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كلية جميرا
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Abu Dhabi to Dubai in 12 minutes?

Hyperloop: The future of Transport?

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Introduction

The Hyperloop (Figure 1) is a hypothetical "fifth" mode of transport which could revolutionise the way we travel. First conceived by Elon Musk in 2012, the original concept works by firing 'pods' at high speeds (over 1126km/h). This is about 3 times as fast as the proposed High Speed Two (HS2) in the UK. The Hyperloop, if it is built, will connect directly from San Francisco to Los Angeles(LA), like a high-speed metro and transport passengers between both cities within minutes.

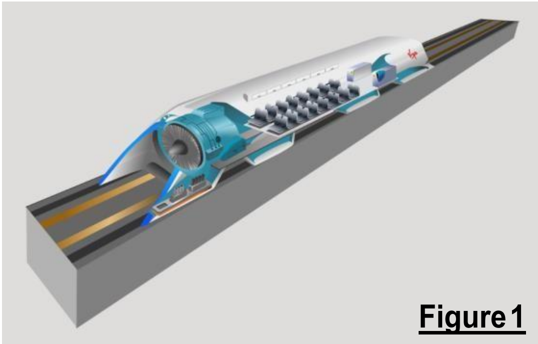


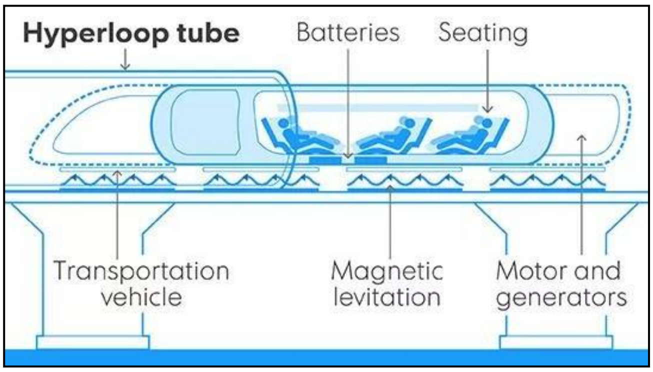
Figure 1

According to the Hyperloop One Website, going from London to Manchester (one of the most common routes in the UK), would take about 23 minutes, over an hour quicker than the HS2.

However, after writing an outline on how the Hyperloop would work, Musk chose not to go any further with the project, instead working on his other ventures. During that time though, other companies such as Hyperloop Transport Technologies (HTT) have taken up the mantle and have since continued working on the Hyperloop. Nonetheless, is the Hyperloop ever going to become as commercially viable and available as a simple train journey?

How will it work?

Figure 2



In theory, the concept is simple. You would have a low-pressure system of about 100 Pascals, hence reducing drag and friction. The pneumatic (propels objects using compressed air or partial vacuum) tube allows the pod to travel at speeds faster than even an aircraft. The pods would also have to be levitated above the track, as the friction from firing a pod that fast would be astronomical. Instead Musk theorized that highly pressurized air can be used to lift the pod. MIT students though instead thought that passive magnetic levitation (maglev) could be used to raise the pod off the tracks (Figure 2). Maglev would work by using linear induction motors, instead of regular conventional motors to create a forward motion from the permanent magnets. This would create a magnetic field which would raise the pod a few millimetres off the ground. The

Hyperloop would use electrodynamic suspension (EDS), which is essentially where superconducting magnets on the rail and train would interact, creating a repellent force like shown on the diagram (Figure 3) to help propel the train forward. The magnets are arranged in Halbach array. They would have a strong magnetic field above them – to help create a maximum repellent force on the train – and a weak magnetic force below, so that there is little magnetic attraction for anything which would pass underneath the pillars of the Hyperloop tube.
The use of EDS would also accelerate the pod gradually to its top speed.
These linear accelerators would be placed at various points of the tube to keep the pods moving. To decelerate, the thrust motion would be reversed, and through regenerative braking, the battery would be charged. This will increase efficiency and making the Hyperloop a more sustainable prospect.

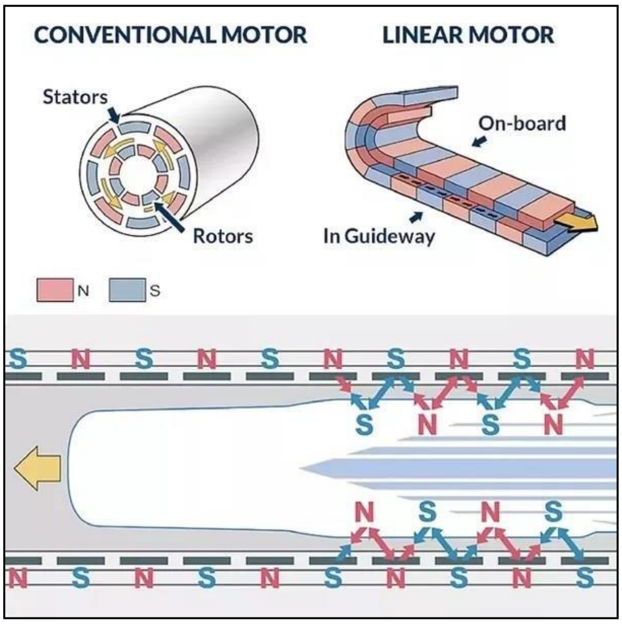


Figure 3

The capsule would be about 2.7m wide and 3m tall, and will stretch across over 760km of land. It would roughly be able to transport 840 passengers per hour. The proposed numbers suggest that the Hyperloop may be able to offer quick and energy efficient travel to over 20,000 passengers per day.

The tube would be supported on pillars; Musk theorized that they should be 6m tall, and occur every 30m, leading to about 25,000 pillars over the whole of the Hyperloop. The pillars would be made from reinforced concrete to reduce costs. In case of earthquakes, lateral and vertical seismic dampers would be used to convert kinetic energy to heat energy, hence the changes to the pylons would be minimal.

What does this mean for transportation?

It could increase economic productivity of a country. If the Hyperloop were to be built from San Francisco to LA, it would allow people to work 643 kilometres away every day and still be home in time for dinner. Furthermore, it could be used to transport cargo around the US, increasing the productivity of business which would help the GDP of America.

In addition, assuming that Elon Musk's pricing is right, it could be cheaper than a plane ticket from San Francisco to LA, while also getting you there quicker. The price of a return ticket of the Hyperloop is estimated to cost around $30 or £22. However, it may be a while before any sort of Hyperloop comes to the UK, as the first planned build is in the US, in the next 20 years.

The Hyperloop is also planned to be energy efficient. By having the Hyperloop in a low-pressure system and partial vacuum, air resistance is reduced and therefore less power is required, hence making it more efficient. Similarly, by using maglev the rail resistance is reduced, again requiring less power. Musk also conceptualized the use of solar panels to power the Hyperloop, which could lead to the train being run on only renewable energy.

A perfect solution?

First of all, the most obvious concern is safety. Firing people in pods at over 1126kmh seems extremely hazardous. Various engineers involved in producing the Hyperloop have considered this problem, and offer several solutions. Musk theorized a mechanical braking system to help stop capsules if the self-powering system were to fail. This does however bring some concerns: if anything were to go wrong in the Hyperloop; due to the great speed it is travelling at, it is unlikely that there would be enough time to rectify it. Musk has said that he wanted the pods to depart every 30 seconds from San Francisco to LA.
If we assume that the maximum deceleration of the loop is 0.5gs, which is about 17.54kmh per second, then it will take 64.2 seconds for the pod to come to stop. Therefore, it is likely that the pods would actually depart every 80-90 seconds, in order to prevent such a tragedy from occurring. Similarly, the departures at each station are theorized to last only 60 seconds, obviously not feasible for all, such as the elderly and the infirm. However, the bigger concern may lie with the actual creation of the Hyperloop.

Secondly, the theory of Kantrowitz Limit. This states that there is a minimum tube to pod area ratio, before which choked flow will occur. This would mean that if the walls are too close to the capsule, then the airflow will build up, forcing the air flow through the system and increasing air resistance. However, to combat this, Musk thought of using a compressor to suck in air from the front to the back of the pod, hence avoiding the Kantrowitz Limit and allowing the pod to reach the desired speed of 1223kmh.

Thirdly, heat expansion. As the tube is not a vacuum, the great velocity of the pods will cause heat, and therefore thermal expansion on the steel tubes. This could be catastrophic for the tubes and the support systems. Musk recognized this and wrote in his briefing how pillars would be used which only constrain the tube vertically but not laterally, to allow for thermal expansion. He also wrote about the use of slip joints at each station. But, considering with over 760km of track, the thermal expansion is likely to increase the length of the tube by about 300m, there is serious apprehension over how this problem will be solved.

Finally, the pricing. Although Elon Musk wrote that the cost will be about $7 billion or £5 billion, many experts have speculated that it will cost up to ten times as much, due to buying the deed to purchase land as well as the building of all the structures. For the project, the New York Times wrote that it could cost $100 billion or £75 billion, more than the net worth of Bill Gates. With the startup costs being so high, it is likely that tickets will be high in price as well, to meet Musk’s plan of breaking even after 20 years of opening.

Conclusions

In conclusion, the Hyperloop appears to be a scientific possibility but an economic impossibility, at least at the current costing. But with more people buying into the idea of high-speed travel, don’t write off the Hyperloop yet. I believe that similar murmurs were made about the impossibility of space travel half a century ago, and we all know how that turn out. However, in order for the Hyperloop to go from science fiction to a conventional part of people’s lives, serious questions need to be asked about the concept, construction and costing of the ‘fifth mode of transportation’.

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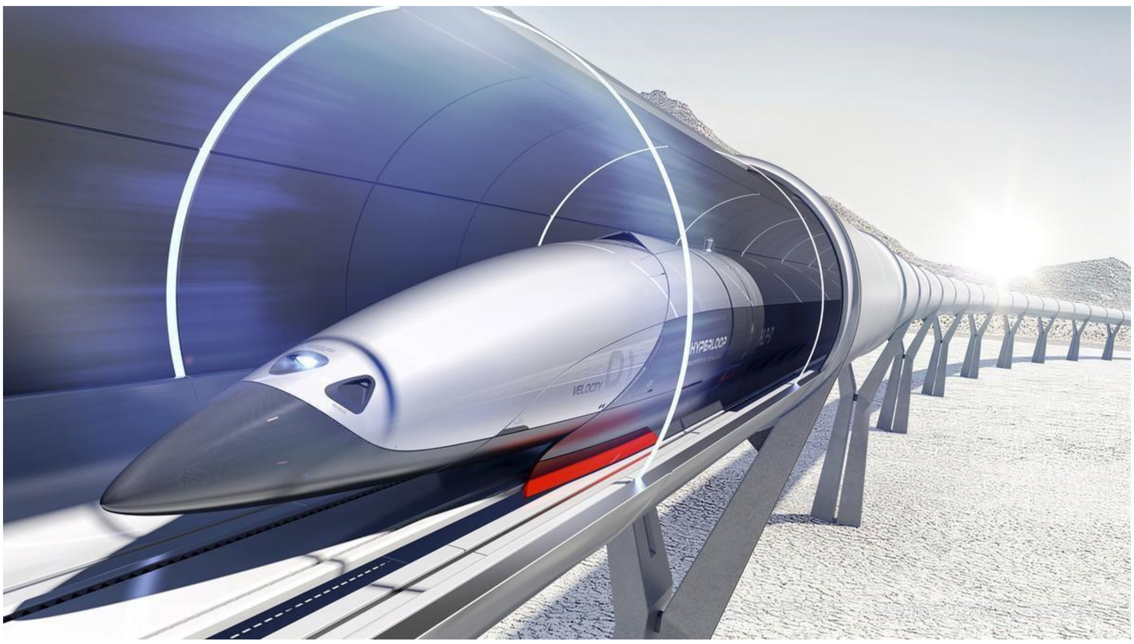


HUMANS: BORN TO RUN?

Adam Al-Hashemi, 12G1

2 million years ago, the human brain went through a rapid expansion in size. From a tiny 400cm^3 pea brain in Australopithecus, to 600cm^3 in Homo Habillis, to around 1000cm^3 in Homo Erectus. The only explanation is that meat had been added to the early-human menu, as they started to eat dead animals, rather than their previous primate veggie diet. But the puzzling thing is, is that the first edged weapons only emerged 200,000 years ago. So for 1.8 million years, how were early humans getting all this dead meat?

The answer *could* be that early humans were pursuit predators. Pursuit predation or even persistence hunting is where the predator chases the prey over long distances for a long time, until the prey becomes exhausted and unable to continue running. The prey will eventually slow down enough so that the predator can easily go in for the kill, or the prey collapses or dies from exhaustion or overheating. There are few other predators that use this method, and other examples include African Painted Dogs, wolves and even some modern day humans.

The theory is that early humans could have been scanning the sky for scavenging birds, then running long distances to reach a fresh kill and steal the meat from whatever animal was unfortunate enough to get in the way of early man. Or that we were the runs actively chasing after the prey ourselves in the newly developing landscape of the Savanah.

But how are humans able to exert themselves for such long periods, but other animals, like the poor antelope, cannot?

Bipedalism emerged in our history around 6 to 7 million years ago in the Hominins Sahelanthropus or Orrorin. Some possible key advantages of bipedalism are that it freed hands for reaching and carrying food, saved energy during locomotion, provided enhanced field of vision, and enabled long distance running and hunting. Unlike almost all other animals, humans sweat as a form of thermoregulation. This added to the lack of body hair means we can really efficiently keep cool when exerting hard for long periods of time, or in hot conditions. Other features of the human body that would have made us perfect pursuit predators include spring-like ligaments and tendons in the feet and legs, a narrow waist and midsection that can turn to allow us to swing our arms and prevent us from zigzagging while running, a highly developed sense of balance, the ability to store about 20 miles' worth of glycogen in our muscles, and the gluteus-maximus, the largest muscle in the human body, is primarily only engaged during running.

Interestingly, the pursuit predator theory could explain why women and men are so evenly matched when it comes to long distance running, and the longer you go, the closer it gets. Men are considerably faster than women when it comes to short distance races, like sprints and short km races. But ultramarathons, upwards of 50 and 100 miles, it becomes are very evenly matched race. It can also explain that when it comes to age, a 19 -year old who keeps running their whole lives will peak at around 27, and then degrade for the rest of their lives, but only get back to the level they were at when they were 19 when they hit their 60s. And it explains how in 2007, Emily Baer finished 8th overall (male and female) in the 2007 '*Hardrock* 100', while stopping to breastfeed her baby at every rest station. Now these things may seem unrelated but if you think about it in the context of early humans hunting in groups.

First, you need everyone running. There's no point for half of the group to be at the site of the kill, and the other half 50 miles away. So that means the children, the teenagers, the adults, the oldies, and the breastfeeding mothers. And they all play their part. The experienced old runners will have the knowledge and experience to be able to lead the hunt. The young adults will be there leading the charge in the centre. And everyone else is around helping keep it all together.

All these physical attributes point us in the right direction that early humans were close to running a marathon every day. But this was millions of years ago, surely we are completely different animals today than we were 2 million years ago? This may be true, but it is still deeply woven into our DNA even today, and there are many examples of this coming through in the modern day.

Modern day human pursuit predators take the form as Hunter-gatherers in the central Kalahari Desert in Southern Africa. They hunt down antelope in midday heat (up to 42°C) at distances up to 35 km (marathons are 42.2 km). The hunter will run at a fast running pace, continually tracking the animal and catching up to it before it has time to rest and cool down. When the antelope becomes too exhausted, it is easily killed with spear by the hunter.

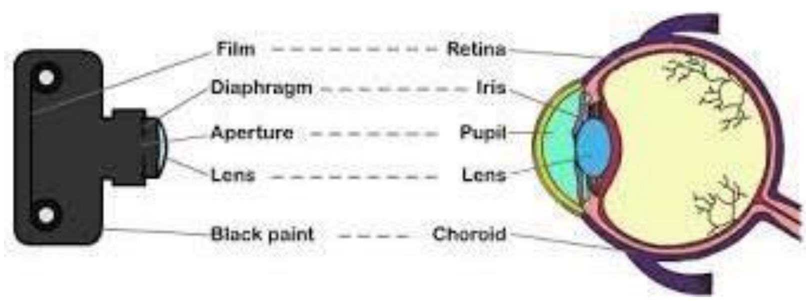
So next time you are being forced to do the 3k run in PE, bleep test or just running for fun, just remember, you were born to run.

The Science and History of Optography

Rashne Vakharia (12M2)

Most people have some notion of the similarities between the human eye and a camera, very few however, know just how alike the two really are. If you think of your eye like a film camera, it makes sense that you should be able to develop pictures from said camera – or eye, now if the retina functions like the photographic plate of a camera, the last image seen before death should stay, like a photo, permanently within the dead person's eyes. This was the basis for optography – a largely popular concept that plagued the minds of late 19th century scientists, so intriguing this new possibility was of being able to see the last sights of a dead man - that optography was even implemented into works of art, philosophy and literature.

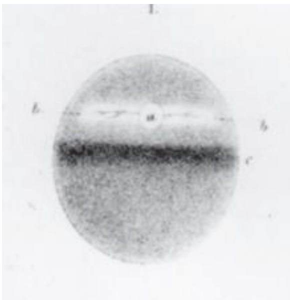
This theory was not just dreamt up one day, it was inspired by the discovery of the chemical rhodopsin also known as "visual purple" by Professor Franz Boll at the University of Rome in 1876. Rhodopsin is a light sensitive chemical substance found in the rods of the retina, it is beached when exposed to light and is resynthesized in the dark. This change in the colour of the retinal pigment is due to a photochemical process resulting from a photophysical change arising from optical interference effects produced by the well-known layered platelets at the end of the rods.



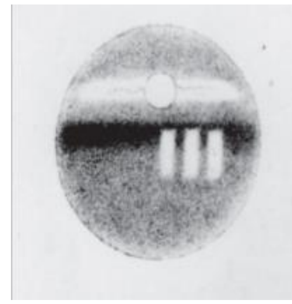
Not soon after the finding, German physiologist Wilhelm Kühne started studying the pigment and in his first paper on retinal chemistry Kühne said, "bound together with the pigment epithelium, the retina behaves mot merely like a photographic plate, but like an entire photographic workshop, in which the workman continually renews the plate by laying on new light sensitive material, while simultaneously erasing the old image." After many failures in trying to take a picture with the living eye he created the process of preserving the details of the retina temporarily using chemical fixatives. He named his technique "optography".

Wilhelm Kühne

Optography is the process of developing the retinas last images, the process results in an "optogram". Bright areas on optograms correspond to where the rhodopsin has been bleached by light, whereas dark areas show where the rhodopsin is still intact, therefore instead of producing a negative like in photography, optography develops a positive. To be clear, no optogram actually still exists – only drawings or pictures of them, because not only are they very hard to capture but it is unclear if it is possible to permanently "secure" the image given the equipment in the 19th and 20th centuries, especially if it isn't even known if it is possible today. The first optograms ever developed were done by Kühne and were acquired in this way:



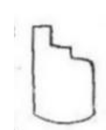
Drawings of the optograms developed by Kühne.



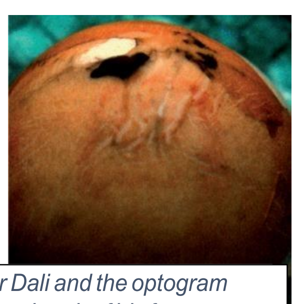
The cross- work of the window panes is sharply depicted.

A rabbit was restrained so only one eye could see the opening in a window shutter, with a gap of $30\ cm^2$ and with the rabbit's eye at 5.5 metres away from the window. The head of the rabbit was covered with a dark cloth for five minutes so that the rhodopsin was as sensitive as possible, then the rabbit's eye was exposed to the window light for three minutes, after which his head was instantly cut off and the eye removed in a dark room. The retina was extracted and placed in a five percent solution of potassium alum. The second eye, which had been kept in the dark throughout the foregoing operation, was then exposed to the window light two minutes after death for the same duration as the living eye. The retina of the second eye was then extracted and placed in an alum solution. Both retinae were kept in alum for twenty-four hours and then examined.

In the entire history of optography, only one human optogram has ever been recorded. In 1880, a 31-year-old man was executed in Bruchsal, Germany. For Kühne and his team this was an opportunity to apply their knowledge and experience to a human being. Immediately after the guillotine blade had dropped the eye was dissected in a lab and an optogram developed. The result confused the scientists as it resembled the guillotine blade, which would've made sense however the man's head could not have possibly seen it as it came down on his head because he was facing the other way. Scientists eventually decided it was the side view of the steps the man had climbed leading up to where the execution would take place.

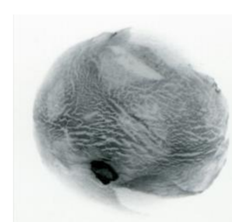


A drawing of 'the human optogram'.



A picture of Salvador Dali and the optogram produced from a sketch of his face.

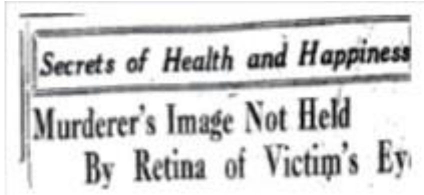
By the end of the 20^{th} century, other scholars were also able to develop optograms on animal retinas. Prof. Dr. Med. Evangelos did an experiment in 1975 like Kühne's using rabbits. For the experiment a portrait of Salvador Dalí as pattern that had been drawn with a black 1.5mm pencil on white paper was used and a coloured photograph of the optogram was taken.



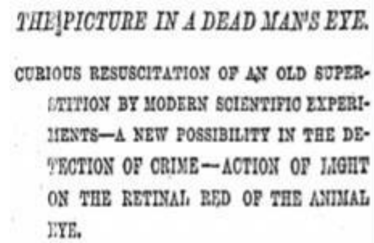
A checkboard pattern optogram Dr. Evangelos did as well.


Science Says Eye
Won't Photograph
Faces Perfectly

The Greeley Daily Tribune, Colorado, June 14th 1932.


Secrets of Health and Happiness
Murderer's Image Not Held
By Retina of Victim's Ey

1The Bridgeport Telegram, September 8th 1920.


THE PICTURE IN A DEAD MAN'S EYE.
CURIOUS RESUSCITATION OF AN OLD SUPERSTITION BY MODERN SCIENTIFIC EXPERIMENTS—A NEW POSSIBILITY IN THE DETECTION OF CRIME—ACTION OF LIGHT ON THE RETINAL RED OF THE ANIMAL EYE.

The New York Times, March 18th 1878.

Though optograms seem interesting experiment with, they are infamously difficult to create, even without the ethical restraints. Published in 1877, in his first long report Kühne willingly admitted that optography portrayed a very unpredictable experimental situation in spite of its potential for objectivity. Not regarding Kühne's warnings, police departments would constantly try and implement optography into their murder investigations, in fact serial killers would often remove their victims' eyes in fear of being caught, of course even if their eyes had remained in their sockets there would be no way an optogram of the killers' face could have been produced, because for that to be possible not only would the victims eye have to be removed immediately after death, but the murder itself would have to be in a very controlled manner in a laboratory setting. I don't know about you, but I've never heard of a murderer so intent on getting caught they decided to make sure people could create an *optogram* from their victim's eyes.

As of right now, optography has no use – it is an obsolete science, maybe as technology develops it may make a comeback, either being developed futher to help with forensic cases or applied to other fields, however it is still present in art and pop culture, even being mentioned in two 'Doctor Who' episodes, one in 1975 and the other in 2013, as well as in the 1999 film 'Wild Wild West' among others. It also featured in Rudyard Kipling's 1891 short story, 'At the End of the Passage' – but in literature and on screen optograms are portrayed in more of a metaphysical or ficticous sense instead of scientific. A place that does stay true to the science behind optography while combining art and history is Derek Ogbourne's Museum of Optography, the Purple Chamber which explores every nook and cranny I may have missed here.

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Recycling Plastics Using Sunlight

Wen Qi Saw, 13S1

Since 1950, over 8 billion tons of plastic have been produced, with approximately one million plastic bottles being purchased worldwide every minute.

Plastics are arguably one of the most useful materials around, due to their low cost and versatile properties, but their disposal has long been a challenge. Since 1950, over 8 billion tons of plastic have been produced, with approximately one million plastic bottles being purchased worldwide every minute. With so much plastic, it is hardly surprising that plastic pollution, in the ocean and on land, is becoming an increasing problem. And although recycling is becoming more widespread, a third of all plastic is considered too small or complex to recover economically. As such, new methods for reusing these plastics are desperately needed. A novel approach to this problem is solar-driven *reforming*, which converts waste plastic into hydrogen fuel, requiring only sunlight and a suitable photocatalyst.

Over 50 million tons of hydrogen (H_2) are produced annually worldwide for use in various industries and is also a promising renewable energy carrier. However, most H_2 is currently being generated via steam reforming of fossil fuels and although the thermal decomposition of waste plastics has been proposed as an alternative, it still requires significant energy input (500-800°C) and releases greenhouse gases (approximately 12kg CO_2 gas per 1kg H_2)

In comparison, photoreforming seems simple, requiring just 4 components - a photocatalyst, a plastic, sunlight and water - to generate H_2 at ambient pressure and temperature. UK scientists Moritz Kuehnel, Erwin Reisner and colleagues devised a method using cadmium sulfide (CdS) *quantum dots* as photocatalysts to reform plastics. The photocatalyst is dropped onto the plastic and the plastic is placed in aqueous NaOH.

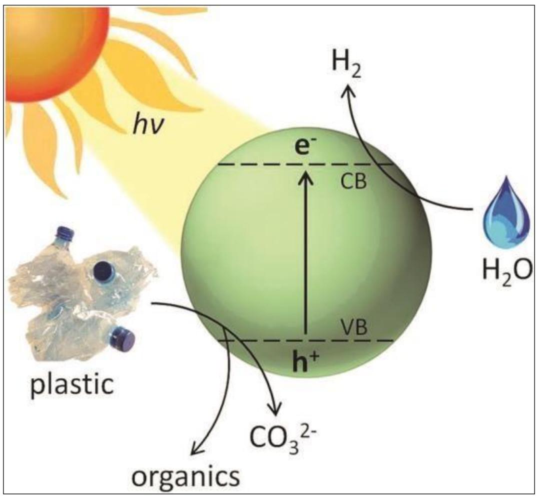
The CdS quantum dots form a thin Cd oxide/hydroxide shell (CdO_x) that prevents photocorrosion; irradiation with sunlight reduced the water to H_2 whilst the plastic polymers simultaneously oxidized to organic compounds. A variety of polymers were tested but polylactic acid (PLA), polyethylene terephthalate (PET) and polyurethane (PUR) produced more H_2 and were therefore selected for further study.

PLA is a biodegradable polymer used for biomedical purposes, 3D printing and environmentally-friendly packaging. Being a potential substitute for PET and polystyrene, it should ideally be utilised at the end of its life cycle rather than merely degraded.

PET accounts for 9% of global plastic production and is used in packaging. While it can be recycled, the resulting material is often not used due to its inferior properties. Other methods, such as using PET-degrading enzymes, are viable but do not produce any useful products.

PUR is found in insulation and vehicle components and is fairly challenging to recycle.

In a typical experiment, the polymers were ground to powders and suspended in 10M aqueous NaOH in the presence of CdS/CdO_x quantum dots in atmospheric pressure and exposed to simulated solar light at 25°C. Hydrogen was only produced when both quantum dots and light were present and photoreforming proceeded efficiently without UV irradiation, suggesting that the catalyst uses visible light. Previously, photoreforming of plastics was limited to using Pt/TiO_2 (platinum/titanium oxide), producing significantly lower yields of H_2 and CO_2. Not only was this method expensive due to its catalyst, it also relied on UV radiation.



To further enhance activity, a pre-treatment was developed: stirring the substrate in 10M aqueous NaOH at 40ºC in the dark, followed by *centrifugation* and using only the *supernatant* as the photocatalysis substrate. Under optimized conditions, pre-treatment improved photoreforming activity by four times for both PET and PUR. The pre-treatment initiated *hydrolysis*, releasing monomers into solution and allowing them to be more rapidly photoreformed. The removal of the undissolved polymer by centrifugation reduces the absorbance and scattering of the solution, allowing more photons to reach the quantum dots and therefore improve efficiency. As such, when there is no centrifugation, photoreforming performance is not enhanced as much. The pre-treatment facilitates photoreforming of complex polymers to H_2 and is only possible because CdS/CdO_x quantum dots can operate under highly alkaline conditions.

Future work on photoreforming will improve this system by identifying alternative catalysts and methods for further enhancing activities.

By controlling oxidation, high-value organic products can be generated instead of CO_2, which further makes it more economical to recycle the plastics via photoreforming. However, less than 40% of all polymers are converted into organic products and many of these undergo slow photo-reforming and remain in solution. This lowers H_2 production, but the discharge of a greenhouse gas (CO_2) is prevented and allows for the accumulation of high-value products.

Photoreforming has also been successful for a PET water bottle - it was crucial to test real plastic samples as these often contain additional chemicals that could make photoreforming more challenging.

Despite the difficulty of recycling plastics, photoreforming utilizes this resource to generate valuable hydrogen gas and organics and is a technique that both addresses the global challenge of plastic pollution and implementing renewable H_2 generation. Future work on photoreforming will improve this system by identifying alternative catalysts and methods for further enhancing activities.

Glossary

Reforming - a processing technique by which the molecular structure of a hydrocarbon is rearranged to alter its properties

Quantum dots - nanoparticles made of any semiconductor material

Centrifugation - a technique used for the separation of particles from a solution according to their size, shape, density, viscosity of the medium and rotor speed. The particles are suspended in a liquid medium and placed in a tube, which is placed in a rotor and spun at a defined speed.

Supernatant - the liquid lying above a solid residue after centrifugation

Hydrolysis - the breakdown of a chemical compound due to a reaction with water

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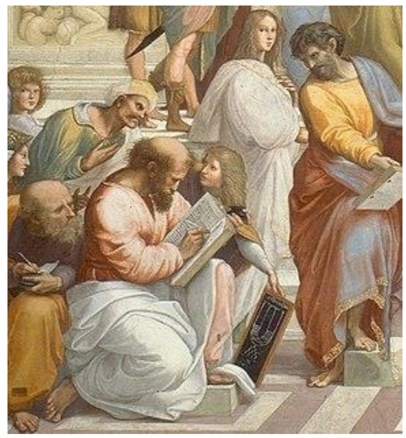
Inherently fascinating - A brief history of the governing discoveries in genetics

Daniel Rodrigues, 11S2

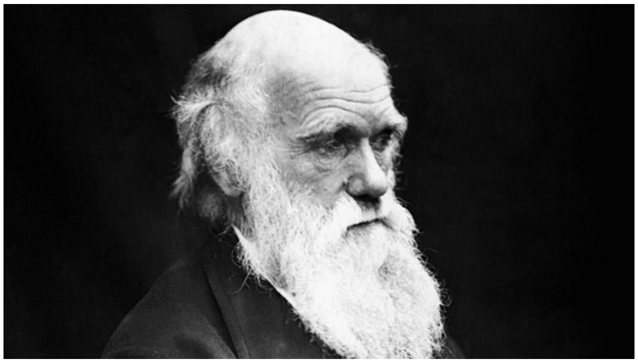
Theories on genetics have undergone a long and confusing journey over several millennia, and many people have contributed to the progress (and the associated confusion) in this field. This article describes the development of the idea of genetics, focusing on the four most significant findings, those of Pythagoras, Aristotle, Darwin and Mendel.



Our story starts in 530 BC in ancient Greece. Perhaps known better for his contribution to mathematics than that to heredity, the ideology of philosopher, Pythagoras, is where we start. Pythagoras noticed a likeness between parents and offspring which led him to believe that information must somehow be transferred down generations. This started him questioning the mechanism of the transfer and where the information came from. He explained, in quite a misogynistic way, that information came only from the father. The information was absorbed by a 'mystic vapour' which was transferred to the mother during intercourse. This information contained the most important instructions for developing the foetus. The mother, he said, only provided the nutrition for the foetus to grow. The theory was not without its (many) flaws, but it certainly represented the birth of genetics.

Of course, the question of inheritance and likeness remained pertinent even after Pythagoras' death and it took the mind of Aristotle to unravel a new solution. Aristotle realised that a child does not inherit features only from the father, but from the mother, grandmother and grandfather too. Aristotle also discovered that features can skip generations. A grandmother might have blue eyes, but her immediate offspring does not, and the feature reappears in her grandchild. Aristotle was able to conclude that both parents contributed in some way to the characteristics and development of the child. Aristotle's theory of inheritance was the one which laid the foundation for the many future theories.

Our next stop is a cold, winter morning in 1831. Seventy-three men set out on a voyage around South America, a voyage which effectively changed the world of science. Among the men was naturalist Charles Darwin, whose mission it was to collect specimens of rocks, fossils, plants and animals. One of the places where the ship docked on its journey was, of course, the Galapagos



Islands. There, Darwin busied himself collecting a variety samples to be analyzed. On returning to England and having the analysis done, Darwin found that the 'variety' of samples wasn't much of a variety at all. Many of the specimens he collected were actually the same except with slight variations. One such example was the 13 variations of finches, each with a slightly different adaptation based on the island they came from. This made Darwin question the process by which this variety was started, and therein lay the dawn of the Theory of Evolution.

Cut to the present day. The Galapagos Islands are home to a huge variety of species and variations. But rewind 2 million years and the place was quite ordinary. It started with an ordinary ancestral finch. As food sources dwindled across the islands, finding an alternative was a necessity. A mutation of genes creates an abnormal finch 'freak', different from the others. The key difference: its beak. Unlike the others, the freak finch could eat nuts, fruit and insects. While others scavenged for food, our freak thrived, not needing to worry about its next meal. Evolution, the hand that brought change and death now becomes the grim mediator of survival. On each island, there was a different kind of finch, one which best suited that island's environment "Each variety was constant in its own Island". By reproducing, this abnormality was passed onto offspring, resulting in the adapted finch becoming common and eventually the norm. This never-ending process became the fuel of Darwin's never-ending cycle of evolution. Yet one major question was left unanswered by Darwin, the mechanism of heredity

The mystery was solved in a monastery in Brünn. It took hours in the fields for Gregor Johann Mendel from 1856 to 1863, cross-pollinating peas, to finally understanding the genetic process. During his time spent planting the peas, he recognised 7 major traits of all the pea plants; colour of the seed, pod and flower, texture of the seed, position of the flower, shape of the pod and the height of the plant. Mendel bred a purebred plant with another pure-bred plant, for example a tall plant with a short plant. He found that the first generation had no blending of genes. A tall plant bred with a small plant produced a tall plant, it didn't become medium sized. The 'tall' allele was termed, therefore, as dominant whereas the trait which disappeared, he called recessive. His experiments did not stop there. He then bred two short-tall hybrids with each other. He found, to his astonishment, the short plants reappeared. This led Mendel to believe that the recessive allele didn't just disappear when the plant bred, but instead became part of a composite of the dominant allele which was visible and the recessive allele which was not. If two recessive short alleles come together, it would result in a short plant. In short, Mendel had discovered the final piece of the puzzle, the gene.

And this concludes the first chapter in the story of the gene, a story that is still in its infancy. Each generation of scientists will undoubtedly write new and interesting chapters in this tome and this field of study will stay relevant for many more millennia. Genetics is indeed inherently fascinating!

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Ghostbusters: A look at neutrinos, *The ghost of physics*

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There is something out there, which has remained elusive to Scientists for many years, with behaviour that we find difficult to explain. They pass through walls, can barely be seen without special equipment, and are very rarely found. Not to mention, they seem to teleport; faster than the speed of light, and might have no mass. I'm not talking about any spooky ghosts, but rather neutrinos, commonly denoted by the Greek letter □ (nu). You may have heard of the 'God Particle', the Higgs boson, found in 2015. Well, for its aforementioned behaviour, neutrinos have been dubbed 'ghost particles'. They barely interact with any matter at all, travelling at speeds close to that of light, making them incredibly difficult to detect at all. "Wait, didn't you say that they travel faster than the speed of light?" you might ask. Good catch, reader.

Faster than light?

There was a report by a group of particle physicists back in 2011, claiming that they had attained results of neutrinos that travelled faster than the speed of light. This breaks physics in many fundamental ways, so it created a huge buzz in the scientific community. Ultimately, though, it was found that the reading was faulty – due to a simple loose cable causing a timing error. Always check your equipment, kids. That claim is not fully wrong, though, since neutrinos do travel faster than light in certain other cases. You may recall me saying that neutrinos barely interact with matter. That means that unlike light, which may be absorbed and emitted repeatedly in a material - for example, water – neutrinos can just pass straight through. I like to compare it to a track and field race. On a straight track, light is faster. But when it comes to hurdles, neutrinos just run in an empty lane. This is due to them interacting only with the weak force (and gravity), since they are uncharged.

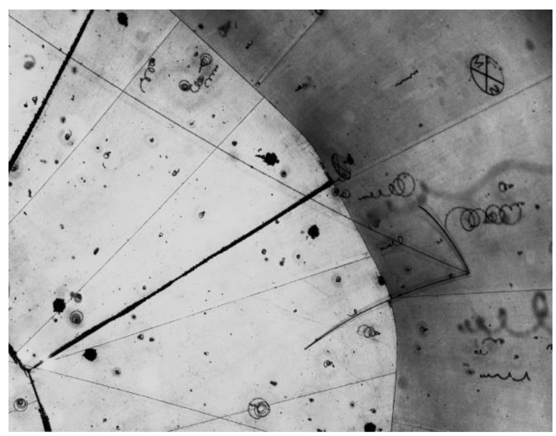


Fig.1: The Neutrino Event, 1970

A haunting problem

Another question then arises. If neutrinos barely interact with anything, how do we know that they're even there? Excellent question, reader. It can be likened to the saying "If a tree falls in a forest and no one is around to hear it, does it make a sound?". Actually, we now know there are about 600 trillion neutrinos passing through you right now; 65 billion per cm^2 every second on Earth from the sun and you don't notice a single one. After the idea of a neutrino was suggested in 1931 by Wolfgang Pauli, a new challenge was presented to physicists. How would one detect the undetectable, how do you find the unfindable, how do you catch a so-called ghost? You see, neutrinos are produced during high energy reactions: nuclear bombs, particle accelerators, fusion in stars etc. While we could attempt to detect those from the sun, there is a large amount of interference due to cosmic rays.

The art of ghostbusting

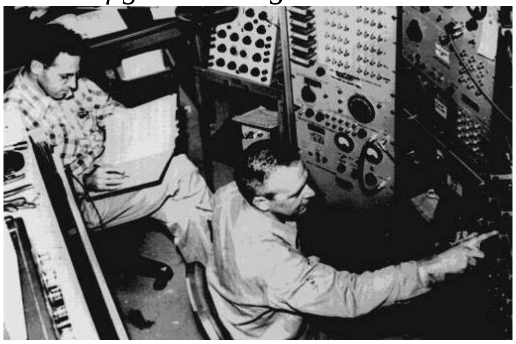


Fig.2: Cowan (right) and Reines (left)

It ended up taking another 25 years until the first neutrino was detected, by Clyde L. Cowan and Frederick Reines in 1956, who won the Nobel Prize in Physics in 1995 for their discovery. They used an interesting setup – using neutrinos directly from a nuclear reactor. The detector itself was surprisingly straightforward, albeit 12m underground. It used a huge tank of water and just waited for a neutrino to react with protons in the water; that would then produce a neutron and positron, then the positron would annihilate an electron in the water, releasing energy as gamma rays. We can then detect those gamma rays to check for a reading. Its surprisingly simple to replicate at home, all you need is a tank of water (and a nuclear reactor). The thing is, they didn't consider the first experiment conclusive enough, so they added about 40kg of cadmium chloride to 200 liters of water – cadmium chloride gives off a gamma ray when it absorbs a neutron, and it should occur 5ms after the first ray from the positron. They even shut off the reactor to make sure they didn't get detections without any neutrinos being present. Today, many other detectors - often referred to as neutrino telescopes - are still up and running, like SNOLAB in Canada, IceCube at the South Pole, and Super Kamiokande in Japan; they help shed a little light on these tiny ghosts. Kind of like Buzzfeed Unsolved. That being said, the more we get to know about them, the less they start making sense. Even more so like Buzzfeed Unsolved.

Pick a flavour

We have slowly gotten to know more and more about neutrinos, and with each revelation comes a myriad of new questions. For example, there are different 'flavours' of neutrino, and they can swap between these flavours at random in a process known as oscillation. We found this out when we tried observing the quantity of electron neutrinos (one of the flavours) from the Sun, and our numbers were way off – despite most of these experiments yielding consistent results for the past 3 decades. For finding this, 2 scientists from SNOLAB and Super-Kamiokande won the 2015 Nobel Prize. While they were previously thought to have no mass, neutrino oscillation proved that, while incredibly small, they do indeed have a mass. Recently, a fourth flavour – the 'sterile' neutrino – has been reported, but results are not yet conclusive. The process of switching between flavours doesn't look the same forwards and backwards in time, breaking another 'rule' of physics called time symmetry – and also has broken the other 2 fundamental symmetries in another experiment. Looking deeper into neutrinos has had some interesting consequences for science, and even geography.

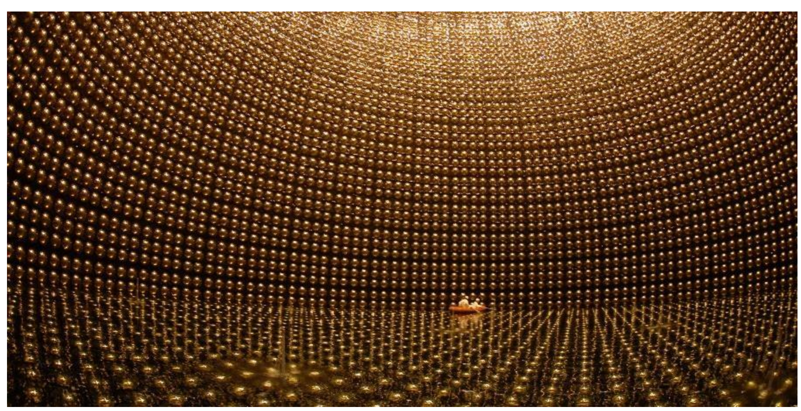
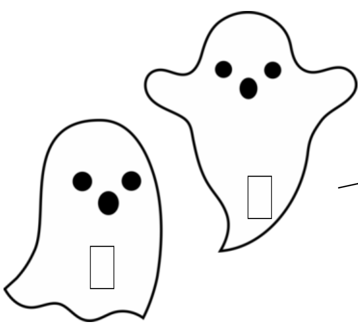


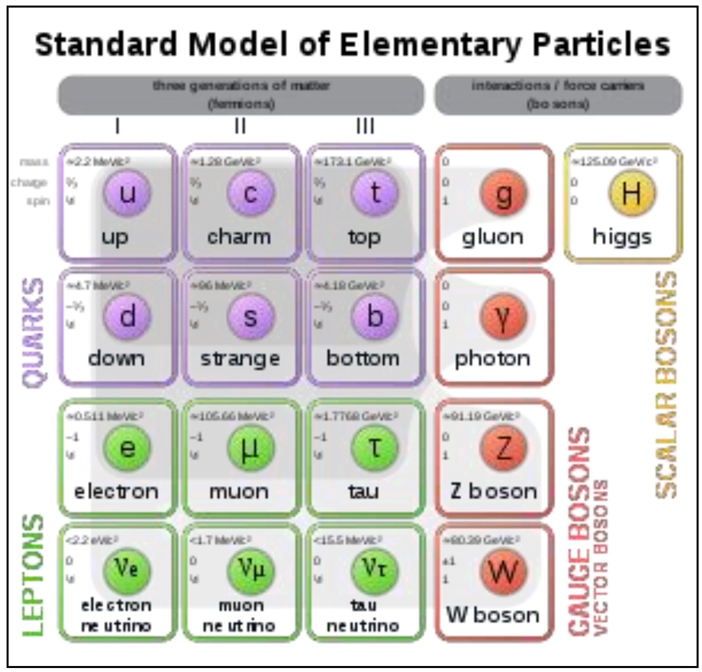
Fig.3: The Super-Kamiokande Detector

The Friendly Ghost

Since we know a lot about how neutrinos behave (relative to people who do not know about how neutrinos behave), we can find about other structures and materials from detecting neutrinos that pass through them. Earth is a pretty good example for this; researchers at the IceCube detector - mentioned earlier - were able to measure the Earth's mass using neutrinos for the first time in 2018 by looking at the magnitude of neutrinos at different angles around the South Pole. While it did not reveal anything particularly new, one might be able to find mineral and oil deposits through these type of scans with neutrinos. Another thing to note is that since they rarely interact, they can travel incredibly long distances, letting us know about cosmic events many lightyears away without being interfered with, unlike electromagnetic telescope methods. They may even provide an insight into why the universe is as it is, with more matter than antimatter and could help detect dark matter.

The field of neutrino research is very volatile, much like neutrinos themselves. Constantly changing, with every new discovery taking us in another direction. In fact, it is one of the only things to challenge the Standard Model in over 20 years (which had assumed neutrinos were massless). They could one day prove to be key in understanding the secrets of our universe, but for now they will remain as tiny little ghosts, popping out of stars and nuclear bombs. In its own way, it's almost poetic.





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Quantum Physics

Rayaan Malik (11F1) and Anurada Walatara (11G1)

Quantum physics is a branch of physics that deals with things that are very, very small, and which are on the level of the atom and smaller. Many of the phenomenon that occur at this very tiny level are highly non-intuitive and make absolutely no sense, even to the smartest of scientists. Quite simply, there are things that happen on the level of the atom which sound like they belong in science fiction, and not in the real world. But experiments have repeatedly proven that these things do actually happen. In this article we explore four fundamental Quantum phenomenon that occur in our everyday lives without us even knowing. We write about Quantum Entanglement, Superposition, Particle-Wave Duality, and Quantum Tunneling. But don't be worried of these complex sounding words as we have simplified the 'Crazy complex' physics so that even a Quantum armature will understand. So, let's begin.

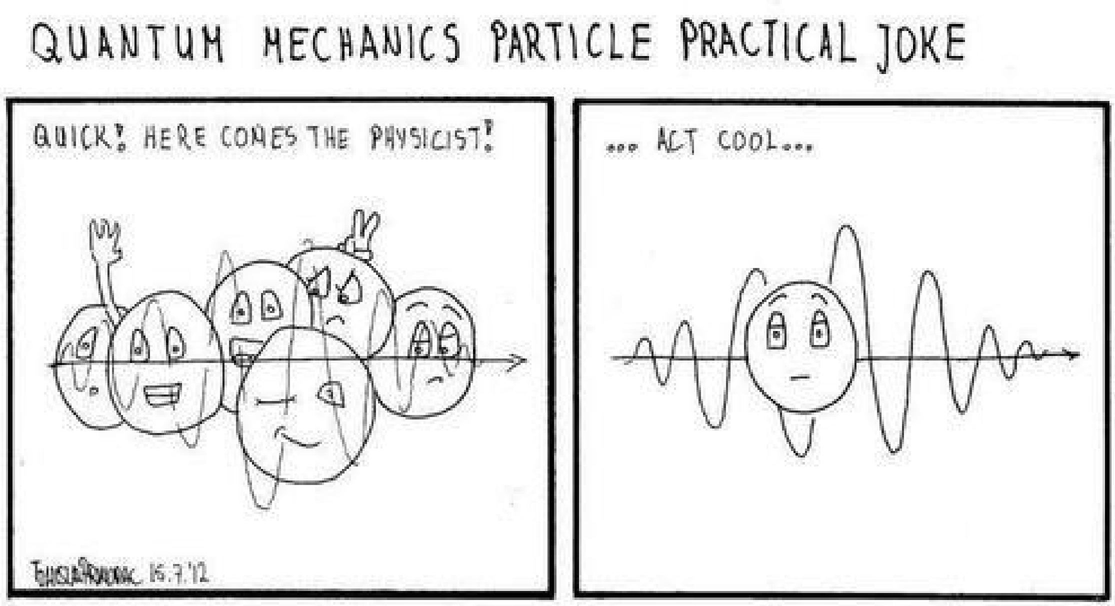
Particle-Wave Duality

Scientific Explanation

In Physics and Chemistry, wave–particle duality is the concept that all matter exhibits both wave-like and particle-like properties - For example, light is a wave because it shows wave like characters such as interference (which is a phenomenon central to waves only). However, it was later shown through some other experiments (photoelectric effect explanation by Einstein) that particles of waves collide with metal surface and eject electrons from them.

Simplified Example

Imagine dropping a ball into a pond. The ball will fall and when it touches the water will disappear. Simultaneously however ripples emerge from the spot at which the ball touched the water. The ripples then spread out until one of the ripples touches a stick floating in the water. Immediately when this happens all the ripples stop, and the ball comes out of the stick back into the air. This is particle-wave duality. As the particle is both a particle (a ball) and a wave (a ripple) and exhibits properties of both.



Quantum Entanglement

Scientific Explanation

Quantum entanglement is a property of quantum mechanics that states that two particles or things in a sense are forever connected because they share information in a way that has to preserve the conservation of mass, energy, momentum or other laws. This can be polarized light where two resulting photons have horizontal and vertical polarization and are connected to each other because light has horizontal and vertical planes. The debated part is that affecting one particle in quantum entanglement will change the other instantly, faster than the speed of light. Quantum entanglement can occur when two particles share information through position, energy, polarization, spin, charge etc.

Simplified Example

Imagine two friends Alice and Bob. They both have two balls Red and Green. Now, Alice goes to planet Mars and Bob goes to planet Pluto. Both are many light-years away from each other. Now, Alice is allowed to pick any one ball from her pocket. She chooses one and gets Red. Now, when Bob was allowed to pick any one ball from his pocket, he will always pick Green. He will always and without error will always pick Green if Alice chooses Red. If Alice chooses Green, then Bob will pick Red. It is confirmed that what Alice picks, Bob will always pick different color. In this sense, we can explain that Red and Green both are Quantum Entangled. This means they both are originated from the same source. As soon as we do a measurement on one, it directly affects the measurement of other.

It is assumed that information exchange travels faster than the speed of light. Einstein called it spooky action at a distance. It all depends upon the measurement. Before measurement, Alice had the same probability to choose Red and Green and so had Bob. But Alice caused disturbance after the measurement, and this caused the state to collapse to any one and this affected the state of the other too.

Quantum Entanglement real life examples:

Scientists are trying to use quantum entanglement for many different things. Some things are sending completely secret messages (passing notes that can't be intercepted), and making computers faster than ever before thought possible. However, entanglement between a pair of particles is a very delicate thing and is easily destroyed. Because of this, it is difficult to use quantum entanglement to do these things. Currently, many scientists are working on making stronger

Superposition

Scientific

Superposition is a principle of quantum theory that describes a concept about the nature & behavior of matter and forces at the atomic level. The principle of superposition claims that while we do not know what the state of any object is, it is actually in all possible states simultaneously, as long as we don't look to check. It is the measurement itself that causes the object to be limited to a single state.

Simplified Example

In 1935, Erwin Schrodinger proposed an analogy to show how superposition would operate in the everyday world: the somewhat cruel analogy of Schrodinger's cat. First, we have a living cat and place it in a thick lead box. At this stage, there is no question that the cat is alive. We then throw in a vial of cyanide and seal the box. We do not know if the cat is alive or if it has broken the cyanide capsule and died. Since we do not know, the cat is both dead and alive, according to quantum law - in a superposition of states. It is only when we break open the box and see what condition the cat is that the superposition is lost, and the cat must be either alive or dead. We use superposition in MRI scans.

<u>Quantum Tunneling</u>

Scientific Explanation

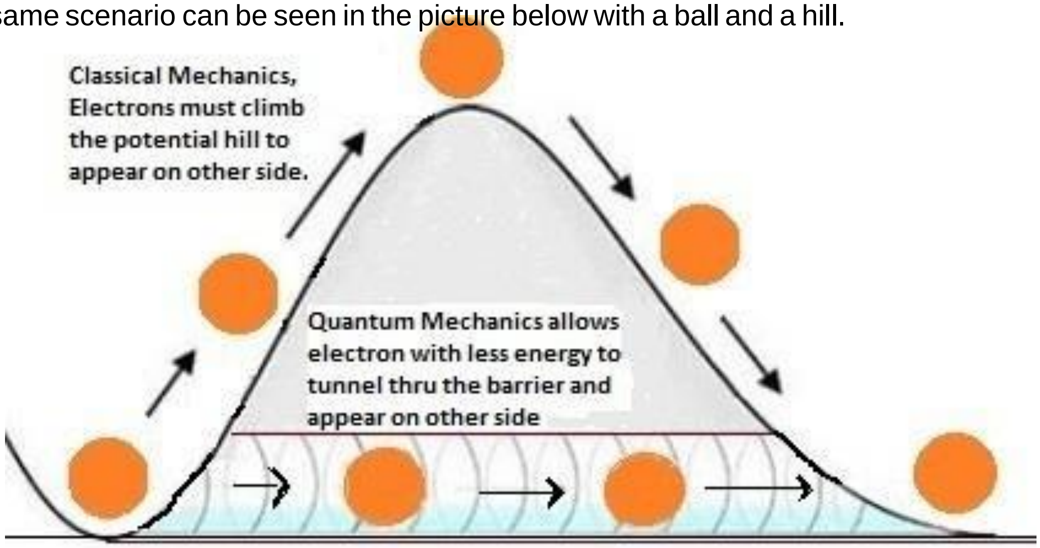
The quantum tunneling effect is, as the name suggests, a quantum phenomenon which occurs when particles move through a barrier that should be impossible to move through according to classical physics. The barrier can be a physically impassable medium, like an insulator or a vacuum, or it can be a region of high potential energy.

In classical mechanics, if a particle has insufficient energy to overcome a potential barrier, it simply won't. In the quantum world, however, particles can often behave like waves. On encountering a barrier, a quantum wave will not end abruptly - its amplitude will decrease exponentially. This drop-in amplitude corresponds to a drop-in probability of finding a particle as you look further into the barrier. If the barrier is thin enough, the amplitude may be non-zero on the other side, so there is a finite probability that some of the particles will tunnel through the barrier.

(Souter, W. (2012, May 15) An Introduction to Quantum Tunneling, Retrieved from https://www.azoquantum.com/)

Simplified Example

To simplify this, imagine a subatomic particle as bouncy ball. If you were to throw the bouncy ball at the wall you would expect it to bounce back. This bounce ball would therefore follow the rules of classical physics as will be unable to have enough energy to pass through the physical barrier of the wall. However, at a quantum level the bouncy ball has small probability of passing straight through the wall and into the other room without interfering with the wall itself. This is due to particle-wave duality which means the ball would turn into a wave and changes if amplitude in order to go through to the other side. But this can only happen if the wall is thin enough for the probability of the ball passing through the wall is not zero. The same scenario can be seen in the picture below with a ball and a hill.



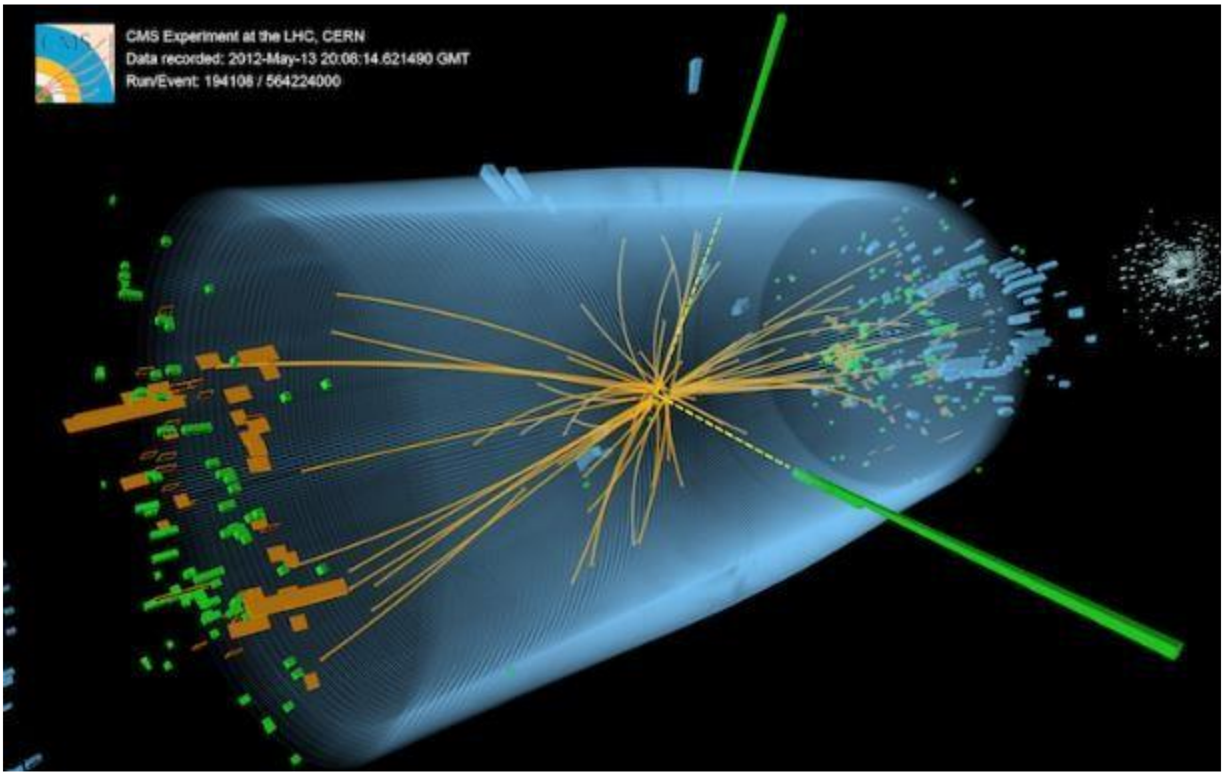
Quantum Tunneling real life examples:

Fusion is the process by which small nuclei can join together to form larger nuclei, releasing huge amounts of energy. Fusion inside stars produces all the elements of the periodic table, except hydrogen, and fusion of hydrogen into helium is the process which gives stars their power. However, fusion happens much more often than we originally thought it should. As all nuclei are positively charged, they repel each other very strongly, and their kinetic energy is very rarely sufficient to overcome this repulsion and allow fusion to occur. If tunneling effects are taken into account, however, the proportion of hydrogen nuclei which are able to undergo fusion increases dramatically. This helps to explain how stars are able to remain stable for millions of years.

The ‘God’ Particle

Harry Tarr, 12G1

Throughout the 1950s, in the ongoing search for a grand unified theory of physics, a common problem emerged from several promising theories. Gauge bosons (the fundamental particles that carry forces between particles), which were always considered to be massless due to their nature as force carriers, appeared to have a small amount of mass which could not be explained.



Graphic showing the collision between two protons that produced a Higgs Boson

The Higgs Boson was the theoretical solution to this unexpected mass described by Peter Higgs in the 1960s. In 2012 it was found experimentally at the Large Hadron Collider (LHC) proton collider in Switzerland. It is a high energy manifestation of an excited Higgs Field - a field that essentially causes particles to have mass as it prevents them from travelling at the speed of light.

Ever since its theorisation by British Physicist Peter Higgs in 1966, the Higgs Boson has developed a large amount of excitement in popular as it was seen as being a large step towards a potential theory of everything. One extremely popular nickname for it is the ‘God Particle’, made famous by the book *The God Particle: If the Universe Is the Answer, What Is the Question?* written by American Nobel Prize winner Leon Lederman in 1993. Lederman at the time was attempting to draw awareness to the Higgs Boson and an experimental discovery of it through the use of a particle accelerator. The same year the US government had pulled its funding for an American super collider that could rival the European Large Hadron Collider (LHC). The use of the nickname was promoted by widespread media, many scientists believe that the 'God Particle' is extremely misleading as a potential experimental discovery would not be significant enough for it to be regarded as God-like.

On 4 July 2012, CERN (European Organisation for Nuclear Research) announced that experiments conducted with the LHC had resulted in the discovery of the Higgs Boson, 48 years after the original papers published by Peter Higgs theorising its existence. Whilst it may not have fulfilled its original title as a 'God Particle', the Higgs Boson has provided theoretical physicists with confidence that the original work of Peter Higgs was correctly not only mathematically but also a model that fits experimental observations. However I do not believe that most people will be disappointed in its failure to produce anti-gravity!