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Human 2.0?

Editing genes for better humans?

Artificial Neural networks

Black Hole Mergers

Metal Organic Frameworks

Teleportation

JUMEIRAH COLLEGE

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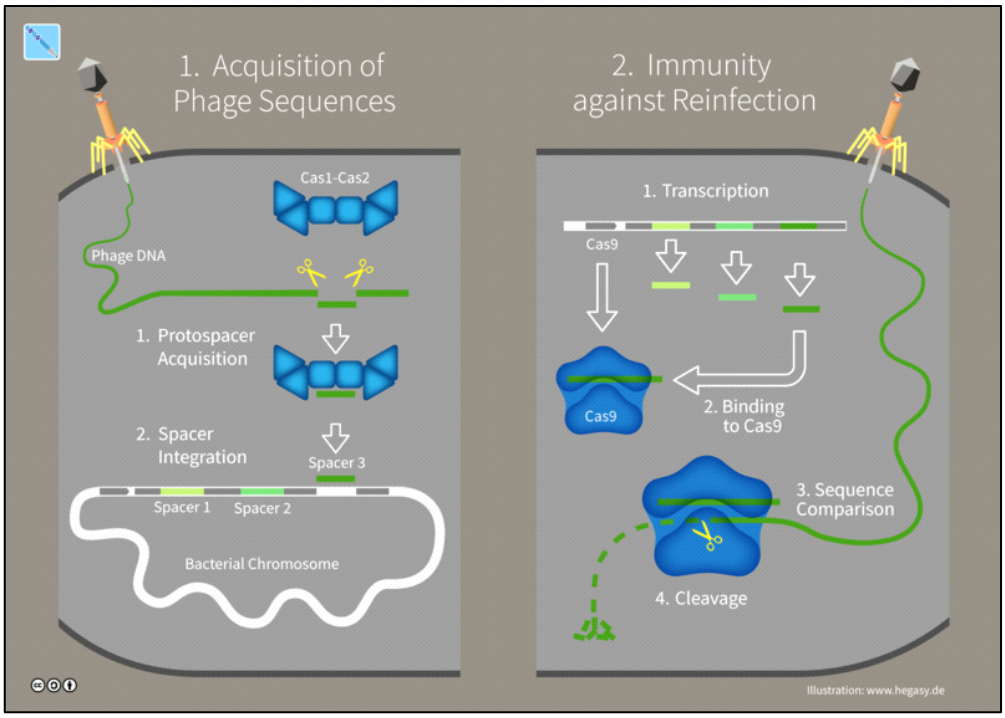
The mechanism behind gene editing

Keerthana Sharath, 13M2

Thirteen years ago the scientific community was considered to be at its pinnacle in biological innovation. Many thought all to be invented existed. However science never sleeps and progress never stops. Today the community is all abuzz but for very different reasons, today we are one step closer to de-extinction. It is hard to believe that we got so far in a very short span of time and that can be accredited to a revolutionary piece of technology called CRISPR.

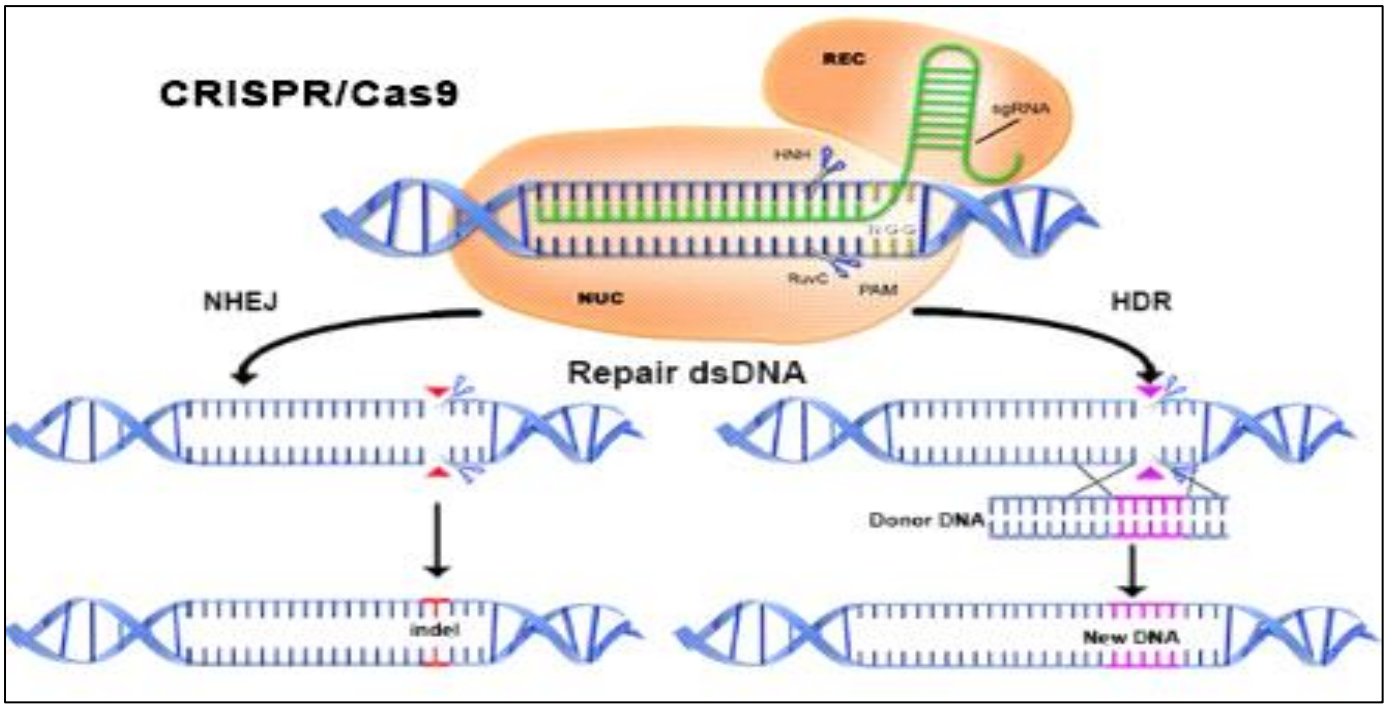
CRISPR is an acronym for Clustered Regularly Interspaced Short Palindromic Repeats. Essentially it is a prokaryotic defence system that was discovered by Francisco Mojica, a scientist at the University of Alicante in Spain. In bacteria CRISPR mechanisms are observed in a circular DNA strand called plasmid. Amidst the genetic code of the bacteria, spacer sequences that contain the genetic code of past invaders are present. For example, after a bacteria cell survives the attack of a virus specific bacteria remnants of the virus will occupy itself into the genetic code of the bacteria. What's really interesting is what happens next.



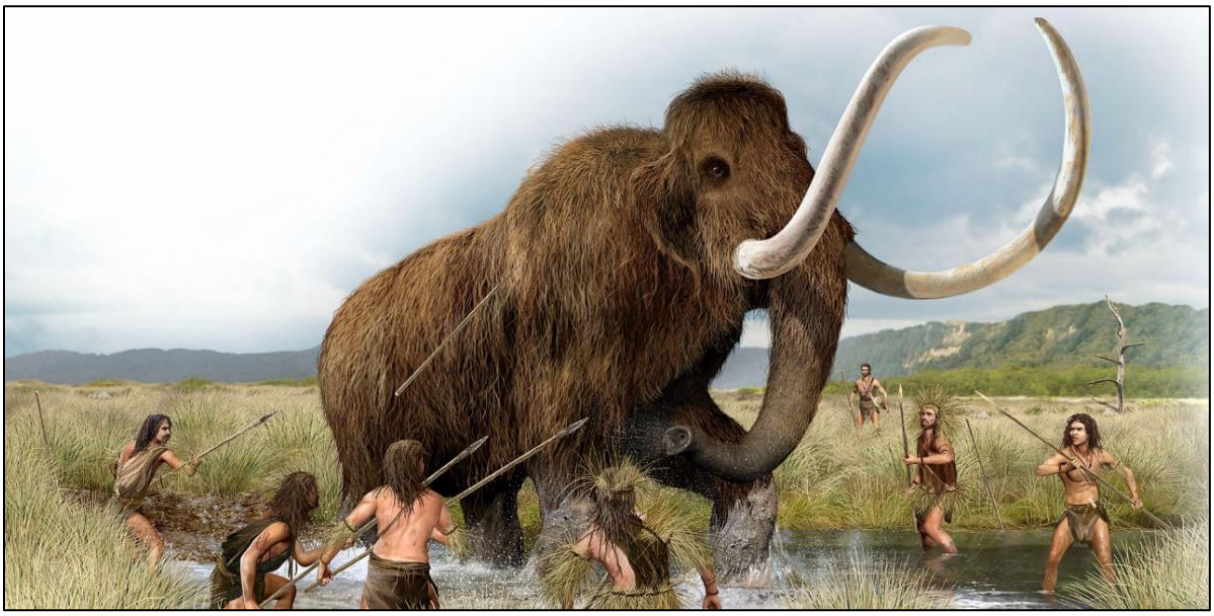
When the same virus strain invades the bacteria once again, the bacteria will transcribe the CRISPR DNA bases to form CRISPR RNA. This formation of CRISPR DNA will trigger the release of a protein called Cas9 and a guide RNA or gRNA, and bind to it. Think of Cas9 as a pair of scissors. If the CRISPR RNA matches the invading DNA, the Cas9 protein will cut up the invading DNA, successfully destroying the invader. It works like the secondary immune response we see in humans. This is how prokaryotes protect themselves against viruses. Scientists however saw an application to this mechanism; gene editing. CRISPR made the impossible dream of finding a financially feasible yet efficient way to edit genes a reality.

Scientists make their own CRISPR RNA base sequence and gRNA and Cas9 protein which will then be added it to nucleus of the cell, the complementary sections of the human/animal DNA will then match up with each other causing the Cas9 protein to cut out the complementary DNA section.

The section of DNA, now cut, will be deactivated as a 'loss of function' mutation will take its place. This way scientists are able to deactivated potentially harmful genes that code for cancer and muscular atrophy. This mechanism is commonly known as 'knocking out'.



Similarly, genes can be 'knocked in' by adding the gene as a form of base sequences into our mix, so instead of a 'loss of function' mutation taking the place of the cut, the added gene will take its place.



Coming back to roam the Earth?

Using this mechanism, we are able to input genes into species genomes similar to those of extinct species/genus essentially creating the extinct organism. A good example of this is the mammoth

There are far more mechanisms the prokaryotic immune system and CRISPR has to offer but so far only the mechanisms involving Cas9 proteins have undergone extensive research. This research just shows us that the possibilities are endless and impossible dreams may not be so impossible after all.

Your insight to oncology

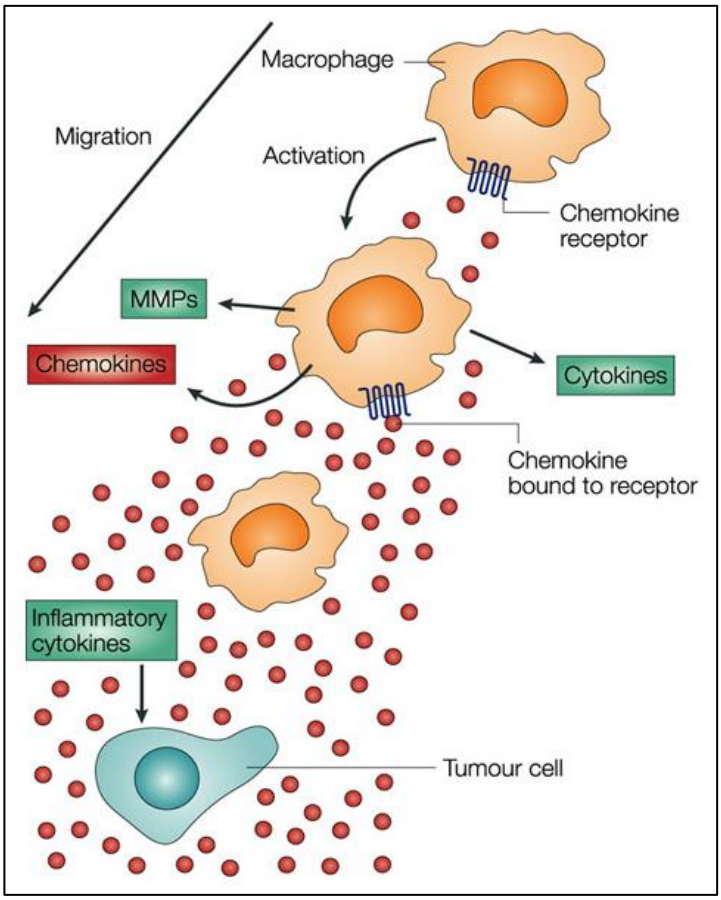
Arsh S Bhasin, 12M1

Brain metastases (also known as secondary brain tumors) are cancerous cells that have spread to the **brain** from primary tumors in alternative organs in the body.

Metastatic (the spreading of cancerous cells) brain tumors begin at a **primary site** in an organ of the body. Usually, carried in the **lymph system** (primary function of the lymphatic system is to transport lymph, a fluid containing infection-fighting white blood cells to all organs in the body) or bloodstream, cancerous cells are able to separate from the primary tumour (they are visible to through a procedure known as flow cytometry - which involves the use of a microscope).

These cancerous cells overcome the suppression of the immune system and often enter the lungs before migrating to the brain. Consequently, these cancerous cells work together forming a **mass of tissue, called a tumor.**

As a result of scientist's extensive research, studies show a correlation between the site of primary cancers and the transmission of cancerous cells to particular organs. (i.e. colon cancer tends to metastasize to the liver and the lung, whereas breast cancer tends to spread to regions of the lungs or the brain. This transmission of cancerous cells to specific locations are a result of small attractant molecules, known as **chemokines**, that pilot tumor cells to the metastatic site. In other instances, cancer cells may be able to adhere only to particular organs based upon adherent molecules expressed in a specific organ.



DIAGNOSIS

Following the patient's CT or MRI scan, a physician is able to identify the brain tumour (due to the availability of contrast dye). In addition, brain tumours can also be identified when the cancer patient undergoes new therapies (clinical trials) such as brain imaging (part of the procedure radiologic staging). In some cases, the site/central location of where the primary cancer began is not found ('unknown' primary site). However, metastatic brain tumor often contains identical cancer cells from the primary site. (e.i small-cell lung cancer

metastatic to the brain forms small-cell cancer in the brain, squamous-cell head and neck cancer forms squamous-cell cancer in the brain).

As a result of thorough examination from imaging procedures, a physician will be able to identify:

- Size and number of tumors
- Exact location of the tumor(s) within the brain or spinal cord
- Impact on neighboring organs

A physician can inform the patient of more conclusive/ accurate information around his/her cancer after a **biopsy** procedure (surgical procedure which involves the extraction of a small amount of tumor for diagnosis).

SYMPTOMS

- Headaches (most common symptom) - a result of the tumour itself twisting and buckling in the brain, also from swelling (edema) resulting from fluid leakage and squeezing of the brain or headaches can derive from bleeding from split blood vessels.
- Seizures (most common symptom) - Involves abnormal electrical activity in the brain caused by a hemorrhage (an escape of blood from a ruptured blood vessel) or a brain tumour. Fatigue or numbness in parts of the body (including the face, arms or legs)
- Memory loss
- Loss of control/balance/coordination.
- Loss of bladder or bowel control (called incontinence)

Quote of the week:

"Cancer didn't bring me to my knees it brought me to my feet" (Michael Douglas- oscar winning actor)

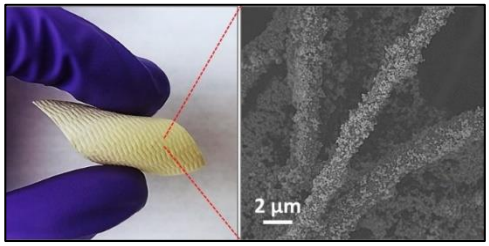
References: American Brain Tumour Association. URL: http://www.abta.org/secure/metastatic-brain-tumor.pdf, Date visited: 30 October 2017

Special Coating Able to Absorb Chemical Weapons?

Sita Williams, 12G1

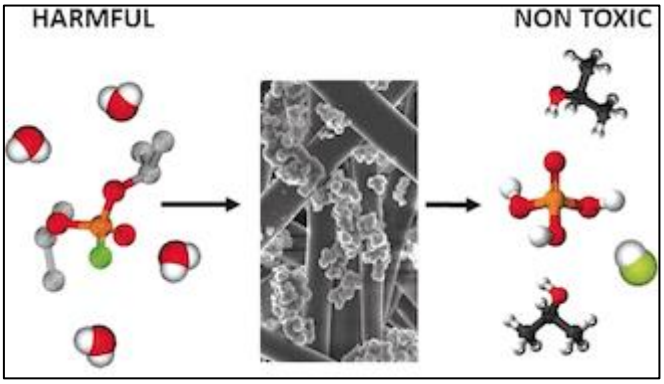
In April of this year, more than 80 people were killed in a chemical attack in a small town in Syria, due to the nerve agent ‘sarin’ being dropped as a chemical weapons bomb from an aircraft. Following this devastating recent chemical attack, scientists and chemical engineers have been working on ways to lessen the effects, should it happen again, by researching substances called MOFs, which would be able to coat clothes and neutralise these toxic materials, thus protecting soldiers and potentially even civilians from chemicals like sarin delivered through the skin.

MOFs or metal-organic frameworks are porous polymers composed of metal ions. The micropores, which are less than two nanometres wide, can trap and break down the chemical; the large surface area helps to absorb and neutralise the toxic material, as well as deactivating it.



However, putting it onto fabrics is proving quite a challenge; according to Greg Parsons, a chemical engineer at North Carolina State University, the MOF "doesn't want to stick to fibres that are typically used in clothing", as it is an un-sticky powder-like substance. To overcome this problem, they used the method of atomic layer deposition to adhere a thin layer of metal oxide onto the fabric (due to a chemical reaction that happens when the surface is exposed to tiny amounts of gases), which allows the MOFs to then stick to the metal oxide, thus sticking to the fabrics.

After treating the fabrics with the MOF, Parsons' team tested it by exposing it to sarin, the chemical used in the Syrian attacks, which is lethal even if a tiny droplet is exposed to your skin, as well as with DMNP (dimethyl-4-nitrophenyl phosphate), a substance with a very similar reactivity to sarin, and in both cases, the MOF was able to deactivate the toxic material in less than five minutes! This is a fantastic result, meaning MOFs should definitely be used in clothes for soldiers and people who live in areas where the likelihood of attacks like this is high.



A key 'ingredient' in many MOFs are carboxylic acids, an example is zirconium-based ones, however, producing MOFs is tedious, as it needs very high temperatures and long reaction times, and is also extremely expensive (so would not be able to help civilians in war-torn countries needing this type of protective clothing) and create a huge amount of waste in the making of them, so scientists in Belgium have been looking into how to produce them from waste plastic water bottles, which would not only be environmentally-friendly, but far cheaper. This is done by hydrolysing the PET (polyethylene terephthalate) found in plastic bottles, which forms the necessary carboxylic acids.

Researchers at Washington State University are also looking into other substances that can capture toxic chemicals such as recent developments in soy-based filters, however these would be used more for filtering the air than protection on clothes.

Further Reading

https://www.sciencenewsforstudents.org/article/specially-coated-fabric-could-turn-shirt-shield

https://www.acs.org/content/acs/en/pressroom/presspacs/2017/acs-presspac-june-7-2017/new-fabric-coating-could-thwart-chemical-weapons-save-lives.html

https://www.chemistryworld.com/news/mof-in-a-bottle/1010176.article

http://www.bbc.com/news/world-middle-east-39500947

Teleportation – Science Fiction or the Future of Transport?

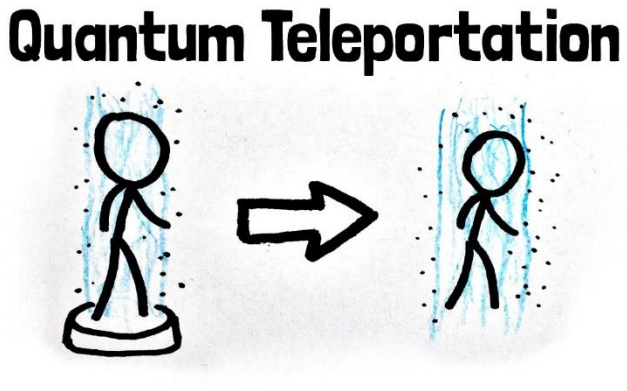
Kazal Oshodi, 12G1

The ability to transport one's self from one location to another has been a staple in science fiction over the past 20 years. If made feasible, it could revolutionise civilisation: from moving armies behind enemy lines to allowing them to go on holiday on the other side of the world and be back in time for dinner. Teleportation is a dream of many a scientist.

Recently in July 2007, Chinese scientists sent a packet of information about a photon from Tibet to a satellite 1.4km above the Earth's surface. This is the furthest distance anything has ever been teleported. However, teleporting humans instead of massless photons may require a bit more research. This does pose the question; can humans ever teleport?

How does teleportation work?

Teleportation relies on our ideas of quantum theory to work. The most successful way to teleport works by using quantum entanglement. This is when two particles have a property which is mutually exclusive (both of them cannot occur at the same time). For example, let's take 2 electrons and the property spin. If we say the total spin of the electron is 0, and each electron can spin either up or down, we know one electron will spin up, and the other electron will spin down. Therefore, even if we separate the 2 electrons and put them on opposite sides of the Earth, if we check the spin of one electron and find that it is spinning up, we know instantly that the other electron spins down – this information travels faster than the speed of light.



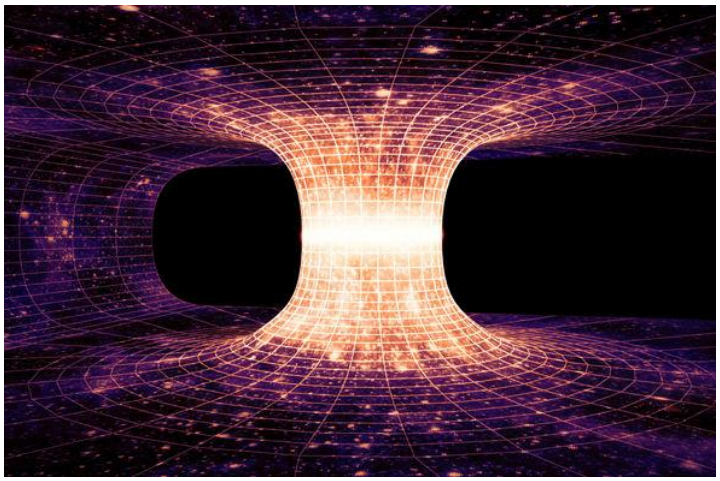
So how does this make teleportation work? Using quantum entanglement, we can obtain information about particles instantly, even if they are separated far apart. Therefore, it is possible that we could apply this to a person. For example, if we represent a person with Particle A, and then we have 2 particles – B and C, both of which are other which each other. If A could give its entangled to B, then C would also contain the information of A, as B and C are both entangled. Using information, a copy of A could be built, hence creating a new person in a different location – teleportation. This does pose some problems though.

Firstly, this teleportation relates more in line with the movie *The Prestige* more than *Star Trek*. In this scenario, instead of the actual object being transported, only its information is transported, and a new object created. Essentially, teleportation would lead to you being recreated every time you used it. However, would that make a different person,

since you would be made of different atoms and molecules. The philosophical questions are endless. Secondly, the human body is made of over 10^{27} atoms, all of which have information which needs to be transmitted. This would require infinitesimal precision, which is why only photons have teleported so far.

What alternatives to teleportation are there?

Despite the seemingly impossibility of the task at hand, scientists have still not given up. One alternative solution being considered is wormholes. A wormhole is a passage through 2 different regions of space-time. This is only theoretical and it has never been observed, however like black holes, it is very likely that they exist. Wormholes, if they could be contained, would be the best way to travel long distances in little time. This eliminates the idea of the human body being destroyed and created, and it doesn't require transferring more information than stars in the Milky Way. However, like all scientific dreams, it doesn't come without its obstacles.



Wormholes, like in *Interstellar* could be used like a corridor around the world. The biggest problem obviously remains that they have never been seen, much less created in a lab on Earth. Wormholes are notoriously unstable; they require negative energy in order to remain open, which is a whole other hypothetical concept which has also yet to be proven. This means the likelihood of a wormhole being used for day to day transportation is very slim. Even if it could be created, wormholes are hypothesised to link far places of the universe together, or even different universes together. Add the fact that they are thought to be 10^{-33} centimetres big, and the dream of instantaneous cross-continental travel starts to fade away.

Is there any good news?

Although the teleportation of humans may be impossible for the next century, that doesn't rule out all the benefits of furthering the research on time travel. For example, the Internet relies on fibre optic cables using pulses of light. Scientists have already teleported photons of light, leading to the possibility that the internet could run on quantum teleportation, allowing for not only faster internet speeds, but also the removal of cables, as information could be teleportation around the world without the use of physical wires. This is a huge advantage as it eliminates lots of the problems which accompany cables, such as loss of signal and slow internet speeds.

Furthermore, quantum mechanics is a relativity new concept. It only originated in the early 1920s from respected scientists such as Schrodinger and Paul Dirac. Therefore, it is entirely conceivable that considering the advancements made in such a short period of time, in the near future teleportation could be viable. In the forthcoming decades scientists hope to be able to teleport complex molecules such as DNA. From there, the possibilities are endless…

The Collision of Neutron Stars

Wen Qi Saw, 12S1

One of the greatest discoveries for astronomers this year was the collision of two neutron stars at a nearby galaxy. The two neutron stars were observed to be spiralling around one another before colliding at nearly the speed of light.

What are neutron stars?

When most people are asked about the life cycle of a star, the common belief is that all stars eventually become black holes, but in fact, some large stars end as black holes, others may become neutron stars, where the star's core becomes a dense mass of neutrons with a small percentage of protons and electrons.

Neutron stars are the densest objects in the universe with a mass of 1.4 to 3 times the mass of the Sun despite having a radius of only 10km, smaller than a section of Sheikh Zayed Road; as a result of their mass, the force of gravity experienced at the surface of neutron stars is 10^{11} times stronger than that on Earth's surface.

Due to its size in addition to the small amounts of radiation that it emits, it is hardly surprising that many neutron stars are undetectable. However, they can be easily observed under the right conditions: a handful of neutron stars can be found in the centre of supernova remnants emitting radiation, but most neutron stars are found spinning wildly with extreme magnetic fields, either as pulsars or magnetars.

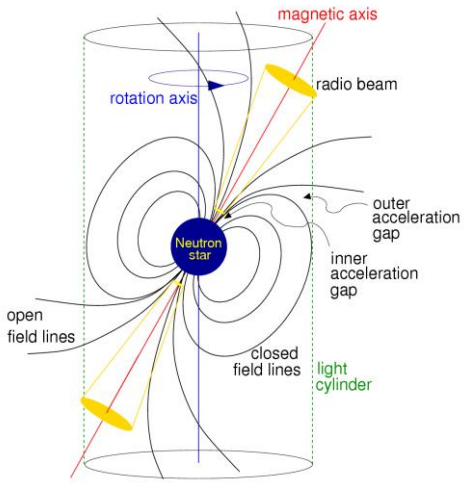


Figure 1: A diagram of a pulsar

Pulsars

Pulsars are rotating neutron stars observed to have pulses of radiation at highly regular intervals that range from milliseconds to 10 seconds. They have strong magnetic fields that funnel particles out from the poles, as shown in Figure 1. These particles produce powerful beams of light. The magnetic axis is not usually aligned with the rotation axis, so the beams of particles and light are swept around when the star rotates, similar to the beam from a lighthouse.

Magnetars

Magnetars are neutron stars that have extremely strong magnetic fields. The magnetic field of a typical neutron star is a trillion times stronger than that of the Earth's magnetic field. Magnetars, however, have magnetic fields that are 1000 times stronger than typical neutron stars, meaning that the magnetic field of a magnetar is 10^{15} times stronger than Earth's magnetic field.

The Discovery of Neutron Stars

Most neutron stars are observed as pulsars and indeed, this was how neutron stars were discovered in 1967 when Jocelyn Bell was studying distant radio sources with a special wave detector, which was used to find variation in radio signals. Bell had found a source of sharp, rapid, intense and extremely regular pulses of radio radiation that arrived precisely every 1.33728 seconds. The exactness of this radiation led scientists to question whether this was a signal from an intelligent civilisation; radio astronomers even jokingly dubbed the source as 'LGM' for 'Little Green Men'. When it eventually became clear that this source of radio radiation was fairly common, scientists concluded that they were unlikely to be signals from other intelligent civilisations.

The Significance of the Collision

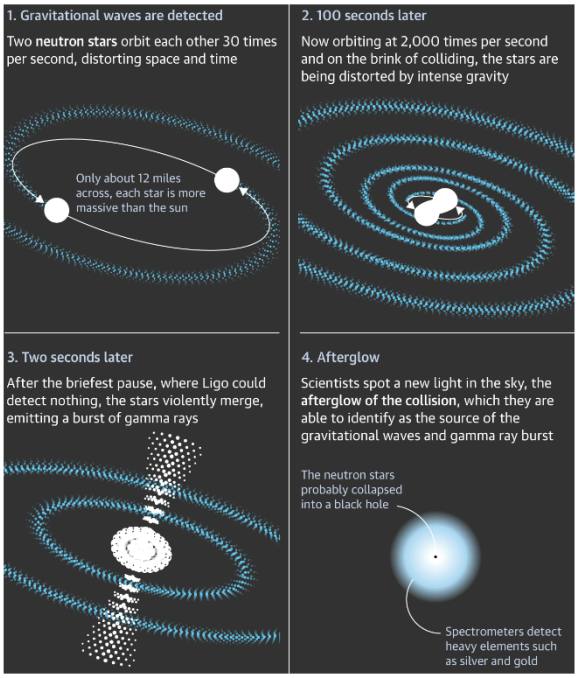


Figure 2: A summary of the collision

You may have wondered where gold comes from, or maybe platinum. Although most people believe these elements are formed by nuclear fusion on stars as the star runs out of hydrogen, only elements up to iron are formed during this stage of a star's life cycle.

The collision of neutron stars, which happened on August 17, 2017, solved a long-standing mystery about the origin of the heavier elements, revealing that these elements are, in fact, created in the collision before being scattered across the universe in what is known as a kilonova. The collision is the first observed instance of a single cosmic event emitting gravitational waves as well as light, both of which are produced by the kilonova. The collision is also historic in that it emitted the longest gravitational wave signal to date and a short gamma ray burst.

The key to the discovery was the detection of gravitational waves, which are 'ripples' in the fabric of space-time. Einstein predicted the existence of these waves in 1916 in his general theory of relativity, showing that massive accelerating objects would disrupt space-time in such a way that 'waves' of distorted space would radiate from the source, travelling at the speed of light through the universe. Although predicted in 1916, it was not until 2015 that these gravitational waves were detected, produced by the merging of two black holes.

However, what is significant about the collision of two neutron stars is the fact that they also emit electromagnetic waves, unlike the collision of two black holes, which were invisible and were only 'heard', lasting for only a fraction of a second. On the contrary, neutron stars produced a signal that lasted for 100 seconds, allowing scientists to study gravitational waves in further detail, revealing that the speed of a gravitational wave was the same as the speed of light. Researchers believe that this information can be used to help them calculate the rate at which the universe is expanding.

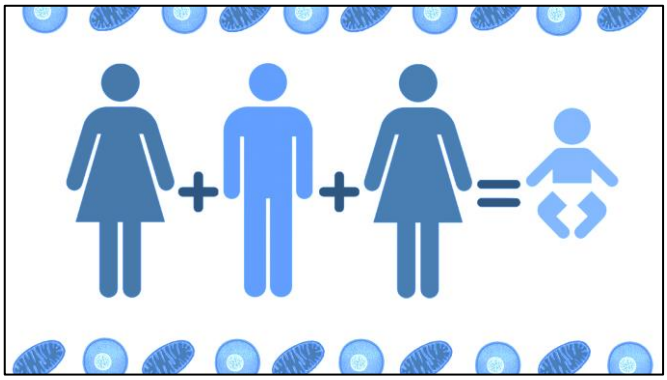
What happened after the collision is uncertain. However, a spokesperson from LIGO (Laser Interferometer Gravitational-Wave Observatory) has stated that: 'there are some signs, some observations that have been made that suggest it is a black hole. But in terms of mass and all of the gravitational wave data, it could either be one of the heaviest neutron stars that's ever been seen or one of the very lightest black holes that's ever been seen.' Although it is very likely that the neutron stars collapsed into a black hole, some scientists have stated that they 'may never know' what the neutron stars will eventually become.

Regardless, many scientists and organisations, including LIGO, have hailed this discovery as 'the dawn of a new era in astronomy'. LIGO executive director David Reitze even went as far as to name this discovery 'the most spectacular fireworks in the universe'.

Three-Parent Babies

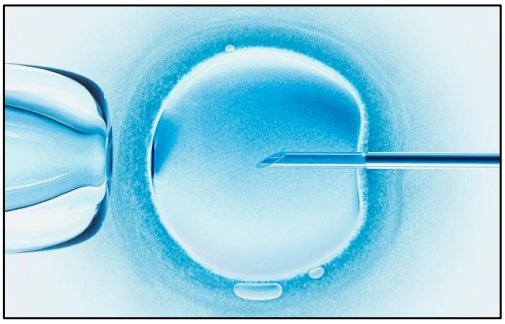
Suha Sagheer 13M2

What exactly is a three-parent baby? Truth be told, a three-parent baby is not that much different from the mundane two parent baby. He or she still contains half the genetic information of the mother, and half the genetic information of the father, and they would still have two biological parents. However, a three parent baby has a miniscule fraction of DNA from another "mother". Here's how they came to be:



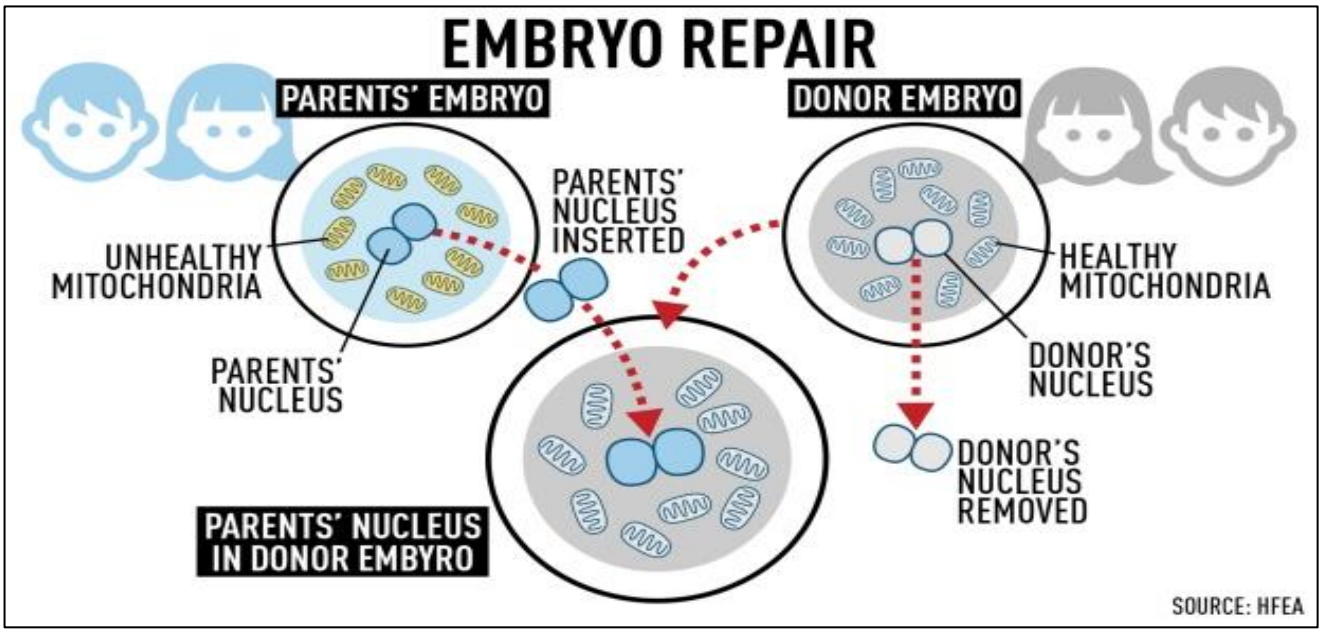
The first three-parent baby was conceived in a laboratory in 1998, as an experimental fertility treatment to boost the health of eggs by injecting them with energy-producing mitochondria from a donor egg. This is known as ***cytoplasmic transfer***. The conceived child therefore has mitochondria from the donor as well as the mother. Since mitochondria have genes of their own, these children technically have three genetic parents - the mother, the father and the donor egg. The children born as a result of this technique are essentially the first genetically modified humans, stirring a scientific and ethical debate.

Further research into this breakthrough took a halt in 2002 when some of these three-parent babies began showing abnormalities; it was unclear whether or not this was a result of the procedure. Nevertheless, researchers knew that children who inherit mutant mitochondria can develop serious and often fatal diseases.



One of these diseases is Leigh Syndrome - a rare disease of the nervous system which can often lead to difficulty in movement, degeneration of nerves, acute respiratory failure and tissue damage in the brain. Inheritance of this disease can only be avoided by some type of mitochondrial replacement, therefore the search for a new procedure began.

In 2003, doctors in China used a form of pronuclear transfer in which they transferred the nucleus from a fertilized embryo to a donor egg whose nucleus has been removed. This meant the majority of the mitochondria should originate from the donor, and none of the mutant mitochondria from the mother's egg cell would be passed on. The embryos used in trial did not survive the term after impregnation, however, further research took place and a modified version of pronuclear transfer proved successful in April 2016; a healthy baby boy was born at physician John Zhang's clinic, New Hope Fertility Center in New York City. The healthy mitochondria from the donor egg prevented him from inheriting Leigh Syndrome.



The modified version of pronuclear transfer used in Zhang's clinic is better known now as embryo repair and it is the first successful treatment of its kind. It involves fertilising both the mother's egg and a donor egg with the father's sperm. Before the fertilised eggs start dividing into early-stage embryos, each nucleus is removed. The nucleus from the donor's fertilised egg is discarded and replaced by that from the mother's fertilised egg.

Although the procedure is a life-saver in preventing genetic mitochondrial diseases, the practice has raised many scientific and ethical concerns. Scientists are unsure whether the child's health will be affected by the traces of the mother's mitochondrial DNA that he carries, which could still prompt some of his mitochondria to function improperly. Zhang's paper reveals that traces can differ between tissues; just 2% of the mitochondrial DNA of cells in the boy's urine came from the mother, but this figure rose to 9% in cells from the child's circumcised foreskin. It is impossible to test organs such as the heart or brain without invasive surgery.

Scientists are unsure of how much of the mother's mitochondrial DNA would cause genetic diseases; a mixture of two women's genetic material could even lead to future neurological disorders or metabolic conditions, as seen in trial runs on mice[1].

Questions of future concerns will not be answered by Dr. Zhang's clinic, however. The baby's parents have refused further mitochondrial testing unless there is a medical need, therefore long-term monitoring is no longer possible in this case. Without knowing the outcomes of the experiment, the procedure may not be used as a treatment for the foreseeable future. Government regulations and other guidelines on human research also deem it unnecessary to perform tests on the boy without his consent, therefore the parents and clinicians priorities have to lie with the best interest for the child.

[1] Wallace, D. C. & Chalkia, D. *Cold Spring Harb. Perspect. Biol.* **5**, a021220 (2013).

…But studies in mice have shown that mixtures of mitochondria can result in neurological disorders or metabolic conditions...

Nevertheless, Zhang's clinic will continue to test the technique using eggs from prospective mothers, this time between the ages of 42 and 47. They are investigating whether mitochondria from young donors' cells can stimulate the older eggs' ability to be fertilized and develop normally. As of December 2016, procedures involving embryo repair were officially approved for trial in the UK as well, so we may still be seeing cases of three-parent babies after all.

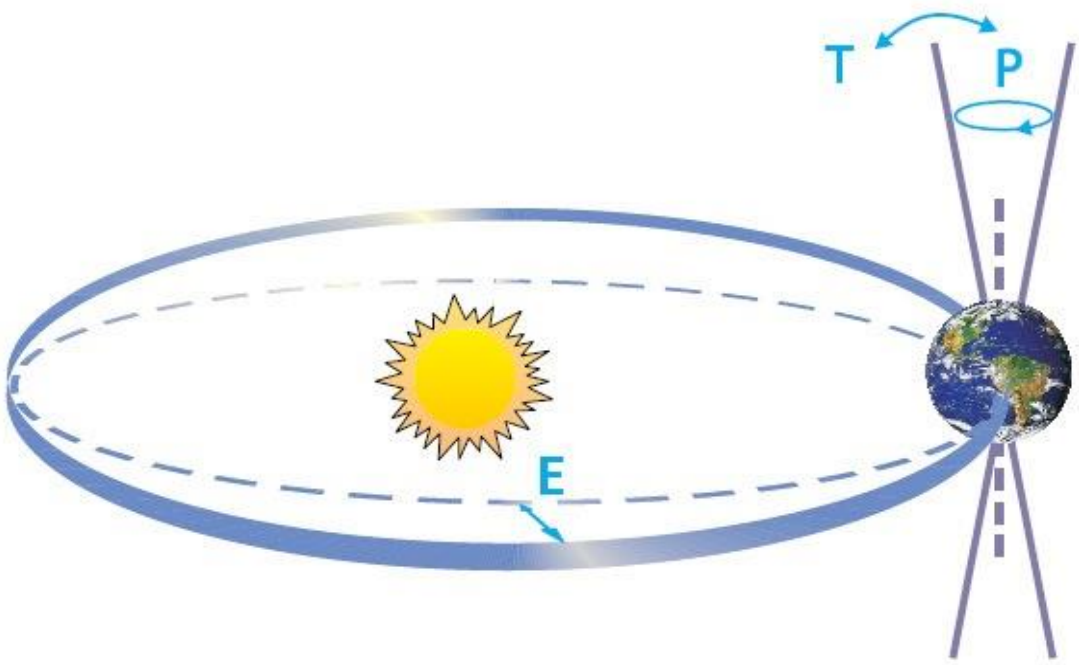
At the end of the day, the question remains: Three-parent babies - a miracle of life, or a play on genetics?

The Milankovitch Cycles

The changes in the shape of the Earth's orbit around the Sun

Ryan Joy, 12F1

Since the beginning of the history of the earth, the Earth has gone from times of glacial and inter-glacial periods. Currently, the world is in an inter-glacial period. This range of different climates are caused by three characteristics of the Earth and are summed up together using the Milankovitch Cycles. These cycles affect the Earth as it regulates the amount of solar radiation in contact with Earth. Therefore, if there was not enough solar radiation hitting the northern hemisphere, then it would go through a glacial period as cold waters would freeze and form ice.



The three characteristics are:

1. **Eccentricity**: The 'E' in the diagram on page 1 denotes eccentricity. Eccentricity is the changing of Earth's orbit from a nearly perfect circle to a more elliptical orbit. This takes around 100,000 years to go from a circular to an elliptical orbit. This gives rise to a larger difference in temperature throughout the year. This is because in an elliptical orbit the Earth in the certain areas are closer to the sun than others. Therefore summers will be hotter and winters would be colder than compared to a nearly circular orbit where there nearly would not be wide temperature changes throughout the year due the circular orbit. This occurs due to the gravitational pull of the sun.

2. **Obliquity**: This also known as tilt ('T' in the image on page 1) and is the tilt that the axis on which the Earth rotates has. Right now the Earth has a tilt of 23.5 degrees. Over thousands of years this tilt has been known to change. It can vary from 22.1 to 24.5 degrees. This also affects the climate and seasons of a place. The more the Earth tilts the more the range of temperatures differs between that of summer and winter. For example if the earth was tilted at a full 24.5 degrees and it was summer in the northern hemisphere, then the northern hemisphere will be closer to the sun, this results in a hotter summer than it is today. In this case that would mean that the southern hemisphere is having winter. Its winter will be colder than usual as it is farther away from the sun. This happens over a 41,000-year cycle.

3. **Precession**: This is 'P' in the image on page one. Precession is the wobbling of the Earth's orbit. This occurs in a cycle of every 26,000 years. This wobbling is the circular rotation of the axis of the Earth. This too effects the seasons. Much like the tilt of the Earth, precession causes certain parts of the Earth to vary in distance from the sun resulting in either an increase or a decrease the range of temperatures across the year.

Climate change is a huge and complicated discussion that has implications in every aspect of humanity. Increasingly, climate change deniers choose to portray climate change as being out of human's control. The question is if or not they are right. The case remains that there is a strong correlation between the CO_2 emissions and the increasing temperature of the Earth. In particular, the Milankovitch cycles cannot be blamed, as their effects do not seem to have a significant enough effect to cause the rapid changes in climate we see today.

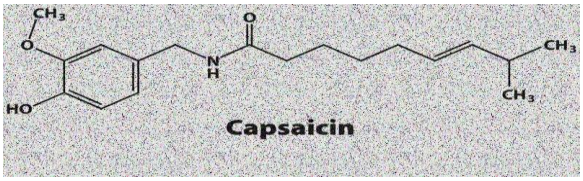
Is food really ‘hot’ if it’s spicy?

Khadijah Anwar 13S2

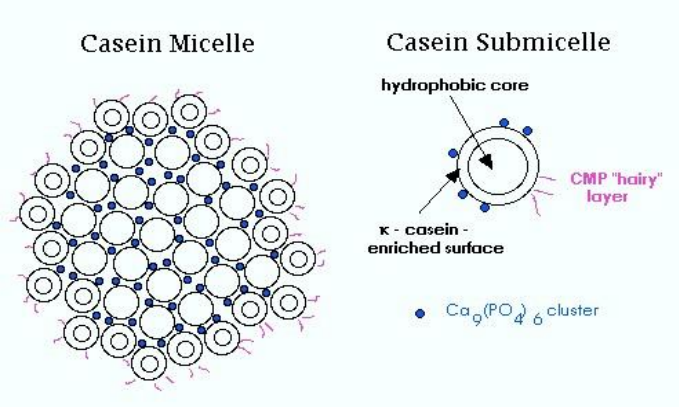
My friends and I faced off in a “pani puri” battle, our plates chock-full with the chili-laden south-asian finger food. To my right, I had the post-spice escapade antidote ready - a glass full of ice-cold water awaited me. On the count of three, I started stuffing “puris” into my mouth. Immediately, the familiar burning sensation spread through me. Cheeks flushed, eyes watery, I fervently fanned my tongue with my hands; I gulped the water, expecting the cold liquid to quell the fire. I mean, it was a simple equation, right? Hot plus cold equals neutral - the simple “fact” most of us are indoctrinated into believing.

Yet, water never seemed to help in these fiery fiascos. At most, it would temporarily numb the feeling before the hot peppers struck back more powerfully. Was I just undergoing biological failure? That’s what I’d always thought until a Fox News article shed light on my existential dilemma.

“Capsaicin” - that’s the scientific term for the chemical in peppers that sets the TRPV1 pain receptors on our tongues alight. Looking at the hexagonal zigzag carbon skeleton of the compound, I felt like an idiot. “Of course!” Being a chemistry student, I couldn't believe I’d never realized - the predominantly non-polar hydrocarbon chain meant “spice” was immiscible with polar water. If anything, the water would disperse the capsaicin molecules all over our tongues, making them burn more. My “antidote” was actually an explosive.



Milk, in all its glory, is often claimed by the cookie lovers of the world. You’ll hear names like Chips Ahoy and Oreo attached to a glass of dairy all the time. But, you never hear anyone say: “hmm, let’s wash this extra spicy Nando’s down with some cold milk.” Ironically, milk is actually a great remedy for a “spice rush.” Milk contains a complex molecule called casein, which has non-polar groups that attract the largely non-polar capsaicin chain. As a result, casein proteins bind to capsaicin molecules and dissolve them - in other words, spice begone!



So, now that some light has been shed on this heated matter, what does it mean for our eating behavior? Should we start teaching kids to pair spicy crisps with a glass of milk? Is that just too unappetising? Is yogurt a more feasible alternative? Or, we could always just embrace the fiery world of capsaicin like our ancestors have since the beginning of time.

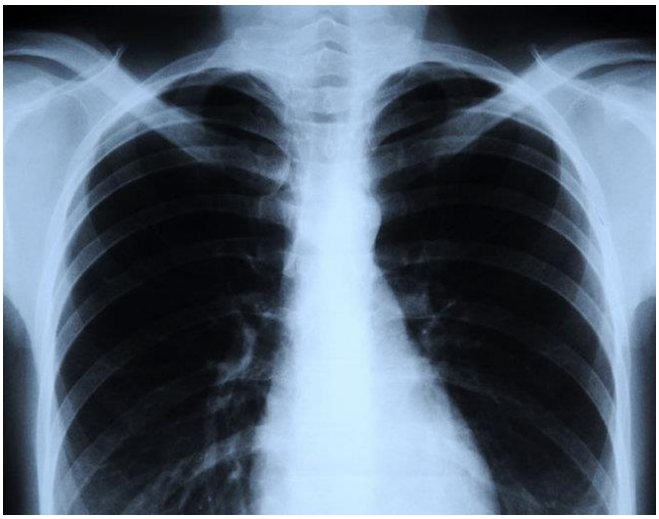
Either way, I can say one thing for sure: my entire life, I'd been confusing thermodynamics with simple organic chemistry.

Physics in Medicine

Wahaj Munir, 13S1

Chemistry and Biology, often the first things that come to mind when thinking about the medical field. However, many forget one of the most important aspects in both clinical and research based medicine, which is physics.

Without an understanding of physics, we would be deprived of many resources that allow us to not just help patients, but also expand our knowledge of the human body that have lead us to further scientific advancements in the medical fields.

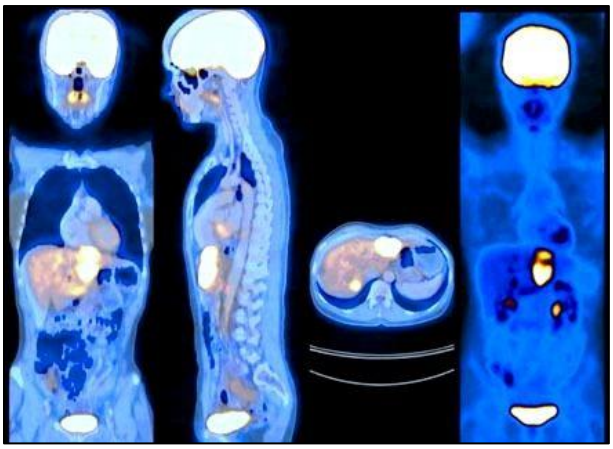


X-Rays. One of the most commonly used imaging tools by radiologists, there were in fact over 22 million X-Rays done from 2015 to 2016, just in the U.K. Yet a large majority of people do not understand how a single scan works. The level of genius behind how X-Ray scan is carried out is amazing. A machine would fire high energy ionizing rays towards the body part, which are absorbed by the hard structures such as bone, but pass straight through soft tissues and ligaments. This creates that simple black and white image that you see, which allows a doctor to recognize and possible fractures or abnormalities. Without such scans, any diagnosis or treatment made may not be accurate, and wouldn't allow the best possible care to be provided for patients.

Radiation - the main drawback of many of these imaging techniques. Although the danger from a CT or X-Ray isn't too harmful to us, it can be fatal for a foetus in a mother's womb. However, the use of ultrasounds help us get past this problem, allowing us to obtain images of a foetus safely. This has allowed us to successfully diagnose and treat many different types of abnormalities during pregnancy. Ultrasounds can also be used to see the heart muscles and valves, which help to successfully diagnose many patients. The high convenience of ultrasounds and ease of use adds to its advantages.

Positron Emitting Tomography, you can't get any more physics than that. This imaging technique is in fact using anti-matter to get visual images of different organs of the body, mainly the brain. A special type of dye is inserted into the veins of the arm which emit positrons (the antiparticle of electrons) and is detected by machines, creating images of the body.

Apart from being used in a clinical setting, many different areas of research rely on an understanding of physics and use equipment that uses physics idea. To be able to pursue an area of medicine to research, one must first be able to understand the part of the body they're studying. You can't even begin to understand how the brain works, yet alone how to improve or treat problems related to it without knowing every physical detail of it. This shows just how crucial an understanding of physics is and how it can be applied, and how vital it is in medicine.



Further Reading

http://iopscience.iop.org/journal/0031-9155 Physics in Medicine

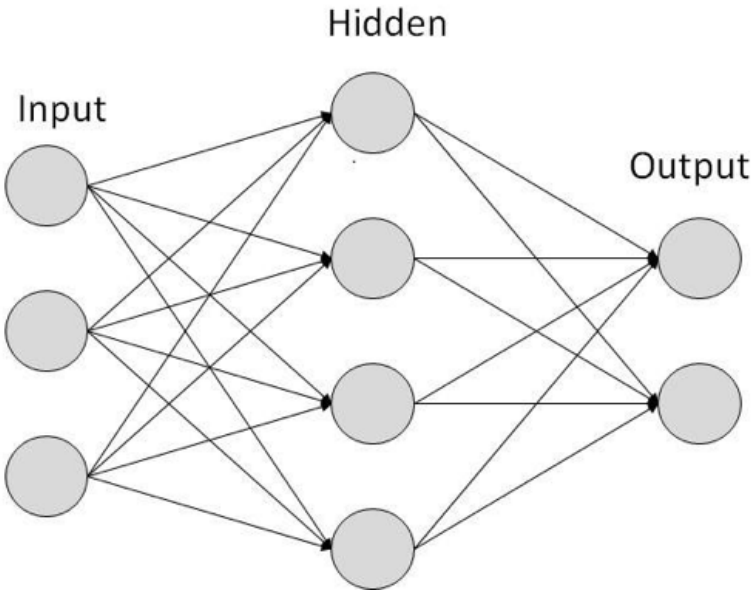
https://sciencebasedmedicine.org/

Artificial Neural Networks

Amir Girgis, 12S2

An artificial neural network is a computing paradigm (inspired by the brain) that is used to train a program against large sets of data. At its core, it is a function that learns an expected output or pattern from some data. To better understand it, we need to look at the brain in more detail. In our brains, we have billions of connected neurons that all communicate with and send signals to each other. These are the building blocks of human intelligence. Research into these biological neurons inspired the discovery of the artificial neural network which is modeled using a more rudimentary structure of the brain.

An artificial neural network mimics the model of a brain using simple math: it is made of up of different layers and each layer contains a set of processing nodes known as neurons. Data (usually) flows through these connected layers in one direction known as forward propagation. Each neuron can be connected to multiple other neurons in the layer before and after it as shown below.



Each neuron is assigned a set of weights which is sent to other neurons. This number gets adjusted and aggregated until a final weight is sent to the output. Think of it as a number that gets tweaked and changed every step of the journey until it gets close enough to represent the data. Besides the weights, there is also a bias value. It's similar to the equation of a line:

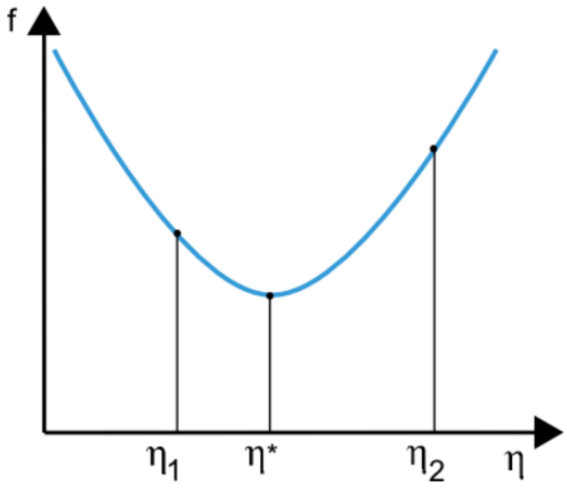
$Y = Wx + B$

Essentially, the computer is trying to create an equation that models the data. However, this is only one computation that artificial neural network. The reason it's so effective is because it uses multiple computations each designed with a specific purpose. (as we will see below).

Let's say we were training a neural network to recognize the digits below:

Like we discussed earlier, we would start by providing some data to our neural net. The next mathematical computation would be to run an optimization function. Given any digit (0 – 9), our model would output a prediction of the number. However, in its initial training stage, it would still be learning so it is likely to get many predictions incorrect. To help it minimize the number of incorrect results it outputs, we run a mathematical function based on the model's initial parameters, to minimize (for example) weights(W) and the bias (B). This occurs during the training process when the neural net is still trying to find the best model for the data. In most cases, all of this is done through a series of matrix multiplications.

Let's approach this problem from a simpler perspective and say that our data was modeled with the equation above *f(n)*. Right now, our model is at n_1 and we want to get to n^* which has the least error value. To optimize it, we would use a technique known as gradient descent which is an iterative process used to find the minimum value.



[source: neutraldesigner.com]

Very simply put, think of this function as a valley and a climber is trying to get to the lowest possible point in as few steps as possible. At n_1, the climber is still quite far away, so he knows he can take a large step downwards. After taking that large step downwards, he knows the bottom of the valley is getting closer, so he is going to start taking smaller and smaller steps until he can reach the bottom. Mathematically, this is exactly what we do. At n_1, we get a vector with the steepest gradient downwards (to represent that larger step). As we get closer to the minimum point, that gradient

is going to start decreasing as it becomes less steep. We model this function (gradient descent) mathematically with this equation

$$b = n - \gamma \nabla F(n)$$

This function keeps iterating over different positions and their respective gradients until it finds a point with a small enough gradient that would indicate it is close to the minimum value. Put simply, this is what it does all in one line:

1. Calculate gradient of current position: $\nabla F(n)$
2. Move in opposite direction: subtract $\gamma \nabla F(n)$ from n
3. γ represents how much you want move

The idea is that this function keeps on cycling through this algorithm until the error value reaches a minimum, and the function is optimized. Programmers have a variety of different set algorithms that can be used to minimize the error value; each algorithm offers a slightly different structure that is advantageous in one or two scenarios.

Thus, despite their intimidating name, artificial neural networks actually operate using simple math. As we continue to learn more and more about them, our understanding of both the brain and artificial intelligence changes, opening up new opportunities for us to use this technology in meaningful and effective ways.

Further Reading

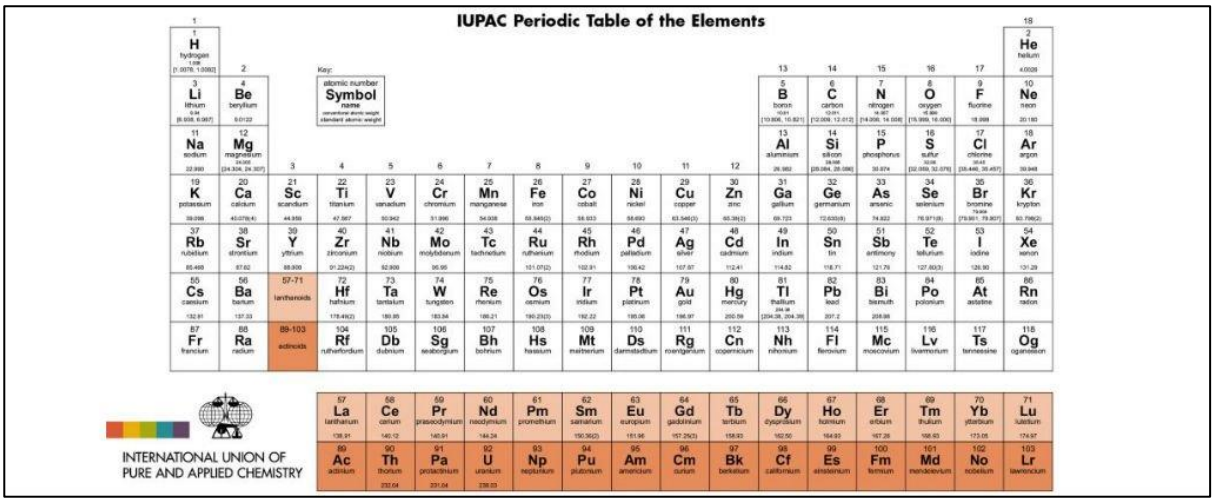
https://www.digitaltrends.com/computing/researchers-use-neural-network-algorithms-for-more-accurate-brain-scans/

http://www.asimovinstitute.org/neural-network-zoo/

Elementary, my dear Mendeleev…

Sita Williams, 12G1

Four new elements have been found this year! Following the official discovery of these extremely heavy elements, the International Union of Pure and Applied Chemistry (IUPAC) are currently revising the proposed names, which honour the places or people that discovered these rare elements that complete the seventh row of the periodic table.



Element 113 is to be named "Nihonium" with the symbol "Nh", which represents a connection to the country it was discovered in, Japan. "Nihon" is a way of saying "Japan" in Japanese, and directly translates as "the Land of the Rising Sun", which is fitting as it is the first element to have been discovered in Asia, at the RIKEN Nishina Center for Accelerator-Based Science.

Element 115 will be called "Moscovium" with the symbol "Mc", after Moscow, the location it was discovered in at the Joint Institute for Nuclear Research in Dubna, and element 117 will be named "Tennessine" or "Ts" due to the extensive research at three institutes in the state of Tennessee, including the Vanderbilt University.

Finally, element 118 is to be called "Oganesson" ("Og"), named not after its location of discovery, but to honour the scientist Professor Yuri Oganessian for his contributions to discovering heavy elements.

So what are the elements allowed to be called? There are a set of rules outlined by IUPAC that ensure the elements are named something sensible each time one is discovered, so it must be named after:

- a mythological concept or character
- a mineral or similar substance
- a place, or geographical region
- a property of the element, or a scientist

Further Reading

https://www.sciencenewsforstudents.org/article/newest-elements-finally-have-names

https://iupac.org/iupac-is-naming-the-four-new-elements-nihonium-moscovium-tennessine-and-oganesson/