Leicester Grammar School's

YOUNG SCIENTISTS' JOURNAL

Trinity 2023

Edition 13

Nanoparticles: For the Future?

Kabeshan Sandrasekaran & Rahul Subramanian look into the role of nanotechnology in the future

'Are you secretly a quantum computer?'

Charles Lawrence investigates the human brain and quantum computers

Lassa Fever

Ben King-O'Reilly discusses the deadly consequences of the Lassa Virus

Aerogel: The Material of the Future

Abbas Khan explores the extreme material properties of aerogel

Welcome Back!

Edition 13, Trinity 2023

A message from the YSJ Team:

We are delighted to bring you the Trinity edition of the LGS Young Scientists' Journal! The YSJ aims to foster a passion for the fields of science, technology, engineering and maths for pupils throughout the school, as well as providing a platform for students to showcase their interest and excitement through research in their respective fields. This term's edition includes articles ranging from nanoparticles and viruses, to the mystery of the Bermuda Triangle.

We're so pleased to have seen so many enthusiastic contributions across different year groups and have thoroughly enjoyed reading them. We would love to see more people get involved next year, so feel free to drop us an email with your ideas! We hope you all have a relaxing summer!

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We would like to thank everyone who has written an article for this edition of the YSJ, as well as Mr. Reeves & Dr. Griffin for technical help with the journal.

Cover Images:

"Lassa fever viruses, 3D illustration." by Kateryna Kon

"Nanoparticles" by Kateryna Kon

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Inside this edition

What is Lassa Fever and why is it so dangerous?

Ben King-O'Reilly

What is Lassa Fever?

Lassa Fever is a viral haemorrhagic fever that is caused by infection with the Lassa virus. Lassa virus was first identified in 1969 after two missionary nurses died from the disease in the Nigerian town of Lassa (Richmond and Baglole, 2003, online).

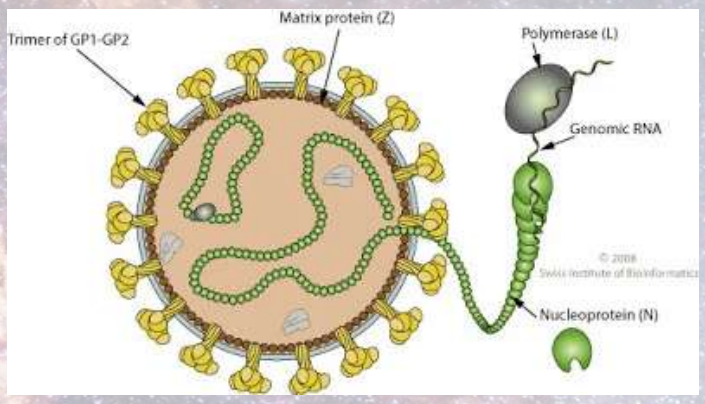
Lassa Fever distribution map (CDC, 2022, online)

Around 100,000 - 300,000 Lassa Fever infections occur each year (CDC, 2022, online). Of these cases, 10-16% are considered to be severe enough to require hospitalization, and around 5,000 people with severe Lassa Fever infections die each year (CDC, 2022, online).

Lassa Fever is especially severe for women and babies in late-term pregnancy, with “a fatality rate of over 80%” (Dillon and Cheprasov, n.d., online). This is because the Lassa virus has a high affinity for the vascular tissues of the fetus and placenta, with the fetus at a particularly high risk as its immune system is still maturing (Okogbenin, n.d., online).

Lassa Fever is endemic in parts of West Africa including Sierra Leone, Liberia, Guinea and Nigeria (CDC, 2022, online). This is because multimammate rats which can carry the Lassa virus live in these areas (CDC, 2022, online). On occasion, people who have been to these areas have exported the disease to other continents.

The structure of a Lassa virus virion



The structure of a Lassa virus virion (SIB, n.d., online). The diameter of the virion tends to be between 90 - 110 nm (Aryal, 2021, online).

Lassa virus is a single-stranded RNA virus belonging to the Arenaviridae virus family (Aryal, 2021, online). To be more specific, the Lassa virus is an old-world Arenavirus (Arenaviridae) as it is endemic in Africa. Arenaviruses are generally spread by rodents.

Lassa virus consists of a helical nucleocapsid containing a genome that

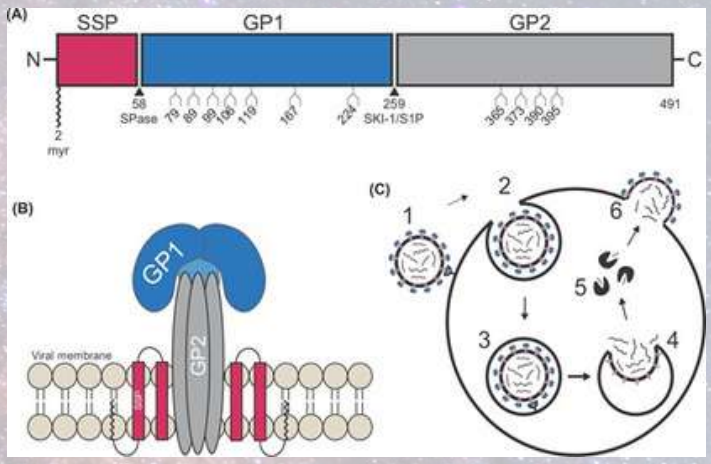
consists of two RNA strands (Strecker *et al*, 2003, online). Every single strand of RNA codes for two viral genes in an ambisense coding strategy (here both the genome and its complement contain coding information), these genes are separated by an intergenic region which signals the end of transcription of the upstream gene and signals the start of transcription of the downstream gene (Strecker *et al*, 2003, online).

Lassa virus is an enveloped virus meaning it is surrounded by a lipid bilayer (Aryal, 2021, online). The bilayer contains glycoprotein complexes which protrude, these glycoprotein complexes on the surface of the virion form T-shaped spikes which extend 7 - 10 nm from the envelope (Aryal, 2021, online), the proteins which make up the glycoprotein complex are glycoprotein one (GP1), glycoprotein two (GP2) and a stable signal peptide. As well as these features all viruses in the Arenaviridae family, including the Lassa virus, are easily identifiable under a microscope due to them all having ribosome-like components that give them a grainy appearance.

In 2018 all strains of the Lassa virus were "grouped into four lineages based on genetic variation" (Hallam *et al*, 2018, online). Each of the four lineages has a slightly different structure and genome. Three of these lineages are endemic to Nigeria, the fourth is found in Guinea, Liberia, and Sierra Leone (Hallam *et al*, 2018, online).

As seen above at the commencement of the study by Hallam et al strains of the Lassa virus could be grouped into four lineages, however during this time, an evaluation of a strain that had been recently isolated suggested the emergence of an additional fifth lineage (Hallam *et al*, 2018, online). This fifth lineage was later officially recognized along with two other lineages, taking the total number of the lineages of Lassa virus to seven (Garry, 2022, online).

Entry of the Lassa virus into cells and replication



The structure of a glycoprotein complex of a Lassa virus virion (Pennington and Lee, 2022, online).

Lassa virus utilises membrane fusion to deliver its genetic material to the host cell, this membrane fusion occurs through a sequence of conformational changes of the glycoprotein complexes on the surface of the virion (Torriani et al, 2017, online). GP1 is the receptor-binding subunit of the glycoprotein complex, it first binds with a host cell receptor called α-dystroglycan (Torriani et al, 2017, online). This binding occurs before a receptor switch is undergone upon delivery to the late endosome. Late endosomes are organelles that are located near the nucleus, their roles are to provide "a central hub for incoming traffic" from mainly endocytic pathways (Scott et al, 2014, online), and a central hub for "outgoing traffic" to the Lysosomes, Golgi apparatus or cell surface membrane (Scott et al, 2014, online). After the transport of GP1 to the late endosome, where fusion occurs, the acidic pH and

change in receptor cause the dissociation of GP1 from the glycoprotein complex exposing GP2, the fusion subunit of the glycoprotein complex (Pennington and Lee, 2022, online). This exposed subunit forms a "fusion pore" (Pennington and Lee, 2022, online) which is a structure that allows the genetic material of the virion into the host cell upon successful fusion with the host cell surface membrane. This process of the virions' genetic material entering the host cell is called "receptor-mediated endocytosis" (Torriani *et al*, 2017, online). The genetic material passes through this fusion pore after uncoating from the helical capsid (Torriani *et al*, 2017, online).

Although both GP1 and GP2 undergo structural changes, the third subunit of the virion's glycoprotein complex, the stable signal peptide, remains associated with the glycoprotein complex (Pennington and Lee, 2022, online). The main role of the stable signal complex is to sense "pH changes to prompt fusion under appropriate conditions" (Pennington and Lee, 2022, online).

Upon cell entry, the genetic material of the Lassa virus replicates in the cytoplasm where viral transcription and replication occur (Torriani *et al*, 2017, online). This produces new viral genomes and capsids, as well as enzymes which can assemble the new virions before they exit the host cell by budding (Torriani *et al*, 2017, online). These newly made Lassa virus particles are then free to replicate by infecting more cells.

Reducing the spread of infection

Most diseases cannot be transmitted from humans to animals or animals to humans. However, zoonotic diseases like Lassa Fever can spread between animals and humans. This is because multimammate rats function as both disease vectors and disease reservoirs (Dillon and Cheprasov, n.d., online). This makes Lassa Fever harder to control as there are large populations of multimammate rats in West Africa.

It is most common for people to contract Lassa Fever zoonotically, as they contract it by touching multimammate rats or household goods and food contaminated by multimammate rat urine or faeces (Dillon and Cheprasov, n.d., online). Although this is the most common way for people to contract Lassa Fever, it can also be spread between individuals through bodily fluid contact (Dillon and Cheprasov, n.d., online).

In order to halt the spread of Lassa Fever people are encouraged to observe good hygiene practices including regular handwashing, storing their food in airtight containers and not consuming multimammate rats (Dillon and Cheprasov, n.d., online).

As well as this, aseptic techniques are recommended when treating family members recovering from Lassa Fever; these techniques protect family members from contact with bodily fluids (Dillon and Cheprasov, n.d., online).

Symptoms of Lassa Fever

Lassa virus incubates between 6 and 21 days in its hosts (Dillon and Cheprasov, n.d., online). The consequences of becoming infected with Lassa virus can range from no symptoms to death.

Some common symptoms of mild Lassa Fever include chest pain, gastric symptoms,

and muscle weakness and pain (Africa CDC, 2020, online). In more severe cases symptoms such as encephalitis (inflammation of the brain), bleeding from orifices, and seizures may be seen (Dillon and Cheprasov, n.d., online).

Treatment

Ribavirin is an antiviral drug that has been used with success in Lassa Fever patients. It is delivered intravenously and is more effective the earlier in the course of the illness it is delivered (CDC, n.d., online). Alongside this, patients also receive supportive care which may consist of giving the patient oxygen and ensuring the patient gets enough rest, as well as the "maintenance of appropriate fluid and electrolyte balance" (CDC, n.d., online).

Bibliography

IAfrica CDC (2020). *Lassa Fever*. [online]. Available at: https://africacdc.org/disease/lassa-fever/ [Accessed 16 June 2023].

Aryal, S. (2021). *Lassa Virus- An Overview*. [online] Microbe Notes. Available at: https://microbenotes.com/lassa-virus/ [Accessed 15 June 2023].

Centers for Disease Control and Prevention (2022). *Lassa Fever*. [online] Available at: https://www.cdc.gov/vhf/lassa/index.html [Accessed 16 June 2023].

Centers for Disease Control and Prevention (n.d.). *Lassa Fever CDC Fact Sheet*. [online]. Available at: https://www.cdc.gov/vhf/lassa/pdf/Lassa-Factsheet-508.pdf [Accessed 17 June 2023].

Dillon, A. and Cheprasov, A. (n.d.). *Lassa Virus*. [online] Study.com. Available at: https://study.com/learn/lesson/lassa-virus-structure-transmission-fever.html [Accessed 15 June 2023].

Garry, R. (2022). *Lassa fever - the road ahead*. [online] Nature Reviews Microbiology. Available at: https://www.nature.com/articles/s41579-022-00789-8 [Accessed 16 June 2023].

Hallam, H., Hallam, S., Rodriguez, S., Barrett, A., Beasley, D., Chua, A., Ksiazek, T., Milligan, G., Sathiyamoorthy, V. and M. Reece, L. (2018). *Baseline mapping of Lassa fever virology, epidemiology and vaccine research and development*. [online] npj Vaccines. Available at: https://www.nature.com/articles/s41541-018-0049-5 [Accessed 15 June 2023].

Okogbenin, S. (n.d.). *CLINICAL FEATURES AND MANAGEMENT OF LASSA FEVER*. [online]. Available at: https://cdn.who.int/media/docs/default-source/blue-print/day1_session1_1_sylvanus-okogbenin_lassa-vaccine-meeting_nigeria.pdf [Accessed 16 June 2023].

Pennington, H. and Lee, J. (2022). *Lassa virus glycoprotein complex review: insights into its unique fusion machinery*. [online] Portland Press Bioscience Reports. Available at: https://portlandpress.com/bioscirep/article/42/2/BSR20211930/230708/ [Accessed 16 June 2023].

Richmond, J. and Baglole, D. (2003). *Lassa fever: epidemiology, clinical features, and social consequences, Lassa fever: epidemiology, clinical features, and social consequences*. [online] British Medical Journal (Clinical Research Edition). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC286250/ [Accessed 15 June 2023].

Scott, C., Vacca, F. and Gruenberg, J. (2014). *Endosome maturation, transport and functions.* [online] Seminars in cell & developmental biology. Available at: https://pubmed.ncbi.nlm.nih.gov/24709024/ [Accessed 17 June 2023].

Strecker, T., Eichler, R., Meulen, J., Weissenhorn, W., Dieter Klenk, H., Garten, W. and Lenz, O. (2003). *Lassa Virus Z Protein Is a Matrix Protein Sufficient for the Release of Virus-Like Particles*. [online] Journal of virology. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC228511/ [Accessed 17 June 2023].

Swiss Institute of Bioinformatics (n.d.). *Mammarenavirus*. [online]. Available at: https://viralzone.expasy.org/83 [Accessed 16 June 2023].

Torriani, G., Galan-Navarro, C. and Kunz, S. (2017). *Lassa Virus Cell Entry Reveals New Aspects of Virus-Host Cell Interaction.* [online] Journal of virology. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5286875/ [Accessed 15 June 2023].

The Bermuda Triangle: What is the mystery behind it?

Kaarthik & Kaushik Santosh

What is the Bermuda Triangle?

The Bermuda Triangle lies in the North Atlantic Ocean where several aircraft and ships are said to have disappeared under mysterious circumstances. Countless sailors and their ships have voyaged along the triangle to uncover the mystery behind it, but unfortunately none of them have returned to explain the truth.

The Bermuda Triangle is also known as the Devil's Triangle.

Origins

Reports of unexplained occurrences in the region date back to the mid-19th century. Some ships were discovered completely abandoned for no apparent reason; others transmitted no distressed signals* and were never seen or heard from again. Aircraft have been reported and then have vanished, and even rescue missions are said to have vanished when flying around the area.

However, the wreckage has not been found, and some of the theories advanced to explain the repeated mysteries have been fanciful. Many theories lie behind the mystery, and some were created. One of the theories outlined supernatural and paranormal causes, whilst having natural and geophysical factors.

The most recent incident occurred on 1st October 2015, on a gloomy day, when a cargo ship named 'SS El Faro' was carrying an enormous load and 33 crew members drowned in this region. After some time, the US naval sent a search team and they seemed to have found the ship 15,000 meters deep in the Atlantic Ocean.

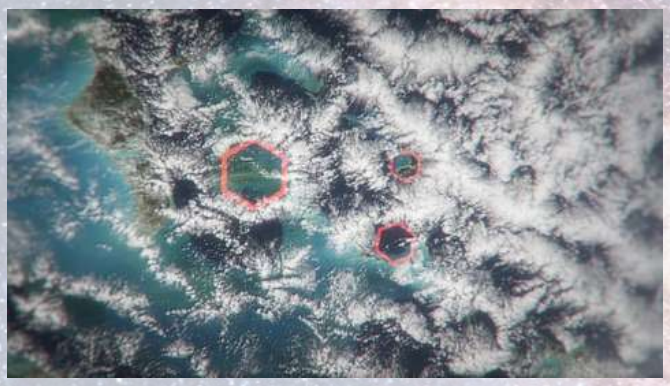
The Last Voyage of the SS El Faro
Photo Illustration by Garrigosa Studio

Causes

There are many theories which state the mystery of the Bermuda Triangle, but we don't know if what the scientists say is true. Some scientists say it is due to freak storms*, while others say that it is because of the waterspouts*.

Others suspect that this is a paranormal activity as they predict that the answer behind this is committed by aliens or UFO's, sea monsters and even ghosts! But the most logical theory has been stated by a group of scientists from the University of Colorado. After analysing satellite imaging of the weather in the area, they noticed a series of hexagonal clouds hovering over the triangular region.

According to meteorologists, the hexa-clouds might just act like real air bombs formed by microbursts. They are a blast of cool air that comes down from the base of a thunderstorm at an incredible speed of around 60 mph, hitting the ocean. These can create waves that reach up to 45 feet in length once they start interacting with each other. Consequently, no plane can soar in this activity.



Another theory quotes that these unfortunate events have happened because of rogue waves or extreme storm waves. These waves can be twice the size of the surrounding waves. They are unpredictable and can act from any direction.

But the mystery still has not been solved, so let us hope that in the future we can know the actual answer behind this.

Glossary

Distressed signals - A signal by radio, very light, etc from a ship or other vessel in need of immediate assistance.
Freak storms - a strange or very weird storm; a storm which happens under highly unusual and unlikely circumstances.
Waterspouts - a rotating column of water and spray formed by a whirlwind occurring over the sea or other body of water.

Bibliography

https://www.britannica.com/place/Bermuda-Triangle

https://en.wikipedia.org/wiki/Bermuda_Triangle

Aerogel: The Material of the Future

Abbas Khan

Mankind has made so much progress in the way of science in the last century, that it is now hard to make significant breakthroughs like before. However, that doesn't mean that it is impossible to do so. One such breakthrough in the way of science lies in the invention of aerogel.

Aerogels, as defined by aerogel.org, the forum regarding aerogels, are 'a diverse class of porous materials that exhibit an uncanny array of extreme material properties, most notably their extremely low densities.' The more technical definition of an aerogel is 'an open-celled, mesoporous, solid foam that is composed of a network of interconnected nanostructures and that exhibits a porosity of no less than 50%.' Porosity refers to the non-solid volume of the substance which is occupied by air, and mesoporous materials are materials which have pores ranging from 2-50 nanometres in diameter.

Aerogels are now synthesized from a wide array of materials. The most widely synthesized and used gel structure which aerogel is made of is usually silica, however many other compounds can be used, such as lanthanide and actinide oxides, semiconductor nanostructures and organic polymers. This article will delve into the particulars of silica-based aerogels (aerogel.org, 2019).

Silica aerogel starts life off as an alcohol based silica gel. The main route for this gels synthesis is usually through using a compound called tetramethoxysilane (Si(OCH3)4), commonly known as TMOS (NileRed, 2020). The TMOS reacts with water in the presence of a basic catalyst, usually dilute ammonia, to form silicon dioxide (commonly known as silica) and methanol. The aerogel is built off the lattice which silica forms in this reaction. The silica gel formed in this reaction is then left to sit still for some time before it is ready to be dried.

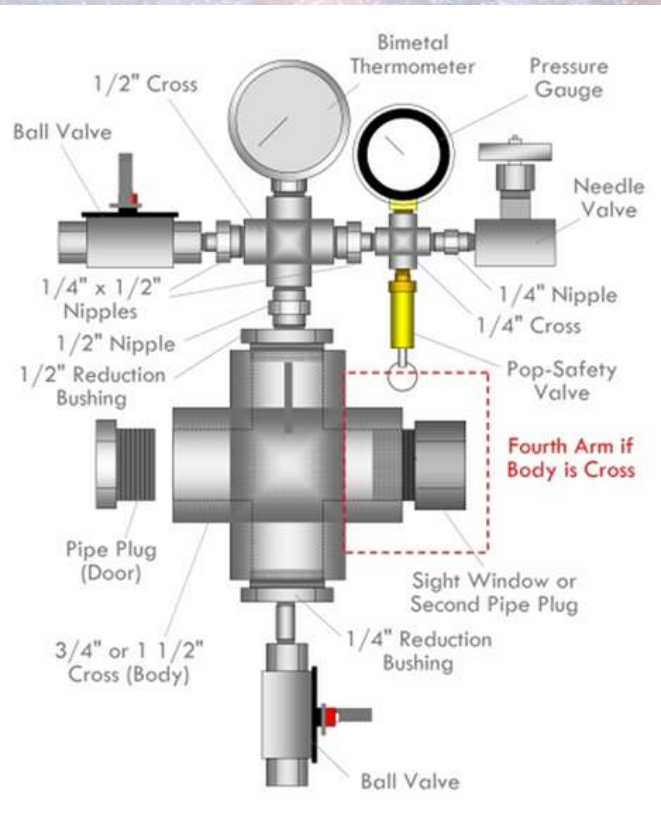
Now, if you let the gel structure dry by straight evaporation, be prepared for disappointment. Your lovely gel mould will crumble into bits. This is due to a phenomenon called capillary action. As alcohol rises out of the pores of the structure, the pores begin to contract from the sides, and collapse on themselves. This is because of the surface tension of the liquid in the pores slinging to the walls of the pores, causing them to crumble into a heap of crumbs.

So how do we avoid this happening? Supercritical drying is the answer.

As I'm sure you know, matter can exist in three states: solid, liquid and gas. However, at specific pressures and temperatures, matter can exist as a supercritical fluid, as a mix between a liquid and a gas. The idea behind supercritical drying is that the liquid in the silica gel can be displaced by the supercritical fluid (usually CO2 when making silica based aerogels) as the temp as the temperature rises. Then, once it is replaced, the pressure of the container can be reduced, converting the gas, bypassing the liquid to gas change of state entirely. Because supercritical fluids

have no surface tension (unlike conventional fluids), no capillary action will occur as it transitions into a gas, thus preventing it from crumbling. This process is done in a chamber specifically designed to withstand high pressure and temperatures, and the chamber is the current limitation in production. You can only make a sample of aerogel as big as your vessel can contain, and costs exponentially increase as chamber size increases.

A typical supercritical drying rig looks like this (aerogel.org, 2019):



The top left ball valve is where CO2 is siphoned into the system, and the bottom ball valve is where it leaves the system. All conditions are carefully monitored by the dials inputted at the top. It is imperative that no leaks are in the system, and throughout the process, soapy water should be applied to valves and connections to check if there are any gas leaks, as it will be impossible to reach supercritical conditions if they are present

. Once the drying process is complete, you should be left with a lovely sample of aerogel. Aerogel has a long list of records based on its properties. Firstly, it is composed of 99.98% air, making it the lowest density solid ever produced, with silica aerogel having a density of 0.0011 g cm¬-3. As a result, it has some remarkable properties. It has the lowest refraction index among solids at 1.002, and has the lowest thermal conductivity of a material, at 0.016 W m-1 K-1 (aerogel.org, 2019) The image below demonstrates this ability in a very poignant manner.

These properties make it a material for the future. Its incredibly impressive properties enable a myriad of uses. In the future, it will be used for sonic and thermal insulation in vehicles and spacecraft due to its light weight and its low thermal conductivity. It is already being used on the Mars Exploration Rovers to protect them from the planet's harsh climate. Furthermore, due to the materials' uncanny ability to absorb hydrophobic liquids, aerogel can be utilized to clean oil spills in the ocean, protecting our aquatic life. In addition to aiding mankind, aerogel can be used to seek out the mysteries of our universe. Because of the way the aerogel is structured, the material is very good at absorbing energy.

This property was exploited by scientists at the NASA JPL to collect comet dust by absorbing the particle's energy as they accelerated at high speeds towards the probe on which the aerogel was installed on. This protected the probe and halted the particles completely, allowing the particles to stick onto the probe so that they may be extracted upon arrival on earth (aerogel.org, 2019).

These are just some of the ways aerogel can be used, and it is safe to say that it is a generational invention. It has and will continue to play a significant role in the development of Earth and of mankind as a whole, and thus has affirmed it's position as a material of the future.

Bibliography

1. aerogel.org. "Aerogel.org» What Is Aerogel?" Aerogel.org, 2019, www.aerogel.org/?p=3. Accessed 19 June 2023.

2. "Aerogel.org» How Is Aerogel Made?" Aerogel.org, 2019, www.aerogel.org/?p=4. Accessed 19 June 2023.

3. "Aerogel.org» Parts and Schematics." Aerogel.org, 2019, www.aerogel.org/?p=667. Accessed 19 June 2023.

4. NileRed. "Making Aerogel - YouTube." www.youtube.com, 30 Apr. 2020, www.youtube.com/watch?v=Y0HfmYBlF8g .

The Development of Genome Sequencing

Ali Khan

Once described as the “Holy Grail” of structural biology (Morse, 1999), genome sequencing is widely regarded as one of the most pivotal biological advancements in the modern era. Fundamentally, genomic sequencing involves the determination of the entire genetic makeup of a specific organism or cell type (NIH, 2018). An organism’s genome is composed of DNA molecules – the basic biological unit of data storage – made up of chemical base pairs. Different combinations of base pair sequences (composed of bases A, T, C, or G) encode blueprints for all foundational polypeptides that life is built upon (Carkett & Honkala, 2022). With approximately 3 billion base pairs in the human genome (GNN, 2003), the prospect of charting this sequence was an exciting (albeit daunting) task: the ability to identify minute differences in our individual ‘codes’ holds the key to identifying the root of genetic disorders, as well as the individual unique nature of humans. Although initially an arduous and inefficient process, the development of modern technologies has significantly increased the viability of sequencing in various biological and medical advancements.

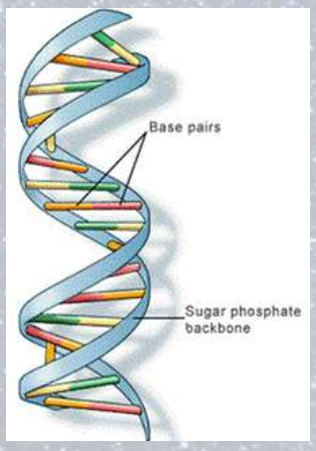
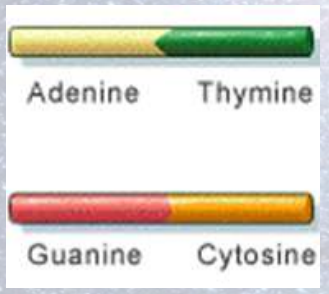


Fig 1: DNA double helix



After the discovery of the structure of DNA in 1953 by Watson, Crick, and Franklin, interest in sequencing the human genome accelerated (Fatima & Ebertz, 2020). However, previous strategies used to infer protein chain sequences did not seem to apply to nucleic acid investigation due to the difficulty of distinguishing longer DNA molecules (Heather & Chain, 2016). Initial methods of DNA sequencing (which eventually would lead to full-genome sequencing) were largely foundational, after previous breakthroughs in sequencing other nucleic acid molecules. This began with Robert Holley’s sequencing of the first tRNA molecule (for Alanine) in 1965 – for which he was awarded the Nobel Prize in 1986 (Schroeder, 2022). Holley’s research team determined the tRNA structure by using ribonucleases to split the molecule into pieces, at locations of specific nucleotides. These were then manually ordered by an entire team, until the mapped sequence was obtained. Further advancements in 1972 by Walter Fiers managed to sequence the DNA of a complete gene (which encoded the protein coat of the bacteriophage MS2) by using RNAses to digest the viral RNA and isolate oligonucleotides. After separation via electrophoresis & chromatography, the entire genome could be isolated (Fiers, et al., 1976).

The first major breakthrough in DNA sequencing technology was made by English biochemist Fredrick Sanger in 1977, introducing the dideoxy chain-termination method together with advancements to previous methods. This came to be known as "Sanger Sequencing" (yourgenome, 2015). Sanger began by denaturing dsDNA using heat to separate the molecule into individual template strands, before using DNA polymerase to make multiple copies of these strands – four of which would be involved in separate sequencing reactions (Schroeder, 2022). A DNA primer was then attached to each of the four strands, providing a starting point for sugar-phosphate backbone formation using regular deoxyribonucleotides (dNTPs), which are DNA strand monomers. At this stage, Sanger introduced dideoxy nucleotides (ddNTPs): these lack the 3' hydroxyl group which is required for DNA chain extension and formation, and are thus unable to form a bond with the next dNTP's 5' end, serving as a chain-terminator (Heather & Chain, 2016). A single type (A, T, G, or C) of radioactively labelled ddNTPs are added to each of the four sequencing reactions at low concentrations so that the ddNTPs are incorporated (and terminate the chains) randomly; this obtains all possible DNA chain lengths. Finally, these are all displayed on four lanes of a polyacrylamide gel by electrophoresis, a method of separating DNA fragments according to size (yourgenome, 2015).

Autoradiography (an X-ray image of the gel) was then used to infer the nucleotide sequence of the original template strand, by comparing corresponding radioactive bands on each of the four samples (indicative of each of the four chemical bases) and thus determining each base's position (Heather & Chain, 2016). The accuracy and ease of Sanger Sequencing led to it becoming the most common method used, starting with Sanger's full sequencing of the 5000-base phiX174 virus genome. Although this showed immense promise, the process was onerous and time-consuming, so research shifted towards discovering a method of sequencing automation that could broaden its potential uses.

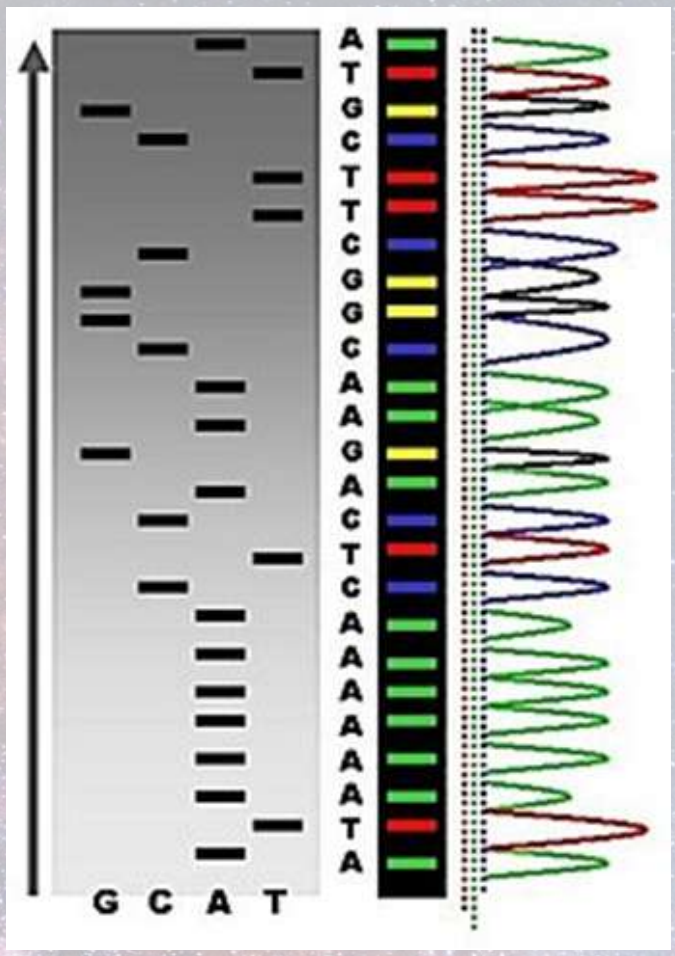


Fig 2: Sanger Sequencing

A major step towards automation was made by Leroy Hood and Michael Hunkapiller in 1987, bringing two profound method improvements. Firstly, radioactive molecules were replaced by fluorescent dyes, which were more easily obtained and allowed the simultaneous sequencing of hundreds of samples (Heather & Chain, 2016). In addition, they began the use of data acquisition/analysis on the computer, known as ABI 370 (Schroeder, 2022). Coupled with the usage of the polymerase chain reaction (PCR) to amplify tiny amounts of genetic material so that it is large enough for analysis (Gyllensten, 1989), the speed and efficacy of Sanger's

'first-generation method' increased exponentially. A newer DNA sequencing technique was introduced in 1996, known as pyrosequencing. This was based on the measurement of luminescence generated from pyrophosphate synthesis during sequencing (Nyŕen, et al., 1998). Pyrophosphate is synthesized during the action of DNA polymerase (Lapenta, et al., 2016), and is thus a natural method of detection. Furthermore, pyrosequencing could be observed in real-time and was automated in the '454' machine, becoming the more widely used 'second generation method' and the first to be commercialised (Heather & Chain, 2016). Heather & Chain (2016) go on to describe the "paradigm shift" which the 454 automation brought in comparison to Sanger Sequencing, increasing the mass of DNA which can be sequenced in a single run.

'Third generation' technique advancements of the last two decades have included innovative methods, such as the ligation method using DNA ligase, yet pyrosequencing has been largely preferred as assembly from ligation is more challenging (Heather & Chain, 2016). Fundamentally, next-generation sequencing (NGS) involves sample preparation, amplification, and DNA output/analysis (Fatima & Ebertz, 2020). Nanopore sequencing, developed by Oxford Nanopore Technologies, has brought further promise – this enables real-time analysis of DNA fragments by monitoring changes to an electrical current as nucleic acids pass through a protein nanopore (Wang, et al., 2021). The compact nature of the machine used (being almost completely portable) enables rapid DNA sequencing at any location; nanopore sequencing allows the whole human genome to be sequenced in one day, for under $1000 (Schroeder, 2022).

Fig 3: Pyrosequencing Machine

NGS sequencing technology has resulted in innovative breakthroughs in medicine and biochemistry. This began in earnest with the completion of the Human Genome Project in 2003 – which successfully identified the (estimated) 80,000 genes in human DNA, determined the sequence of 3 billion chemical bases, and stored this information in a database (Boehm, 1999). With NGS technology generating large volumes of genetic data at the fastest rate in history, advancements in 'Big Data' harvesting and storage are elevating sequencing applications to the next level of medical treatment. A singular human genome sequence produces approximately 200GB of raw data, yet the storage of millions of individual genomes could allow for a personalised approach to healthcare (known as 'precision medicine') using personal information, such as genetic and lifestyle data, to prevent and treat complex diseases specific to the patient (getsmarter.com, 2022). As storage of 100 million genome sequences would accumulate 20 billion GB of raw data (Labiotech, 2021), 'Big Data' management methods (such as cloud computing) would enable precision medicine to be a viable form of treatment for the wider human population. However, this prospect has also been met with some ethical concerns, particularly regarding the security of personal biological information storage (Johnson, et al., 2020).

They expand on the challenges which may be associated with a supposed 'clinical genomics service' and note that this idea deliberately integrates clinical practice and research; these have historically been kept distinct. However, they argue that the concept of such a service is built upon a diverse database of genetic information; such a system would only be of collective benefit to society, heightened by maximal participation and thus an increased 'sample size'. While inequalities in access to genomic services would need to be addressed early on, this data security risk should be balanced against potential patient benefit. Furthermore, not all data stored would need to be attached to personal information (e.g. genomic and phenotypic data would, in many cases, rely on the analysis of data as a collective).

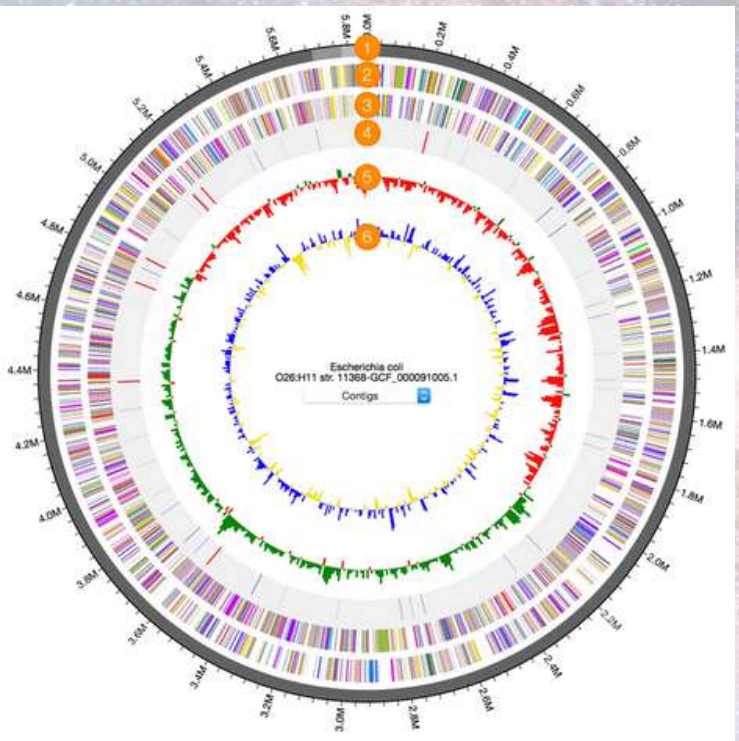


Fig 4: Genomic Map

Sequenced genomic maps have been used to identify specific gene point mutations which cause hereditary diseases (such as cystic fibrosis and Alzheimer's disease), by comparing the sequenced base DNA to the DNA of those affected. With third-generation sequencing techniques (e.g. nanopore sequencing) being able to conduct genomic sequencing of newborns within 24 hours, this functionality can be developed into a diagnostic test that enables geneticists to detect carriers within family pedigrees. This prospect would help overcome obstacles in hereditary disease detection that previously seemed insurmountable and will continue to uncover the sources of various other genetic disorders. With the understanding of mutations causing these disorders, researchers can accurately develop and trial new classes of drugs or immunotherapy techniques (Boehm, 1999). Effects are not limited to human genomes; efficient modern methods of DNA sequencing allowed for rapid mapping of the Sars-CoV-2 genome in 2020, identifying 'superspreader' sources of community coronavirus outbreaks in Australia to ensure containment of the disease (Visontay, 2020). Pathogen genome sequencing is also being used to detect and investigate foodborne bacterial outbreaks, enhancing our ability to detect infection trends and antimicrobial resistance (CDC, 2022).

Genome sequencing has given rise to CRISPR-Cas9 - a method of genome editing. Understanding human gene loci for specific genetic disorders, such as sickle cell anaemia, could allow direct editing and replacement of defective genes (NIH, 2022). There are two key molecules involved in the system: a Cas9 enzyme to act as a pair of 'molecular scissors' to cut strands of DNA at specific locations, and a piece of gRNA (guide RNA) to ensure the Cas9 enzyme is led to the right part of the genome. Finally, foreign DNA molecules are introduced and combined with the original DNA (yourgenome, 2017). DNA sequencing technology has allowed the complete mapping of specific areas of the genome which may need to be edited, which allows

highly specified and focussed editing (e.g. altering viral structure so that the molecule becomes non-virulent). However, researchers are still determining how safe this process is, as well as facing ethical concerns over the extent human genetics should be artificially modified. Most of the changes introduced currently are limited to somatic cells and are only isolated in particular tissues rather than being heritable; however, germline cell editing (egg or sperm cells) could allow artificially enhanced traits to pass on to future generations (NIH, 2022).

Ultimately, the rapid development of genome sequencing has unlocked novel pathways in medical treatment and biochemical analysis. Modern NGS technologies such as nanopore sequencing, largely built upon the foundations of Sanger's original methods, enable the treatment of genetic disorders with previously unknown sources, as well as wider applications in genome editing and viral detection. Coupled with 'Big Data' processing advancements, this may give rise to new, highly effective treatment approaches. Although ethical concerns of genome editing and sequencing data storage still must be fully explored, the current trajectory of genome sequencing will save the lives of millions.

Fig 5: CRISPR-Cas9

Bibliography

Boehm, D., 1999. Applications and Issues of the Human Genome Project. [Online] Available at: https://www.ndsu.edu/pubweb/~mcclean/plsc431/students99/boehm.htm#:~:text=Current%20and%20potential%20applications%20of,and%20risk%20assessment%20(3). [Accessed 03 04 2023].

Carkett, M. & Honkala, A., 2022. What Is Genomic Sequencing and Why Does It Matter for the Future of Health?. [Online] Available at: https://institute.global/policy/what-genomic-sequencing-and-why-does-it-matter-future-health [Accessed 03 04 2023].

CDC, 2022. Whole Genome Sequencing. [Online] Available at: https://www.cdc.gov/pulsenet/pathogens/wgs.html [Accessed 03 04 2023].

Fatima, T. & Ebertz, A., 2020. A Journey Through the History of DNA Sequencing. [Online] Available at: https://the-dna-universe.com/2020/11/02/a-journey-through-the-history-of-dna-sequencing/ [Accessed 02 04 2023].

Fiers, W. et al., 1976. Complete nucleotide sequence of bacteriophage MS2 RNA: primary and secondary structure of the replicase gene. Nature, 260(1), pp. 500-507.

getsmarter.com, 2022. How Big Data is Changing Genetic Research. [Online] Available at: https://www.getsmarter.com/blog/market-trends/how-big-data-is-changing-genetic-research/ [Accessed 04 04 2023].

GNN, 2003. Genome Sequencing. [Online]
Available at: http://www.genomenewsnetwork.org/resources/whats_a_genome/Chp2_1.shtml# [Accessed 04 04 2023].

Gyllensten, U., 1989. PCR and DNA sequencing. Biotechniques, 7(7), pp. 700-708.
Heather, J. & Chain, B., 2016. The sequence of sequencers: The history of sequencing DNA. Genomics, 107(1), pp. 1-8.

Johnson, S., Slade, I., Giubilini, A. & Graham, M., 2020. Rethinking the ethical principles of genomic medicine services. European Journal of Human Genetics, Volume 28, pp. 147-154.

Labiotech, 2021. Is Cloud Computing the Answer to Genomics' Big Data Problem?. [Online]
Available at: https://www.labiotech.eu/in-depth/cloud-genomics-big-data-problem/
[Accessed 03 04 2023].

Lapenta, F., Silva, A., Brandimarti, R. & Lanzi, M. G. F., 2016. Escherichia coli DnaE Polymerase Couples Pyrophosphatase Activity to DNA Replication. PLOS ONE, 11(4).

Morse, A., 1999. Searching for the Holy Grail: The Human Genome Project and Its. Journal of Law and Health, 13(2), pp. 219-255.

NIH, 2018. genomic sequencing. [Online]
Available at: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/genomic-sequencing
[Accessed 03 04 2022].

NIH, 2022. What are genome editing and CRISPR-Cas9?. [Online]
Available at: https://medlineplus.gov/genetics/understanding/genomicresearch/genomeediting/
[Accessed 03 04 2023].

Nyŕen, P., Uhlen, M. & Ronaghi, M., 1998. A Sequencing Method Based on Real-Time Pyrophosphate. Science, 281(5375), pp. 363-365.

Schroeder, K., 2022. A History of Sequencing. [Online]
Available at: https://frontlinegenomics.com/a-history-of-sequencing/#:~:text=The%20first%20major%20breakthrough%20in,him%20his%20second%20Nobel%20Prize.
[Accessed 03 04 2023].

Visontay, E., 2020. What is genomic sequencing and how is it being used against Covid-19 in Australia?. [Online]
Available at: https://www.theguardian.com/australia-news/2020/aug/18/what-is-genomic-sequencing-and-how-is-it-being-used-against-covid-19-in-australia
[Accessed 03 04 2023].

Wang, Y., Zhao, Y., Bollas, A. & Wang, Y. F. A. K., 2021. Nanopore sequencing technology, bioinformatics and applications. Nature Biotechnology, Volume 39, pp. 1348-1365.

yourgenome, 2015. The dawn of DNA sequencing. [Online]
Available at: https://www.yourgenome.org/stories/the-dawn-of-dna-sequencing/
[Accessed 03 04 2023].

yourgenome, 2017. What is CRISPR-Cas9?. [Online]
Available at: https://www.yourgenome.org/facts/what-is-crispr-cas9/
[Accessed 03 04 2023].

AI in Medicine

Mariam Syed

‘Artificial Intelligence’ can be defined as technology using programs to emulate human intelligence. This is achieved by its ability to gather and interpret data, spot patterns and trends and produced an output response. This computer technology follows an ‘Input Processing Output’ model which is based on the Cognitive Psychological approach that explains how human behaviours and responses are formed.

Already in the NHS, healthcare technology is widely used and many of the infrastructures are supported by AI. Currently, AI systems are being developed and designed to accurately produce a diagnosis from medical imaging scans and microscopic slides. AI is also being used to assist in screening processes, such as IVF, which can determine how likely a fertilised embryo can result in a successful pregnancy.

Aside from its general usage, AI can also be used in a more specific and targeted way. An example of this is in Radiotherapy. Radiotherapy typically uses dose prescriptions which are generalised to all patients. These methods result in a disregard for the individualistic characteristics of tumours. However, recent AI development has been advantageous in analysing patients’ CT scans and electronic health records to produce a personalised prescription dosage.

AI can also be used to tackle part of the major issue of understaffing in the NHS. New developments in technology have made way for the possibility of achieving virtual nursing, through robots.

Devices that are wearable and easily accessible are designed to offer advice and guidance to patients within their own homes. These virtual robots can provide simple, but effective uses such as reminding people to take their medication on time. An example of a wearable device is called “Current” which can measure a patient’s pulse, temperature, respiration, and oxygen saturation.

This device can also give doctors regular updates on their patients' health remotely and is used both at home and in the hospital. Ultimately, this means that more patients can receive care whilst simultaneously reducing the stress that is placed upon nurses and doctors. An idea has been proposed to introduce virtual nursing to be implemented into the NHS111 service. However, we must consider all aspects of this decision as patients may feel neglected talking to a robot which is unable to empathise. So, although this would reduce strain on the NHS and tackle, waiting times, it may be considered unethical and could cause controversy about the quality of patient care.

Bibliography

Care at home platform (2022) Current Health. Available at: https://www.currenthealth.com/.

Premela (2022) Ai in medicine, The Medic Portal. Available at: https://www.themedicportal.com/application-guide/medical-school-interview/nhs-hot-topics/ai-in-medicine/?v=79cba1185463.

Are you secretly a quantum computer?

Charles Lawrence

The human brain and the quantum computer have many similarities but also many differences. Whether it is possible for the quantum computer to be better than the human brain is undoubtedly a broad and complicated topic.

Firstly, the human brain is defined as “The organ inside of the head that controls all body functions of a human being” (conver.gov, n.d.). Whereas the quantum computer is “an area of computer science that uses the principles of quantum theory” (Investopedia.com, 2023), to further explain quantum theory is, put simply, the “behaviour of matter and light on an atomic and subatomic level” (Brittanica.com, 2023). The possibility of the quantum computer being able to map the human brain depends on the scale that you want to map the brain and understand it. This could need a few quantum computers involved, where there are currently around 11 (as of June 2018), in which there are over 8 billion brains with different mechanics and differences about them, which can be compared to different learning requirements in different individuals.

The quantum computer has many advantages and disadvantages, some of the advantages include that they are high-powered computers that can process many ‘bits’ of information, and because of this they can handle complex problem solving, this would make them a brilliant candidate for processing and mapping three-dimensionally, which would help provide information and predictions about the effects and side effects of certain treatments and vaccinations. Some of the disadvantages of quantum computing include that they are expensive to maintain and run due to the high-power usage and the intricacy of the parts of the computer. There is another issue with quantum computers as they are sensitive to the environment that they are situated in, they are sensitive to the humidity of the air, or the amount of noise inside of the room or area that they are positioned in. Another disadvantage of quantum computers is that if, in the future, we have high-powered AI (Artificial Intelligence) contained in a quantum computer, the efficiency of the computer and the amount that it can store could be a threat to humanity, as the more powerful the computer is the more powerful the AI can become.

The human brain has many advantages and disadvantages, but this is more generalised as some brains work and function differently from others. Some of the advantages are that the human brain is the most evolved brain out of all mammals, so the human brain inside would be more complex compared to the other brains in other animals, such as sheep or pigs. Another advantage of the human brain is that it stores emotions and the past things that have happened to you, or that you have experienced, this is stored in short-term memory and then transferred to long-term memory. This shows that the human brain is constantly evolving and becoming better at making decisions more effectively and efficiently. Another advantage of the human brain is that it controls the human body

functions, as stated in the introduction, it is the central processing point of any human functions and thoughts. Some disadvantages of the human brain are that it must be maintained healthily, this can be done by eating healthily, going out for regular exercise, or just spending some time in the fresh air. However, it can also be damaged. Another disadvantage of the human brain is that it sometimes forgets information and data in the short-term memory, or it doesn't transfer to long-term memory quickly enough. Another disadvantage of the human brain is that it is easily distracted by other things, you could be writing something down on a piece of paper and then hear the dogs barking down the street or the sound of the kettle boiling. One thing that I have learned from doing meditation at LGS is that I have learned that the brain is 'like an animal' it finds other things to think about rather than the thing that you want it to think about.

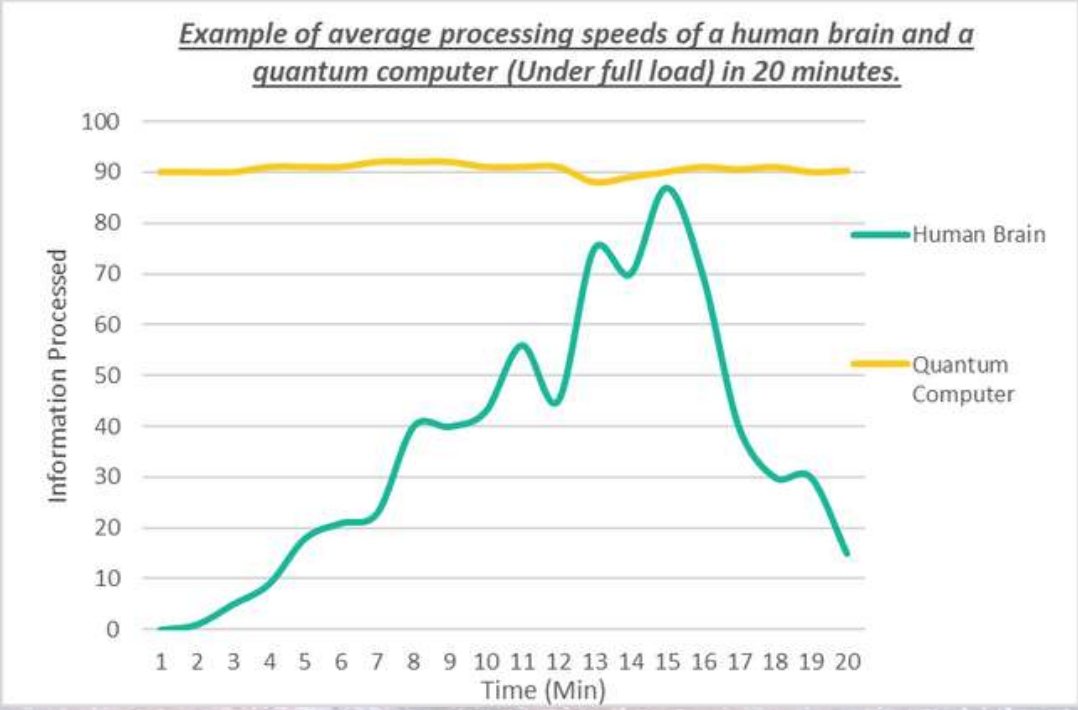
Some of the similarities between the human brain and the quantum computer are that they are both complex systems, the quantum computer uses qubits that store information differently to normal computers by having either an on, off or on and off value. Whereas the brain uses neurons for functions. Another similarity of the human brain to the quantum computer is that they both learn and adapt.

The human brain makes new connections to neurons, speeding up processing times as it has found a faster route to the neuron, whereas the quantum computer makes and learns new qubits, and their necessary locations and then maps out the fastest routes to get there.

Another similarity between the human brain and the quantum computer is that it can do multiple tasks at one time, the human brain can do much more at one time, such as writing an essay whilst listening to music or hearing the rain outside, just as an example. The quantum computer can perform multiple calculations thanks to the qubits which make it faster than ordinary computers, this is a much faster process due to the third value that you can have on and off, this is in addition to the normal binary values that you will or might have seen in computer science.

The differences between the human brain and the quantum computers are presented in the following chart:

Elements / *Scenarios*	**Human Brain**	**Quantum Computing**
Storing Information	Changing neurons and creating new linkages	Stores in qubits using quantum mechanics to store the information.
How it processes	Communicating a situation from short term memory to the long term. This takes in smells, sound, sight, touch, and taste.	Processing information in qubits – 0, 1, 0&1 values. This is quicker to store more information as it can store one more load of information.
How long to process information	The brain is both software and the hardware for itself. It processes by neuroplasticity, which is the changing of the linkages between the neurons in the brain.	The quantum computer is both reliant on the hardware and the software, without any of these it would not function. The hardware has a set range of linkages that can be connected, this causes it to be quicker as it has a set bandwidth for both.



In making this conclusion, I decided to conduct primary research with different Artificial Intelligence chatbots to obtain their response to the question: "Do you think that the Quantum Computer works like a human brain". I planned to ask 2 main chatbots, Google Bard and OpenAI's ChatGPT. When Google Bard was asked, it responded by saying "Quantum computers and brains are both complex systems that are capable of performing complex tasks." It concluded its 800-word long response by saying "There are similarities between the brain and the quantum computer, perhaps every brain might be a quantum computer without you knowing." When OpenAI ChatGPT was asked the very same statement however it said, "Both the Quantum Computer and the Human Brain work with vastly different principles." It also stated that "both of their mechanisms and architectures are fundamentally distant from each other."

It is possible that the human brain could be remarkably similar to the quantum computer, however without significant technological advancements proving this theory at present is problematic.

These technological advancements would come at such an inflated cost that they would likely not happen in the next 15 or 20 years. This developing technology is a massive risk that we as an entire world are taking, the quantum computer can break security keys in a matter of hours, where it would take the normal average high end computer thousands of years to achieve and crack. If an artificial intelligence software was put on the quantum computer though as seen in the graph of average processing speeds under a full load, we can see that the quantum computer gets things achieved at roughly the same rate, it is around the 90 regions, and it stays there. If we were to load an AI onto it, it would become more powerful than our brains, and because of the Qubits, we would not be able to make a normal computer with this amount of power. This is an example of AI being misused which would have dreadful consequences. With the right laws and regulations towards this matter, we should and would not have to worry about this.

Bibliography

Frankenfield, J. (2023) Quantum Computing: Definition, how it's used, and example, Investopedia. Available at: https://www.investopedia.com/terms/q/quantum-computing.asp/

Quantum Mechanics (2023) Encyclopædia Britannica. Available at: https://www.britannica.com/science/quantum-mechanics-physics.

Neurodevelopment in early childhood and autism in young people

Zainab Sabat

What is Autism?

Autism is a mental disability that is caused by differences in brain development. The full name is autism spectrum disorder. With autism, there are degrees of how severe the disability is, yet this is very hard to distinguish as autism is difficult to diagnose. There is no medical test which indicates if a child has autism, so the diagnosis is up to a doctor's observation of the patient's behaviour, thus many ASD patients do not get the help they need due to difficult and late diagnoses. (Centres for Disease Control and Prevention, 2020)

How does development in the brain differ in ASD children?

In children with ASD, a lot of circuits in the brain have been disturbed; this has occurred in the: sensory, prefrontal, hippocampal, cerebellar, striatal and other midbrain regions. In these areas of the brain, the signalling pathways are altered to cause a disturbance in the brain which leads to changes in their behaviour. This change in neurodevelopment causes impaired social interactions and elevated repetitive behaviours. (Kumar et al., 2019)

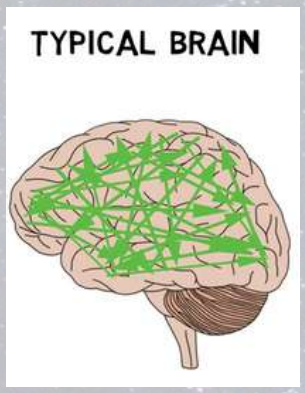
Research has been done to figure out the major differences and why it is so hard to diagnose this disability. MRI's have shown that the cerebellum has been reduced in size. The cerebellum regulates body movements and coordination in muscles used for speaking. If this is, then when this is reduced in size it limits the kids in their social interactions, and will affect their verbal and physical behaviours. Common behaviours in children with autism show delayed language and movement skills which could possibly be caused by the reduction of size in the cerebellum. (Centres for Disease Control and Prevention, 2020).

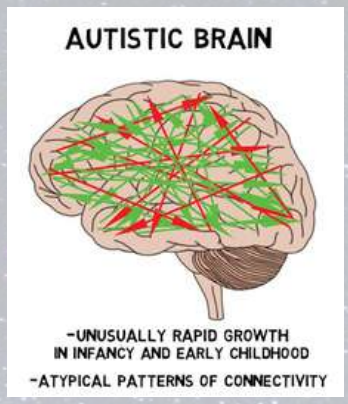
The hippocampus and the amygdala in a child with ASD are also smaller but this is not the only thing different. The neurons in this part of the brain are more tightly packed. As the neurons are more tightly packed there is more cell-to-cell contact so there is more cell differentiation. The amygdala controls your emotional responses. Research was done on the relationship between the size of the amygdala and neuroticism. It was found that if the amygdala is smaller in volume there was an increased vulnerability to anxiety. (Hu et al., 2017) it is also found that anxiety is experienced more intensely in children that are autistic. (Raising Children Network, n.d.)

A major difference in the brain for ASD kids is the size of the brain cavities. The ventricles (brain cavities) in the brain are enlarged in children with autism. This has led to ASD kids to have a higher chance of having hydrocephalus. Hydrocephalus is when the ventricles are larger than normal which then leads to a build-up of cerebrospinal fluid, the enlarged ventricles then compress the brain which can lead to brain tissue damage. (www.ninds.nih.gov, n.d.). A study was done to see if there was a relationship between hydrocephalus and ASD, and it was found that there is an

association. (Tina Noergaard Munch et al., 2021)

From this, you can see the differences in the neurodevelopment in an ASD brain and then some of the behaviours and effects resulting from it.





Bibliography

Centres for Disease Control and Prevention (2020). What is autism spectrum disorder? [online] Centres for Disease Control and Prevention. Available at: https://www.cdc.gov/ncbddd/autism/facts.html.

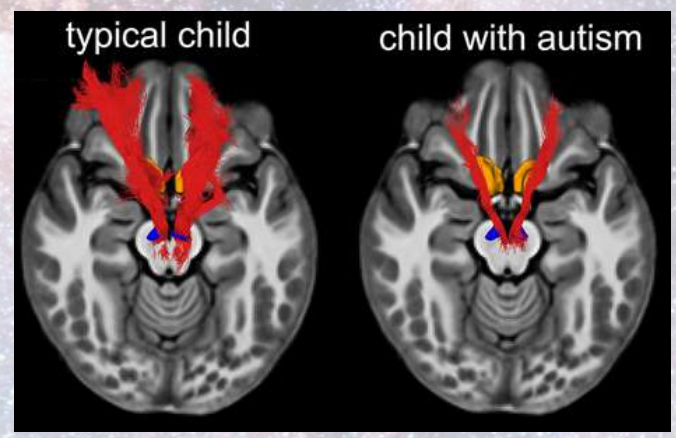
Hu, Y., Moore, M., Bertels, Z., Phan, K.L., Dolcos, F. and Dolcos, S. (2017). Smaller amygdala volume and increased neuroticism predict anxiety symptoms in healthy subjects: A volumetric approach using manual tracing. Neuropsychologia, 145. doi:https://doi.org/10.1016/j.neuropsychologia.2017.11.008.

Kumar, S., Reynolds, K., Ji, Y., Gu, R., Rai, S. and Zhou, C.J. (2019). Impaired neurodevelopmental pathways in autism spectrum disorder: a review of signaling mechanisms and crosstalk. Journal of Neurodevelopmental Disorders, 11(1). doi:https://doi.org/10.1186/s11689-019-9268-y.

Raising Children Network. (n.d.). Anxiety: autistic children and teenagers. [online] Available at: https://raisingchildren.net.au/autism/health-wellbeing/mental-health/anxiety-asd#:~:text=Autistic%20children%20and%20teenagers%20can.

Tina Noergaard Munch, Hedley, P.L., Hagen, C.A., Bækvad-Hansen, M., Bybjerg-Grauholm, J., Grove, J., Merete Nordentoft, Børglum, A.D., Preben Bo Mortensen, Werge, T., Melbye, M., Hougaard, D.M. and Christiansen, M. (2021). Co-occurring hydrocephalus in autism spectrum disorder: a Danish population-based cohort study. 13(1). doi:https://doi.org/10.1186/s11689-021-09367-0.
www.ninds.nih.gov. (n.d.).

Hydrocephalus | National Institute of Neurological Disorders and Stroke. [online] Available at: https://www.ninds.nih.gov/health-information/disorders/hydrocephalus#:~:text=Hydrocephalus%20is%20a%20neurological%20disorder.



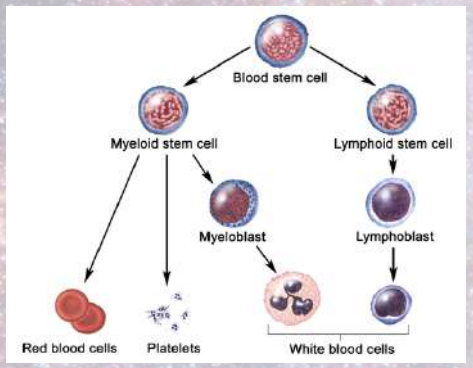
Stem cells and 3D bioprinting in the future of organ transplantation

Diya Premkumar

At present, a staggering "7,000 people are on the UK Transplant Waiting List. Last year over 420 people died while waiting for a transplant" (NHS, n.d.a). The COVID-19 pandemic resulted in these numbers sky-rocketing with "living donor transplants falling by 58%" (NHS, n.d.b). The UK's transplantation scheme has since faced unprecedented challenges due to issues regarding the capacity needed to accommodate patients, the "reduced ability to care for patients who have received transplants and weighing out the risks versus benefits of immunosuppressed transplant recipients" (NHS, n.d.c). Now, organ donation and transplantation is making convincing progress and the rates almost match the pre-COVID statistics. Despite this, there will always be a shortage of organ donations against the extremely high demand for transplants. To overcome this problem there are two futuristic solutions: stem cells and 3D bio-printing, and both are most definitely within reach.

Stem Cells

A stem cell is an undifferentiated cell that is capable of giving rise to a specialised cell by differentiation. It can self-renew by dividing by mitosis many times to produce daughter cells of the same type. Embryonic stem cells are the ultimate stem cell and are the most effective. They are classed as being 'pluripotent' cells, meaning that they have the potential to differentiate into almost all of the specialised cells in the body, and thus help to form all the different tissues and organs needed to develop a new organism. The process of harvesting involves removing the embryonic stem cells from the "inner cell mass of the human blastocyst, an early stage of the developing embryo lasting from the 4th to 7th day after fertilisation" (National Library of Medicine, 2002) and from embryos that have been created using a cloning process known as somatic cell nuclear transfer (SCNT) (Vestal, 2008). Other sources of stem cells existing in the adult form can also be used, such as in the bone marrow, skin, umbilical cord blood and other organs such as the liver and brain. However, these stem cells are labelled as 'multipotent'. Therefore, they can only differentiate into a limited number of cell types. For instance, adult haematopoietic stem cells from the bone marrow may only differentiate into platelets, white blood cells, red blood cells, and other cells of the blood.



Differentiation of haematopoietic stem cells

Stem Cells in Medicine

Stem cell technology has the potential to

repair damaged organs by growing new tissue from stem cells and eventually could replace them. The new tissue would be produced by using embryonic stem cells obtained from stem cell donors or therapeutic cloning. Adult stem cells could also be cultured (growing tissue cells in an artificial medium containing nutrients) in a lab but they are partially specialised and thus, differentiate into a limited range of specialised cells.

Globally, this has been scaled up and doctors have begun to explore producing whole organs using stem cell technology. In the USA, Massachusetts General Hospital and Harvard Medical School are researching induced pluripotent stem cells (iPSCs) which can give rise to almost all cell types. Adult somatic cells, such as skin or blood cells, are reprogrammed into iPSCs, essentially by "reverse differentiation". The iPSCs can be grown in 3D culture systems leading to the development of 'organoids', which are "miniature models of real human organs from stem cells" (Ward, 2021, pp34) and aim to mimic the way they function. Scientists from the esteemed institutes listed above have used iPSCs to form tissue resembling that of a developing human heart. When it was given an electric shock, the replica began to beat. In addition to this, doctors in the USA have adopted a way of treating burn victims by using a thin layer of stem cells taken from the patient. These stem cells are sprayed onto the wound, allowing the skin to heal evenly and completely, without the need for painful skin grafts which often cause infection.

Furthermore, 3D cerebral organoids (of the brain) have been developed and, due to their complexity, have raised intriguing ethical questions. Some of which include whether they are conscious and how long it will take until an entire "humanoid" could be created. For these reasons, the use of stem cells has to be monitored carefully and legislation would have to be enforced. However, the use of brain organoids can be, by far, "considered a more acceptable form of experimentation than that on human fetuses (weeks 9 and beyond after fertilisation), animals and voluntary human adults." (Lavazza and Massimini, n.d.)

Tissue resembling human heart, beating once given an electric shock.

Therapeutic cloning

Modern advancements in scientific technology have allowed human embryos to be grown in the lab and later, doctors may extract embryonic stem cells from them. Therapeutic cloning is the process of using cloning technology for medicinal purposes. One method is to use an individual's DNA to clone one of their organs for use in transplants. The task involves the transfer of a nucleus from the body cell of a patient to an enucleated egg cell from a donor. The egg cell is then stimulated to divide (usually by an electric shock) and this develops into an embryo. After 4-5 days the stem cells are removed from the embryo because 5-day-old embryos are the best source of embryonic stem cells. These are then cultured in a petri dish and are left to differentiate into specialised cells, which can be transferred to the patient.

Therapeutic cloning uses cells from the patient, resulting in fewer complications regarding rejection from the patient's body. There is also a reduced need for the patient to take immunosuppressant drugs, which would reduce the body's ability to overcome infection.

Clinical, Ethical and Social Issues

Firstly, it is important to consider the clinical issues involved in culturing stem cells in a lab. The stem cells obtained could become "infected with a virus which could be transmitted to the patient and stem cells can mutate, behaving like cancer cells" (Alistair, n.d.). There is also a limited number of stem cell donors and these must also be suitable donors to the patient. Moreover, it is difficult and costly to obtain and store embryonic stem cells as these would have to be collected before birth. Who would need to give consent for this? Alternatively, some hospitals store blood from the umbilical cord at birth.

Ethical questions such as the following emerge: Should an embryo be regarded as a person or as a commodity (considering it is beneficial to scientific research)? After how many stages of development should an embryo be considered and treated as a human? It also must be kept in mind that embryos could be created solely for therapeutic cloning and then, destroyed in the process. Undoubtedly, this will not align with everyone's moral principles. It must also be considered who is granted ownership over the embryo and makes decisions regarding it. Furthermore, stem cells may be obtained from unused embryos produced in IVF (in vitro fertilisation) treatment. Is it morally right to use these embryos for this purpose and who should give permission?

Social issues involve informing the public about what stem cells can and can't do to avoid the development of unrealistic expectations. Sufficient education should be provided to the general public about whether the benefits of stem cell use outweigh the risks and objections. Several people disapprove of stem cell technology due to a "lack of peer-reviewed clinical evidence of its success" (Alistair, n.d.). In addition to this, it is possible to store embryonic stem cells collected from the amniotic fluid (before birth) or the umbilical cord blood (after birth) in a clinic. However, this isn't financially feasible for many and thus, isn't an option.

Bioprinting

Bioprinting is a branch of regenerative medicine that is currently under research. It is very similar to 3D printing which is a technique that deposits materials layer by layer to assemble a 3D object. To construct organs and tissues, a 3D printer uses bio-ink which is a printable material comprising of "water-rich molecules named 'hydrogels' and mixed into these are living cells", along with "various chemicals that encourage the cells to communicate and divide" (Jones, 2019). Bio-inks can either consist of a single type of cell or several different cells resulting in the formation of more complex structures.

Ong et al. (2017) explain that stem cells provide an "unlimited cell source for 3D bioprinting" due to their properties of "self-renewal and potency". In the UK, around "274 people are in need of a heart transplant" (NHS, n.d.d) for which there is an

undeniable shortage of donors. Fortunately, various 3D bioprinting techniques can be used to produce 3D cardiovascular tissue constructs, which beat just the same as a real human heart.

3D Bioprinting

Extrusion-based bioprinting is a promising method, whereby bio-ink made using "decellularised extracellular matrix derived from cardiovascular tissue" is loaded into the printing chamber of a printhead and is pushed through "a round nozzle that is 400 microns in diameter" (Jones, 2019) (around the thickness of a fingernail) producing a continuous filament. A computerised image of the heart tissue construct acts as a template and guides the placement of the strands into a liquid bath which helps to hold the structure together as it stabilises, or onto a flat area. After printing, some structures solidify immediately, and others need UV light treatment or other chemical or physical processes to stiffen. If printing is successful, the cells in the cardiovascular tissue will begin to act like those in a real tissue; communicating, exchanging nutrients and dividing. The 3D construct obtained could then be "seeded with human IPSC-derived cardiomyocytes to fabricate aligned myocardium that could spontaneously and synchronously contract" (Ong et al. (2017) .

The bioprinted heart produced can be surgically transferred to the patient to replace the damaged one, as would occur in a regular heart transplant.

How realistic is bioprinting and what challenges are associated with it?

The world of bioprinting has already witnessed numerous successes. For instance, we can already print relatively small structures such as a meniscus, bioprinted bladders have also been successfully implanted and skin tissue obtained from bioprinting has assisted facial nerve regeneration in rats. In addition to this, scientists have produced lung tissue, skin, cartilage and even miniature, semi-functional replicas of organs such as kidneys, livers and hearts.

Nevertheless, a great challenge comes with "replicating the complex biochemical environment of major organs" (Jones, 2019). How can oxygen and nutrients be supplied to all the cells in a full-size organ? This is why most successful attempts have been with flat or hollow structures and so, ways to incorporate blood vessels are being researched. A large percentage of cells in the bio-ink may also be destroyed in extrusion printing if the nozzle is too small or if the pressure is too high. Therefore, bioprinting must be carried out with extreme precision. There is also the issue of cells mutating and possibly becoming cancerous, which would pose an increased threat to patients. Another consequence of 3D bioprinting which challenges its practicality is the prolonged time it occurs over. For example, for an adult-size heart, it would take as long as 8 weeks. However, this proves to be better than the wait for

"several months, or possibly years" for a heart transplant as stated by the NHS (2019).

In general, with the highly promising quality and level of research and testing around stem cells and 3D bioprinting, we will likely witness their use in the future of transplantation. Undoubtedly, the way these are used will have to be monitored strictly and will be faced with some disapproval. However, if delivered successfully, it's safe to say these technologies could transform the current transplantation scheme.

Bibliography

NHS Blood and Transplant, (n.d.a). Organ donation and transplantation. [online] Available at: https://www.nhsbt.nhs.uk/what-we-do/transplantation-services/organ-donation-and-transplantation/#:~:text=Thanks%20to%20our%20amazing%20donors,the%20UK%20Transplant%20Waiting%20List [Accessed: 14/04/23].

NHS Blood and Transplant, (n.d.b). Organ donation achieved three quarters of its normal activity last year despite global pandemic. [online] Available at: https://www.nhsbt.nhs.uk/news/organ-donation-achieved-three-quarters-of-its-normal-activity-last-year-despite-global-pandemic/ [Accessed: 14/04/23].

NHS Blood and Transplant (n.d.c). Organ and Tissue Donation and Transplantation Activity Report 2021/22 [pdf] pp3. Available at: https://nhsbtdbe.blob.core.windows.net/umbraco-assets-corp/27107/activity-report-2021-2022.pdf [Accessed: 14/04/23].

National Library of Medicine (2002) Stem Cells and the Future of Regenerative Medicine. [online] Available at: https://www.ncbi.nlm.nih.gov/books/NBK223690/ [Accessed: 15/04/23].

Vestal, C (2008). The Science Behind Stem Cell Research. [online] Pew Research Center. Available at: https://www.pewresearch.org/religion/2008/07/17/the-science-behind-stem-cell-research/#:~:text=Embryonic%20stem%20cells%20are%20harvested,cell%20research%20argue%20is%20immoral. [Accessed: 17/04/23].

Ward, L. (2021). Stem cells in research. Biological Sciences Review, Volume 33 (4), pp34.

Lavazza, A. and Massimini, M. (n.d.) Cerebral organoids: ethical issues and consciousness assessment. [online] BMJ Journals. Available at: https://jme.bmj.com/content/44/9/606. [Accessed: 15/04/23].

Alistair (n.d.) The Use of Stem Cells. [online] SaveMyExams. Available at: https://www.savemyexams.co.uk/a-level/biology/ocr/17/revision-notes/2-foundations-in-biology/2-6-cell-division-cell-diversity--cellular-organisation/2-6-11-the-use-of-stem-cells/ [Accessed: 15/04/23]

Jones, T. (2019) How to 3D print human tissue - Taneka Jones [online] Ted-Ed, Youtube. Available at: https://www.youtube.com/watch?v=uHbn7wLN_3k [Accessed: 15/04/23].

NHS Blood and Transplant, (n.d.d). ORGAN TRANSPLANTATION. [online] Available at: https://www.nhsbt.nhs.uk/organ-transplantation/heart/is-a-heart-transplant-right-for-you/heart-transplant-faqs/#:~:text=How%20many%20heart%20transplants%20are,2021%2F2022%20in%20the%20UK.&text=How%20many%20people%20are%20waiting,need%20of%20a%20heart%20transplant [Accessed: 14/04/23].

Ong et al. (2017). 3D bioprinting using stem cells. [online] Available at: https://www.nature.com/articles/pr2017252 [Accessed: 15/04/23].

NHS, (2019). Waiting List Heart transplant. [online] Available at: https://www.nhs.uk/conditions/heart-transplant/waiting-list/#:~:text=It%20may%20be%20several%20months,need%20to%20remain%20in%20hospital. [Accessed: 1/04/23].

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Differentiation of haematopoietic stem cells - Winslow, T (2017). NCI Dictionary of Cancer Terms. [online] Available at: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/hematopoietic-stem-cell [Accessed: 3/07/23]

Tissue resembling human heart, beating once given an electric shock - Reeves, S (2018). 7 HUMAN ORGANS WE CAN GROW IN THE LAB. [online] Available at: https://blog.sciencemuseum.org.uk/7-human-organs-we-can-grow-in-the-lab/ [Accessed: 13/04/23].

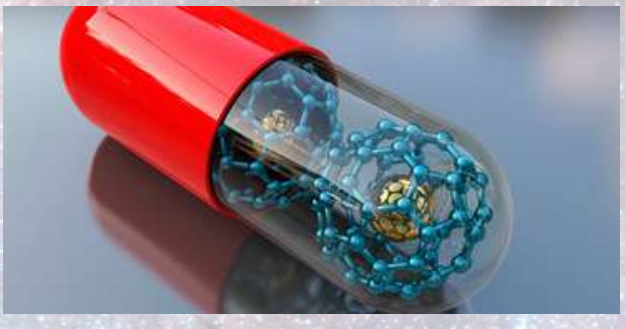
3D Bioprinting - Wake Forest Institute for Regenerative Medicine (n.d.) A Possible Weapon Against the Pandemic: Printing Human Tissue. [online] NY Times. Available at: https://www.nytimes.com/2020/07/27/science/bioprinting-covid-19-tests.html [Accessed: 17/04/23].

Nanoparticles: For the Future?

Kabeshan Sandrasekaran & Rahul Subramanian

Over the recent years of scientific advancement and developing technology, we have seen the introduction of Nanotechnology, which has been successfully implemented in many sectors of our society for maximum efficiency. A nanoparticle is a small particle that ranges between 1 to 100 nanometres in size. Undetectable by the human eye, nanoparticles can exhibit significantly different physical and chemical properties to their larger material counterparts to improve their function. Due to the wide range of applications of nanoparticles in several different industries, the production and manufacturing of nanomaterials is a rapidly developing area, which could indicate that Nanotechnology may be key to our developing technology for years to come. (hse.gov.uk, n.d) However, as mentioned, Nanotechnology is a recent discovery and may have some hidden negatives that are yet to be discovered due to insufficient research on the topic. This poses the ever-pressing question; to what extent can we truly rely on nanotechnology to pave the way for the future?

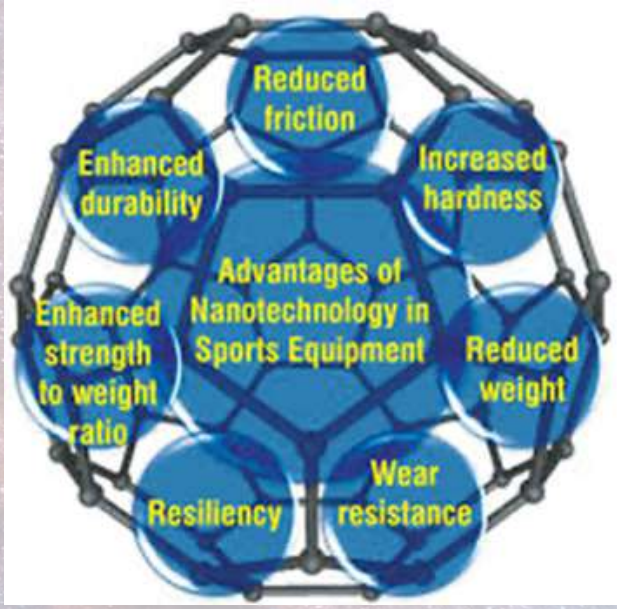
Nanoparticles play a monumental role in the recent development of technology within several industry sectors, whether it be in healthcare, sporting equipment or air purification, we can clearly see the growing use of nanoparticles to improve products. (Nanowerk.com, n.d.) The healthcare field utilises nanomaterials in a variety of ways, with one major use being drug delivery. One example of this process is whereby nanoparticles are being developed to assist the transportation of chemotherapy drugs directly to the cancerous growths. This is made possible by carbon nanotubes, which are also particularly useful in creating bacteria sensors. (Twi-global.com, n.d.) As nanotechnology develops, we can be sure to see its use in hospitals to prevent loss of life in a few years since nanotechnology permits treatments which were previously thought to be impossible. (Understandingnano.com, 2019) Researchers at John Hopkins University are using nanoimprint lithographyto manufacture a sensor that can detect Covid-19 and other viruses that can be used with a handheld testing device for quick results. Researchers at Worcester Polytechnic Institute are using antibodies attached to carbon nanotubes in chips to detect cancerous cells in the bloodstream. The researchers believe this method could be used in simple lab tests that could provide early detection of cancer cells in the bloodstream. (Understandingnano.com, 2019). With research ongoing about the use of nanoparticles in medicine, we can be sure to see increased use of nanotechnology in years to come and several potential breakthroughs in treatment which will be essential for various life-saving treatments.



In the cosmetics industry, Mineral nanoparticles – such as titanium oxide, are used in sunscreen due to the poor stability that conventional chemical UV protection offers in the long term. (Twi-global.com, n.d.). Zinc oxide may also be used as a potential alternative to titanium oxide making the tiny particles not only effective at blocking out UV radiation but also feel lighter on the skin. This property is hence why modern sunscreens are nowhere near as thick and gloopy as the sunscreens we were slathered in as kids. (Marr, B. 2020). Furthermore, the sports industry has been quick to implement nanotechnology within sporting products; such as baseball bats which have been made with carbon nanotubes to make the bats lighter and therefore allow for an improved sporting performance. (Twi-global.com, n.d.). Tennis balls have been adapted with the use of nanotechnology to allow the ball to keep their bounce for longer periods of time. This effect can be observed in relation to the nanotechnology used in tennis racquets which implement carbon nanotubes to make them lighter in weight. Hence, both the tennis ball and racquet work together efficiently to give the tennis player a far greater advantage. (Marr, B. 2020).

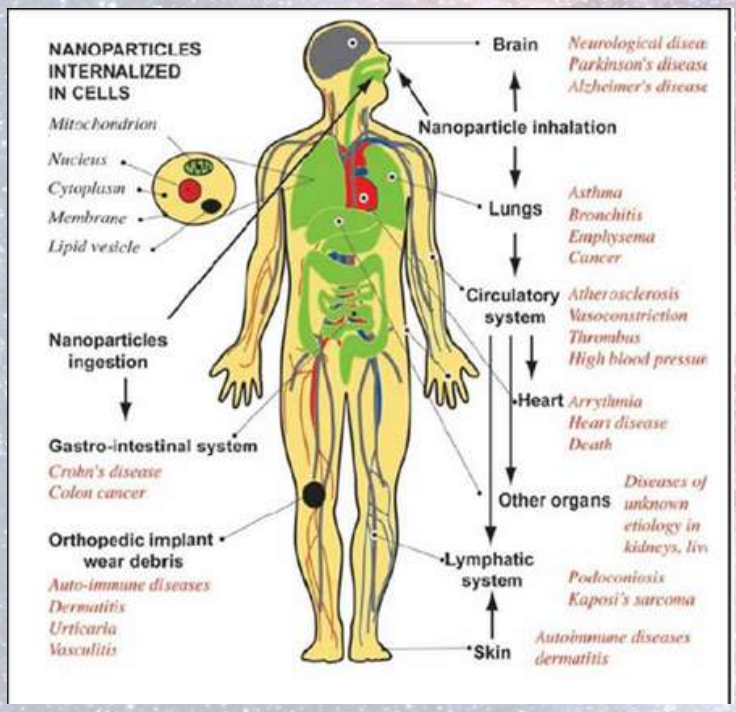
Controlling the size, shape and material of the nanoparticle enables engineers to design photovoltaics and solar thermal products with tailored solar absorption rates. Absorption of solar radiation is much higher in materials composed of nanoparticles than in thin films of continuous sheets of material. (Twi-global.com, n.d.). This allows new methods to be invented such as the Sol-Gel process, a method for producing solid material from nanoparticles and used extensively in many industries such as abrasive powder manufacture, coatings production and optical fibres. (Twi-global.com, n.d.).

The use of nanotechnology is apparent through the everyday use of products, and we can be sure to see the implementation of more nanomaterial in several sectors to maximise efficiency, profit, and performance. However, though the thought of nanoparticles may seem all good and exciting, nanoparticles can potentially bring about some potential dangers if not handled appropriately.



Whenever a nanoparticle is used, the aim is to boost its effectiveness and reactivity. However, this means it is usually expected to also boost its toxicity when used in a nanoparticulate form. Currently, the methods used to detect risks from nanoparticles are not enough, as there is insufficient investigation into the long-term effects. Furthermore, pre-clinical screenings (tests taken to ensure the safety of the medicines used) only yield negative results very late into the trials. Nanoparticles are used usually in diseased animals and volunteers so the negative effects may be difficult to examine when tested only over a brief period (De Jong and Borm, 2008).

In a short time frame, the nanoparticle forms may cause the same effects as the bulk versions of the medicines. However, due to the drastic increase in surface area, the effects may be more potent. One type of nanoparticle, for example, is in the form of poorly soluble particles (PSPs). Many studies have indicated that within the body of the rats, the PSPs cause more pulmonary inflammation, as well as sometimes cause lung tumours when the particles get much finer. “Effect is surface area mediated” (De Jong and Borm, 2008): this indicates that the poorly soluble particles can become much more harmful when in a nanoparticulate form, as opposed to when as a fine powder. “However, nanoparticles could also cause new types of effects not previously seen with larger particles (e.g., mitochondrial damage, uptake through olfactory epithelium, platelet aggregation, cardiovascular effects).” (De Jong and Borm, 2008).



When used as drug carriers, it is difficult to tell whether the medicine is a toxic substance, or if the nanoparticle carriers are toxic themselves. As previously mentioned, substances in nanoparticle form have a higher reactivity due to increased surface area. “The use of nanoparticles as drug carriers may reduce the toxicity of the incorporated drug but it is sometimes difficult to distinguish the toxicity of the drug from that of the nanoparticle. The toxicity of gold nanoparticles, for instance, has been shown at high concentrations. In addition, nanoparticles trapped in the liver can affect the function of this organ.” (ec.europa.eu, n.d.). This effect on the function of the liver could have negative side effects in the long run, however, as nanoparticles are a relatively recent technology within medicine, time has not permitted scientists and researchers to examine the long-term effects of using nanoparticles in drug treatments. This can be especially worrying as, depending on the material of the nanoparticle, the solubility can change too. If the particles are not soluble enough, they can stay within the body and certain organs, potentially causing them to be poisoned. (ec.europa.eu, n.d.).

As previously mentioned, nanoparticles can be used in medicine is many numerous ways. One specific way is to form drug carriers to deliver medicine to specific areas or organs within the body, usually in the case of chemotherapy to treat cancerous areas. However, as found by De Jong and Borm, if these nanoparticles are inhaled by people who are being treated with this nanotechnology, or the people who administer the drugs using nanoparticles may become more susceptible to developing lung tumours or inflammation in vivo. (hse.gov.uk, n.d.) Another downside to these nanotechnologies is that the substances that are usually not harmless can become harmful to the body due to increased reactivity. Ergo, each new form of nanoparticles must be tested and proved to be safe before its use in medicine.

Nanoparticles can also cross the blood-brain barrier with ease, making them useful for administering chemotherapy medicine directly into the brain. Yet conversely, it makes it equally as possible for the potentially toxic nanoparticles to also enter the brain and cause irreparable damage. (ec.europa.eu, n.d.). “Also, because of their high surface area to mass ratio, nanoparticles are highly reactive, and may trigger as yet unknown chemical reactions, or by bonding with toxins, allow them to enter cells that they would otherwise have no access to.” (Paddock, 2012). There is an issue currently, not just in medicine, but in all of science, in which as the nanotechnological world advances, the safety of consumers becomes increasingly at risk.

As the days go on, more materials are being used in nanoparticle form, which are tested less rigorously and so could contain potentially harmful substances. These types of substances could cause severe illnesses and effects. On the other hand, these drawbacks could be minimal, and the benefits of nanoparticles more likely than not outweigh these. So really, if you are considering a career in medicine or something else scientific, just ask yourself – will nanotechnology be in my future? Will it be a viable option within medicine?

Bibliography

De Jong, W.H., Borm, P.J. (2008) Drug delivery and nanoparticles: Applications and hazards, Int J Nanomedicine, [online] 3(2) pp. 133-149. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2527668/ [Accessed 17 Jun. 2023]

Ec.europa.eu (n.d.) Nanotechnologies [Online] Available at: https://ec.europa.eu/health/scientific_committees/opinions_layman/en/nanotechnologies/l-2/6-health-effects-nanoparticles.htm [Accessed 17 Jun. 2023].

hse.gov.uk, (n.d.) What is nanotechnology? [Online]. Available at https://www.hse.gov.uk/nanotechnology/what.htm. [Accessed 17 Jun. 2023]

Marr, B. (2020). 7 amazing everyday examples of nanotechnology in action. [Online]. Available at https://www.forbes.com/sites/bernardmarr/2020/07/03/7-amazing-everyday-examples-of-nanotechnology-in-action/?sh=174070173e82. [Accessed 17 Jun. 2023]

Nanowerk.com, (n.d.). Nanoparticles types, properties and uses. [online]. Available at https://www.nanowerk.com/what_are_synthetic_nanoparticles.php. [Accessed 17 Jun. 2023]

Paddock, C. (2012). Nanotechnology In Medicine: Huge Potential, But What Are The Risks? [online] Available at: http://www.medicalnewstoday.com/articles/244972.php. [Accessed 17 Jun. 2023]

Twi-global.com, (n.d.) What are nanoparticles? [Online]. Available at https://www.twi-global.com/technical-knowledge/faqs/what-are-nanoparticles. [Accessed 17 Jun. 2023]

Understandingnano.com, (2019). Nanotechnology in medicine – nanoparticles in medicine. [online]. Available at https://www.understandingnano.com/medicine.html [accessed 17 Jun. 2023]

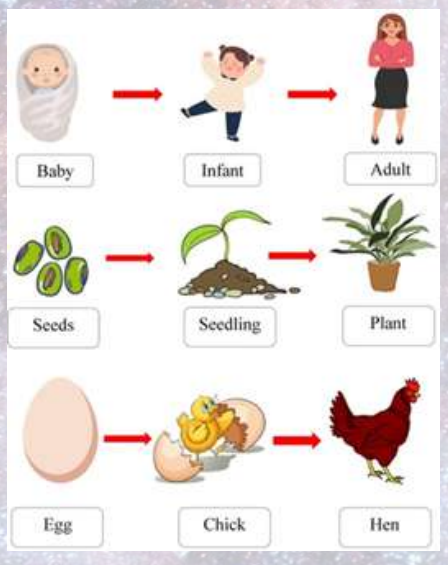
Are viruses alive?

Nikhil Srinivas

A very relevant question, in light of the recent global pandemic which saw a rush towards creating an antidote to combat the virus. This begs the question - if scientists wanted to stop the virus, was it alive to begin with? (Centres for Disease Control and Prevention, 2023)

What makes something alive?

Biologists categorise something as living if they fulfil certain key characteristics and functions. Fundamentally, living organisms, even if unicellular, are highly organized. This means their parts are arranged in a particular manner so that functions important for their life can be carried out. (McKendrick, 2021) (LibreTexts Biology, 2021). Living organisms should be able to respond to environmental stimuli, be able to reproduce, grow and develop. Despite environmental changes, they should be able to keep their internal conditions stable (homeostasis). Living organisms should be able to process (metabolise) energy derived from a source, be it plants processing solar energy through photosynthesis or animals deriving energy from a food source. (LibreTexts Biology, 2021) Only living organisms are said to possess all these characteristics, although certain non-living things may show some of these properties. For example, small tremors under the earth's tectonic plates can develop due to seismic activity (stimulus), can grow into earthquakes using geothermal energy, eventually dying out after releasing the energy. However, they are not alive as they are not organized, cannot reproduce and cannot maintain homeostasis. The above defining characteristics for life are rather restrictive and can be challenged. For instance, birds lay eggs which don't move. Would you then consider eggs non-living, based on the above criteria? Similarly, a butterfly spends a considerable part of its life cocooned as a non-mobile pupa. Does that make it non-living? Are immobile plant seeds living? Infertility is a condition well recognised in humans; mules which are offspring of female horse and male donkeys cannot reproduce. Does this inability to reproduce make infertile humans and mules non-living? Some organs and tissues are harvested for transplant after death of a donor (Van Diest, 2003) when they are viable. Viability is defined as the capacity of a living organism to stay alive, sustain its life, growth, and development (Biology Online, 2022). If a donor is not alive, how then is their tissue living? (The very molecule of life, DNA, is considered a chemical molecule and non-living!)

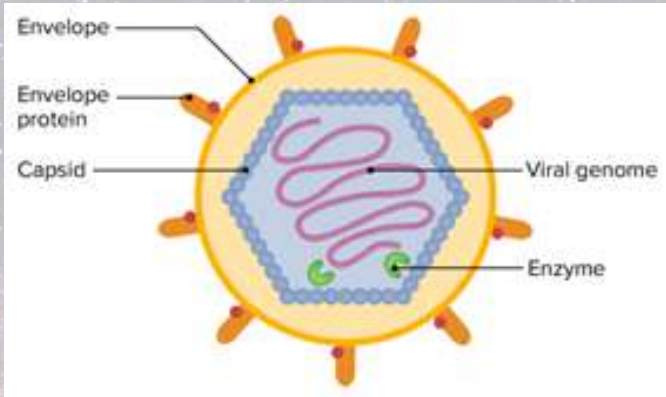


Based on my above examples, I think that the definition of life has definite chinks in its armour.

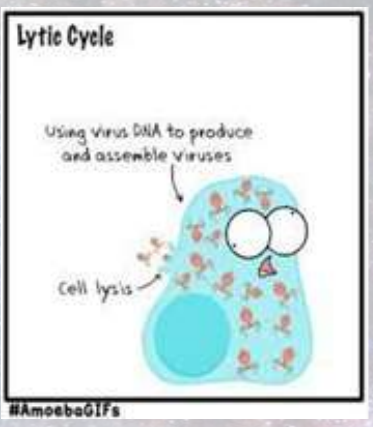
Let us look at the topical question. It is to be acknowledged that the scientific community has been debating this question for a very long time and is still divided in its opinion with no collective outcome in imminent sight. In order to attempt to answer this question, let us start by investigating what viruses are.

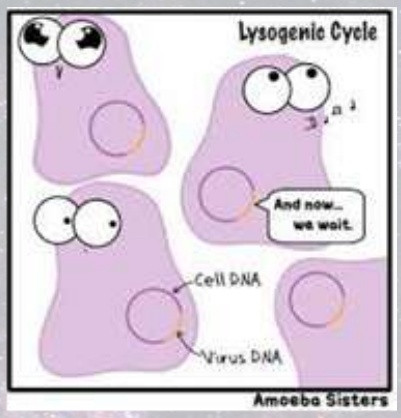
According to Britannica, viruses are infectious agents of small size and simple composition, that can only multiply in living cells (Wagner, 2023). On a cellular level, these tiny entities are made of nucleic acid (DNA or RNA), surrounded by a protein shell (capsid), sometimes by an additional lipid envelope (Lopez-Garcia, 2012). They are unable to replicate outside of a host cell or survive in an extracellular environment for prolonged periods of time (Gelderbloom, 1996) (Brown, 2016), making them an obligate intracellular parasite. They attach to host cells through viral attachment particles that bind to host cell receptors and then inject their genome into a host cell (Maginnis, 2018).

Given their simple structure i.e. nucleic acid covered by a protein coat and no specialised organelles within them, viruses cannot be called cells. Cells are a basic structural and functional unit of living organisms, capable of carrying out biological processes such as nutrition, respiration etc. (Andrew, 2023) (National Cancer Institute, n.d.). Viruses are chemicals (genome) in a box (capsid) and could be compared to a chemical protein such as DNA. Similar to DNA, viruses replicate, and their genome is also a chemical code. They can survive without energy, but then, they do not have intracellular organelles/processes to support. Could this be perceived as an evolutionary mechanism? They derive their energy from host cells for replication. Viruses cannot maintain homeostasis (Shwetha, 2018) as they lack the organelles/ internal environment. They are considered non-living for these reasons.



Based on the current characteristics of life and the above reasoning, viruses could be considered non-living outside the host cell. But could their 'non-living' phase be considered a dormant phase in their 'life cycle', like a spore or a seed? Viruses possess genetic material. They are able to reproduce and multiply, albeit not autonomously but inside a host cell. Viruses exhibit growth within the host (Shwetha, 2018). The fact that they are able to infect host cells shows that they sense environmental change to start their 'living' phase. An environmental trigger is sensed by the virus causing it to enter the lytic phase from its dormant state, causing the host cell to ture and release virions (LibreTexts Biology, 2022), as exemplified by the dormant chicken pox virus which causes shingles when immunity is low (the trigger). Lytic and lysogenic phases of viral replication could also be considered an adaptative response. Viruses can alter their genetic make-up through mutations, thereby evolving their genome, some of which may confer a survival advantage such as drug resistance or avoidance of detection by the host immune system (Williams, 2021) (Lucas, 2001). In these respects, they can be considered alive.





A key argument against viruses being alive is the fact that they depend on host cells to replicate, and use its metabolic machinery. I would counter this by saying that life is interdependent. Humans depend on external energy sources to meet their metabolic requirement. Ecosystems in nature are interdependent. Viruses do not have intracellular organelles. Where the case for organization/ intracellular organelles is concerned and to further my argument of the interdependence of life, I would say that as per the endosymbiotic theory, eukaryotic organelles such as mitochondria and plastids have their origins in endosymbionts (a microbial cell which resides in a host microbial cell where both derive mutual benefits from this arrangement) (Garg, 2016). I infer from this theory that very early eukaryotes/ cellular organisms did not have any organelles either. So did viruses just choose a different pathway for survival, preferring a dormant non alive state to symbiosis? Furthermore, research on genome protein folding suggests a common ancestry between viruses and cellular organisms (Shwetha, 2018)(Brown, 2016). Should viruses then be considered a fourth domain of life (Shwetha, 2018)?

So, are viruses merely chemical entities or are they clever living genetic engineers?

Viruses are a curious evolutionary story that have likely existed for centuries and still continue to baffle the scientific world. Biologically speaking, categorising them as living or not depends on how we define life.

From my point of view, they have successfully replicated all these years and continue to independently evolve alongside cellular organisms. Alongside genetic perpetuation, I consider this a critical feature that defines life, as evolution ensures continuity. Perhaps, we need to re-define what constitutes life based on its essential purpose - survival!

Bibliography

1. Centres for Disease Control and Prevention (2023), Understanding How COVID-19 Vaccines Work, available from https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines/how-they-work.html, accessed 14 April 2023

2. McKendrick (2021), Organization, available fom https://www.biologyonline.com/dictionary/organization, accessed 14 April 2023

3. LibreTexts Biology (2021), 4.1: What makes something living?, available from https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_Principles_of_Biology/01%3A_Chapter_1/04%3A_What_is_Life/4.01%3A_What_makes_something_living, accessed 14 April 2023

4. Van Diest, P.J et al. (2003), Cadaveric tissue donation: a pathologist's perspective, available from https://jme.bmj.com/content/29/3/135, accessed 14 April 2023

5. Biology Online (2022), Viability, available from https://www.biologyonline.com/dictionary/viability, accessed 14 April 2023

6. Wagner, R. et al. (2023), virus – what is a virus?, available from https://www.britannica.com/science/virus, accessed 14 April 2023

7. Lopez-Garcia, P et al. (2012), Origin and Early Evolution of Life – Viruses in Biology, available from https://evolution-outreach.biomedcentral.com/articles/10.1007/s12052-012-0441-y , accessed 14 April 2023

8. Gelderblom, H.R (1996), Structure and Classification of Viruses, available from https://pubmed.ncbi.nlm.nih.gov/21413309/, accessed 14 April 2023

9. Brown, N (2016), ARE VIRUSES ALIVE?, available from https://microbiologysociety.org/publication/past-issues/what-is-life/article/are-viruses-alive-what-is-life.html, accessed 14 April 2023

10. Maginnis, M.S (2018), Virus-Receptor Interactions: The Key to Cellular Invasion, available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6083867/, accessed 14 April 2023

11. Williams, N (2021), What is a Viral Mutation?, available from https://www.news-medical.net/health/What-is-a-Viral-Mutation.aspx, accessed 14 April 2023

12. Lucas, M. et al. (2001), Viral escape mechanisms – escapology taught by viruses, available from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2517780/, accessed 14 April 2023

13. Garg, S. et al. (2016), Endosmbiotic Theory, available from https://www.sciencedirect.com/topics/medicine-and-dentistry/serial-endosymbiotic-theory, accessed 14 April 2023

14. LibreTexts Biology (2022), 6.2: The Viral Life Cycle, available from https://bio.libretexts.org/Bookshelves/Microbiology/Microbiology_(OpenStax)/06%3A_Acellular_Pathogens/6.02%3A_The_Viral_Life_Cycle, accessed 14 April 2023

15. Shwetha, S. (2018), Virus – The Biological Brain Twister, International Journal of Current Microbiology and Applied Sciences, Vol 7, No 5, pp55-56, available from https://www.ijcmas.com/7-5-2018/S.%20Shwetha.pdf?fbclid=IwAR1A4N9sn2KLXZkrJV2FsMIqRj9IkLfJOi9NPBwnRBo_2G3zvyuI9pN5xIM, accessed 14 April 2023

16. Andrew, S.L (2023), Cell, available from https://www.britannica.com/science/cell-biology, accessed 14 April 2023

17. National Cancer Institute (n.d.), cell, available from https://www.cancer.gov/publications/dictionaries/cancer-terms/def/cell, accessed 14 April 2023

Dark Matter

Anupam Cunden

What is dark matter?

So far, scientists do not fully understand what dark matter is. “Dark matter does not interact with the electromagnetic force” (Anon., n.d.) meaning that it doesn’t emit, absorb, or reflect light making it impossible to spot. It is most likely made from WIMPs which are weakly interacting massive particles, axions or MACHOs which are massive astrophysical compact halo objects. WIMPs are very heavy and slow-moving, subatomic particles. They have a mass that only interacts very weakly with regular matter through gravity. Axions have a very low mass and low energy. MACHOs are massive compounds of regular matter such as neutron stars, and brown and white dwarfs. All these emit little, to no light at all, making them very hard to detect. All three particles are theoretical as of now. Dark matter may be invisible, but it can be seen through its effects on galaxy clusters.

How was dark matter found?

The first real evidence for dark matter was found by Fritz Zwicky when he observed the Coma galaxy cluster and its mass, and “found that it was much too small to prevent the galaxies from escaping the gravitational pull of the cluster” (Clavin, 2020). Zwicky saw that individual galaxies within this cluster were moving extremely fast and it shouldn’t be possible for the cluster of galaxies to stay intact. This meant that there must be something with a gravitational force, holding the galaxies in their orbit, so he called the new phenomenon “dunkle Materie” meaning dark matter in German. To back up Zwicky’s theory, he needed to know the mass of the galaxy. To do this, he first needed the distance of how far away the galaxy is. A standard candle, a star with a known brightness e.g., a supernova, is used to compare the actual brightness to the apparent brightness. Light obeys the inverse square law, allowing distance to be calculated using:

$$Distance\ (parsecs) = \sqrt{\frac{Intrinsic\ Brightness}{4\pi\ x\ Observed\ Brightness}}$$

Using the calculated distance, brightness, colour of the star, and the Hertzsprung-Russell diagram, the radius and the mass of the star can be estimated due to the relative position of the star on the diagram. As cosmic distances are so big, we don’t see galaxies moving, so calculating speed required measuring the Doppler redshift. Stars are always emitting white light. The white light changes frequency depending on if the star is moving towards us (blue) or away from us (red), the relative motion of the star to us, determines what colour it appears as. This light cannot be seen by the naked eye, it must first be split into the colours of the visible light spectrum. Gaps are then found and compared with where they are expected to be since stars are made from hydrogen.

The Virial theorem predicts that the average

kinetic energy in a planetary system is always half the average gravitational potential energy. Zwicky used the Virial theorem:

$$M = \frac{V^2 R}{G}$$

to calculate how much mass is needed to make a galaxy cluster move, purely under the influence of gravity. The calculated mass was much too small, implying that there was an additional mass that couldn't be seen.

Vera Rubin added more compelling evidence to Zwicky's ideas by mapping out the distribution of hydrogen in many galaxies and compared that to the rate of rotation of the galaxy. A graph of distance from the centre on the x-axis and density of hydrogen on the y-axis showed the mass distribution to get thinner towards the edge. This should have correlated almost exactly to a graph with distance from centre on the x-axis but now orbital speed on the y-axis, but the data showed that the speed comes to a plateau rather than decreasing. This proved that stars very far from the centre of the galaxy, in less populated areas, were moving at the same speed as stars closer towards the centre of the galaxy. The mass of the galaxy visible was still too small to hold such fast-moving stars in orbit showing that "galaxies must contain about ten times as much "dark" matter as can be accounted for by the visible stars" (Anon., n.d.).

Gravitational Lensing

Although dark matter is invisible, its effects can be seen through gravitational lensing. It is known that gravity is the force of attraction that acts between all forms of matter, but it can also act as a lens. Gravitational lensing occurs when a lot of matter, for example, a star or a galaxy, or even a cluster of galaxies, creates a very strong gravitational field around it, which is strong enough to bend the light coming from dense masses, distantly behind them. Gravitational lensing allows scientists to view distant galaxies, which are usually blocked by the galaxies in front of them. The galaxies posing as an obstacle also act as a lens as they curve the light from the distant galaxy making it visible to the observer.

The idea that light bends around a massive body relates to Einstein's theory of relativity. This theory states that "what we perceive as the force of gravity arises from the curvature of space and time" (Wolpert, 2019) meaning that matter distorts the fabric of time and space around it. Einstein's theory implies that gravity bends light waves and makes their paths curve around objects, such as stars, galaxies, and black holes. The way we see objects proves that light travels in straight lines directly to our eyes, but if we make the path of light curved by putting a glass of water between the light source and our eye, our view is distorted. General relativity uses the curvatures of the 4th dimension, space-time, to explain gravity. The sun is very heavy and bends space-time. The earth is attracted to the sun, but there is no force. Einstein says that light, even though it has no mass, can bend, due to space curvature. As space bends, it impacts objects on the curve, such as the Earth.

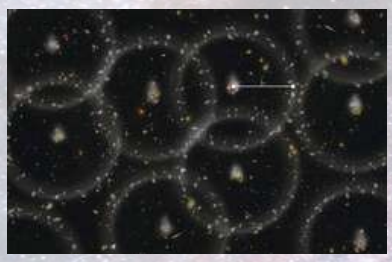
Using our understanding of general relativity and optical physics, we can use the bending of light to see celestial bodies which should be blocked from our view. To use gravity as a lens, 3 things are needed which are the source, the lens, and the observer. In this example, the source will be a galaxy cluster, the lens would be a region of dark matter, and the observer will be a scientist. When the source, lens and observer are perfectly aligned, the result is an Einstein ring. As dark matter has mass, light bends equally around the region of dark matter forming a ring shape around it and allowing us to see the galaxy cluster we would normally not be able to see. As we can see the galaxy cluster, we know that there is something in between the cluster and us as the observer, even though we cannot see it. This in-between object is dark matter.

Distribution

Dark matter is not evenly distributed in space but arranged in filaments and clumps. These filaments form a complex structure called the cosmic web. This network refers to the cosmic web which is “the largest known coherent pattern of structures, pervading the entire known observable universe, integrating and connecting gravitationally bound physical structures,” (Stapelberg, 2022). It shows that galaxies are distributed in geometric patterns and outlines by filaments or sheets, separated by giant voids. At the beginning of time, small pairs of particles and anti-particles were coming into existence spontaneously and hitting each other. Usually, these particles destroy each other when they hit, but due to the rapid expansion of the universe, this did not happen.

As space expanded, so did the fluctuations which caused areas of different densities in the universe. The matter was attracted by gravity and clumped together in some areas but not in others. After the rapid inflationary period (10-32 seconds after the Big Bang), the universe was full of primordial plasma. When the matter grouped together, “it created pressure that counteracted gravity, creating ripples akin to a sound wave in the matter of the universe” (Davis, 2019) called baryon acoustic oscillations. These ripples are made up of regular matter and dark matter. As dark matter only interacts with gravity, the ripples did not affect it, so it did not move, but regular matter was pushed out. After the universe cooled, many thousands of years later, the pressure that pushed the regular matter outwards was released by photon decoupling. This process describes how after cooling, matter could form, and photons travelled freely. This locked matter into place, but some was re-attracted to the middle due to the strong gravitational attraction of dark matter. It resulted in a bullseye with matter in the middle and a ring shape around the edge. These processes resulted in the cosmic web, which provides structure to our universe. Images of the cosmic web show a structure that resembles a spider’s web, but it only shows a small part of the full cosmic web as only its luminous mass component is visible. It is known that the cosmic web has a prominent “dark side” made up of dark matter in the same geometric, web shape. Although we cannot see this side of the

cosmic web, it is the reason for galaxies in clusters or filaments as dark matter forms these structures and it arranges itself in patterns which follow dark matter's gravitational attraction.



Bibliography

Anon., 2007. *Hertzsprung-Russell Diagram*. [Online], Available at: https://www.eso.org/public/unitedkingdom/images/eso0728c/, [Accessed 22 May 2023].

Anon., 2015. *Gravitational Lensing*. [Online], Available at: https://www.esa.int/ESA_Multimedia/Images/2015/07/Gravitational_lensing, [Accessed 21 May 2023].

Anon., n.d. *Dark Matter*. [Online], Available at: https://home.cern/science/physics/dark-matter, [Accessed 21 May 2023].

Anon., n.d. *Vera Rubin and Dark Matter*. [Online], Available at: https://www.amnh.org/learn-teach/curriculum-collections/cosmic-horizons-book/vera-rubin-dark-matter#:~:text=Her%20calculations%20showed%20that%20galaxies,for%20by%20the%20visible%20stars., [Accessed 22 May 2023].

Clavin, W., 2020. *Where is Dark Matter?*. [Online], Available at: https://magazine.caltech.edu/post/where-is-dark-matter-hiding#:~:text=The%20first%20real%20evidence%20for,gravitational%20pull%20of%20the%20cluster., [Accessed 22 May 2023].

Davis, M., 2019. *What is the cosmic web?*. [Online], Available at: https://bigthink.com/hard-science/cosmic-web/, [Accessed 22 May 2023]

HubbleTelescope, 2011. *A Horshoe Einstein Ring*. [Art]., Lamb, R., 2010. *HowStuffWorks*. [Online], Available at: https://science.howstuffworks.com/science-vs-myth/everyday-myths/anthropic-principle.htm, [Accessed 9 May 2023].

Larson, S., 2015. *Write Science*. [Online], Available at: https://writescience.wordpress.com/tag/vera-rubin/, [Accessed 22 May 2023].

Stapelberg, S., 2023. *The Cosmic Web of Galaxies, Dark Matter and How it Emerged*. [Online], Available at: https://structures.uni-heidelberg.de/blog/posts/2022_12_cw/index.php, [Accessed 22 May 2023]

Sutter, P., 2021. *LiveScience*. [Online], Available at: https://www.livescience.com/multiverse [Accessed 8 May 2023].

Wolpert, S., 2019. *Einstein's general relativity theory is questioned but still stands 'for now'*. [Online], Available at: https://newsroom.ucla.edu/releases/einstein-general-relativity-theory-questioned-ghez#:~:text=Einstein's%201915%20general%20theory%20of,the%20Earth%20change%20this%20geometry., [Accessed 21 May 2023].

Organ Donation in the UK: Opt-in vs Opt-out

Meghna Rao

Organ donation is described by the NHS as "when you decide to give an organ to save or transfer the life of someone else". Upon death in circumstances that leave organs viable for donate, one individual has the ability to save up to 9 lives. However, individuals can also donate certain organs whilst still alive. This includes one kidney or part of a liver, since it can regenerate. Additionally, after the death of an individual, provided their organs are viable, Post-Mortem Organ Donation (PMOD) can take place. This means that some/all of the organs from the person who has died can be transplanted to patients in need. These organs include the heart, lungs, kidneys, liver, corneas, pancreas, tissue, and small bowel.

It is important to note the different types of consent that we will be referencing (Etheredge, H., 2021):

- Hard Consent – Any preferences stated whilst alive are binding.
- Soft Consent – The family is involved in the decision of the deceased.
- Mandated Consent – A decision must be made while the individual is alive.

Who can and can't donate?

People of any age, ethnicity, gender, or sexual orientation can donate organs. Those who are smokers, heavy drinkers, or who cannot donate blood may be allowed to, unless their organs are deemed unsuitable by a healthcare professional. If the individual is under 18 at the time of registration, parental agreement would be required for donation to take place, but this rule is only applicable to under 12s in Scotland.

Those who cannot donate include those with Creutzfeldt-Jackob Disease (CJD), Ebola virus, Active cancer, and most people with HIV. However, the possibility of organ donation is always assessed by a medical professional before donation. This will consider the circumstances of death and all the individual's medical history to reach the right conclusion (NHS, n.d.)

Max and Keira's Law

The Law surrounding PMOD in the UK is known as Max and Keira's Law, sometimes referred to as the Organ Donation (Deemed Consent) Bill. This law was inspired by the story of Kiera Ball, a 9-year-old girl whose tragic death in a road traffic accident led to her donating organs to 4 separate people in need. This included giving her kidneys to two adults, her liver to a baby, and her heart to another 9-year-old, Max Johnson. Max recovered and is now 14-years-old thanks to his new heart, changing his life and sparking a reform in the UK law (The Aspiring Medics, n.d.).

"Keira lives on in Max and the other people she helped, and we are super proud of her" – Joe Ball, Keira's father (Ford, R., 2021)

The law itself was formally approved by the palace thus passing the Organ Donation Act on 15th March 2019. Later, the law was put into effect on the 20th of May 2020 with the aim to spread awareness about PMOD and prompt conversations between families to express their own wishes surrounding organ donation. The law introduced an opt-out system - meaning that every UK citizen is an organ donor when they die if they are over 18, have not opted out and are not part of an excluded group. These excluded groups are those under 18, lacking mental capacity, visitors to the UK and those who have lived here fewer than 12 months.

- *"Opt-out – A donation policy that presumes all individuals residing in a country/state to be a willing deceased organ donor unless they specifically "opt-out" of doing so. Also known as "presumed consent". Opting-out would require individuals to state their preference against deceased organ donation whilst alive. Such preference is often recorded in a national opt-out register." (Etheredge, H., 2021)"*
- *"Opt-in – A donation policy that requires individuals to manifestly express their preferences for being a deceased organ donor. It is the opposite of opt-out, because no one is presumed to be a willing donor unless they make an express statement regarding their preference for deceased donation. Also known as an "express consent" policy." (Etheredge, H., 2021)*

This aims to increase the numbers of organ donors in the UK, allowing for more transplants just like it has in Wales where a highly effective opt-out system has been in place since 2015. Moreover, in England, Wales and Northern Ireland, an individual can nominate up to two representatives to make the final decision on their behalf (Chisholm, J., 2019).

The PMOD system in the UK is drastically different from the systems in many other countries. A common comparison can be made between the opt-out system here and the opt-in system in the USA. The opt-in system means people must actively sign up to register as a donor else their organs will not be donated in the event of their death. This registration usually takes place when applying for or renewing a driver's licence. The United Network for Organ Sharing (UNOS) is the organisation that manages the organ transplant system in the USA, and

they require the explicit consent of the donor or the donor's immediate family for any organ donation to take place.

Pros and Cons:

Which organ donation is "the best" is a huge subject area for debate in the medical community, hence it is important to reflect on both the pros and the cons of the opt-out system currently in place.

A study conducted by the University of York shows that the opt-out system does increase the number of donors by making it an easier process for those willing to donate. However, certain viewpoints state that this is deemed/presumed authorization: a case of a false positive when a person becomes a donor despite not wanting to. However, this can be rebutted since autonomy is still respected throughout the process.

The choice is the same: do you want to donate or not? It is only expressed differently. This altered expression of the question at hand engages the public on issues surrounding organ donation by increasing awareness and education in schools and the general public. This also avoids the issue of people being too busy, uneducated, or finding the process too complicated to opt-in to overcome the lack of education and awareness. Therefore, individual preferences are better reflected. For example, in 2019 over 80% of the population supported PMOD yet only 38% of UK citizens opted-in to donate.

The success of this will combat organ shortage and increase the supply of organs for transplantation since being an organ donor becomes the norm in society. Ultimately, this increases the number of lives that can be saved due to PMOD from organs that would have otherwise been disposed of or left to decompose. This system has proved to be effective since in Wales in 2019 only 6% of the population opted out. This led to Wales having the leading number of donors of all the countries in the UK with 25.4 donors per million population! (The Aspiring Medics, n.d.)

However, ethical issues surrounding informed consent, presumed consent and capacity are all incredibly relevant talking points. This level of education and investment into the opt-out system is not available in some countries since organ harvesting, transport and transplant are all complex procedures requiring appropriate infrastructure, equipment, and trained specialists. Moreover, it is true that the increased rate of organ donation doesn't necessarily increase the number of successful transplants. A study has shown that 79/674 donated organs had detected malignant tumours, meaning overall 11.7% received organs with cancerous cells which further complicated their health (Hussain, N.M., Soni, D., 2019).

In Hussain and Soni's research in the British Student Doctor, they outline several alternatives to organ donation that certain groups argue are more worthwhile investing into rather than PMOD education and infrastructure.These include 3D bioprinting organ tissue and xenotransplantation (transplanting organs from a non-human donor – usually pigs). Both procedures are highly experimental and at the forefront of medical research so arguably are more worth dedicating money and research to.

Regardless of personal opinion on the subject, it is important to remain informed about your options and choices using reliable and impartial sources. Weigh up the pros and cons for yourself to decide what you are comfortable with happening to your body in this unlikely circumstance. Most importantly, speak with your families about their wishes and your own wishes, both to expand your views and to ensure you know each other's wishes just in case!

Bibliography

Chisholm, John, April 12 2019, An opt-out system has the potential to increase donation rates and save lives, The BMJ Opinion, Available at: https://blogs.bmj.com/bmj/2019/04/12/john-chisholm-an-opt-out-system-has-the-potential-to-increase-donation-rates-and-save-lives/ [online], Accessed 9 May 2023.

Hussain, Niha Mariam, Soni, Dhruv, 16 November 2019, Max and Keira's law: a discussion surrounding the advantages, disadvantages and alternatives to an opt-out organ donation system in the UK, The British Student Doctor, Available at: https://storage.googleapis.com/jnl-uc-j-tbsdj-files/journals/1/articles/109/submission/proof/109-1-948-2-10-20200211.pdf [pdf], Accessed 9 May 2023.

Etheredge, Harriet Rosanne, May 13 2021, Assessing Global Organ Donation Policies: Opt-In vs Opt-out, National Library of Medicine, Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8128443/ [online], Accessed 10 May 2023.

McIntosh, James, 24 September 2014, Organ donation: is an opt-in or opt-out system better?, Medical News Today, Available at: https://www.medicalnewstoday.com/articles/282905 [online], Accessed 10 May 2023.

Williams, Nicola, O'Donovan, Laura, Wilkinson, Stephen, 16 February 2022, Presumed Dissent? Opt-out Organ Donation and the Exclusion of Organs and Tissues, Oxford Academic – Medical Law Review, Available at: https://academic.oup.com/medlaw/article/30/2/268/6529455#:~:text=Another%20key%20benefit%20claimed%20of,public%20support%20for%20organ%20donation [online], Accessed 10 May 2023.

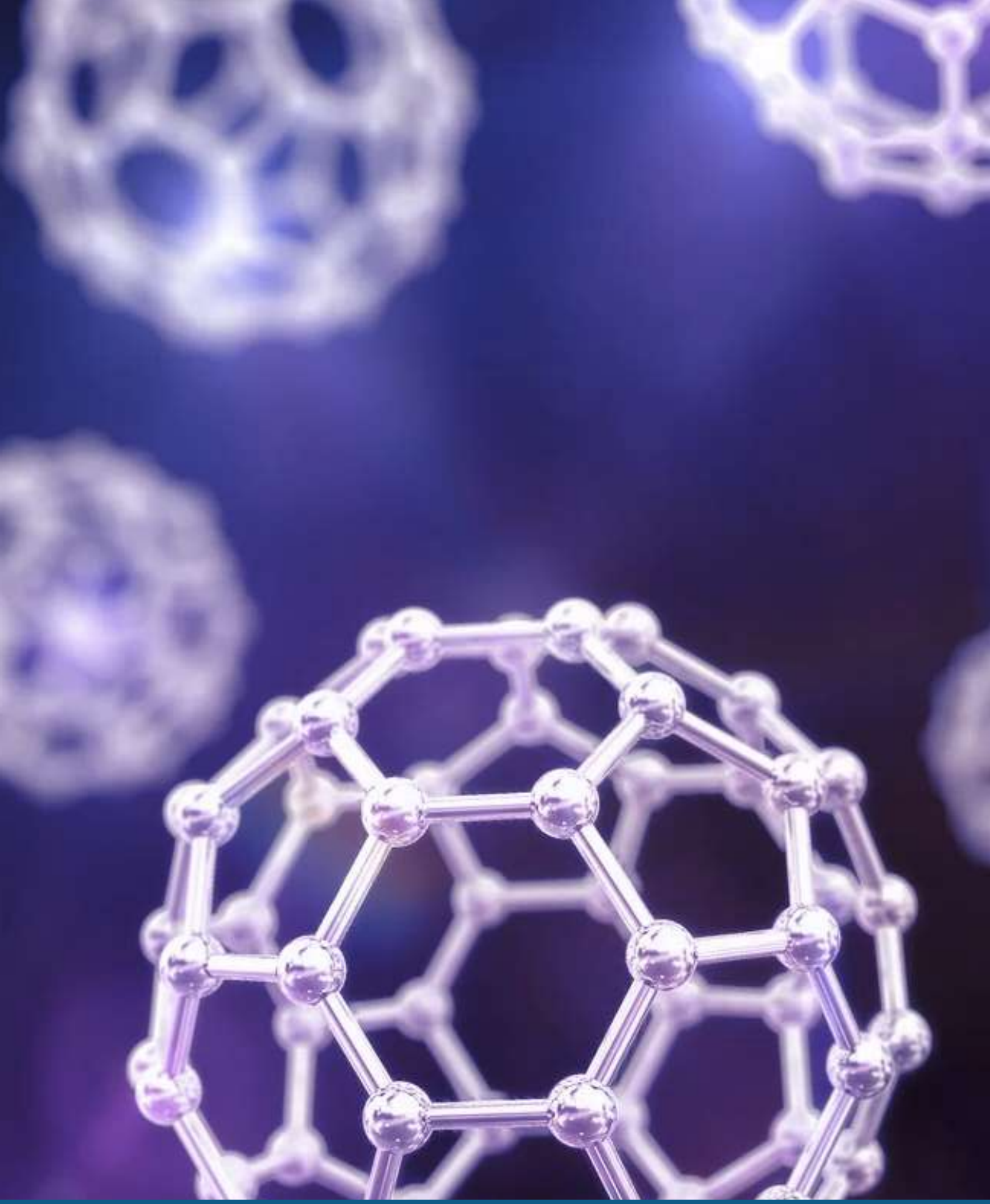
Anonymous, N.d., Max & Keira's Law, The Aspiring Medics, Available at: https://www.theaspiringmedics.co.uk/post/max-and-keira-law [online], Accessed 10 May 2023.

Anonymous, N.d., Organ donation law in England, NHS UK Blood and Transplant, Available at: https://www.organdonation.nhs.uk/uk-laws/organ-donation-law-in-england/ [online], Accessed 10 May 2023.

Anonymous, N.d., What is organ donation?, NHS UK Blood and Transplant, Available at: https://www.organdonation.nhs.uk/helping-you-to-decide/about-organ-donation/ [online], Accessed 14 June 2023.

Rudge, Chris J., 2018, Organ donation: opting in or opting out?, British Journal of General Practice, vol. 68, pp62, Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5774938/ [pdf], Accessed 14 June 2023.

Ford, Ryan, 7 September 2021, 'Max And Keira's Law' Makes All UK Adults Organ Donors By Default, Diply.com, Available at: https://diply.com/130930/max-and-keiras-law-makes-all-uk-adults-organ-donors-by-default [online], Accessed 14 June 2023.



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