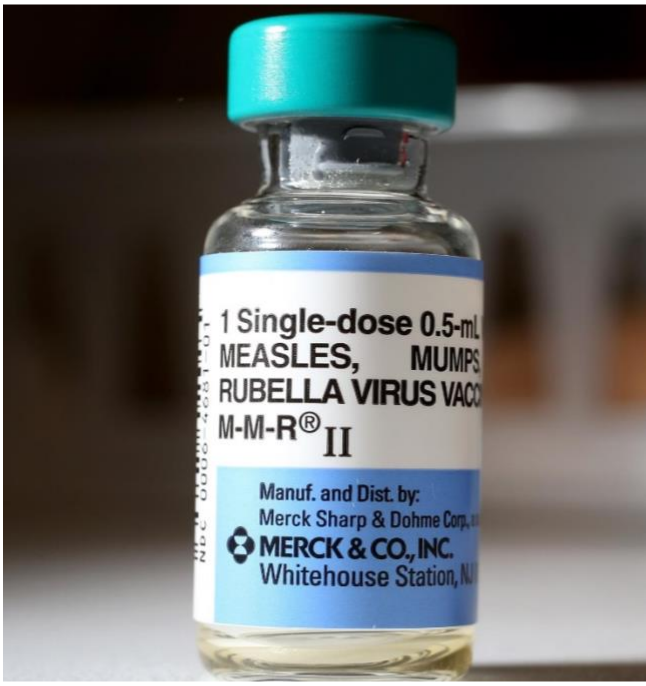
Measles. It was first reported in the United States in 1765. It killed 6000 people annually in the early 20th century. However, it was eliminated in the year 2000 due to widespread vaccination. Despite immunisation saving 23 million lives, the highly contagious viral illness re-emerged in 2018 with a staggering 10 million cases, therefore being reported as the world's fastest moving and largest epidemic.

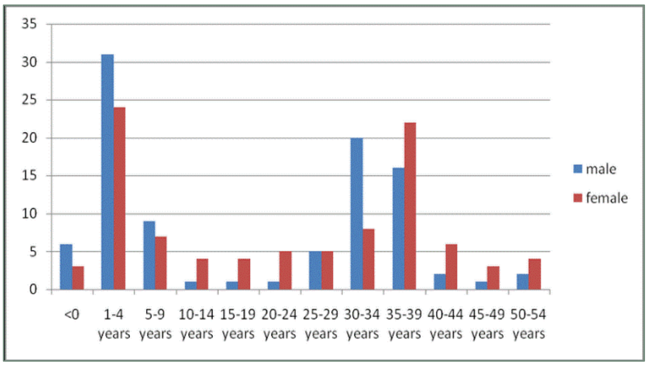
What is measles? It is caused by a virus that can be passed through direct contact or through the air by infected droplets when coughing, sneezing or even talking. The virus is inhaled and infects the respiratory tract, and then spreads throughout the body. While most people can survive measles with a 99.8% chance of survival, there may be complications such as ear infections and, in serious cases, pneumonia. Some symptoms of measles include fevers and rashes, and it is incredibly contagious: a measles patient can transmit the virus to up to 90% of the people they come into contact with.

As a vaccine preventable disease, the main reason measles has managed to return to this extent is due to the reduction in vaccinations. This may be due to an increase in vaccine refusals worldwide (predominantly in higher income countries), lack of access to the vaccine (such as in lower income countries), unvaccinated people spreading the virus, lack of knowledge, civil wars reducing vaccine rates or the ongoing COVID-19 pandemic, with 23 countries suspending measles vaccination campaigns.

Take the Democratic Republic of the Congo (DRC), which is going through the most serious measles outbreak in the world. In 2019, there were 250,000 cases. The country momentarily suspended measles vaccine distribution to respond to the COVID-19 pandemic; as a result, the overall immunisation rate fell below 95%, which is the minimum proportion of the population that should be vaccinated to allow for herd immunity. Many children in lower income countries do not receive a second measles vaccination dose, which reduces overall immunisation. The virus is more contagious than coronavirus – if one person contracts measles, they would spread it to around 12 to 18 other people, whereas the coronavirus averages around 2. The DRC's population struggles with malnutrition and vitamin A deficiency, which makes measles even more fatal. The DRC also struggles to pay for two doses of the vaccine per child with 3.5 million children being born annually.

To conclude, measles poses a great risk for every country because of how interconnected the world is. The best way to protect communities is a more practical approach to vaccine distribution. A vaccine delivery system is currently being developed in Atlanta, Georgia and Sydney, Australia, where a 'microarray patch' carries a small amount of freeze-dried vaccine in hundreds of microneedles. It can be applied with a small push and delivers the vaccine in five minutes. Because it is safe, thermostable, doesn't take up too much space and is easy to use, it is a viable solution to end the measles epidemic.





BLACK HOLES: THEORY TO REALITY By Aakriti Singh 12SCH

Black holes. The demons that live deep in the hearts of galaxies.

In this article, we will travel through time to learn how black holes morphed from theory to reality while answering FAQs such as W*hat is a black hole? What if our Sun was a black hole? How does a black hole form? What happens if you get too close to a black hole? Are black holes gateways to other universes? Where did the name black hole originate?*

In the 18th century (1783), *John Michel* was the first physicist to propose the idea of a black hole. Also known as a *Dark Star*, a black hole was described as an object with escape velocity that exceeds the speed of light. Next, came physicist *Rector Michell*. He reasoned that objects within gravity will require a certain speed to reach infinity, which we now call *escape velocity*. When an object is small and dense, the escape velocity might exceed the speed of light. In 1796, *Pierre–Simon Laplace*, a French mathematician, had a similar idea to the scientists before him except he addressed black holes as *invisible bodies*.

So, **what is a black hole?** A black hole is a region of gravity so strong that not even light can escape it. Essentially, if a black hole is dense enough, its escape velocity will and can exceed the speed of light, making it impossible for light emitted by the star to escape its gravity. This concept of black holes uses Newton's older theory of gravity instead of Einstein's more modern theory of relativity.

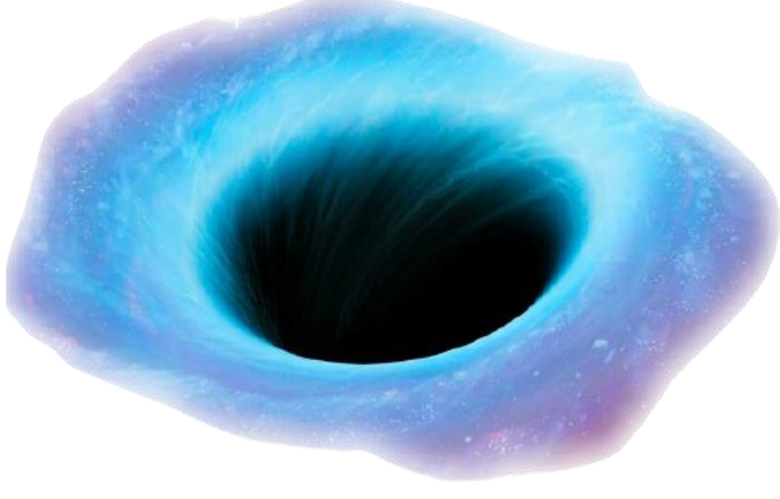
Stars follow either of two life cycles depending on their masses.

Low mass stars tend to spend up to 80 billion years in the main sequence stage, burning through their hydrogen core. At the end of time, they will depart the main sequence and puff up to become red giants. Slowly, the star consumes its helium core. The core collapses but never reaches the temperature hot enough to ignite its carbon fibres,. Therefore, the end of life is quiet compared to the end of the high mass star. All low mass stars just like our Sun eventually end up as a *white dwarf* close to the size of Earth and then a *black dwarf*.

*High mass stars*live fast, die young, and in a highly explosive manner. The explosions are so massive that they can be witnessed from other galaxies. The size of the explosion depends on the amount of hydrogen they contain: the more hydrogen, the hotter they are. They burn through hydrogen cores at a much faster rate, after which they burn carbon. The more massive the star was at birth, the closer it can get to an iron core. They then go through a giant phase (possibly even a supergiant phase) as the outer envelope swells before dying. Eventually, all the stars die off which results in the production of elements that can feed into the next generation of stars.

Creation of Black holes

Large stars compress inwards to become smaller and denser while keeping the amount of matter unchanged. As the star shrinks in size, the escape velocity increases until it's equal to the speed of light. Newton's theory of light predicts that light won't be able to escape from the star, and it will appear dark. Einstein's theory of gravity demonstrates a so-called dark star would exert a stronger force due to gravity than predicted by Newton. Additional inwards gravitational force makes it impossible for a star to have a stable size. For stars to exist, there is a delicate balance between their gas molecules, which exert an outwards pressure that is balanced by the attraction of gravity, allowing stars to stay the same size over time. When a star gets so small that its escape velocity is the speed of light, then the required outward gas pressure is infinite. There is no way to create infinite gas pressure therefore star is unstable and begins collapsing inwards. The black hole is what remains after a star is unable to resist gravity and collapses inwards.



What if our Sun was a black hole?

Earth could orbit a black hole with the same mass as the Sun and the same distance, but it would be very cold near the black hole, with no warmth and no light. The gravity of
the black hole would suck Earth in.

What would happen if we get too close to a black hole?

Black holes have a special boundary called the event horizon. The event horizon is a sphere with a radius called the *Schwarzschild radius*. Anything and everything can escape as long as it's outside the event horizon, but if the boundary is crossed, no escape is possible.

Are black holes gateways to other universes?
Anything that falls into a black hole is caught there, and it can't be shot out of a white hole somewhere else in the universe. Theories have allowed the existence of wormholes (direct connection between a black hole and a white hole), essentially, shortcuts in space-time. However, wormholes are yet to be detected.

What about a manmade wormhole? Artificial wormholes would require enormous amounts of energy to create. So, it is better to leave them in science fiction.

Where did the name black hole originate?
The cosmic beasts were named by physicist *John Archibald Wheeler* in the 1960s. At that point in the black hole discovery timeline, they were purely ideas, no one had any proof that black holes could exist.

Latest updates on black holes
The well-known picture that was released two years ago, which resembles a searing bizarre circle, is more convoluted than it looks. The bright ring emanates from hot gas, but the dark centre is not the black hole itself. Rather it is a "shadow" cast by the black hole as its gravity distorts or "lenses" the light from the gas in front of it. The edged mark 50% farther out where 50% space-time is distorted instead of the event horizon.

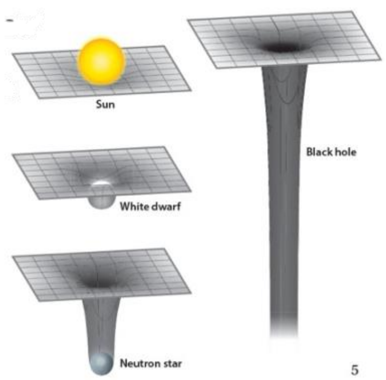
Since the first release of an image of the black hole, astrophysicists have done it once again. On March 24, 2021 a new view of the black hole has been released shedding light on how magnetic fields behave close to black holes.

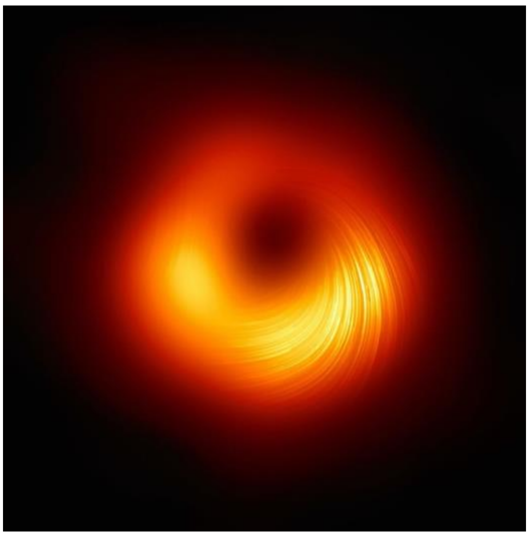
In this image, compared to the previous one, astronomers noticed the significant amount of polarised light around the black hole.

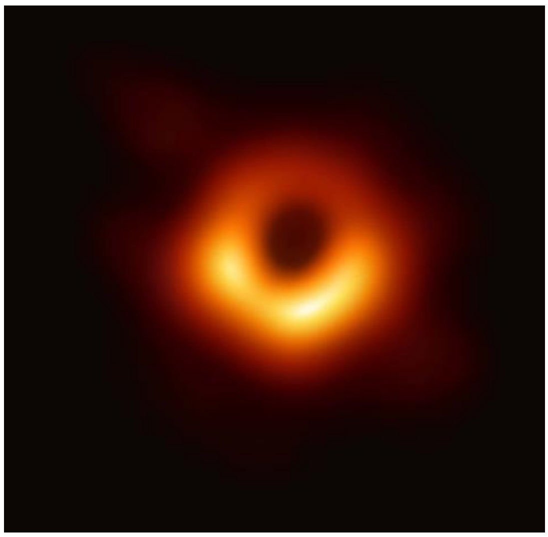
Polarised light waves are light waves in which the vibrations occur in a single plane, the same as the direction of propagation. The act of converting unpolarised light to polarised light is also known as polarisation. Polarisation occurs and can be seen in our daily lives e.g. light polarises when it passes through sunglasses. Light is also polarised when it's emitted in magnetised and hot areas of space. Polarisation is the foundation of magnetic fields, making it very evident that the black hole's rings are magnetised.

Monika Moscibrodzka, the coordinator of the EHT explained "emission in the ring is produced by magnetic fields located very close to the event horizon". Jason Dexter, assistant professor at the University of Colorado, Boulder and coordinator of the EHT Theory Working Group further talked about "how the new polarised images mark important steps for learning more about the gas near black holes and how they grow into launch jets".

Even along these lines, the picture holds signs of ablack hole at the centre. Freyal Özel explains, "so far researchers have seen no spectral distortion". This is now the traditional image of a black hole. Due to the effects of general relativity, they are counteracting the bulge that should be formed because of the event horizon.





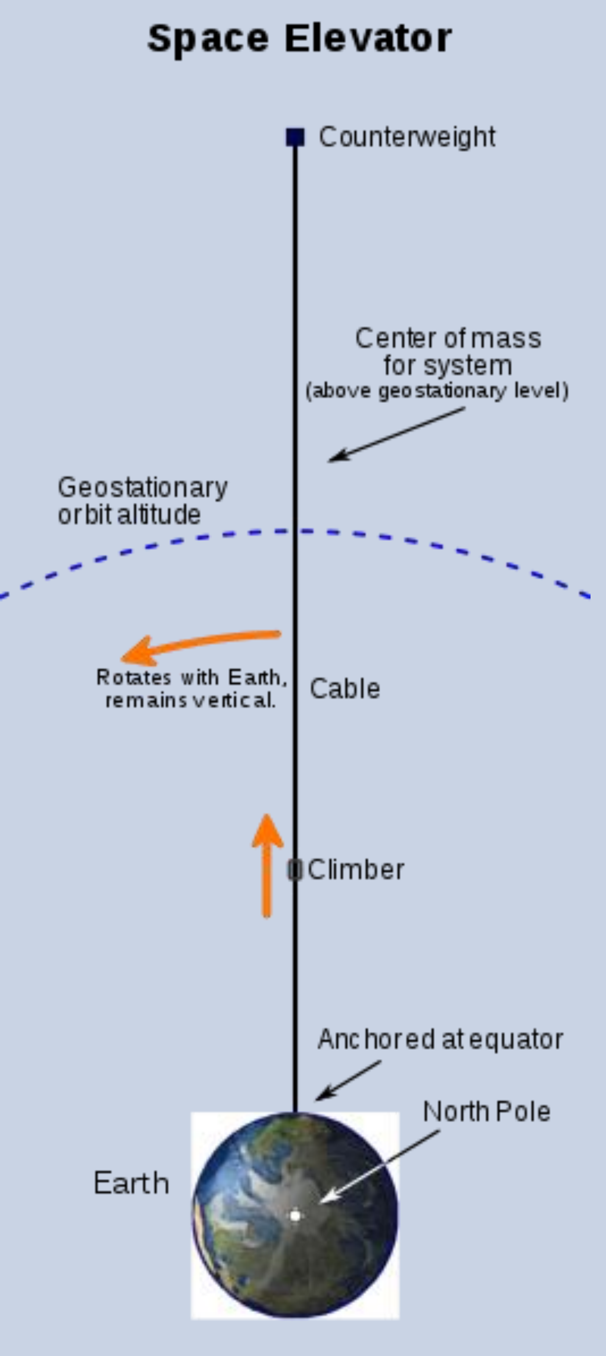


Space Elevator: Will it revolutionize space technology?

For the last several decades, travelling to space and payload delivery has been extremely expensive and prevents it from being done often. The space elevator is a proposed method of earth to space transportation that could greatly reduce the costs of conventional space travel that entails rockets or shuttles. Is the idea of an elevator extending beyond the earth's orbit itself absurd?

How would the elevator work?
The basic structure consists of a tether-like cable attached to a base on the earth's surface, and another end beyond the geostationary orbit at around 36000km attached to a counterweight. The forces of gravity at the earth's surface and upwards centrifugal force result in the cable being kept upright in one position. The cable would move as the earth is rotating. As the cable is taller and moves further away from the Earth, its gravitational pull decreases so the opposing centrifugal force is stronger than gravity, causing objects attached to the cable to move upwards.

Soumil Mukherjee 11SBR



SPACE ELEVATOR

Structure of the elevator
The space elevator would consist of a few main components. There would be an anchor on the earth's surface, the actual tether going to space, a counterweight beyond the geostationary orbit at the end of the tether and climbers for transportation along the tether. The anchor and the base area of the elevator could be placed in multiple areas. If it is constructed on land in a stationary position, it could also be built at higher altitudes which would reduce costs during construction as less cable is needed. However, if it is in an oceanic area allowing for mobility, it could allow operators to move the base depending on weather conditions as the cable would be fragile. In international waters, there would also be less conflict and multiple parties from different countries could use the elevator. The cable extends out from the base and would have to operate with heavy weights being transported along it. This means a potential material for the cable needs to have increased tensile strength and lower density for mobility. Potential materials include Kevlar or allotropes/variations of carbon such as a graphene roll or a diamond nanothread.

A counterweight could reduce the amount of cable material needed for the elevator as, without it, the cable would need to go further beyond the geostationary orbit. A possible counterweight could be some sort of station or port where cargo can stop. The space elevator will also have climbers carrying cargo up the tether. If climbers are at a feasible speed of about 400km/h, it would take 3-4 days to reach the end. At quicker speeds and if calculated properly, payloads can be launched or released and with a proper trajectory, they could reach certain planetary bodies. This could greatly help with the proposed plans of the colonisation of the moon or Mars. When it comes to a fuel source for the climber, the most sustainable option is using solar power after a certain height. However, this would be too slow, so the more likely option is the use of wireless power transfer.

Why would a space elevator be useful?
If a space elevator is properly constructed, it would allow for greater amounts of payload to be delivered to space as it costs significantly less to use this method than space shuttles or rockets. A shuttle uses around $10000 per pound to put a payload into low earth orbit. This price only increases as the distance needed to travel increases. The space elevator also makes space construction easier and cheaper as it is still possible to launch cargo off the cable using high speeds. Construction on other planetary bodies could be possible as the payload is cheap to deliver, and even more efficient solar power stations could be constructed that can collect more energy from the sun and used on earth.

What problems would there be during construction and operation?
As lucrative as the project may seem, it poses incredible challenges. The biggest problem is the ability of the cable to hold its weight below it with tension. This means an extremely strong but light material is needed for construction. Possible candidates such as carbon nanotubes or graphene are very rare and expensive to mass-produce. This means that we may not have the technological advancements for the production of the cable for decades as it is difficult to produce these materials in high quantities. There is also the engineering problem of constructing such a tall structure that surpasses the geostationary orbit which is a technical challenge that is hard to overcome. During operation there is also the issue of radiation from the Van Allen belt meaning if passengers are transported, extra shielding and mass would need to be added onto the climber. The cable is also at risk from debris and passing aircraft, however as mentioned before, a mobile base can solve this problem.

What has the UK done to reduce the impact and lessen the risk of COVID-19 transmission in dental practices?

Since its arrival in December 2019, COVID-19 has created many challenges over the past year, not only within the UK but also within the dental profession as a whole. The pandemic has been full of uncertainty, leading to fear, anxiety and anger as we've struggled to deal with the unknown. It has been extremely difficult for dentists to deliver patient care due to the strict new Infection Prevent and Control procedures implemented to control theCOVID-19 pandemic. Every office must comply with digital screening, aerosol-generating procedures, and rigorous documentation of every procedure done (Infection Prevention and Control Before and After COVID-19 in Dentistry, 2020). The dental profession needed this specific guidance to support a safe return to practice so they could continue to provide high quality care for their patients (Mills, Horton and Dhanoya, 2020).

COVID-19 has also had a significant impact on the financial side of dentistry. Many dental practices have been forced to close for months at a time due to restrictions put in place by the government. As the majority of dentists in primary care are self-employed, the closing of practices makes them much more financially vulnerable than NHS-employed medical colleagues. Although the government promised supportive schemes and the continuation of NHS contract payments, mixed and private practices will receive less support. This causes uncertainty regarding individual practice development plans and the future of employment in the sector (Noh, Loke and Kim, 2020).

The UK has tried to mitigate the financial hardships caused by the pandemic by attempting to bring dental clinics back into business as safely as possible. They have attempted to accomplish this through outlining procedures and risk assessments. For instance, the Faculty of General Dental Practice in the UK has tried to combat the COVID-19 pandemic through the release of a risk matrix for application within a dental practice. A risk matrix provides a structured approach to thinking about risk. It helps identify risks, consider their impacts, their likelihood and what can be done to reduce them (Implications of COVID-19 for the safe management of general dental practice A practical guide, 2020). This risk matrix has been devised to follow the journey of a patient: pre-appointment (before patient arrival); patient attendance (pre-treatment); during treatment; after treatment; general management. By following this risk matrix along the journey of a patient, the risk of COVID-19 transmission within the dental practice can be reduced.

The pre-appointment stage of the risk matrix aims to ensure patients are well informed and suitably prepared ahead of their visit to the dental practice,

Amara Singh 12SZO

so that all face-to-face administrative contact and total time spent in the surgery is reduced (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). This can be achieved by ensuring all administrative tasks are undertaken ahead of visit (including medical history, triage questionnaires, COVID screening, patient forms etc), and good patient communication before their visit providing them with up-to-date information through a digital means of communication.

The risk is reduced pre-treatment after patient arrival through 'patient attendance'. Patient attendance aims to provide protection of patients and reception staff, for the period between patients entering the surgery and accessing the clinical area (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). This protection can be achieved by communicating arrangements and protocols for social distancing, adoption of high standards of infection prevention and control (IPC) in line with National Guidance, and temporal and spatial zoning. Reception staff can be protected by social distancing, wearing of appropriate PPE, and/or barrier screens and wearing of masks by patients when entering the premises.

During treatment, the main goal is to provide protection of patients and staff due to the closer proximity in the clinical surgery area as this could result in potentially greater risk of virus transmission (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). During the patient treatment, consideration falls into 4 main areas: personal protective equipment (PPE); procedural risk mitigation; decontamination; air ventilation in surgery. All dental visits will involve risk of exposure to aerosols and droplets, whether they are naturally occurring or produced by mechanical dental interventions (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). During treatment, the risk of virus transmission can be reduced through the use of aerosol vacuums, staff wearing PPE for high-risk exposure, use of rubber dams, avoidance of intra-oral tools when possible and instead using extra-oral tools (for example when carrying out dental radiographs). There are of course other, more sustainable, ways in which we can minimize aerosols. The use of chlorhexidine 0.2% rinse prior to starting Aerosol Generating Procedures (AGPs) is shown to significantly reduce the aerosol contamination, especially when you combine this with the use of high-volume aspiration. (Wood, 2020).

After treatment, the main aim of the dental practice is to ensure the safe exit of already treated patients and the protection of staff and all subsequent patients (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). This can be carried out by following standard HTM 01-05 decontamination procedures, air ventilation within the surgery, floor cleaning at the end of each session, no paper records retained in surgery during higher risk Aerosol Generated Exposure (AGE), and avoidance of wearing scrubs outside the practice to reduce contamination and further possible spread of transmission.

The general management in the dental practice plays a very significant role in the goal to reduce transmission of COVID-19 in the clinic. General management should have systems, support and protocols in place to ensure the safety of all staff, patients and visitors; these should be reviewed and adjusted in line with risk assessment and alert levels (Implications of COVID-19 for the safe management of General Dental Practice - Synopsis, 2020). Examples of what these systems and protocols could include are: ensuring all premises area are kept clean, tidy and free of waste at all times; review of stock control to ensure appropriate PPE is available; regular assessment, validation, documentation, and service of mechanical ventilation systems. Although it is difficult to predict, following the COVID-19 pandemic the future of dentistry could be impacted in various ways. For example, patients could initially focus only on emergency procedures or the treatment that really matters to them (Bhatnagar, 2020). Or, alternatively, new approaches such as Teledentistry could also help dentists assist patients without adding the risk of cross infection (Katge, 2020).

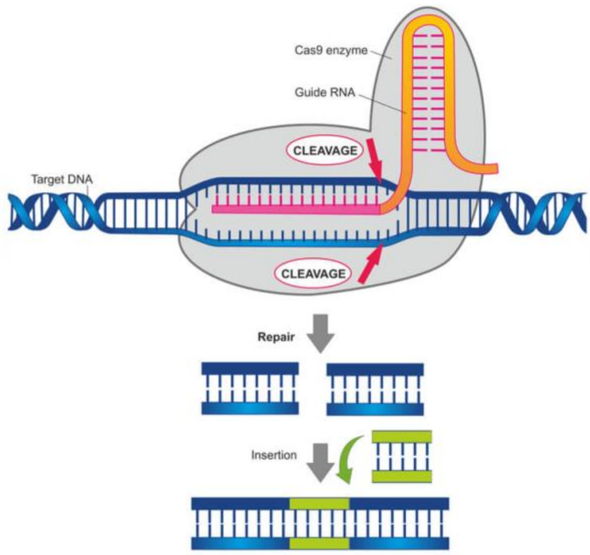
Although it is difficult to predict, following the COVID-19 pandemic the future of dentistry could be impacted in various ways. For example, patients could initially focus only on emergency procedures or the treatment that really matters to them (Bhatnagar, 2020). Or, alternatively, new approaches such as Teledentistry could also help dentists assist patients without adding the risk of cross infection (Katge, 2020).

COVID-19 is unlikely to be the last global virus outbreak in our lifetime. Our healthcare and dental community must learn important lessons from today to become more resilient to future infectious crisis (Noh, Loke and Kim, 2020). Overall, the COVID-19 pandemic has had a very significant impact on dental healthcare in the UK and worldwide too, both physically in and out surgery, as well as financially too. With the cessation of routine dental care, introduction of national personal protective equipment (PPE) guidelines and prioritised distribution of PPE to Urgent Dental Centres (UDCs), the fear of COVID-19 transmission through dental work has decreased (Noh, Loke and Kim, 2020). Systems and protocols, like the risk matrix put in place by the Faculty of General Dental Practice in the UK, can and are proving to help to lower the risk of contamination and transmission of COVID-19 within the dental clinic.

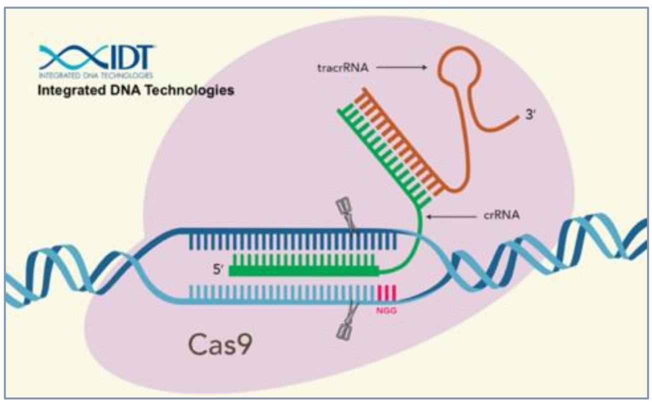
What is CRISPR and how does it work?

CRISPR was first discovered in the genome of bacteria as a tool for immune defence. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats. If we break this down, “repeats” are basically “short” segments of DNA, which in this case are “palindromes”, meaning a sequence of letters or better known as the bases (A, C, T, G) read the same backwards or forwards. Therefore, the genome has regular repeats of DNA which are “interspaced”, so they have an equal gap between each one of the repeats. In these regions, non-coding DNA known as Spacer DNA is present. In the early 2000s, scientists discovered that this Spacer DNA from a bacteria’s genome matched up perfectly with viral and bacteriophage DNA. They also identified a number of genes associated with CRISPR and CAS genes which make CAS proteins, such as helicases (proteins that unwind DNA) and nucleases (proteins that cut DNA).

How CRISPR works in a bacteria:
When a bacteriophage injects its DNA into the bacteria, it would normally take over the cell and destroy the bacterium in the process. However, with the help of its CRISPR system, a translation and transcription of the CAS complex proteins as well as the DNA of CRISPR (called crRNA) will occur. The combination of this complex with RNA efficiently breaks down the viral DNA of the bacteriophage, essentially preventing the infection altogether. However, if the bacteria genome does not have that specific Spacer DNA to break down the pathogen’s genetic material, it will use a CAS protein to identify the chain of base pairs and then create a CRISPR Spacer DNA which can break down the Bacteriophage’s viral DNA for the future. This is similar to the way our antibodies work: if a novel disease invades the human body, some antibodies will be produced to act as memory defense systems so if the same disease tries to infect us again, the immune system already has their defense in place.



How CRISPR will be utilized for curing human disease:
Jennifer Doudna and Emmanuelle Charpentier created a protein called Cas9. The nuclease of the Cas9 protein allows DNA to be cut, two long strips of CRISPR RNA (crRNA) match the genetic material of the viral DNA, and tracrRNA hold the crRNA in place. Jennifer Doudna and Emmanuelle Charpentier combined them to form the trctRNA-crRNA chimera (a mythical creature that was a combination of multiple animals), better known as the guide RNA. If there is a mutated gene, a guide RNA can be created to have a corresponding piece of RNA so when the faulty DNA is passed through the cas9 protein, it will cut the mutated section out, deactivating the genes. The next step is to insert a correctly performing and corresponding section of the DNA which is called the host DNA. The DNA will gradually repair itself with the replacement of the host DNA which could potentially cure the disease altogether.



An Example:
In Cystic Fibrosis, we can use CRISPR and CAS9 to remove the faulty allele which causes the disease and then insert a segment of non-faulty DNA which does not give rise to CF.

Maha Nawaz 9MHA

THE CURIOUS CASE OF THE PREHISTORIC GIANT SLOTH

Aarush Vir Banerjee Kharbanda 8SOR

Cute, *cuddly*, *furry*, *adorable,* and *slow*. These are all words that would commonly be associated with *choloepus hoffmani*, or the 'sloth' as we know of it today. However, this has not always been the same… Almost 35 million years ago, before the age of dinosaurs and before the age of us, *homo sapiens*, there lived, on this Earth, a gargantuan creature, named *Megalonychidae* (translating to 'large claws'). As its Greek name suggested, this mammal, measuring up to 3 meters long, had large claws, resembling those of a lion, but much longer arms than any other animal at that time. This was the giant prehistoric ground sloth.

These incredible creatures inhabited the tropical forests of North and South America and roamed the Earth until just 10,000 years ago which is when they started reducing in numbers. Whilst the cause of their "extinction" is still debated among scientists, we know that some of the smaller sloths did survive. In attempt to save themselves from the predators, these smaller sloths fled to the trees.

As the Prehistoric ground sloth became extinct, many other prehistoric fruits became extinct. Prehistoric giant sloths are one of the main reasons why avocados still exist today. Very few animals in the tropical rainforests of South America and the plains of Africa could digest the fruit, due to its large tough seed in the centre. Despite this, sloths can gulp the huge fruit in one go and disperse the seeds of the fruit effectively in their droppings'. Nowadays, there are only six species of sloths left, with the 'pygmy three-toed sloth' being classified as the rarest to spot.

The leafy diet of the half-blind herbivore explains its lethargic and sluggish behaviour. Animals receive their energy from the food they eat which is then used to maintain body temperature, move, and keep their organs working (amongst many other things). A sloth's restricted herbivorous diet of leaves is not an efficient source of energy, compared to other foods such as fruits, nuts, and meats. This lack of energy means sloths must be very careful to waste energy. Sloths rarely leave their tree expect for once a week when they take a risk and begin their treacherous journey to the forest floor – to defecate.

Surprisingly, sloths defecate in the exact same location, every time. It is thought, by scientists, that this is a way of marking territory. Other scientists suggest that this journey is their only way of finding a mate, keeping in mind their solitary lifestyle. Since sloths only defecate once a week, they are capable of losing almost a third of their body weight in one go.

An extremely interesting adaption of sloths is their fur. The damp conditions of the rainforest enable many algae to grow, which in turn produces a green tone on the sloth's fur. This aids the sloth to camouflage itself from predators. Additionally, a sloth’s fur serves as a host to an entire ecosystem – including parasites, bacteria, and a type of beetle that lives nowhere else. Furthermore, three-toed sloths have the ability to twist their neck around 270°, allowing them to see almost everywhere around them, without having to waste energy to turn their whole body. Whilst the speed of a sloth may seem like a disadvantage, sloths are often so slow that their predators cannot even sense their presence as some animals rely on movement to hunt.

Unfortunately, sloths are colour-blind, as they lack cone cells (responsible for colour vision), which further explains their slow behaviour – it is difficult to move around with confidence with poor vision. However, they make up for their poor eyesight with an astonishing sense of smell and superb spatial memory. However, predators are not the only troubles for sloths. Some of the six species of sloths are endangered by habit loss/deforestation which means the sloths lose their homes and their food, as trees are cut down for wood, paper, etc. In response to this, the WWF (World Wildlife Foundation) created a fund of $215 million for the Brazilian government, to aid them in managing and maintaining the habitats of these endangered sloths.

“This landing is one of those pivotal moments for NASA, the United States, and space exploration globally – when we know we are on the cusp of discovery and sharpening our pencils, so to speak, to rewrite the textbooks.”

- Acting NASA Administrator,
Steve Jurczyk.

THE PERSEVERANCE ROVER

Aleeza Ahmed 9SAB

According to the Collins Dictionary, perseverance is the quality of continuing with something even though it is difficult. And it's fair to say that we've all been persevering this year, managing to balance everything in our busy lives, despite a pandemic looming at the back of our minds. It is during these times that having a bit of inspiration is motivating. This incredible mission embodies exactly that.

After a 292.5-million-mile journey from Cape Canaveral to Jezero Crater, the rover became 1 of only 5 to land successfully on Mars' surface. This rover was named the Perseverance Rover, or 'Percy' for short.

The mission is another testament to the goals we can achieve and the places we can go if we persevere. The Perseverance team really did live up to its namesake during the final stages of the rover's journey to Mars as they executed a flawless landing despite the problems posed by the pandemic.

According to Ken Farley, a geochemist and the project scientist for Mars 2020, "Perseverance's sophisticated science instruments will not only help in the hunt for fossilised microbial life, but also expand our knowledge of Martian geology and its past, present, and future."

In other words, the Perseverance rover will be used to search for biosignatures to detect life and analyse Mars' climate and geology. This mission is an instrumental step towards the greater goal of sending humans to Mars.

What 'sophisticated scientific instruments' was Ken Farley referring to? The rover's design was based on that of the Curiosity Rover. However, the Perseverance Rover utilised new instruments and tweaked parts. For instance, after observing the deterioration of Curiosity's wheels over time, the team decided to create more durable, aluminium wheels for Percy.

Furthermore, the rover has a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), which provides power and two lithium-ion batteries as backup. This means that the rover will be able to operate better at night and during dust storms because it doesn't solely rely on solar power. Its core drill and arm will allow it to collect the samples and the rover has 19 cameras and two microphones to record the Martian environment.

How much did this mission cost? $2.8 billion over 10 years. Once adjusted for inflation, this makes the mission the sixth-most expensive NASA robotic planetary mission. However, they reused some spare parts from Curiosity which saved them "probably tens of millions, if not 100 million dollars," according to Mars 2020 Deputy Chief Engineer, Keith Comeaux.

Do you ever want to go to Mars? 10,932,295 people went to Mars with the Perseverance rover. Well, kind of. To raise awareness for their missions, NASA's 'Send Your Name to Mars' campaign invited people around the world to submit their names to be sent to Mars. This proved to be extremely popular with nearly 11 million names (including mine) being stencilled by an electron beam onto three microchips. These microchips were then mounted to a small plate attached to the centre of the aft crossbeam on Perseverance.

The rover's journey has only just begun but it has already revolutionised our understanding. It will continue to send images back to earth and collect samples that could greatly enhance our understanding of life on Mars. This mission serves as a testament to our progression over time but has showed us how much we are yet to learn.

SYNCHROTRON RADIATION By Aanya Tashfeen 13ACR

Synchrotron radiation is widely used for experiments across science disciplines. It is extremely powerful electromagnetic (EM) radiation emitted by electrons moving at speeds close to the speed of light. These speeds are defined as relativistic speeds. Synchrotron radiation is part of the continuous spectrum and can include EM radiation ranging from microwaves to the hard X-ray region.

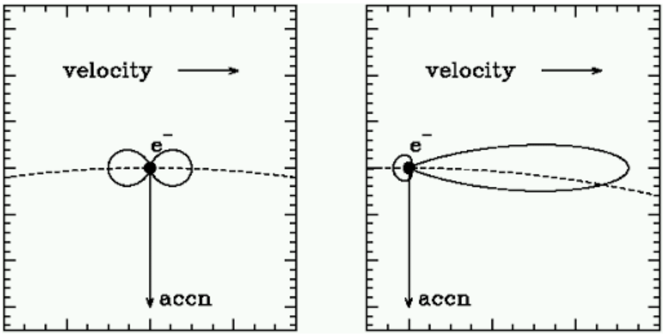


Figure 1: Electron moving at non-relativistic (left) and relativistic (right) speeds

In 1895, Wilhelm Röntgen, a German physicist, discovered X-rays through his experiments with cathode ray tubes and glass. Since their discovery, X-rays have been used in applications ranging from medical use to revolutionary crystallography and diffraction experiments to resolve the structure of DNA and proteins. X-rays produced at synchrotron radiation facilities has since been involved as the main tool in many Nobel prizes such as investigating the mechanism behind respiration and DNA transcription.

How is synchrotron radiation produced?

The key idea when producing synchrotron radiation is that charged particles must be accelerated to relativistic speeds. In the case of synchrotron facilities, electrons are used due to their charged nature and very low mass, which means, due to Newton's second law, less force needs to be used to accelerate the particle by large amounts. As laid out by Einstein's theory of special relativity, when objects move relative to observers at relativistic speeds, fundamental properties like time, length and mass can be observed differently. In synchrotron radiation, the electromagnetic radiation emitted is tangential to the curved path of the electron, since the electron is accelerated through a curved path at relativistic speeds. This is shown in Figure 1. This tangential emission is due to relativistic effects, as at non-relativistic speeds electromagnetic radiation is emitted at a dipole

The basic design of a synchrotron facility

A moving charged particle in a magnetic field experiences a force. Therefore, synchrotron facilities use magnetic and electric fields to accelerate electrons to relativistic speeds, in order for them to emit powerful synchrotron radiation. Magnetic fields are used to curve the path of the electrons and electric fields are used to accelerate the electrons. As the path of the electrons curve, they emit radiation at tangents to the path they are moving in, and this radiation can be emitted into beamlines where it can be used for experiments.

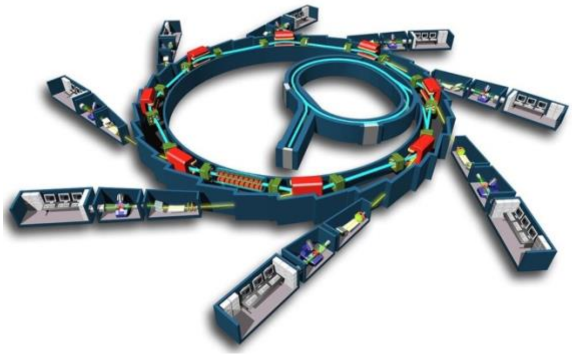


Figure 2: An image showing a synchrotron facility with the booster ring in the middle and the storage ring on the outside. The straight section connecting to the booster ring is the LINAC.

Synchrotron facilities, as shown in Figure 2, consist of many different components. The basic design includes an electron gun, linear accelerator (LINAC), booster ring, storage ring, the beamline and the experimental hutch.

The electron gun is at the start of the LINAC and involves thermionic emission. This is when a metal is heated to a temperature high enough for electrons to be released from the surface (e.g. 1000°C with 200,000 volts running through a tungsten-oxide disc). The electron gun forms part of the cathode which then repels the electrons. These electrons are attracted to the oppositely charged cathode at the end of the LINAC tubes. The LINAC contains Radio Frequency (RF) cavities with fields at 2,856 MHz that can energise the electron beam and replenish any energy losses. The RF cavities accelerate electrons to energies of 250 MeV which gives the electrons a speed of about 99.9998% of the speed of light. The LINAC then produces pulses and bunches of electrons to be injected into the booster synchrotron via the Booster Transfer Line. The whole LINAC and beamlines are in a vacuum with fewer than 10 particles per cm^3 so that the path of the accelerating electrons is not blocked, and they don't slow down.

The booster ring is shaped "like an athletics track", as shown in Figure 2, with magnets placed across the bends and RF cavities along the straight-lined portions. In the booster ring, the electrons gain more energy from the RF cavities with every lap and are sent into the storage ring once they reach 6 GeV.

The electrons are accelerated further to about 99.999998% of the speed of light, allowing even more powerful radiation to be emitted by the electrons. Electrons have a tendency to follow a straight path and so when the magnets in the booster ring force them to change direction, they lose some of their energy. This energy is regained in the straight sections of the booster ring as the beam passes through the RF cavities to stop the electron beam slowing down too much. The booster ring also injects electron bunches into the storage ring to 'top up' the stored beam and maintain intensity which can be lost due to an imperfect vacuum. This 'topping up' only happens for some minutes throughout the day and, when this does happen, the booster ring can send bunches of 6 GeV electrons into a storage ring every 50 ms.

The storage ring is encased in a concrete and aluminium-alloy chamber to prevent any harm from the powerful radiation to humans. It also contains RF cavities. The storage ring at the Diamond Light Source in the UK consists of 25 straight sections which are angled to produce a circular ring. 3GeV of energy is transferred as electrons complete the 560 m path in two millionths of a second. Across the circular path travelled by the electrons, there are numerous electromagnets called bending magnets which cause the electrons to change direction between the straight sections. There are also undulators and wigglers (types of magnets) along the straight sections which cause the electron beams to bend so the electrons emit synchrotron light. This synchrotron light travels into beamlines where it can be used for experiments.

There are many different uses of the variety of wavelengths of synchrotron radiation produced. If the wavelength of the synchrotron radiation emitted falls into the X-ray region, it can be used for X-ray Absorption Near-Edge Structure (XANES) spectroscopy. XANES is used to identify and quantify the chemical structures present within the structure. X-ray diffraction can also be used in experiments at synchrotron facilities that produce X-rays. This can be useful for resolving the structure of proteins.

Synchrotron radiation is of clear interest to scientists from many disciplines, ranging from materials science and chemistry to structural biology. The immense variety of useful characteristics such as power and brilliance make synchrotron radiation an unparalleled and incredibly useful tool for scientists.

The Depths of our Oceans

Anay Bindroo
10CSI

Scientists today have better maps of the surface of Mars than of our ocean. This begs the question: what creatures are living down there? What phenomena can scientists not explain on the sea surface? Although our image of the ocean are deep blue bodies of water with calm waves, with the occasional passing storm, these hotspots of life have created some of Earth's most mysterious creatures, and phenomena. The ocean is teeming with life. Scientists estimate that there are a million species of animals in the sea, 95% of which are invertebrates. The ocean is the perfect recipe for life: a whole range of temperatures, plant life and prey everywhere, an abundance of oxygen and various depths and terrains. This results in some of biology's strangest animals. Modern marine scientists have divided the ocean into 5 zones:

Epipelagic (sunlight zone) – 0-200m

Mesopelagic (twilight zone) – 200-1000m

Bathypelagic (midnight zone) – 1000-4000m

Abyssopelagic (The Abyss) – 4000-6000m

Hadalpelagic – 6000m+

The Epipelagic Zone

Also known as the photic zone, the epipelagic zone is the layer of the ocean at which sunlight can pass through. This is where common forms of algae are found (such as Chlorophyta algae), as they can photosynthesize on the surface of the ocean. This layer is where divers dive down to, and where dolphins, sharks, and most edible fish are found. The pressure here is low, and experienced divers can dive to the bottom of the epipelagic zone without a suit. Although 90% of theocean's life lives in this sun-filled zone, only 2% of the ocean's species live here, due to the lack of habitat variation. One of the most impressive life forms found here is the Great Barrier Reef, which is the largest gathering of coral in the world. The coral relies on algae called zooxanthellae, which provides the coral with energy, as the coral is sessile.

The Mesopelagic zone

At these depths, only 1% of light from the Sun reaches the waters. Common animals include jellyfish (Scyphozoa), blobfish (Psychrolutes marcidus) and the famous giant squid (Architeuthidae dux). The giant squid is a 12-13m long squid and is adapted to the low-light by feeding on deep-sea fish with its very powerful tentacles and beak (radula). Most of the animals found here have adapted to these conditions, such as the lanternfish (Symbolophorus banardi), which uses photophores to produce light. The mesopelagic zone also has lots of fish, which however, is unable to be fished due to its depth under most fishing vessels' reach. Fish at these levels have many adaptations to the harsh conditions. These include glow-in-the-dark pores, strong organs to cope with the extreme pressure, colours of red and black to blend in the environment and being low-energy efficient. Most animals feed on organic matter which sink from the epipelagic zone. Some fish also ascend to the epipelagic zone for food, also known as 'vertical migration'.

The Bathypelagic zone

Also known as the midnight zone, this is the point in the ocean where there is no sunlight from the sun. There aren't many animals here, as temperatures are at a frigid 4 degrees, and there are no plants able to photosynthesize. The bathyal zone is the first place where you can see an interesting adaptation of animals: non-eyed fish. As there is no light, fishes often don't have eyes as they are rendered useless. Fish are weak and slimy and rely on very slow metabolism as there is almost no energy or food at these depths. At these depths, a common adaptation are swim bladders. These are gas filled organs which help fish conserve energy by maintaining buoyancy. The anglerfish (from the Lophiiformes family) has adapted to this region of the ocean by using luminescent bacteria in an antenna-like extension called the esca, to lure in fishes which it devours with its large teeth. It is likely that the anglerfish evolved over time to allow bioluminescent bacteria to enter the esca, and now it can form its own.

Abyssopelagic zone

The Abyssopelagic zone has temperatures of almost freezing and is the point where most of the ocean floor is located. Animals here are detrivores, which are animals that feed off detritus (dead matter) which has sunk from the upper depths. The pressure is almost 600 times as much as it is on the surface. Information about these depths is very limited; most submarines' walls would crush under these extreme pressures. Bacteria use chemical energy by converting carbon-based detritus into sulfates for energy. Fishes' eyes are hypersensitive to blue light, as it has a short wavelength which can travel to these depths. Scientists believe 90% of animals use bioluminescence due to the lack of sunlight or have well adapted eyes to extreme darkness. Unlike most eels, the cusk-eel (Abyssopotrula galathae), which scientists believe to be the lowest-living major animal found at 8300m below sea level, has bones which help it maintain its structural integrity under the unforgiving water pressure. Cusk-eels also do not have fins, but have a fork-shaped organ which helps them travel.

Hadalpelagic zone

Deriving from ‘Hades’ (Greek god of death), the Hadalpelagic zone is a dark, devoid of oxygen, lifeless part of the ocean. Consisting of the deepest trenches, such as the Mariana Trench, the pressure at these levels can reach up to 110 megapascals of force. Due to the very small number of missions that have reached these depths, knowledge about its ecology is very limited. However, scientists do know that the few animals that do live here, which are species of eels, worms and snails, feed off hydrogen sulfide producers, called ‘cold seeps’ on the ocean floor. Notable missions to these depths include the famous Piccard and Walsh exploration to Challenger Deep; however, this was not intended to research the hadal zone. Research missions to these depths have often been lost at sea, and those that have successfully reached these depths often don’t go lower than 8000m.

To conclude, the ocean is a vast, unexplored haven for life who have adapted in the most interesting ways. These pockets of life will probably never be affected by those issues which affect us at the surface, such as global warming and climate change. The intense pressure and freezing waters leave life at the lowest depths undisturbed, navigating the seas of total darkness.

How did scientists figure out the structure of our Earth?

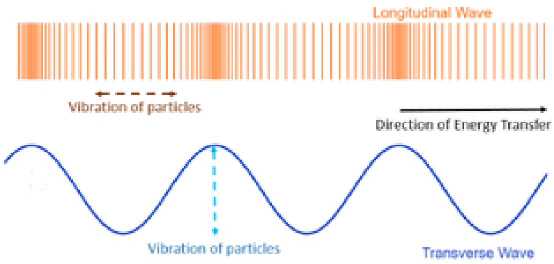
Is it possible that deadly natural disasters could actually revolutionise our understanding of our planet?

Here's a clue:
The Earth has thousands of holes that are leaking molten rock. Hence, it's clear that some of the Earth's interior is molten. We're told in science class that the ground we're standing on, the Earth's crust, is just a few miles thick, with a much thicker mantle underneath that gives way to a molten outer core and a solid iron inner core. But how do we know that there is a mantle? How do we figure out the structure of Earth's interior without probing it directly?

The answers to these questions boil down to infrasound. Infrasound are sounds with a frequency less than 20Hz, which are too low for humans to hear. They can travel further than higher frequency waves.

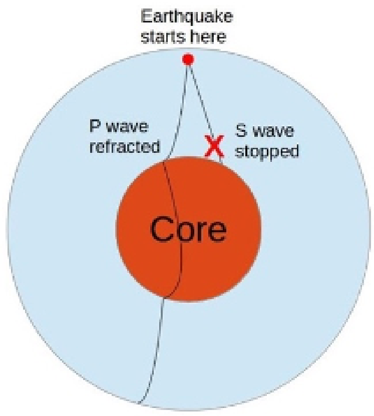
Natural events, like earthquakes and eruptions, create infrasound. The vibrations produced by earthquakes are called seismic waves. These waves can be used to investigate the internal structure of our planet, just like ultrasound is used for foetal scanning.

Seismic waves from large earthquakes are detected around the world. Their paths are curved as the waves refract due to the gradually changing density of the layers of Earth. Energy released can travel through Earth as longitudinal P waves and transverse S waves. P stands for "primary" and S stands for "secondary," simply because the primary waves are typically detected before the secondary (scientists are very practical!). Seismometers are placed around Earth to detect speed and time of waves.

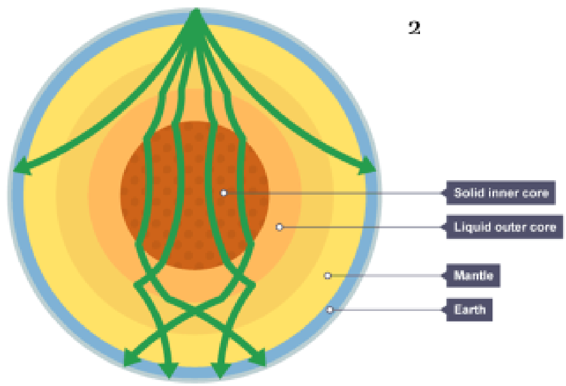


S-waves only travel through solids. S-waves are not detected on the opposite side of the Earth, in the S wave shadow zone – this suggests that the mantle has solid properties, but the outer core must be liquid. They cannot be transmitted through the inner core, indicating that it is liquid. Based on the time difference between the direct waves and the reflected waves, we can make detailed maps of the paths that these waves take through the Earth.

P-waves can travel through solids and liquids. P-waves are detected on the opposite side of the Earth. Refractions between layers of different densities cause two shadow zones (where no P-waves are detected) – the size and positions of these shadow zones indicate there is a solid inner core.



1



2

As seen in Diagram 2, P waves are refracted as they travel through the Earth.

Viha Kedia 11AYO

Genetic Algorithms: Applications of Simulating Evolution Through Code

"It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change."- Leon C. Megginson (1963)

Normally, we think of evolution as a strictly biological process – organisms within a species vary by chance through mutation, fitter ones are more likely to survive, they breed, and their traits are passed on to their children. This is a concept that has been taught for decades in biology classes worldwide. But is there a way that we could simulate this? One where we could represent this natural process algorithmically on a piece of machinery? The answer to that, amazingly, is **yes**; computer scientists have been utilising techniques that mimic the seemingly perfect nature of evolution for decades now. The list of ways in which they are used is surprisingly extensive, spanning from depicting economic models to generating art.

In the edited work of Alan Turing's *The Essential Turing*, B. Jack Copeland writes that:

> 'An important concept both in Artificial Life and in Artificial Intelligence is that of a genetic algorithm (GA). GAs methods analogous to the processes of natural evolution to produce successive generations of software entities that are increasingly fit for their intended purpose.' (p.513)

This may just seem like a load of words, so what does it all mean? Essentially, a genetic algorithm (GA) is a search technique that programmers can use that uses elements present in nature. That is to say, it implements the concepts present in Darwinian natural selection and evolution into a computer algorithm. For a given problem, a GA implementation begins with a set of 'genomes', which are encoded solutions to that problem that vary in their 'genotype' (the actual contents of the solution). The GA then continually 'evolves' this set of genomes over some number of generations to generate better solutions.

In his 2012 publication, *The Nature of Code*, author and popular CS professor Daniel Shiffman (who goes by 'The Coding Train' on Youtube) notes that there are 3 fundamental concepts that a simple GA must adhere to. From my current understanding, they are:

Heredity: Traits of a parent genome are passed down to its child genome(s) via some sort of crossover function that combines the contents of the parent's genotype(s) to generate the child or children.

Natural Selection: Genomes that are considered to be 'fitter' individuals are more likely to be picked to breed as parents, and hence pass on their traits to the next generation of genomes. The relative fitness of a genome is calculated using a fitness function specific to that application of the GA.

Mutation: Every genome has a probability of mutating – altering its genotype by somehow changing the encoded solution. This is to introduce variation such that actual progress can be made over successive generations.

These 3 concepts are present across all organisms on this planet, normally abiding by a similar set of rules. Because of these consistent rules, it can also work when simulated through a programmed algorithm.

I will not go too deep into the technical aspects of how a given GA would work, but I'll give a brief overview via pseudocode. The steps for a simple GA are:

1. Generate a random initial population of potential solutions to whatever problem you are trying to solve. This is the first generation.
2. Rank the current generation solutions in order of 'fitness', which can be evaluated using whatever metrics are appropriate to the problem
3. Pick 'parent' solutions. Ensure that solutions with higher fitness scores are more likely to be selected.
4. By crossing over these parent solutions via some crossover function, generate 'child' solutions.
5. Add the children to the next generation of the population.
6. Repeat steps 3 and 4 until the next generation is of the desired size.
7. Repeat Steps 2-6 until the current generation has a suitably optimal solution.

Whilst the idea of simulating evolution programmatically may be somewhat intriguing, you may be wondering what the point is, or perhaps how this can benefit the average non-computer science researcher. The answer to that question is that it likely already has, or at least it will in the near future. GAs have seen a recent surge in popularity amongst researchers and CS hobbyists alike, possibly due to their simplicity to implement amongst other factors.

One exciting application of GAs is in the engineering field; there have been attempts at using GAs at simulating simplified models of dynamic systems such as those found in vehicle and fluid dynamics. This can aid in creating more complex, intuitively designed automobiles as well as anywhere where the flow of liquids and gases are concerned (which, in our industrialised world, is everywhere). Xiaopeng Fang discussed this in his 2007 research paper for the University of Iowa *Engineering design using Genetic Algorithms*.

GAs are often paired with common machine learning techniques. ML is a topic that can occupy a whole other article, but in simple terms, it is the subfield of Artificial Intelligence that is considered with programs learning new information through previous knowledge and/or some mathematical model, all while not being specifically programmed to do so. GAs can be employed as the actual method in which the programs learn; they start with random solutions, see which ones are better, breed those together to generate genetically advantaged children, and so on until a suitably optimal solution is found. An exceedingly popular technique is the concept of neuroevolution. This involves combining neural networks (AI models that vaguely mimic the function of a simple brain) with GAs to create an extremely versatile learning algorithm. Neuroevolution is the subject of my A-Level CS coursework, which will involve using a GA to train a computer to play an Endless Runner game similar to Temple Run. Neural network controllers have been used to drive mobile robots, automobiles and even rockets in a limited capacity. Further investigation of this could lead to some extraordinary breakthroughs in the years to come.

We can even venture outside of the STEM world and look at what impact GAs can have on, say, economics. John H. Miller worked to introduce the economic world to the wonders that GAs could present to them in 1986. Since then, they have been used to characterize various economic models, including the cobweb model, asset pricing and different models of game theory.

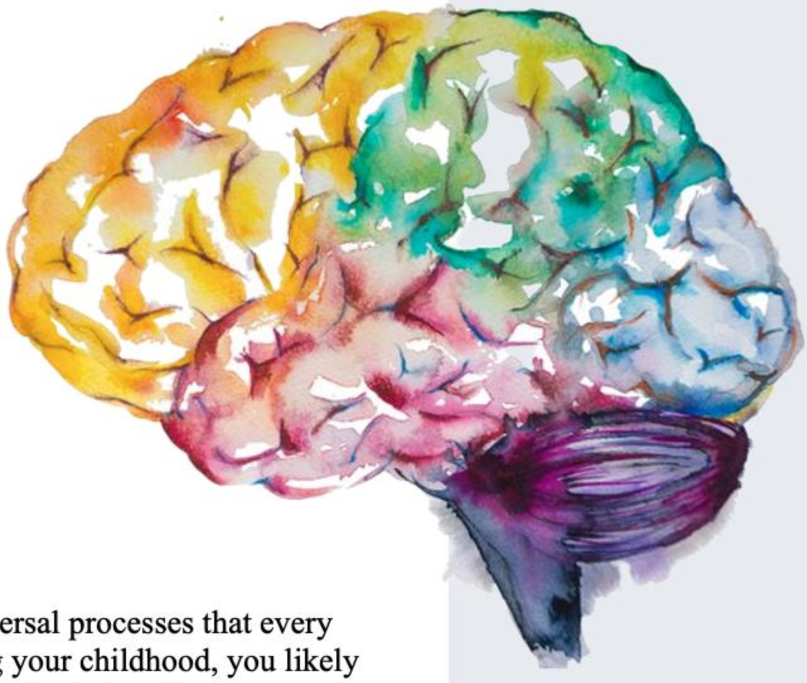
The application of GAs that I find the most fascinating is Artificial Creativity. Simply put, this concerns any instance where an AI is shown to exhibit signs of human creativity e.g music-making or drawing. There have been numerous different attempts at this over the years. For music, there are the likes of Google's Magenta initiative, which features a browser-based lo-fi music generator as one of its projects, as well as Jukebox by OpenAI. For art, we have the 'Vincent' model by Cambridge Consultants, which can complete a drawing or painting given a rough sketch by a human. These ventures use just neural networks rather than GAs, but there have been efforts at music generation using GAs. I'm actually working on making an album consisting of tracks generated by my own GA, so stay tuned for that!

In summary, genetic algorithms are truly intriguing things. The list of their use is practically infinite as long as you have a problem and a way of measuring how good a solution is to that problem. I am truly excited to see where the world of evolutionary programming takes us next.

Taimur Shaikh 12SCH

HOW DOES BECOMING MULTILINGUAL ALTER YOUR BRAIN AND BENEFIT YOU?

Ansh Bindroo 10CSI



Learning a language is one of several universal processes that every human experience in their lifetime. During your childhood, you likely learn a maximum of 2 languages, including English and/or your mother tongue (you might instead learn ASL or Braille instead depending on your physical condition) and you may learn more languages later in life through your education. This could include your country's native language and/or mandatory languages you study at school. At Dubai College, students can learn Arabic, French/Spanish and even Latin over the course of their education. Due to the diversity of curriculums in the UAE, students from other schools might even learn languages such as Hindi or Mandarin.

How does the brain process learning a language?

Firstly, before I delve into the facts, I want to begin by explaining how the brain handles learning a language exactly. According to Dr. Ping Li, the Psychology and Linguistics professor at Pennsylvania State University, achieving fluency in a language includes:

- Remembering the lexicon (words)
- Learning its phonology (sound system)
- Acquiring the orthography (writing system)
- Getting familiar with the syntax (grammar)
- Pragmatics – knowing the subtle ways to express oneself

These distinct elements require different parts of the brain to be activated, such as the Broca's area (responsible for speech production and articulation, located in the left frontal lobe) and the Wernicke's area (associated with language development and comprehension, in the left temporal lobe).

However, the procedure of language learning is not limited to either of the brain's hemispheres, but instead involves the exchange of information between them. This is done using the corpus callosum, a white matter pathway that connects the brain's left and right hemispheres, enabling the transfer and consolidation of information between them.

Finally, learning a language requires the use of 'executive functions' which are cognitive processes such as working memory, attentional control and problem solving. Therefore, the regions relevant to these processes are also involved; this includes the dorsolateral prefrontal cortex, the orbitofrontal cortex (commonly associated with impulse control and response inhibition) and the anterior cingulate cortex (involved in emotion assessment and emotion-related learning).

How does learning a language alter our brain?

How learning affects our brain can be compared to how exercising affects our muscles: by making them work, they increase in size and become stronger. Since learning a language is a complex process, the brain takes effort to do the procedure and thus adapts to do it more effectively by changing structurally and functionally.

In terms of structure, there is an increase of white and gray matter (which contains most of the brain's neurons and synapses) in parts of the brain involved in language learning, particularly in frontal and parietal areas (such as the Broca's area) and the parts involved with executive control (like the dorsolateral prefrontal cortex).

In addition, it also leads to an increase in the corpus callosum' white matter volume (providing greater cortical connectivity) and the size of the anterior cingulate cortex due to the significant role it plays in monitoring which language is being spoken and keeping the other languages from affecting our speech.

Finally, as for changes in function, brain imaging techniques like fMRIs have shown that learning languages can result in greater activity in the primary auditory cortex and other linguistic parts of the brain, even when not engaged in language-related activities.

What are the benefits as a result of these alterations?

Firstly, the enhancement of the parts of the brain involved in executive control leads to an improvement in multilinguals' executive functions, making them better at skills such as multitasking and analysing their surroundings. In addition, they exhibit more cognitive flexibility, thus demonstrate more creativity when solving problems.

Furthermore, they tend to make more rational decisions as they are able to draw from their understanding of a problem using all their languages (relying heavily on analytical processes rather than emotional bias).

Penultimately, multilinguals' enhanced inhibition skills allow them to focus on relevant information and edit out the rest. As a result, they are highly perceptive; they are better at observing their environment and spotting misleading information.

Finally, the biggest and undoubtedly most useful benefit is the enhanced ability to handle degenerative diseases such as Dementia or Alzheimer's. While multilinguals don't gain immunity to them, they are able to better cope with the diseases' symptoms due to their improved compensatory mechanisms. Additionally, multilingualism can even delay the onset of such conditions by an average of 5 years.

Are there any risks?

While it can be presumed there would be none, the possible risks of multilingualism must be acknowledged. The only one I could find is the assumption that children learning many languages at a young age may become confused and struggle with their lacking vocabulary. However, this belief has been rejected by findings that multilingualism during childhood is paramount in acquiring a new language accent-free later in life.

In summary, becoming multilingual actually provides a host of neurological benefits as there are many skills involved with learning a language, such as attentive control and inhibition skills. Parts of the brain involved with learning a language are also physiologically enhanced along with those parts involved with language processing. If you're planning to drop one or more of your languages after your education, remind yourself of the benefits of learning and mastering a language: it will not only look good on your CV, but learning languages can improve your memory, make you a better multitasker, communicator, enhance your sensory processing… just to name a few.

Rockets, Take Two:

Tarn Timmermans 10CSI

Unfortunately, sequels are never as good as the original. It's been seen throughout the ages, from Robocop to Transformers to Star Wars, even with all their new VFX technology to animate all the hyper and ion drives.

Wait.

Stop.

Right there. Okay? Pan out.

That's not an animation. That's reality.

That's right folks. Welcome to the future. Humans now possess the elements of science fiction. And with names as cool as ion drives, what's there not to like?

The Mileage (and science) of Rocket Engines

I have said before that, quite simply, rockets need boom out the back. That was a white lie. What rockets really need is stuff. It doesn't matter what this stuff is, it just needs to be moving in the opposite direction. It could be anything with mass, regardless of whether it be an explosion of super-hot fuel, cold gases or, as Mark Rober put it, a bunch of hammers.

To really get into some nitty-gritty details, let's take a look at the mileage of a rocket engine.

It turns out that the faster this stuff is moving, and the lighter it is, the better this stuff is as fuel; more miles per gallon. This fact is critical to rocket scientists, who are out to squeeze performance from their rocket engines in any way, shape or form – as you will shortly see.

However, rocket science is, has and always will be a balancing act, and the most efficient fuels are sometimes not what they advertise themselves to be. For, you see, lighter fuels are, by definition, less dense, meaning more space – and therefore weight – is needed to store them. That's why the Space Shuttle was so chunky: it carried the lightest element known to man

Ion Thrusters

You're 8 years old, messing around with some buckyballs you found next to your desk at school. They move in weird shapes, and some stick together. You cast them aside.

It's year 7, chemistry class. The teacher is at the front, waving their arms at some diagram of an atom. You look up and catch something about an 'ion' and 'charge'. Bored, you look back down at your buckyballs.

Putting these two situations together gives you something great. No, I'm not talking about a distracted student. This is something much better. Something that can get us to Mars in 6 weeks. A little something called an ion engine.

Alright, now we've got the climactic introduction out of the way, let's dig into some science.

Get some gas. The less reactive the better. May as well make it dense while we're at, so you can store a lot of it. Xenon? Good choice.

Now get an atom of this gas and kick out one of the charged particles from that atom. Now you have an ion.

Now, picture a fan walking across a street. The fan sees their favourite band. What does the fan do? They rush to the band as fast as humanly possible. But then, through sheer speed, the fan speeds past the band so turns around. But they see their ex-girlfriend out of the corner of their eye. They bolt like lightning.

Replace the fan with the ion, the band with a positive charge, and the girlfriend with a negative charge, and you now understand ion thrusters.

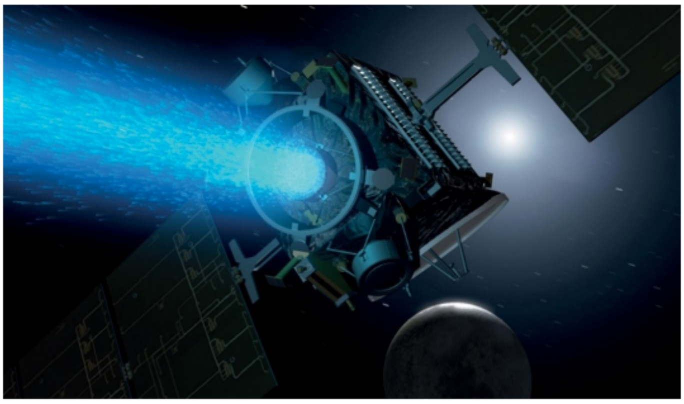
This technology does come with some drawbacks.

Imagine cars covered in sandpaper screaming past your skin, thousands of times per second. Each one grating against the flesh, removing a tiny piece, bit by bit.

Now, swap the cars with these ions, and your skin with the metal of a rocket engine, and you can see we have a problem. Should probably let Houston know on that one.

To counteract the 'weathering' of the engine, scientists turn the ions back into atoms by adding electrons back into the 'ion beam' (not making this stuff up) – the scientific equivalent of replacing sandpaper with talcum powder.

Oh, by the way, the atoms end up travelling at 30 kilometres per second. Not bad for the mileage.



Water Rockets - on Steroids

Astronauts have every right to be considered crazy. At the best of times, they sit on top of a controlled explosion, and, at the worst, an uncontrolled one. So, a new engine might not be considered too large a risk.

Not this time.

Imagine experiencing two Chernobyl events every second, hours on end. That's right. You can't. Why? Because you're dead. On the other hand, you've got some pretty good efficiency.

It may sound crazy, but this is a legit idea being considered seriously by scientists: the combination of high thrust and high mileage is a rarity in the world of rockets, and this unit manages to do just that. Enter the world of nuclear salt-water rockets.

When a virus replicates, it makes two. Two make four, four make eight, eight make sixteen and so on. Replace the virus with a splitting atom, and you have a nuclear reaction.

This is good.

For, you see, each time an atom splits, it releases a lot of energy. And I mean a lot. If you could eat uranium, you would only need three grams to power a human for an entire lifetime.

Anyway, this fissile material is dissolved in water and is mixed in with some plutonium salts to give a radioactive jungle-juice. At a certain weight, enough of this stuff is present to cause that virus-like replicating phenomenon. And this is when things get interesting.

The stupendous amount of energy released goes into the water, which turns into the fourth state of matter – plasma. This is an extremely hot (hundreds of thousands of degrees) gas. And boy, does it move. This radioactive plasma comes screaming out of the exhaust at sixty-six kilometres per second, giving crazy-high levels of efficiency and thrust, and just fans out into space.

Of course, there are problems.

Not the least being all the radioactive stuff spewing out the back of your rocket. But this is fine for deep space missions (the original intention) – the material just dissipates into the nothingness of space.

The real issue shows itself when things heat up. The salt-water can just, well, explode within the engine. That's bad. Really bad.

To counteract this, some really smart people found a way to make the brunt of the explosion happen outside the engine, so the whole thing doesn't implode on itself. They also found that this thing would give out six hundred Gigawatts of power – every second.

No wonder this thing's been dubbed 'non-stop Chernobyl'.

So you - being a rational person who prefers being alive - may ask why this idea is even worth mentioning.

The real reason scientists are considering this is pretty simple: it can actually happen. Other engine concepts require some super material or processes which haven't even been sorted out here on Earth (let alone in space), but the nuclear salt-water rocket builds on already developed knowledge. The paper was released using technology from the 1990s and look how far we've come from there. The hardest hurdle in getting this beast going is the assembly, which has to be done in orbit (unless we want to keep our biosphere).

But this thing has real potential. A fleet of Starship (SpaceX's new vehicle) sized spacecraft powered by these engines will be able to fling humanity to the far reaches of the solar system with remarkable speed and efficiency, unlocking even more complex features of science fiction like asteroid mining and off-world bases. With that being said, I'll see you on the Dark Side of the Moon.

Antimatter Engines

We've all heard of antimatter in some way, shape or form. It's the candy of science fiction writers, having been seen from movies to tv shows to books. It's become the stuff of pop culture, with some companies advertising 'anti-matter putty' or 'anti-matter advertising'. But, in reality, this mysterious substance couldn't be more different.

Quite simply, when matter meets antimatter, there's a big boom. The same three grams of uranium that would power a human converted to antimatter would wipe out 90 thousand kilometres of land. When these two opposite particles meet, they destroy each other in a process called annihilation (best name yet!) and release pure radiation in the form of light. And the energy? Why that's a big number. Decided by the most famous equation of all time. That's right. $E=mc2$. And c is a really big number.

So anyway, an antimatter engine works by throwing together some antimatter with matter, releasing these crazy-high amounts of energy. To contain and direct it, scientists use magnets to direct the raw energy out the back. That's right. A magnetic nozzle.

Rocket science is really cool.

Of course, being a 100 per cent energy-efficient process, this thing has one of the best efficiencies (mileages) of any rocket engine. Ever. But things that are too good to be true sometimes are, so there are a few hurdles we've got to overcome.

Antimatter is expensive due to its tendency to, well, explode whenever it comes into matter - and matter is everywhere. The absence of antimatter in nature is one of the great unanswered questions in physics. But this absence means we must make it ourselves, which, at the current moment, carries a hefty price tag of 2700 trillion US dollars per gram. And we need tonnes of the stuff. Also, the same matter/antimatter explosion makes the stuff extremely hard to hold on to once you've got it: the container can cause the antimatter to blow up.

Antimatter engines remain, unfortunately, in the realm of far-fetched science fiction. However, when the day comes that humanity sees these bad boys in action, it will be a great moment for the advancement of space travel. A nuclear salt-water rocket will unlock the solar system; one powered by antimatter will unlock the galaxy.

It'll be interesting to see whether any of these technologies actually play out as their designers intended and propel humanity among the solar system and beyond. More designs will come along and may replace their 'outdated' predecessors as new revolutionary breakthroughs are made.

I finished my last article by saying that progress drives exploration. Looking towards the future, this concept will become even more fundamental, albeit taking new forms. Who knows? Maybe progress will become exploration, so it recursively drives itself forwards. Whatever the circumstances, wherever we may be, this will hold true. Always.

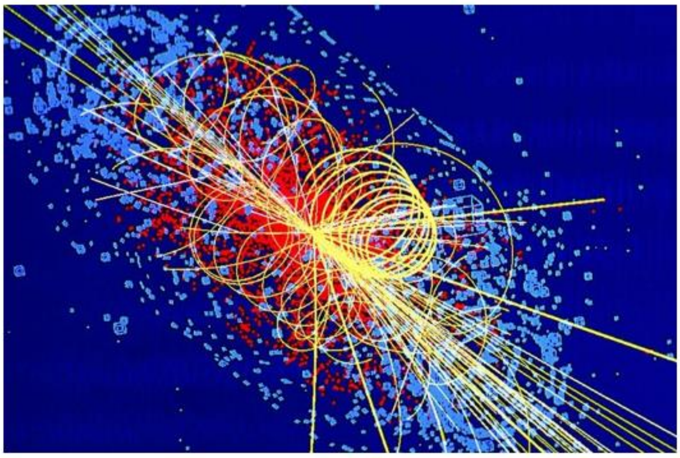
Higgs Field, Boson, and the Universe

The Higgs field is an omnipresent energy field that permeates space and gives mass to all elementary subatomic fundamental particles through its interaction with them. The Higgs boson, also known as Higgs particle, is the fundamental particle associated with the Higgs field.

Origins of the Higgs field and the Higgs boson

When the universe came into being after the Big Bang, particles were sans mass, travelling at the speed of light. Seconds after the universe originated, as it started cooling and the temperature fell below a critical value, the Higgs field came about. Unlike other fields, Higgs's minimum vacuum expectation value is not zero but 246 GeV, enabling it to break the electroweak (electromagnetism and weak nuclear force) symmetry. This symmetry-breaking gave quarks, and many other fundamental particles mass, leading to the formation of atoms.

The Higgs field is an energy field which is scalar, which means it does not have direction. It exists throughout space and is homogenous. Higgs acts as a drag on particles, and as they move through it, they acquire mass; the slower the particles move through the field, the more they interact with the field, and the heavier they become. By interacting, the Higgs field gives resistance to the motion of the particles, thereby making it heavier, causing the particle to slow down. Particles which do not interact with it (like the photon) have no mass. If the Higgs field did not exist, particles would be moving at the speed of light and would not have the mass to attract each other.



Simulation of particle collision in which Higgs is produced. Source: CERN

Higgs boson - Like all fundamental fields, the Higgs field has an associated particle – the Higgs boson, which is the boson (carrier) of the field. The Higgs boson is the visible manifestation of the Higgs field, like a wave at the surface of the sea.

Properties of Higgs Boson and Higgs Field:

- The Higgs field generates the Higgs boson. It's the excitation of the Higgs field.
- The Higgs field uses the Higgs boson to interact with other particles and give them mass.
- The Higgs boson gets its mass from its own interactions with the Higgs field.
- Higgs boson has a mass of 125.35 GeV.
- The mass of the Higgs-Boson is related to how stable the vacuum of empty space-time in the universe is.

- There is a probability that there may be more than one Higgs boson.
- The Higgs boson only exists for one zeptosecond (that's one sextillionth – 10^{-21} of a second) and then decays into lighter, more stable particles.

How much does Higgs boson contribute to the world around us?

Everything around us that we touch has substance which requires mass. The Higgs boson gives mass to the quarks that make up a proton; however, it only provides about 1% of a protons mass. The balance 99% comes from the energy that binds protons and neutrons constituent quarks together. The protons and neutrons, form the nuclei of atoms, which are the building blocks of molecules, cells, plants, animals, humans, planets, stars – everything in our universe.

So, while the Higgs mechanism is not directly responsible for our mass or for that of anything around us, it is responsible for the 1% mass of the fundamental constituents of the universe. Without the Higgs field and boson, there would be no life or at least not as we know it.

The mass of the Higgs boson is about 126 billion electron volts (about the 130 times a protons mass). This level of mass means that the universe is on a narrow line of stability. Physicists theorize that the delicate balance may eventually collapse, and the universe will become unstable. If the Higgs mass were just a bigger, the universe's stability would not have been in question. Similarly, if it were the other way around,

Higgs field and Higgs boson: Evidence

The Standard Model of particle physics elaborates on the fundamental forces and particles, and how they interact. The Model could, however, not explain how mass came about. In 1964, Peter Higgs, François Englert, and four others propagated the theory of the Higgs field and Higgs boson to explain the origins of mass in the universe. However, there was no proof of the same.

The Higgs boson exists only for a small fraction of a second, and then decays (transforms) into other lighter particles. The only way to prove if a Higgs boson has been generated is by looking for other particles it could have decayed into.

In 2012, the existence of Higgs boson and consequently the Higgs field was confirmed, by the ATLAS and CMS experiments at the Large Hadron Collider (LHC) at CERN in Switzerland. Higgs and Englert were awarded the Nobel Prize for Physics in 2013 for their work on Higgs boson.

The LHC at CERN is the highest-energy particle collider in the world. Beams of protons are shot into each other. When they collide at nearly light speed, their kinetic energy converts into a spew of subatomic particles, occasionally forming heavy particles such as the Higgs boson. Higgs bosons are only produced in roughly one out of a billion LHC collisions.

Using the ATLAS and CMS detectors at LHS, scientists have so far been able to watch the Higgs boson morph into gamma-ray photons, different types of bosons such as W and Z, heavier fermions such as tau leptons, into the heaviest quarks (top and bottom), and into muons. By measuring the rate at which the Higgs boson decays into different particles, the strength of their interaction with the Higgs field can be inferred: the higher the rate of decay into a given particle, the stronger its interaction with the field.

Higgs field and Higgs Boson – many mysteries to be solved

The discovery of Higgs boson has confirmed the Standard Model. However, properties of Higgs-Boson particles are still relatively unknown. Going forward, scientists hope that they might help to explain the mysteries of the universe more, such as how it came to be. One thing we know is that without the Higgs field, the Universe as we know would not exist: us humans would not exist.

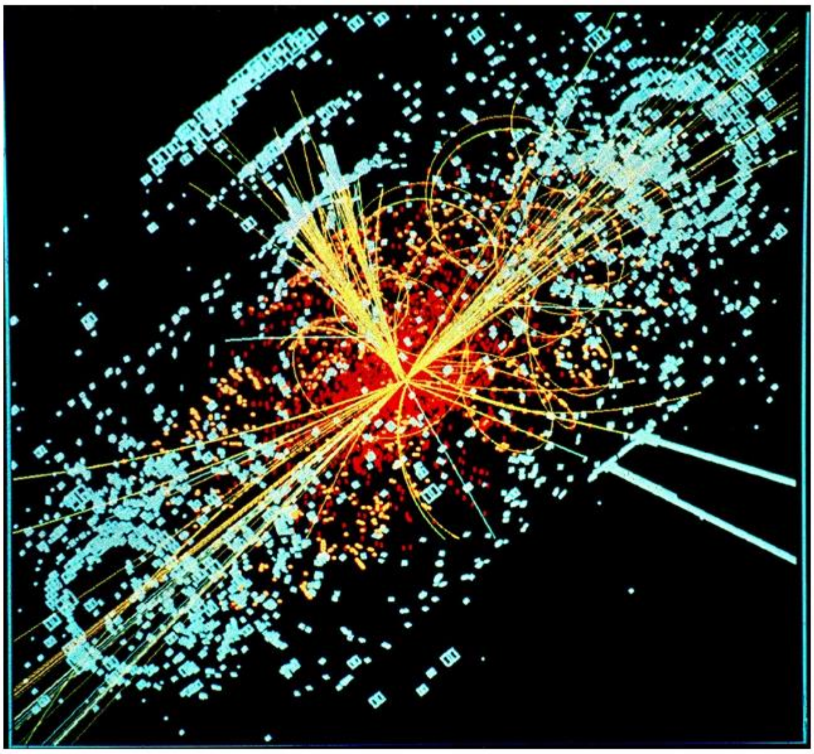
Classification of Particles

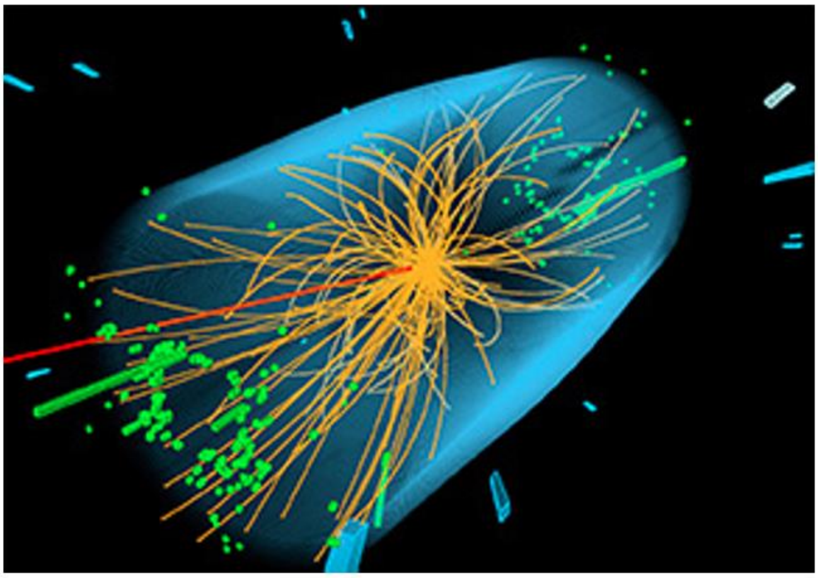
There are more than 200 types of sub-atomic particles of which some are elementary particles, (cannot be split into smaller parts) which combine to form composite particles. The Standard Model classifies all particles as either fermions or bosons. Fermions are building blocks of all matter, and bosons are responsible for transmitting the forces that control how matter behaves.

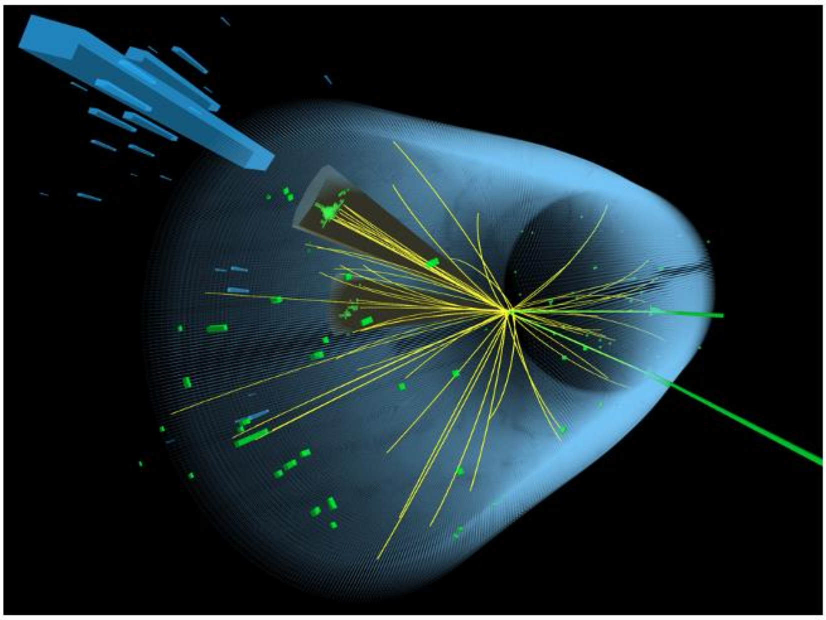
Fermions comprise of quarks (which combine to make composite particles) and leptons. There are 6 quarks of which the more important are the "up" and "down" quarks which make up protons and neutrons; important leptons are the electrons and electron neutrinos.

Bosons are particles that are force carriers, function as the "glue" holding matter together. Bosons consist of gluons (strong force), photons (electromagnetic force), W and Z (weak force) and Higgs boson.

By Philip Manipadam 9BST







More simulations of particle collision in which Higgs is produced.

Cats, computers and particle colliders

The surprising realities of quantum physics

"I think I can safely say that nobody understands quantum mechanics."

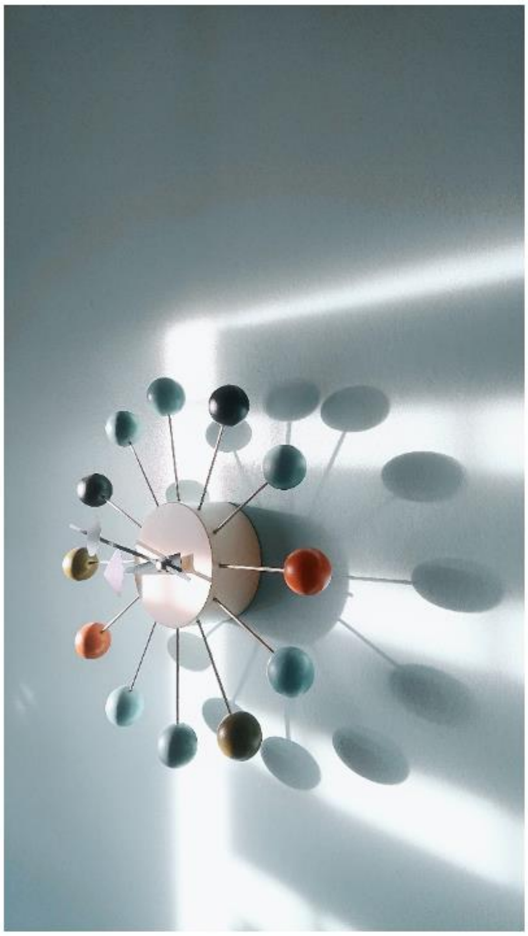
Those brave enough to venture into the murky depths of quantum physics would without a doubt agree with this famous quote from Richard Feynman. With its particles in multiple places at once, entangled particles, dead-and-alive cats, and the strange notion that the act of simply being an observer embeds us in the fabrication of reality, quantum theory is one of the most rigorously tested theories in all of science. Despite it never giving a wrong prediction, it's pushed even the most educated of minds over the edge.

This article aims to be a brief introduction to what we know about quantum mechanics, how it came to be, as well as some of the mind-blowing consequences it presents. Just keep in mind, if you don't arrive at a complete understanding of quantum physics over these five pages, you're in good company…

The Origin of Quantum Mechanics

In 1894, a consortium of electric companies had commissioned physicist Max Planck to design a light-bulb filament that can generate the maximum light for the least energy. Perhaps a mundane start to one of the greatest intellectual journeys in all of science.

Planck's lightbulb calculation quickly encountered a problem. The physics at the time predicted that a heated object should absorb and emit electromagnetic radiation at all frequencies, meaning that the object is essentially generating unlimited energy. Experimental data, not to mention common sense, contradicted this. Obviously, this needed to be fixed.



Quantum theory's time in the spotlight had only just begun
(Photo by Tom Swinnen from Pexels)

A few years later, Planck had a revolutionary notion: if energy is absorbed or emitted in discrete packets, then the energy radiated by a heated object would be finite. His idea seemed controversial at the time, but physicists started noticing these "quanta" all over the place. As quantum theory evolved, it became clear that not just energy, but other quantum properties like spin and electric charge, came in units of a minimum size. No one knew why.

Planck initially thought these quanta as a limitation of the theory, not as a description of reality. But in 1905, Albert Einstein showed that the way some metals expel electrons when light shines on them – the photoelectric effect – could also be explained by describing light as discrete particle-like quanta. He called these particles photons.

Yet another problem emerged. Einstein's new idea contradicted the hundreds of experiments that showed light behaves like a wave. The only possible explanation was that light behaves like a particle *and* as a wave. In 1923, Louis de Broglie built on this idea by proposing that just as light could behave like this, the fundamental particles of matter could behave like waves. This is one of the most fundamental concepts of quantum theory, known as the wave-particle duality. However, the waves associated with quantum particles are totally abstract things, unlike any waves anyone has ever seen or even imagined.

To further understand this problem, we need to understand that all waves can be described in mathematical terms. For example, ripples across a pond are a disturbance in water; its "wave function" describes it shape at any point and time, whilst the "wave equation" predicts how the wave moves. On the atomic scale, however, things aren't that simple, and dealing with it requires a new, highly abstract field of mathematics developed by Werner Heisenberg and other scientists.

Quantum mechanics is born.

The Austrian physicist Erwin Schrödinger realised that every quantum system, photon, particle, and others, has a wave function attached to it. Though he struggled to explain the actual physical nature of the disturbance, he managed to develop an equation bearing his name that describes how wave functions, and as an effect the particles that are the building blocks of matter, evolve over time.

Wave Weirdness

Schrödinger's pioneering work led to a new picture of the quantum reality. While his equation encoded all the possible behaviours for a quantum system, the certainties become probabilities, and this is where quantum mechanic's odd nature really becomes apparent.

For example, picturing the simple system of an atom flying through space. If you know its wave function, you can use Schrödinger's equation to work out the probability of finding the atom anywhere. You however can't work out its exact position without measuring it. So far so good.

These waves are nothing like quantum ones
(Photo by Kammeran Gonzalez-Keola from Pexels)

But even if you measured an identical particle, under the exact same conditions, it might end up somewhere completely different, according to the probabilities encoded in the wave function. What? How can a different outcome under the same conditions be possible?

The mathematics works though, and quantum mechanics has stood up to every experiment and test we've given it. But the insert weirdness of the entire field of science has some very interesting consequences, of which we'll cover just a few of, over the next pages…

The consequences of the atom

Quantum computers

The computer is undoubtedly one of humanity's greatest inventions. It's used in everything from personal entertainment to content creation (what I'm doing right now!) to even national security, and as the years pass by our brain machines' power increases exponentially. But this process is about to meet its physical limits, due to an interesting concept in quantum theory called "quantum tunnelling".

Before we understand this problem, we first need to get some basics about computers clear. In a nutshell, computers work by making calculations using a small, simple machine called a transistor. It's basically a switch that can either let electricity pass through or prevent it from passing. These values are represented as 0 and 1.

Okay, so how does this help us?

By arranging billions of these transistors together, you can calculate much more difficult problems by chaining these simple "bits" of logic together. The actual operations themselves are literally simpler than first-grade math.

Think of it like 7-year-olds doing very simple maths questions. Given a large enough group of them, you could calculate everything from astrophysics to Minecraft. In the context of a computer, the seven-year-olds are the bits, and the group is 7.5 billion of them.

Today, transistors are beginning to approach the size of an atom, typically about 14 nanometres (60 atoms) across! However, at this scale traditional computers just stop making sense.

The problem is that a transistor is responsible for either blocking an electron, or letting it pass, but in the quantum world electrons can use "quantum tunnelling" to get past a barrier, so the transistor basically becomes useless. The only way around this problem is to exploit these quantum properties themselves.

Enter the quantum computer.

Quantum computers work on the principle of "qubits", a special type of bit where the transistor is a quantum particle itself. A two-state quantum system, like polarisation or electric charge, can be used to represent ones and zeros. Basically, they're identical to normal transistors, right?

But there's a catch.

Quantum particles can be in any proportion of multiple states at the same time.

The many improvements a quantum computer could bring would reduce today's most powerful desktops to electric rocks

(Photo by Designecologist from Pexels)

However, when you actually measure the particle's state, it must choose to collapse to a specific, concrete state. This means that you, as the observer, are deeply engrained in the fabric of the mathematics itself.

Think of it like this. Imagine a cat sealed in a box, with a highly radioactive substance and a vial of poison. If the substance begins to decay, the vial of poison is smashed, killing the cat. However, how do you know the state of the cat? As long as you don't open the box and check the feline's condition, the cat is BOTH alive and dead! Once you lift the lid however, the state of the cat collapses to one of these states. The thought experiment is known as Schrödinger's Cat, and was developed by the very same physicist who formulated the famous wave equation. In this context, as long as you don't measure the state of the qubit, the particle remains in both states at the same time.

Who knew a cat could help you understand particle physics?

(Photo by Yerlin Matu on Unsplash)

This concept is known as superposition, and it's the main concept behind quantum computers. To understand this, imagine four classical bits. They can be in one of 16 possible combinations, but four qubits can be in all 16 combinations at once! This number increases exponentially with each extra qubit added, and just 20 of them can store over a million values in parallel.

Another crucial quantum concept for our computer is the principle of "entanglement". This means that multiple particles can be linked together, and a change in state in one of these particles will cause a change in the other particles without any sort of delay. This means that entangled particles can still react at the same time as the others, even when they're separated by millions of light years!

This means that you can deduce all the values of entangled qubits simply by measuring just one of them.

To use this concept usefully though, you need to be able to manipulate these superpositions. A quantum computer, therefore, would first entangle some qubits, manipulate their superpositions and probabilities, and then give a final superposition which when measured will collapse down to a definite value. This means that all the calculations required for the final output will be performed in parallel, due to the manipulation of different probabilities and superpositions.

So, incredibly intensive calculations that could take thousands of years for a normal computer could be performed in the span of just a couple minutes with a quantum computer. This could include all sorts of problems, such as unsolved physics equations to even simulating the weird quantum world itself! Once the first stable and affordable quantum computers hit the market, science and computation will experience immense strides in progress that could lead to several new advancements in the fields of physics, medicine, and beyond!

This is just one of the many good things that we can look forward to, thanks to the inert oddities of quantum mechanics. Quantum computing is likely going to be one of humanity's most successful fields, and soon the entire world will see it not as far-fetched sci-fi, but as real as the car in your garage.

How to destroy the universe with quantum physics

But quantum theory has a much darker side. The entirety of physics hinges on the quantum world, so if we can manipulate it, we can affect all of physics! To explain this, let's play a little game.

What's the most efficient way to destroy the universe?

Well, the answer lies in one of the most exciting discoveries of the previous decade. In 2012 quantum mechanics had one of its biggest victories yet, the discovery of the Higgs Boson at the Large Hadron Collider at CERN, a large organisation dedicated to quantum research. Quantum theory was about to give the universe a run for its money…

It all started with a quirk in the Standard Model, a highly successful theory explaining the fundamentals of matter and its behaviour in the universe. One of its concepts is the "electroweak" force, a unification of the weak force and electromagnetic force, two of the four fundamental forces. The equations correctly described the electroweak force and its force-carrying particles, particularly the photon, and the W and Z bosons. However, they said that the particles do not have a mass. While this is true for the photon, we know the W and Z bosons have a mass nearly 100 times that of the proton. To solve this, in the 1970s the theorists Robert Brout, François Englert and Peter Higgs made a proposal, that the W and Z interacted with an invisible field to get mass. Today this is known as the Higgs field, and its force-carrying particle the Higgs boson.

This concept eventually extended to having all particles interacting with the Higgs field to gain mass. As particles interacted more with the Higgs field, they gained more mass. Since the photon did not interact with the field, it had no mass at all.

And the discovery of the Higgs boson in 2012 confirmed the existence of the Higgs field.

However, there's a catch. Everything in

the universe strives to reach the state of maximum stability. All objects intend to get rid of all entropy (disorder) in their systems. Think of it like a ball on a hill, the ball wants to roll down the hill to get rid of all its potential energy and reach its most stable state.

And the discovery of the Higgs boson in 2012 confirmed the existence of the Higgs field.

However, there's a catch. Everything in the universe strives to reach the state of maximum stability. All objects intend to get rid of all entropy (disorder) in their systems. Think of it like a ball on a hill, the ball wants to roll down the hill to get rid of all its potential energy and reach its most stable state.

Imagine if the universe could be chucked into a recycle bin (Photo by Tobias Tullius on Unsplash)

The same is true for fields, including the Higgs field. While all the other fields are believed to have reached their most stable states, there is speculation that the Higgs field has not. This fake imitation of stability is known as a false vacuum.

This means that the parts of the Higgs field, given enough energy, could collapse to their most stable state with the lowest energy, becoming a true vacuum. The incredible amount of energy released would excite other parts of the field, and the chaos will spread until the entire universe is engulfed in a stable Higgs field. However, the energy required to do so would be immense.

So, we're safe, right?

Wrong.

Via quantum tunnelling, parts of the Higgs field could suddenly collapse without warning, forming a rapidly expanding sphere that consumes everything in its path. Everything that the sphere contacts will promptly be destroyed. But it gets even worse!

Inside the sphere, a new universe will exist with a completely stable Higgs field. Since this field controls mass, most of physics and chemistry is influenced by it. The new universe inside the sphere will have completely new laws of physics and chemistry, likely making it impossible for matter as we know it to exist. This means that even if you got past the deadly coat of pure energy surrounding the sphere, life as we know it would not be able to exist inside the sphere.

We likely wouldn't see it coming either, or the entire planet would be consumed within a fraction of a second.

However, chances are that these spheres haven't formed yet, and likely won't for googols (that's one followed by a hundred zeros) of years. Even if they did manage to form, they could only expand at the speed of light, meaning that the universe would expand much faster than the spheres. Earth would likely stay out of the reach of them forever.

As well as this, scientists still have not fully agreed whether the Higgs field is a false vacuum or not, as most of it is based on speculation and our current understanding of particle physics. Quantum theory is a young field, and chances are that we're wrong and the field is already completely stable. It's likely vacuum decay is just a scary idea, and in this time and age we have many more problems to worry about than decaying fields. Let's deal with those first, then tackle the existential ideas.

Conclusion

To conclude, quantum mechanics is one of our youngest fields, yet one of the most successful intellectual journeys of the 20th century. The digital age would never have happened without quantum mechanics. Many inventions such as the mobile phone, computer and MRI scanner owe their existence to quantum theory, despite the oddities and various problems it presents for us. The two consequences of quantum theory we've covered are just a few of the many interesting conundrums in the quantum world, and chances are there's many more down the path. Quantum mechanics has only showed us a few of its surprises.

It's likely quantum mechanics is going to remain a murky field for a long time (Photo by Thong Vo on Unsplash)

To conclude, studying quantum theory might make the world a little less surprising.

But a whole lot more awesome.

Shaurya Rishi 8TSO

Should we allow people to select genetic characteristics of their IVF babies (designer babies)?

Foteini Kalamatianou 11AYO

INTRODUCTION

Designer Babies – a medical breakthrough or a horror awaiting to happen? Over the course of the past few decades, advancements in technology and resources have allowed scientists to combat many issues regarding the world of medicine, and after years of research and experiments, humankind are on the border of addressing what can be argued as the most important one: genetic engineering and characteristic selection. The knowledge available today, although limited to an extent, has allowed science to expand into new and unprecedented territories trying to achieve human perfection through the means of genome manipulation and 'designer babies' that have been envisioned to address pressing issues such as disease inheritance and harmful genome mutations. However, as time and technology progress, the field of gene altering may also raise questions as to what is considered a perfect organism and touch the concept of eugenics - a sensitive subject that is often associated with negative and discriminatory connotations. As fascinating as the new field of gene editing might sound, there is a dark side masked by the glamorous advertisements and advantages that it may hold. We are at a crucial moment in time, where we need to proceed with extreme caution, as making a single mistake can affect the entire gene pool of humanity, and the only way to save ourselves is to design rules for these designer babies, as abusing the power we acquire can lead to a very tragic downfall for the human race.

1. THE HUMAN GENOME AND GENE EDITING

The human genome is incredibly complex. Our biological traits are a result of many different genes intertwining and creating the organism, as we know it. Alleles are different types of the same gene which contribute to an individual's genotype and phenotype, meaning its genetic makeup as well as its physical features. Different alleles predetermine each organism's characteristics; however, they vary from human to human creating genetic diversity. Genes can also cause complications in the body that are harmful to humans and can have negative effects. The most important thing genes determine which scientists have been trying to understand for decades in order to grasp the field of genetic engineering, is how they cause diseases, specifically in terms of inherited alleles from previous generations as well as mutations in the genome. These diseases can range from genetic disorders such as haemophilia and cystic fibrosis, to communicable ones such as HIV. Scientists have tried using the concept of genetic engineering as a response to dealing with these disorders and have conducted huge amounts of research to develop technologies that can remove 'faulty' alleles and DNA sequences from the body.

Designer babies are, by definition, babies that are genetically engineered in vitro (IVF) for specially selected traits. Essentially, it can be described as a human form of selective breeding and gives parents the chance to choose babies that possess healthy alleles, removing the risk of developing diseases. Genetic engineering via designer babies in our current time have a very specific purpose to achieve: it is the mean to providing a better and safer lifestyle to children, who have been screened and deemed at risk of developing inherited disorders, prior to or throughout the course of their life. For the time being, it is predominantly seen as a tool to eradicate medical disorders. However, genes also have another function; they determine our visible characteristics, such as eye colour, height, and the colour of our skin, which are regulated by the alleles inherited when individuals are born. By developing the field of gene editing, many experts believe that science will steer away from treating disease, and instead focus on assembling a 'superhuman being', that possesses all traits deemed to be desirable by modern society. Will it be inevitable that questions such as how to create the paragon of a human will be raised as the field advances further and further? Losing control can lead to a scary and unprecedented future, that despite its advantages can turn dystopian in the blink of an eye.

2. RESEARCH AND CURRENT TECHNOLOGY

Technology in the modern world is developing at incredible rates and researchers predict that science will achieve in the next few decades what scientists and doctors have been dreaming for centuries. For years, genetic engineering has been a lengthy and costly process, and so the notion of manipulating one's characteristics was considered a fiction fantasy, with limited knowledge of procedures and technologies that were unsafe and untested. Many of the methods being used by researchers at the moment do not actually involve editing the genome, but rather selecting for medical purposes the best choice of embryo for parents to use, however the common ground between all methods available is that they are carried out through screening or manipulating embryos through IVF.

One of the most popular and simplest methods, as it does not require gene altering, is Preimplantation Genetic Diagnosis (PGD). In PGD, the most suitable egg that best satisfies the parents' needs, is picked out of multiple trials, and this method has been used in the past as treatment in instances of gene-specific inherited conditions or sex-linked disorders. During IVF, early-stage embryos are screened for indications of the genetic condition in question and the most suitable one is selected and transferred to the womb for fertilisation. Another emergent technology is that of "Three-parent babies", where the mitochondrial DNA of the original fertilised egg is replaced by that of a donor, ultimately preventing issues such as muscular dystrophy as well as certain heart diseases, giving the baby three genetic parents. The most controversial procedure currently being developed is CRISPR Cas-9 (Clustered Regularly Interspaced Short Palindromic Repeats), a process discovered in the sequence of bacterial DNA after researchers studied the behaviour of bacteria under attack from phages, where they stored viral genes in a location called CRISPR and used Cas-9 proteins to cut out dangerous DNA. It is a clean and cheap technique that allows precise edits to any gene by altering DNA sequence. Despite CRISPR being new and underdeveloped, it is regarded as a scientific breakthrough amongst researchers, as it promises numerous advantages for science, mainly that it can be carried out on living cells and can further aid ongoing medical research. In PGD cases, the embryos that are available for selection have a specific range in the quantity of genes provided, as there are limitations to the types of alleles parents carry. However, with CRISPR technology scientists can theoretically insert and replace any gene into the organism which opens up the possibilities of gene manipulation to much more than disease prevention or the phenotype of a baby.

Although the above technologies can create countless possibilities for science, they are not considered safe enough for full use. In addition, further understanding of the human genome is vital to solidify these methods, including the challenge of mapping out all alleles in the human genome, and reach a conclusion as to how each single gene contributes to the organism. However, with promises from researchers to create reliable and trusted procedures in the next few decades, there is increasing pressure on governments to create rules and regulations that will ensure gene editing is used responsibly, making the question of where the line should be drawn more relevant than ever.

Genome editing for human reproduction purposes is illegal in most countries. For decades, the ban on genome editing has been considered a red line that scientists should not cross. Therefore, the world was shocked upon announcement of the first gene-edited babies being created by Dr. He Jiankui, a Chinese doctor, in November 2015. During the second World Summit of Human Gene Editing, he published a report on the births of twin girls Lulu and
Nana with man-made Cas5 protein mutations, claiming to have achieved HIV immunity for the children. The scientific community received the news with great scepticism and heavily criticised Dr. He Jiankui's project, who was claimed to be reckless and inexperienced, and who was sentenced to three years in prison. This resulted in many scientists around the world calling for a five-year moratorium on gene-editing to temporarily prevent its use.

Fairly recently, certain countries, including the UK, have permitted scientists to genetically edit human embryos for purely research purposes and for a maximum of 14 days after which all embryos must be destroyed. At international level, the Convention on Human Rights and Biomedicine (Oviedo Convention) of 1997 of the Council of Europe is the main legally binding instrument on the protection of human rights in the biomedical field. Although ratified by only 29, mostly European, countries (not including the UK), it plays an important role, nevertheless, as it represents agreement and paves the primary steps to forming collective regulations. According to Article 13 of the Convention, any genome modification (in research or in treatment) may only be undertaken for preventive, diagnostic or therapeutic purposes, and not to introduce genetic changes that are passed on to the human gene pool. In the UK, the Nuffield Council on Bioethics recently concluded that the potential use of genome editing could be ethically acceptable in some circumstances if the welfare of the person who may be born is secured and do not increase disadvantage, discrimination or division in society.

Are scientists just trying to reach towards disease eradication, or could the above actions be showing a shift of perspectives regarding the debate on gene editing overall? Forming a conclusion in relation to the control measures that need to be placed on genome editing will be largely dependent on society's stance regarding the ethical perspective of the debate. As is the case for most ethical dilemmas, all arguments, either in favour or against, are based on mere hypotheticals, making it difficult to determine the 'right' answer. The magnitude of the impact designer babies would have on society is, at the moment, incomprehensible and impossible to measure, hence making it difficult for scientists to come to a definite conclusion.

Genetic enhancement has often been described as the first stride towards disease eradication, a huge advancement for humanity that would provide collective benefit within society and would potentially contribute to the end of human suffering. Supporters of genetic engineering argue for a world with less diseases, a higher lifespan, a better quality of life, less disabilities and, thus, less discrimination within society. In essence, it is argued that it would give everyone a fair chance in life – to attempt their battles with a sense of equality and to not be dragged down by weaknesses predetermined by their genome.

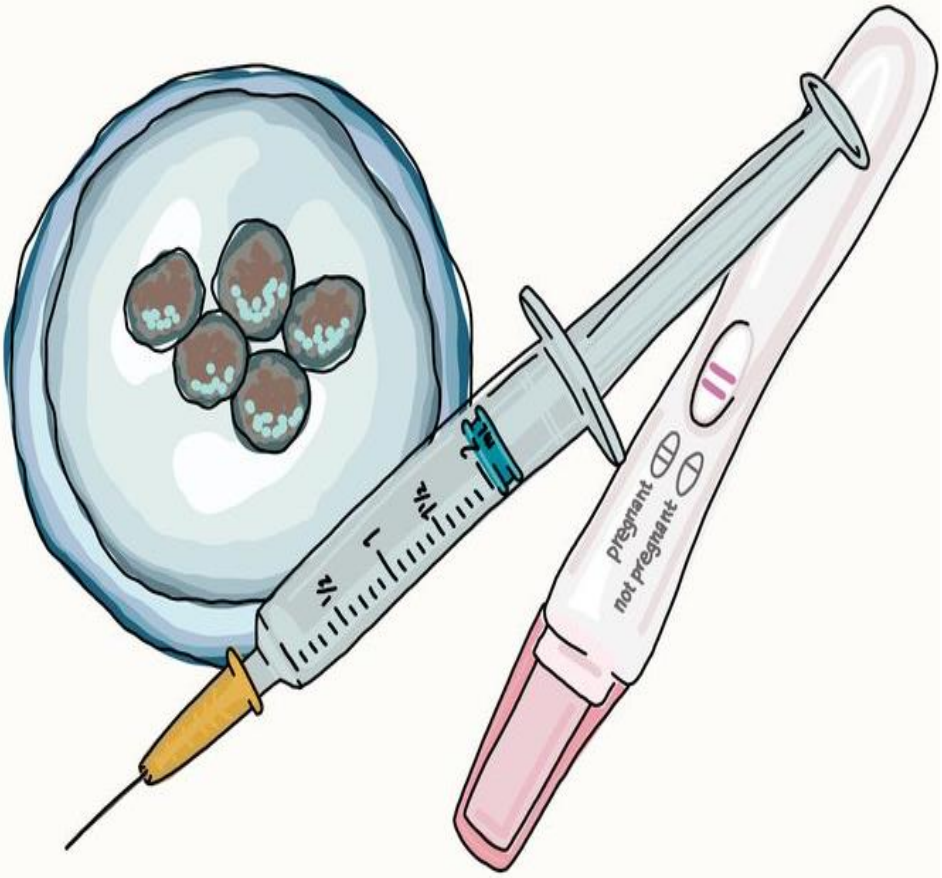
However, what if the opposite takes place? Experts have stated that genetically modified humans would alter the genome of the entire species, and hence creating one baby would cause an impurity to be passed on to the entirety of the human gene pool. Everyone will be affected regardless of their stance on the field, and even though this would not be such a major issue for technologies such as PGD which only allow parents to select an embryo from multiple options, how could it be ensured that introducing foreign alleles into the human gene pool using technologies like CRISPR will be safe and create no unintended side effects on the human species?

In addition, as knowledge and use of gene editing technologies increases, the notion of handpicking characteristics (from gender selection and specific physical features to enhanced intelligence and abilities) might start being increasingly more accepted by society, potentially to the point where it is seen as unethical to refrain from using such technologies, as it would condemn children to preventable
suffering, and deny them the cure to avertible disorders. As this notion becomes more accepted, temptation to use genetic enhancement would increase significantly and many have predicted a 'turning point' where moving past it would lead to a world where non-perfect humans will be rejected from society based on their lack of characteristics or traits. Hence, segregation and inequality will increase, putting those without the financial means or chance to acquire these characteristics at an immense disadvantage regarding jobs, education, and social status. On the other hand, it can be argued that the hierarchy in modern society is already largely structured based on peoples' prejudices predominantly regarding sex, colour, race, and religion. For this reason, many believe that any discrimination created by genetic enhancement would only add to an already unjust system, and any extra segregation produced would be negligible and hardly noticed in the overall scheme of society. As for the rejection of 'natural' humans, this is already happening to an extent when it comes to childbirth and deciding pregnancy. In Europe, 92% of pregnancies where down syndrome (the most popular genetic malfunction) has been detected have led to an abortion, where the mere suspicion of the disorder was enough to terminate the pregnancy.

The above issues barely skim the surface of all potential consequences as a result of selecting characteristics, and the more we concern ourselves in the field, the more we will see an increase in possible future scenarios, as many new questions would arise. However, it is already clear to see that the answer to this debate is much more complicated than a simple 'yes' or 'no'.

CONCLUSION

In summation, the prospect of genetic engineering is still at its foundations, however, is developing alarmingly fast following huge advancements in technology and research conducted by scientists. Despite its obvious and significant advantages, the topic should not be regarded lightly, as losing control of the power scientists currently hold could lead to a very scary and dehumanising life for future generations. This being said, technology should not be seen as 'per se' problematic. It will continue to develop throughout the next few decades in order to be able to gradually accommodate the increasing pressure from both sides of the debate regarding genetic editing. However, it is up to humans to create strict, collective regulations on an international level, binding for all, and clearly draw the line on the procedures that should be allowed. Leaving it unregulated or creating ambiguous rules that do not set definitive boundaries can lead to many miscommunications and ultimately, many cases where editing the genome of individuals would introduce uncertain and foreign genes into the human gene pool, altering it forever. Stepping into the world of genetic engineering is like cracking the door ajar to a Pandor a's box, a room that there is no way out of, and should be treated with extreme caution and care. At the moment, the most sensible action is to place a moratorium on most procedures, since there is such pressing debate about the ethical complications following gene enhancement, in addition to limitations caused by the uncertainty of the safety of technology, which should be a top priority amongst researchers. In addition, it is imperative to focus on spreading awareness to the public, so everyone can familiarise themselves with the topic in order to fully realise what is at stake. Considering a bottom-up approach and factoring the opinions of society is vital in making decisions, as governments should strive towards collective benefit rather than positional growth that will inevitably be created in certain scenarios (due to gaps in class, wealth and education). However, banning all actions connected to genome manipulation would not be a successful route to follow and would cause numerous secretive and reckless decisions from scientists that are keen on developing the field. Instead, research should be allowed strictly following predefined regulations, which would provide a sense of openness and transparency, allowing the government and researchers worldwide to form suitable and intelligent decisions which will ultimately pave the path to our future society, and dictate the fate of generations to come.



SOURCES AVAILABLE AT :

1. Fergus Walsh, Baby created to save older sister, BBC news, http://news.bbc.co.uk/2/hi/health/954408.stm 4 October 2000
   Katie Hudson and Adrienne van der Valk, CRISPR babies – one year later, https://www.geneticsandsociety.org/biopolitical-times/crispr-babies-one-year-later,
2. Marcy Darnovsky, Bioengineered Gametes: Techno-Liberation or Techno-Trap?, https://www.geneticsandsociety.org/biopolitical-times/bioengineered-gametes-techno-liberation-or-techno-trap , 15th June 2020
3. **Tess Johnson, Human genetic enhancement might soon be possible – but where do we draw the line?,** https://theconversation.com/human-genetic-enhancement-might-soon-be-possible-but-where-do-we-draw-the-line-127406**, 2020**
4. **Sheetal Soni, Human gene editing: who decides the rules?,** https://theconversation.com/human-gene-editing-who-decides-the-rules-128434**,**
5. **Designer Babies: the science and ethics of genetic engineering, The friendly brain, 5th August 2018,** https://www.youtube.com/watch?v=k1a2larfMIA
6. Nuffield Council on Bioethics, Genome editing and human reproduction: social and ethical issues, https://www.nuffieldbioethics.org/assets/pdfs/Genome-editing-and-human-reproduction-short-guide.pdf,
7. Ronald T.K.Pang and P.C.Ho, Designer babies, https://www.sciencedirect.com/science/article/pii/S1751721415300063,
8. Phillip Ball, Designer Babies – an ethical horror waiting to happen? https://www.theguardian.com/science/2017/jan/08/designer-babies-ethical-horror-waiting-to-happen,
9. Genetic Engineering Will Change Everything Forever – CRISPR, Kurzgesagt – In a nutshell, 10th August 2016, https://www.youtube.com/watch?v=jAhjPd4uNFY
10. How CRISPIR lets you edit DNA, Ted-ed, 24th January 2019, https://www.youtube.com/watch?v=6tw_JVz_IEc
11. Laura Hercher, Designer Babies aren't futuristic. They're already here. , MIT technology Review, https://www.technologyreview.com/2018/10/22/139478/are-we-designing-inequality-into-our-genes/,
12. The Ethical dilemma of Designer Babies, Paul Knoepfler, TEDxVienna | October 2015 ,https://www.ted.com/talks/paul_knoepfler_the_ethical_dilemma_of_designer_babies?language=en

Junior Medical Society Essay Competition Winning Essay

Fotetini wrote this essay for the 2020 Junior Medical Society Competition in September and won the Year 10 and 11 division of the competition! We are excited to include it in DC Quantum Vol. 2! Congratulations Foteini from 11AYO!

Should vaccinations of children against common infectious diseases be compulsory?

Aarush Vir Banerjee Kharbanda 8SOR

Junior Medical Society Essay Competition Winning Essay

Aarush wrote this essay for the 2020 Junior Medical Society Competition in September and won the Year 7 and 8 division of the competition! We are excited to include it in DC Quantum Vol. 2! Congratulations Aarush from 8SOR!

In the late 1950s, thousands of babies were born with severe birth defects due to the adverse drug Thalidomide, used to treat nausea in pregnant women. Its cause: drug companies hastily launching Thalidomide without much prior testing, and with only one goal in mind-to make a profit. Numerous catastrophes similar to the Thalidomide tragedy have occurred, primarily as a result of negligence, but few are as devastating as the Thalidomide tragedy. Due to such disasters, many parents are skeptical to vaccinate their children, however in this article I will be providing a few reasons as to why it should be mandatory for all children to be vaccinated against common infectious diseases. I do so, by presenting a short historical review and ethics discussions demonstrating whether childhood vaccination should be compulsory and then I conclude that for both ethical and practical reasons, routine vaccination should be made compulsory as the benefits outweighs the costs.

In his autobiography Benjamin Franklin, the great philosopher and founding father of United states wrote his tragic eloquence, “in 1736, I lost one of my sons (Francis Folger) a fine boy of 4 years old by the smallpox. I long regretted bitterly and still regret that I had not given it to him by inoculation”[1]. In general, the benefits of vaccination far outweigh the risks. The risks of vaccine-induced injury are hundreds to thousands of times lower than the risk of similar complications of the natural wild-type infection (Plotkin & Orenstein.1999). Vaccines provide the immunity that comes from natural infection without the consequences of natural infection. The first vaccine ever invented was Edward Jenner’s creation to combat the deadly Smallpox disease in the 1790s. Ever since, the world has benefitted from numerous vaccines preventing and containing the spread of and eradicating deadly diseases such as Smallpox and Rinderpest. Vaccines played a crucial part in our clash in the 1790s. Ever since, the world has benefitted from numerous vaccines preventing and containing the spread of and eradicating deadly diseases such as Smallpox and Rinderpest. Vaccines played a crucial part in our clash against contagious viruses and diseases. Small observations such as that of Edward Jenner, when he noticed that most milkmaids received protection from smallpox after having suffered cowpox, have helped save millions of lives.

However, we now face the question: ‘How effective are vaccines?’. Firstly, according to the CDC (Centers for Disease Control and Prevention), a yearly study from 2017-2018 showed that flu vaccination’s during 2017-2018 “prevented an estimated 6.2 million influenza illnesses, 3.2 million influenza-associated medical visits, 91,000 influenza-associated hospitalizations and 5,700 influenza-associated deaths.” [1], which strengthens the argument of the effectiveness of vaccines. Secondly, by vaccinating children you not only protect them but also protect others. Some infectious diseases are uncommon in certain parts of the world and therefore children are not vaccinated against those diseases. An example of this is measles. Cases of measles occur in the United States but ever so barely. In 2008, a family from San Diego took their unvaccinated children to Switzerland (measles mainly occurs in Europe as some countries do not believe in vaccinations and instead in herd immunity). One of the children caught measles, and as he returned home the disease infected other unvaccinated children in a doctor’s office, and from there a chain reaction continued. An entire outbreak of measles within the state of California started with just one unvaccinated child. Thirdly, “vaccines protect future generations” [1] from infectious diseases. By using vaccines, we can eliminate epidemics and pandemics that may occur in the future. A case of this is smallpox. Once smallpox was eradicated, there were no more outbreaks of smallpox at all as the disease no longer exists. If every single person in this planet is vaccinated, we can put our full assurance on the fact that numerous common infectious diseases that exist today will no longer be found many years into the future. Finally, we reach the last, albeit, most important reason preventing

millions of people around the world from being fully vaccinated-the price. Vaccines are expensive. According to data collected by the Association of State and Territorial Health Officials in 2014, the cost to fully immunize a child had increased by 500% from 2000, when it costed just $282.19 compared to 2014 when it costed almost $1985. The ASTHO also predicted that the cost of immunizations would increase in the future. The only possible solution for countries ridden with poverty to fully vaccinate their citizens, would be for foreign governments to aid each other and promote and fund all vaccinations.

Routine childhood vaccinations are compulsory in many parts of the world. Arguments used to justify compulsory vaccination infringement have centered around the autonomy of parents to make choices about child rearing, an autonomy which we generally respect unless doing so seriously endangers the child's health (Isaacs, Killham & Marshall, 2004). However, arguments used to justify making vaccinations mandatory include enhancing the health of the community and treating as paramount the rights of the child to be p rotected against vaccine- preventable diseases (Isaacs, Killham & Marshall, 2004). The Issue of common good must be taken into consideration. Aristotle espoused the importance of the community and favoring such a communitarian viewpoint that the vaccination benefits the whole community and protects the common good of society and since its significance in protecting the common good outweighs its significance in limiting individual freedom, therefore vaccination should be compulsory.

In conclusion, I believe that vaccinations against infectious diseases should be made compulsory in every nation around the globe, due to a) Factual considerations- Vaccines saves lives and failure to immunization costs lives. The eradication of smallpox in the 1970s, by targeted use of smallpox vaccine, has not only prevented many thousands of deaths, but it has estimated to have saved USD 1.2 billion annually (Ada, G., Isaacs, D.2000*).* b) Some argue that vaccines are frequently the subjects of public concern: worries about safe manufacturing, deep distrust of government, effects of additives and vaccines side effects are so me of the concerns raised in recent years. However, the well documents benefit of vaccines should not be undermined and finally c) Protect future generations by exterminating diseases (an example of this could be the elimination of the smallpox disease by the first ever vaccine).

References

Ada, G., Isaacs, D. (2000*). Vaccination: The Facts, the Fears, the future*. Allen & Unwin. Sydney.

Isaacs, D., Kilham, H.A., Marshall, H. (2004). Should routine childhood immunizations be compulsory? *J. Paediatr. Child Health* (2004) **40**, 392–396.

Offit, P.A., Moser, C.A., (2011). *Vaccines and Your Child: Separating Fact from Fiction.* Colombia University Press.

Plotkin, S.A., Orenstein, W.A. (1999). *Vaccines.* 3rd edn. Philadelphia: WB Saunders.

Plotkin, S.L., Plotkin, S.A.(2005). *A short history of Vaccination*. Nat Med, 11(4). S5-S11. [Google Scholar]

VOL. 02 | APRIL 2021

DC QUANTUM