***Issue 1**: Friday 20th December 2019*

The first issue of the student STEM magazine

BIOLOGY | COMPUTER SCIENCE | PHYSICS | ENGINEERING

Introduction

Science is about much more than we learn in school every day. It's a universal source of endless knowledge of which we have only scratched the surface. It is a new dawn for scientific journalism at Wilson's and without further ado, we would like to welcome you to the first issue of Wilson's Science Magazine officially named 'The Wilson's Intrigue', written by students for the students.

Our mission/aims:

- Expand your knowledge
- Contribute to the Wilson's community
- Make complicated parts of science more accessible
- Popularise science and make it interesting
- Inspire creativity through wider research

We would definitely like to hear more from you, as the readers, as to what you like about the magazine and what more we can do to make the magazine more interesting, accessible and dynamic. And so please visit https://www.surveymonkey.co.uk/r/MLSL22F where you will be asked to complete a short survey.

All references for each article can be found at the end of the magazine (from pages 62 to 67) which includes recommended websites, books and scientific articles for further reading/research, to explore a topic which has piqued your interest, beyond the contents of the article.

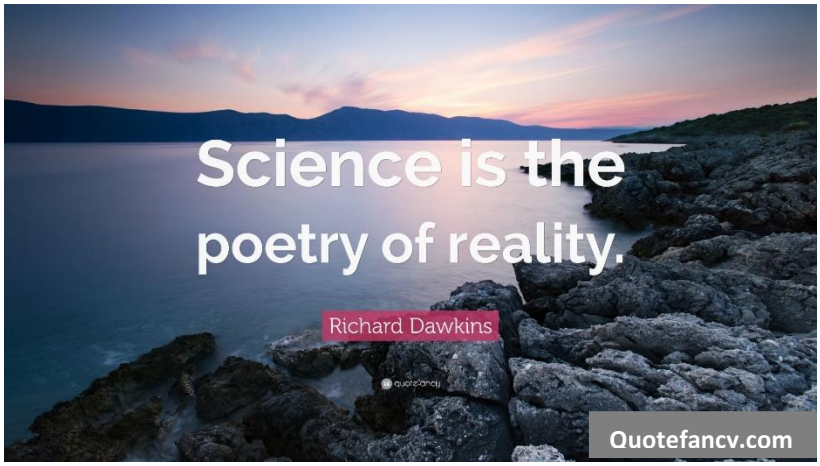
A small key terms section may also be found at the end of articles which define technical terms found in those articles, without needing to search anything up whilst reading.

Thank you to Miss Banner, Mr Lissimore and Dr Whiting whose advice and support was very helpful in setting up and running the Science Magazine. Thank you also to Mr Alderson, Miss Ip and Miss Roberts for their help in confirming the scientific accuracy of the articles to minimise misinformation.

If you would like to write for the magazine and join a like-minded group of science and engineering enthusiasts, please email me at *murugesand@wilsonsschool.sutton.sch.uk* for more information.

The page outlining the Wilson's Intrigue Team (Editors and Writers) can be found on the next page.

The contents page outlining all the articles can be found on page 4 (Please view this magazine on a PC for automatic hyperlinks from the contents page to the relevant articles)



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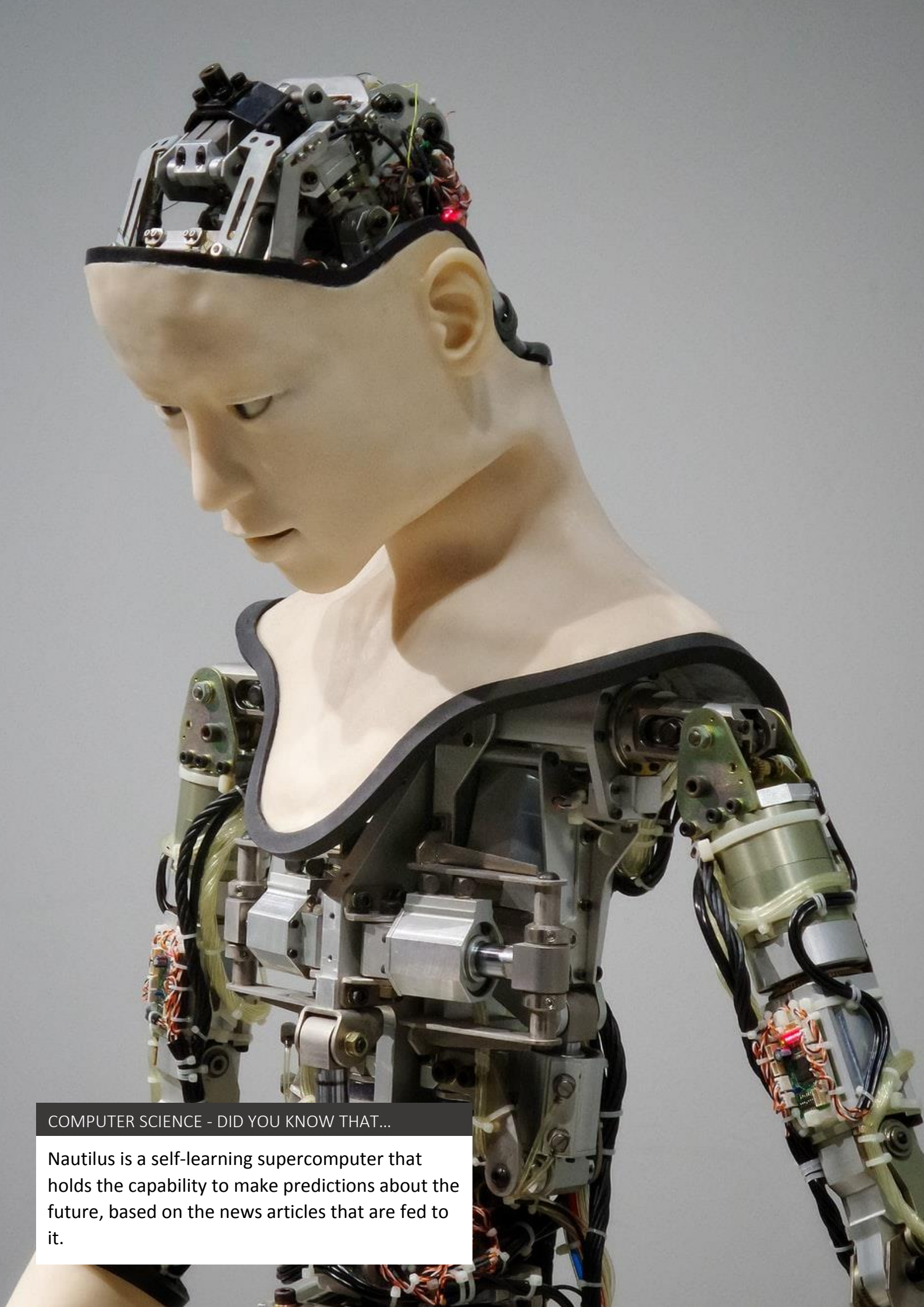


COMPUTER SCIENCE - DID YOU KNOW THAT…

Nautilus is a self-learning supercomputer that holds the capability to make predictions about the future, based on the news articles that are fed to it.

The Age of the Primes: Why You - and the Most Powerful People on the Planet - are at the Mercy of the Mathematician

by Kiran Lee (Y12)

Since the time of the Ancient Greeks, and possibly even before, prime numbers have fascinated mankind. Primes have proven to be some of the fundamental building blocks of our reality - from the life cycles of cicadas, to the fundamental theorem of arithmetic, to our current global security systems - they are everywhere in our lives and in the world around us. Unfortunately, the primes still hold many mysteries (The Riemann Hypothesis being the most famous) and one of these problems is incredibly dangerous to modern civilisation. It may seem like the plot of a film (and indeed it is - the film *Sneakers* is based on this scenario) but the world's banking systems are, by and large, unsafe. All it would take is one mathematical breakthrough for a large portion of the world's internet security to be at risk of hacking, for the chance of financial crime on an inconceivable scale, and possibly for entire governments to collapse under the crisis. The reason is simple - many of our current cybersecurity systems are based on an unproven assumption, which could turn out to be false at any time.

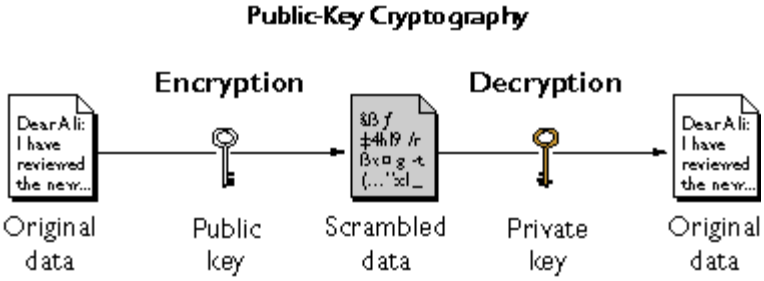
The origin of these security systems begins in 1977, when a computer scientist named Ron Rivest - along with two mathematicians, Adi Shamir and Leonard Adleman - were attempting to create one of the first true public-key cryptographic systems in history. After a celebration of Passover, Rivest telephoned Adleman, unable to sleep, and relayed to him the idea of a system based on the factorisation of prime numbers. Adleman considered the computer scientist's proposal, agreed with it, and from there the foundations for a successful internet were born. But to understand why this discovery was so vital, let's break down what RSA (the system named after its three inventors) is, how it works and why it could be potentially very vulnerable.

A huge issue for many cryptography systems is that both the sender and receiver of messages need to agree on a method of encryption and decryption beforehand, so they can understand each other's messages. For many systems, this might be a keyword that has been agreed upon, or a random sequence of characters (in order to be more subtle) - for the Enigma machines in WWII, there was a list of particular settings that changed each day.

The Enigma machine - This device needed to have agreed-upon settings plugged into it each day

While this type of encryption proved functional for a large part of human history, by the dawn of the Internet it was becoming impractical. Imagine having to receive a 'secure' letter or email (with no real guarantee that it remained secure) containing a key every time you tried to shop online and protect your data, and then imagine billions of people needing to do the same! The logistics and timing just wouldn't work, which is why a new system was needed.

Public-key cryptography is the solution to this logistical nightmare. Instead of having a single 'key' to encode and decode messages, this type of system uses one key to encode them and a different key to decode them.



How Public-Key Cryptography Works.

Suddenly, the key to encode the message you wish to send does not need to be kept secret - you can distribute it to whomever you like, and as long as they do not have the second key, they cannot read any secret messages. This is so important because suddenly there is no need for us to agree on keys beforehand - when we are shopping online, for example, we can use the company's freely available encryption key to send our data, and they can use their secret decryption key to decipher the data that we've sent. The issue is in finding a pair of encryption and decryption keys that will work (the decryption key must be able to unscramble what the encryption key has scrambled, but it also must not be able to be deduced from how the encryption key works). With most two-key systems, it is easy to deduce what the private key is from the public key, because they have to do opposite things to the message - scramble and unscramble it. Most of the time, this means that one can easily deduce the private key by looking at what the public key does, which is obviously a problem when one wishes to create a secure cipher.

Prime numbers are great for this, because we do not currently know how to easily break a large number down into prime factors. Take two large primes, and multiply them together (primes are used so that the resulting number will be semiprime, having only have two factors other than itself and one). This product will be very large, but simple multiplication is not difficult for a computer to do. The issue lies in calculating the reverse - how do we get the primes back from the large number? While there are known methods of solving this, they all take a long time even for a computer, and as the number of digits in the primes increases, that time to solve also increases dramatically. Just after the system was developed, for example, a prize was announced for cracking an RSA code with a semiprime of 129 decimal digits. This took 1600 computers and months to crack by brute force. Since then, while computers have become much more powerful, the size of the numbers to crack has also become much larger (the largest number available to crack has 617 digits, and the largest we've cracked so far had 232. The effort to solve that problem required thousands of hours of modern computational power). This is great for cryptography, because it means we can use the semiprime as the encryption key that everyone can see - even with that key, nobody can find its constituent primes in a reasonable length of time. We can then use those secret primes as the private key and decipher the message with them, and we have a fast and ostensibly secure method of sending sensitive information around the web.

There’s just one small issue - we don’t know if this encryption method is actually secure! So far nobody (that we know of) has figured out how to calculate the prime factors of a big number efficiently or in a reasonable amount of time, but that doesn’t mean a much quicker method can’t be discovered. If somebody does manage to work out how to efficiently calculate these factors, then they will have access to a sizeable chunk of the information available on the internet. This could include private banking secrets (usernames and passwords), along with confidential government information (for example the Bank of England secures private information, at least in part, with RSA). It is also possible that new advances in computing will let us ‘brute force’ these encryption systems with relative ease, since theoretically all public-key encryption systems - including RSA - are vulnerable to this type of attack, given enough computing power. One such example comes from the world of quantum computing - Shor’s algorithm is one way that prime factorisation could potentially become very fast, using a quantum computer. Since quantum computing is still in its infancy, the largest number factorised with this method as of today is 21 - not a huge threat to cybersecurity yet. However, as quantum computers become larger their computing power grows exponentially, so they are definitely something to keep an eye on in the years and decades to come (see ‘Go Small or Go Home’ for more on how quantum computers work). Many of the world’s security systems rely on this problem remaining unsolved, and, while it has stood the test of time so far, there’s no guarantee it will continue to do so.

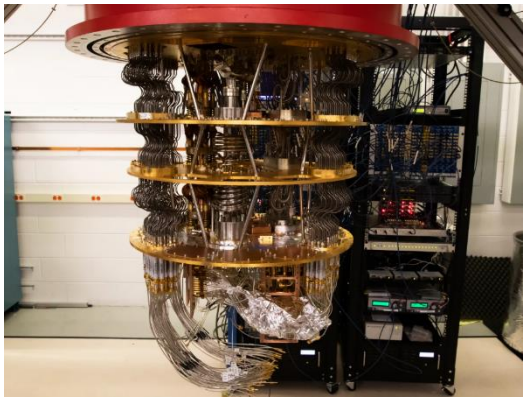
Edited by David Kuc

Go Small or Go Home by Ansh Sharma (Y12)

According to Moore's Law, the number of transistors in a chip doubles each year as they get smaller whilst the thirst for more powerful machines gets greater. However, as we rapidly approach the physical limit, a new generation of computing has arisen: Quantum Computing. This is essentially an evolved version of the classical computers derived from Alan Turing's machines from the 1940s (not to be confused with Turing Machines). These new systems have the capability of revolutionising the computing world as it is today.

Whereas the classical bit (used in classical computing) comprises of either 1 or 0, through superposition, a quantum bit (Qubit) can simultaneously be both at once; that means that while 4 classical bits can be in 1 of 16 scenarios, 4 qubits can be all of the 16 scenarios at once. This allows the qubit to be attributed with far more information than the classical bit; the upper limit of this new capacity is known as Holevo's Bound and can be calculated using Holevo's Theorem. With the prospect of quantum computing strengthening each day, it seems that previously impossible tasks, will be impossible no more.

Richard Feynman, winner of a Noble prize in Physics, first suggested that a quantum computer may be able to solve and further develop the knowledge and understanding of Physics and Chemistry in the 1980s due to its better capability in simulating complex molecules and quantum systems. However, realising this would take decades as the challenges faced by the scientists and engineers would continue to persist despite the best efforts of organisations around the world. Nearly four decades later, a major breakthrough has been reported.



Google declared 'Quantum Supremacy' in the Nature journal on the 23rd October 2019 which essentially means that their Sycamore processor has experimentally proved that Quantum computers have been shown to solve and run problems at a much faster rate than classical computers. While Sycamore (the name of the computer) had 54 qubits, only 53 worked during the experiment.

However this was enough for Google to declare that Sycamore took 'about 200 seconds to sample one instance of a quantum circuit a million times' which they estimate would have taken a classical system 10,000 years (although disputed by IBM researchers who say it can be done in 2.5 days on a classical system as well). However, either way, it still stands that this accomplishment is a precursor for a paradigm shift in the computing landscape.

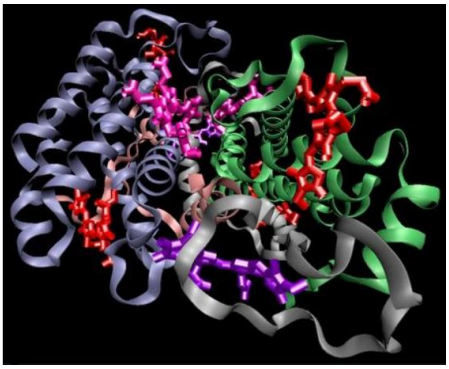
How they work:

A qubit is not a defined object but a system that is used - it must be a two level quantum system in order for the superposition of the two to represent the 1 and 0. For example, it can be a photon where the 1 and 0 is represented by either the vertical or the horizontal polarisation of the particle or it may be an electron in the outer orbital of a phosphorus ion where the spin in a magnetic field determines the value of the qubit. However, there are conditions that must be maintained in order to sustain a qubit:

- A radiation free environment
- Temperature maintained at close to 0 K

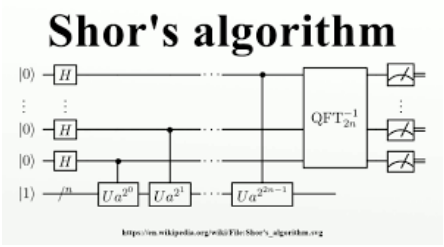
Due to this, objects which are visible to the eye can also be used as qubits. For example, Google, IBM and other companies have used a metallic ring which is a superconductor to act as qubits. This is because the metal will conduct a current in both a clockwise and anticlockwise direction which can in turn be interpreted as 0 and 1.

What this means for the future:



With the prospects of quantum computing being available in commercial computers still being distant, the main advantages seem available to cutting-edge researchers for now. With the newfound ability to potentially simulate complex molecules such as proteins, study elementary particles with greater depth and simply compute previously impossible calculations in the faction of a second, researchers may be able to accelerate their work. Finding cures to incurable diseases, solving unsolvable puzzles and finding unknowns is simply the tip of the iceberg.

However, as always, there are also problems associated with the development of technology. Due to the astronomical capabilities of quantum computers, encryption today (where multiplying 2 large prime numbers result in a key to be used for encrypting) could be very easily broken. Thus, a large threat is posed to internet security due to the concept of quantum computing.

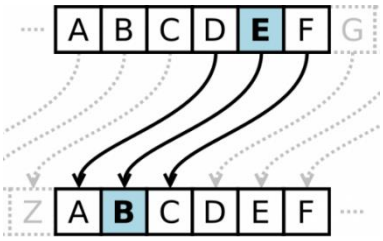


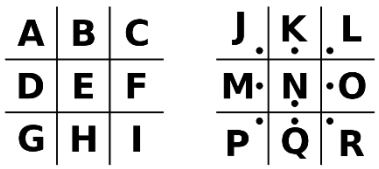
Shor's algorithm can be used more efficiently with a quantum computer due to its capability to produce several results (due to the superposition of the qubits) as well as the fact that the answers that are likely to be wrong interfere destructively. This essentially leads to the power 'p' being found at an exponentially higher and faster success rate. If you would like to know more about this see the 'Age of Primes' article for a more detailed explanation there.

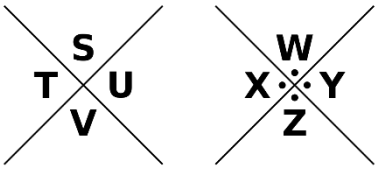
Edited by Ray Wang

Encryption and Ciphers by David Kuc (Y12)

Encryption is a method of manipulating plain text to create an unidentifiable sequence of characters/symbols, which can only be understood by its intended recipient only and nobody else.



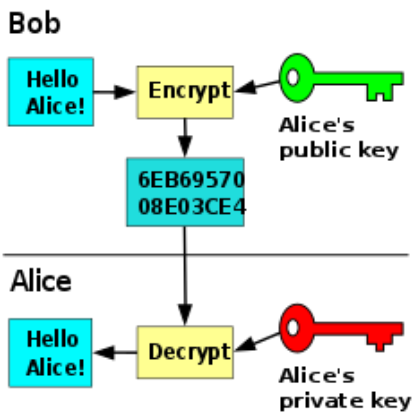




During the first century CE, the first recorded cipher (encryption method) was developed. It was named the Caesar cypher in honour of Julius Caesar, who was said to have used it to communicate with his armies. It was generated by shifting each character by 3 positions in the alphabet, and decoded by shifting each character backward three positions. Despite its simplicity, it was only believed to be cracked between four and eight centuries after its creation.

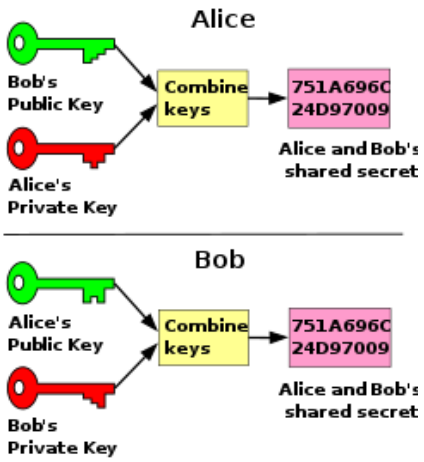
Since then, many new ciphers have been developed, e.g the pigpen cipher by the masons circa 1500s, and the enigma cipher circa 1919. Each of these ciphers had one issue though, in that before you sent a message you would need to agree on an encryption and decryption method, e.g how many places with the Caesar cipher, what each symbol means for the pigpen cipher, and how to set up the enigma machine. This is because they are all forms of symmetric encryption and therefore the encryption method and decryption method can easily be inferred from one another.

With modern technology, we send thousands of data pieces every day, every time we send an email, every time we call a friend, even a simple Google search can send hundreds of packets. Due to our frequency of communication, we can't store every key we use, and setting up a new encryption method every time we want to talk to someone is useless as hackers can easily intercept the key, so they then can access all communications. Because of this, a new encryption method, unlike any before was developed, this is called Asymmetric Encryption.



Asymmetric encryption works by using 2 keys, both of them are mathematically linked. Data encrypted using the public key can only be decoded using the private key, and data encoded using the private key can only be decoded using the public key. So if you were to send a message to Mr Cole for example, and you wanted to make sure only he could read it, you would access his public key, use it to encrypt the message, and send it, then, once he had received it, he would decode it using his own private key (something only he has access to) and then be able to read it.

If this were to happen though, then he would still not be able to confirm that it was you who sent it, so rather than encrypting it with just his public key, you rather merge your own private key and his public key to create a combined key, and encrypt your data with that, then when he receives said data, he merges his private key with your public key to create a symmetric combined key to the one you used, and he can therefore decrypt the data using that combined key.



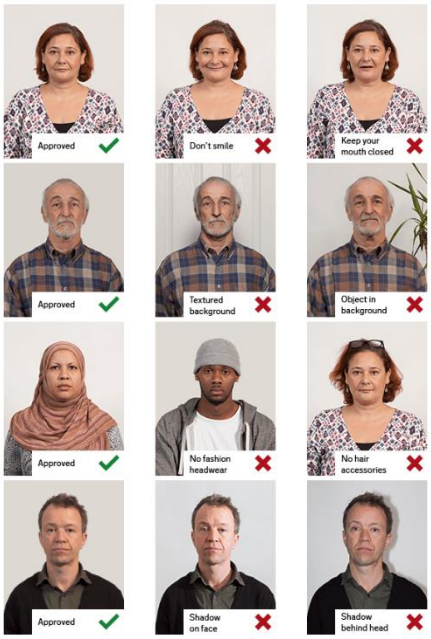
Private keys can be inferred using public keys, however this is a highly complex, advanced and resource intensive process, which means that it would take a supercomputer a long time to do so. Every method of encryption currently available is crack-able, even the most advanced ciphers can be cracked, and most, if not all, methods of encryption that we have invented have been cracked. This doesn't mean that you should worry about your data being stolen, or just decide not to bother as that data will be stolen anyway. In order for someone to crack your data, they first need to have all of your data, and second have the resources to crack it. When you send data over the internet, it is separated into smaller 'packets' which each contain parts of that data and are sent along different routes to the final destination. Therefore, it is unlikely that someone will be able to access the entire data file, and even if they could, very few people have the time/dedication/resources required to decrypt a message without the required key, and of those people, I can almost guarantee that none of them would be concerned enough about your specific data to try and decrypt it. They would probably be more concerned with other valuable data as opposed to a student's search history.

Finally, if you are excessively self-conscious about your data, and want it to be as secure as possible, the trick is to not stand out. If you don't encrypt it, then thousands of unskilled hackers will be able to access it, and one of them probably will, and if you excessively encrypt it with a new advanced encryption, then some skilled hackers will probably see it as a challenge or opportunity to be the first to hack it, and therefore eventually your data will be stolen, so the safest way to secure your information is to do what everyone else does, and just blend in.

Edited by Devanandh Murugesan

Discrimin-AI-tion by Michael Lowe (Y12)

In June 2016, the UK Government released a service which uses AI to check if a passport photo is valid. It's not perfect, as you would expect, but it provides instant feedback on whether it thinks the photo meets the requirements. (For example, it checks that the subject of the photograph has their eyes open and mouth closed.)



A diagram from the Government's website showing some of the requirements for a British passport photo

Since it went live, though, users have been having problems with it misidentifying facial features. For example, the facial-recognition system mistook black sports coach Joshua Bada's lips for an open mouth. And Cat Hallam, a black technology officer, was incorrectly told that her eyes were closed and her mouth was open.

It quickly became clear that these misidentifications were much more common with people with dark skin. The Home Office later stated (in a document released in response to a freedom of information request) that "user research was carried out with a wide range of ethnic groups and did identify that people with very light or very dark skin found it difficult to provide an acceptable passport photograph".

But, while they say they are "continuing to conduct user research and usability testing", the service is still live, without any acknowledgment of the issue on the website.

Furthermore, facial recognition being used by the government to identify people in CCTV footage has been shown to be less accurate with people with dark skin—especially black women. As these technologies are used to identify suspects and can play a role in the justice system, we need to make sure they are accurate.

Machines making decisions:

In some courts in the US, algorithms are being used to predict how likely a defendant is to repeat offend, assisting judges in deciding sentence lengths. These algorithms are being used to combat subconscious biases and inconsistencies in judges' decisions. (A machine won't be any harsher if it hasn't had its lunch yet!)

Some of the more complex systems use huge datasets of previous convictions and criminal records to determine the likelihood of a defendant repeat offending. The best ones are significantly more accurate than any human in making their predictions.

However, while these algorithms tend to be more accurate and consistent, they're not always fair. For instance, they are much more likely to falsely flag a black defendant as having a high risk of repeat offending than they are a white defendant.

We could, of course, try to correct for this—but in doing so we might reintroduce the very biases that this kind of system is trying to prevent.

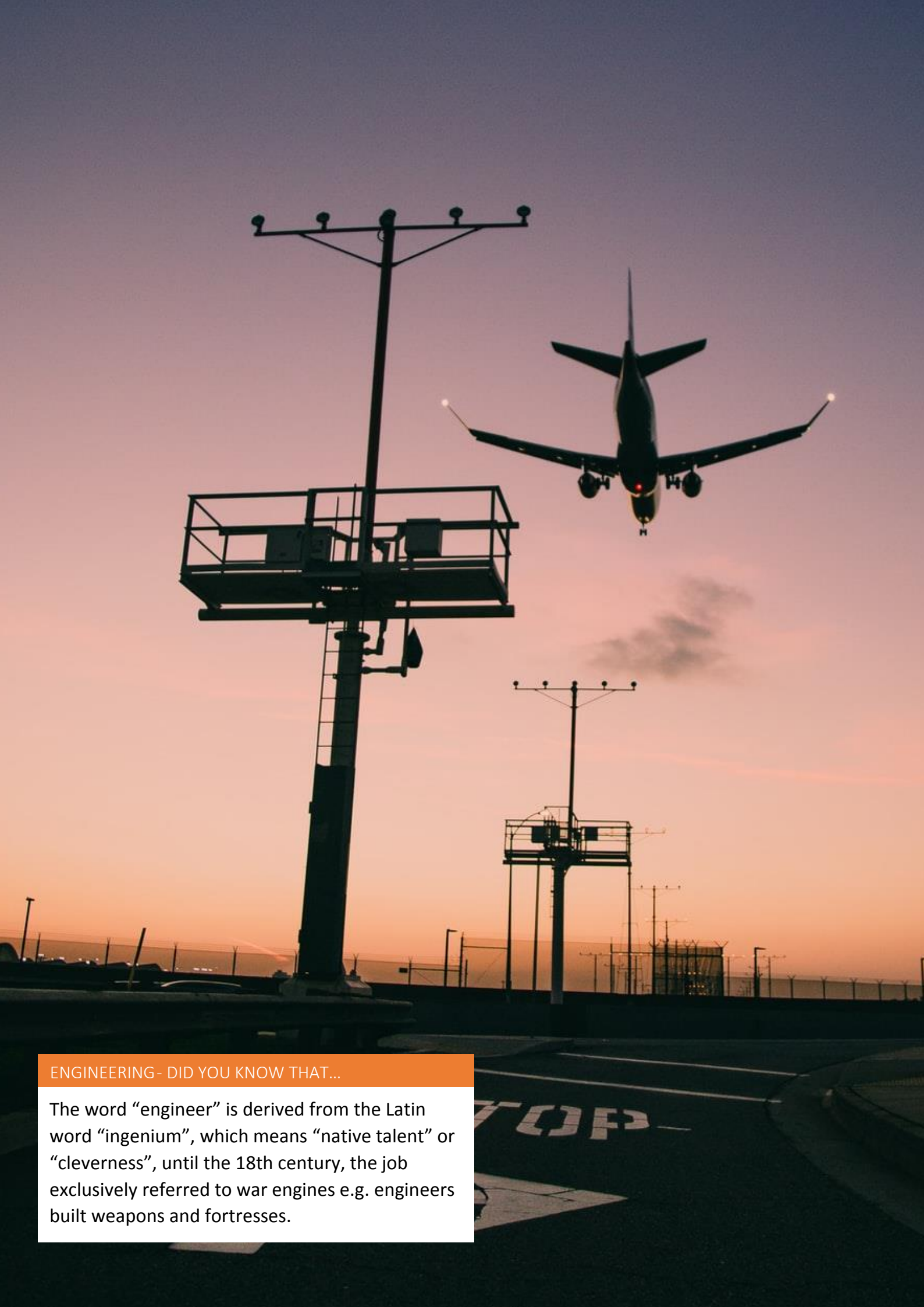
Human bias in machines:

In March 2016, Microsoft released a Twitter bot called Tay (@TayandYou). It was an experimental chatbot designed to interact with users but, within hours of its launch, many of its tweets became racist, sexist and genocidal. Why? "The more you chat with Tay the smarter she gets, so the experience can be more personalised for you," said Microsoft when she was released. The problem was, Tay was being taught by many of her users to speak like this.

It's important to remember that in many (but not all) of these cases it isn't the machine that's flawed. It's us. We humans are the ones introducing our own biases to the world of AI. If the data is 'racist' (whether it be twitter replies or criminal convictions), then so will the system that is built upon it.

Yes, in some situations, technical limitations mean that "very light or very dark" skin tones won't show up as well—but it's our responsibility to intervene: we need more diverse teams, datasets and mindsets and we can't accept these kinds of issues as a given.

Edited by Devanandh Murugesan



ENGINEERING- DID YOU KNOW THAT…

The word “engineer” is derived from the Latin word “ingenium”, which means “native talent” or “cleverness”, until the 18th century, the job exclusively referred to war engines e.g. engineers built weapons and fortresses.

The Car Interior of the Future by Harsh Sinha (Y12)

A recent survey By What? Car Magazine's Motoring Panel, consisting of more than 4,000 respondents, found that the interior of a car is one of the highest priorities for the average UK buyer, with 'relaxing and quiet driving environment' and 'interior finish' being given priority above 'exterior styling', 'fuel economy' and even 'vehicle price'. This means that automakers in recent years have been investing more resources into making their interiors as appealing as possible, leading to a recent flurry in innovative technologies which all aim to make the interior of the future as appealing a place as possible to be.

Interactive Surfaces:

The norm at the moment is for occupants to interact with the vehicle through the use of touchscreens, buttons and switches. Unfortunately, this means that the centre console of the vehicle can look cluttered.

To combat this issue, a Mexican company called Faurecia (famous for their invention of sustainable seats made of hemp) have designed their "First Inch" technology. This is the concept name for their concept centre console, which has switchless "piezo" switches with customisable 3D haptic feedback. This means that the buttons themselves can be laser etched and integrated into any material and provide the same feedback, removing the need for dedicated switches. The example pictured has the switches etched onto aluminium, however they would be just as functional if you were to use wood. Though only a very recent innovation, Faurecia implemented a simplified version called DeCo Display into the 2018 Alfa Romeo Giulia.

Intelligent seating:

Biometric measurements and 'wellness monitors' have been in vehicles for close to a decade now, however have largely been limited to emitting warning sounds when they detect driver drowsiness. Lear Corporation, an American company which specialises in automotive seating and electronics, has devised the "Intu Intelligent Seating Ecosystem". This works by altering seat settings, such as positions and heating, in order to improve alertness. The closest thing to this we've seen in the past is the from JLR's Driver Condition Monitor, which can automatically turn on the massage function of the seat if it feels it is required. The Intu Ecosystem works to a much more extensive degree than this, changing heating and cooling and even changing seating to the safest possible position when it considers an accident inevitable. This combination of features which are optimised to maintain driver attentiveness should help to reduce road deaths due to drowsiness.

This is a serious issue, as shown by the fact that one study found that one in six accidents resulting in deaths or injuries on major roads are a result of fatigue. Therefore, car makers have a strong incentive to adopt similar systems for use in their vehicles.

Brain-to-vehicle communication:

In January last year at CES, Nissan announced their "Brain-to-vehicle" concept to the world. They said that it would detect brainwaves in order to both anticipate the driver's next moves as well as to detect discomfort. This could allow the vehicle to respond to these inputs more quickly when they eventually do happen, improving the driving experience.

This could be further improved when it detects distress, such as that experienced before an accident, in order to decrease response times even further, leading to a greater likelihood of successful evasive manoeuvres. When asked for comment, Nissan refused to give any official predictions for when we can see this technology in production vehicles, however their engineers suggest that we should be seeing similar technology in the next five to ten years.

Cameras for rear-view mirrors:

The exterior mirrors in cars have long been considered an annoyance by many of the leading designers in the industry. Furthermore, they have practical downfalls, from decreased fuel efficiency due to drag to increased wind noise. As a result, automakers have been trying to replace them with cameras instead.

The most prominent example of this is the recent Audi E-Tron, which offers this as standard on the highest trim (Launch Edition). The technology has already started to trickle down to mass market vehicles, such as the Honda e, which will offer this as standard. With range anxiety being more of a concern today due to the spread of battery powered electric vehicles, the reduction in drag that this technology provides is sure to be appealing to designers in this segment.

Modular cars:

Modular smartphones were promised to be the future in the not-too-distant past, with Google Project Ara being the pioneer in this field. However, Project Ara folded and modular tech seemed to be a dream that would never be realised. However, the people at Fiat have decided to give the modular dream another go with their new concept, the Centoventi (named in honour of their 120th anniversary). The Centoventi will be sold in a single, base trim with no roof and a single battery offering 62 miles of range.

From there, buyers would be able to buy a wide range of fittings to apply to their car to make it perfect for them, from a digital display for the tailgate to more batteries (up to four more) for increased range. The interior is where a large amount of effort has been put in, with over 120 types of fitting available, each in a range of materials and colours, in order to allow each Centoventi to be a personalised fashion statement for the owner. Fiat say that this is part of their ambition to "bring motoring to the masses", with buyers only ever having to purchase exactly which features they require, and that we can expect to see a production version in the next two to three years. In keeping with their socially advancing aims for this vehicle, they have also said that they would be willing to share their concept with other companies if approached. The modular dream is closer to realisation than ever before.

So, what is the future of the car interior?

From what we've seen above, the future of the car interior is very exciting indeed. We can expect to see the advent of AI helping to make out interiors safer and more intelligent. We can also say with a great deal of confidence that we can see interiors which are cleaner and more minimalist in their designs, with the possibility of using large slabs of material without interruption by buttons and switches. The array of screens is only likely to increase as well, with even the exterior mirrors being replaced by screens on the inside and a greater amount of technology to control. We may see headsets instead of steering wheels to control the vehicle, and various pieces of completely interchangeable trim. The only thing that we can say for sure is that the interior of the future is an exciting place to be.

Edited by David Kuc

A guide to the past, present and future of the Jet Engine

by Ray Wang (Y12)

The jet engine has pushed the limits of speed and altitude: it has been used to wage wars; it has brought continents together and it has allowed ordinary people to travel the world. It would be fair to say that the jet engine is one of the most influential inventions of the twentieth century and almost certainly the most significant in the field of aviation. The invention of the jet engine was so revolutionary that we have an entire era in our history named after it: The Jet Age.

The jet engine was invented in 1930 by Frank Whittle, a man who is given far too little credit for what he gave to the world. The concept of a jet engine is fundamentally quite simple: Air is drawn in from the front before being passed through a series of progressively smaller blades that squeeze the air. Fuel is then added to the compressed air and this mixture of fuel and compressed air is ignited which causes a chemical reaction known as combustion (combustion requires both fuel and oxygen). E.g. $C_2H_4 + 2O_2 \rightarrow 2CO_2 + 2H_2O\ (-\Delta H)$ This reaction is exothermic (releases thermal energy) which causes gases to heat up and expand. These hot gases exit the back of the engine as exhaust generating thrust and pushing the aircraft forward. On its way out the exhaust gases also passes the turbine, spinning the turbine shaft which is connected to the compressor fan blades at the front of the engine to draw in more air from the front, allowing the cycle to continue.

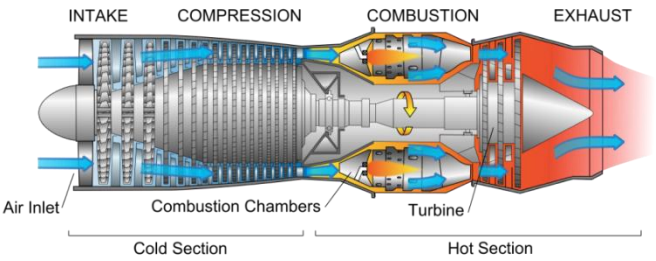


Diagram of a typical gas turbine jet engine (Jeff Dahl 2007)

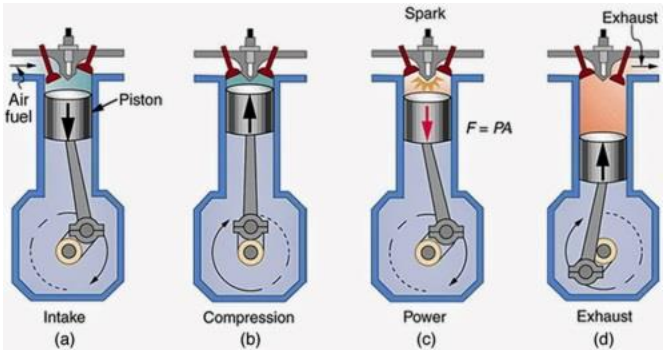


Diagram of a typical piston engine

To understand why the jet engine was such a huge leap forward, first we need to get a sense of what flying was like before it. Up until the 1940s, planes were powered by internal combustion piston engines, which are essentially the same type of engines found in cars. Piston engines simply cannot be as powerful as jet engines in the way that they work, despite using the same scientific principles as jets with the same four stages of intake, compression, combustion and exhaust.

In the first stage when the piston is moving towards the bottom of the chamber, the air and fuel mixture is sucked into the chamber through the intake valve.

The intake valve then closes and the mixture is compressed by the piston moving up due to the momentum of the crankshaft. The compressed mixture is then ignited creating hot expanding gas that pushes the piston down, turning the crankshaft while exhaust gases exit through the exhaust valve.

So why are pistons not as powerful as jets? Notice how the piston engine is actually a whole lot more complex than the jet. There are so many different components: crankshafts, pistons, connecting rods, valves etc. The jet engine is a lot smoother without the restrictions to inlet and exhaust gases that piston engines have. Conceptually, jet engines have far fewer complex moving parts and the flow of air is more or less in a straight line, unlike in a piston engine. All the complex movement in a piston engine means that there is a lot more friction in the piston engine than in the jet engine.

Also, in a jet engine all the four stages are happening simultaneously while in a piston engine, they happen chronologically. This means that with a piston engine, full power is only produced during that instantaneous ignition stage while in a jet engine, full power is produced continuously.

Put simply, jet engines are designed to suck in huge volumes of air, mix it with huge volumes of fuel and burn them generating a lot of thrust. Pistons just aren't designed to work like that.

Ultimately, this means that jet engines have a far greater power to weight ratio than piston engines.

At this time, most planes were still predominantly made of wood and fabric, materials that would never even be considered for construction of a new aircraft just a couple of decades later. You can probably begin to piece together an image of what it must have been like to fly on one of these older piston-engined aircraft. Incredibly noisy, slow, but also, since aircraft couldn't carry that many people, flying didn't come cheap and was reserved for the upper class. Flying transatlantic took 24 hours on a flying boat and came at a hefty price of £4,000.

So when the jet engine made its way into commercial aviation, the changes were drastic. In the space of a couple of decades, flying had been revolutionised. Now, the average working class could afford to travel in relative comfort to these faraway destinations they could only have dreamed about just a few years ago.

The four JT9D turbofan jet engines let the 747 carry over 500 passengers in 1969, while the two J58 turbo-ramjets on the SR-71 took it to the edge of space at over 3.5x the speed of sound in 1965. But there's no getting around it, flights with jet engines use a lot of fuel. And throughout the 70s, the Middle East started getting a little frisky and oil prices went through the roof. In the years to come, oil was no longer going to be a stable low cost commodity. Today, fuel costs account for 23.5% of the global airline industry's operating costs *(IATA Fuel fact sheet June 2019).* More fuel efficient engines had to be developed.

Enter the turbofan. The core of the turbofan is exactly the same as the jet engine. The turbofan just has a huge fan in front of that jet engine and a casing around it. This is the key, this fan actually produces thrust itself by acting as a propeller, drawing air past the jet engine core and accelerating it out of the back. Since this bypass air doesn't go through the core, it doesn't require any more fuel, making turbofan engines a lot more efficient than turbojets.

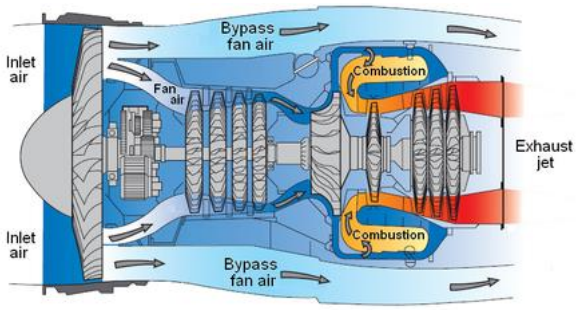


Diagram of a turbofan engine

Trent 1000 on a Boeing 787 prototype Boeing/Omega (MilborneOne 2010)

Pratt & Whitney JT8D-219 engine on the 707RE flight test aircraft (Alan Radecki 2007)

More recently, you may have noticed engines on newer airliners being much larger. This is because these engines have higher bypass ratios. A bypass ratio refers to the volume of air passing through as bypass air in relation to the volume of air that goes through the engine core. Engines such as the Rolls Royce Trent 1000 have bypass ratios of 10:1 which means that for every 10 units of air that passes through as bypass air, only one unit actually goes through the core. This makes airliners that use the Trent 1000, such as the 787, among the most efficient aircraft in the world.

Rolls-Royce RB211-22B high-bypass turbofan

GE90 turbofan (David Monniaux 2005)

Trent 1000 fan blade (Rolls Royce 2014)

There are many more recent advancements in turbofan engines, take the shape of the fan blades for instance: The fan blades on newer engines have an advanced, meticulously designed curved shape to them to allow as much air to be drawn in as possible.

But what does the future hold for jet engines? As the effect of climate change becomes more prevalent than ever, it is clear that a new source of propulsion for our aircraft is needed. But this is far easier said than done. As it stands, there is not really a viable solution. Electric planes are so far off with the current largest electric aircraft being a two seater and can fly for around three and a half hours before it conks out. Getting from that to the 650 tonne aircraft that can fly 14,000km A380 that we have today is not going to be easy, to say the least, and as it stands it's pretty much impossible. The issue is that kerosene used in aircraft is vastly more energy dense than what current batteries can offer. While hydrogen fuel cells are a possibility, let's just say that the last time we tried to fill a massive aircraft with hydrogen it didn't end too well. (The *Hindenburg* disaster – hydrogen airships)

So as it stands, the jet engine isn't really going to face any competition anytime soon. It is kind of concerning that we still have no idea how mass air transportation would be possible without the jet engine, and just goes to show just how reliant the modern world is on Frank Whittle's humble invention.

Edited by Devanandh Murugesan

BIOLOGY- DID YOU KNOW THAT…

Before the invention of microscopes, people believed that illnesses were the result of poisonous gases or evil spirits. Once the microscope was created and people could see viruses and bacteria, these beliefs began to change.

Recent advances in Genetics by Divy Dayal (Y11)

The theory behind genes is no new concept, dating from Gregor Mendel's work on pea plants, involving the breeding of certain plants to achieve certain physical characteristics. However, without a doubt, in the last few years, the impact that genetics has had to the scientific community and to our daily lives, is immense. From new DNA to designer babies, cancer fighting codes and left handedness, genetics gives foundation to them all, and here is the update on all recent advances in genetics.

Discovering more DNA bases:

All school textbooks state the four bases present in DNA: Adenine, Thymine, Cytosine and Guanine. However, scientists have discovered that by adding certain proteins to existing bases, they can make variants [1]. This is a phenomenal discovery, with implications stretching to cancer treatment and longer lives. It is said that with more bases we could potentially condense our genome to a smaller chain. This makes DNA easier to copy and thus, when we grow (our cells duplicate during growth), it can happen faster and with less mistakes. It means that there is less chance of harmful mutations, such as those triggering cancer or long-term genetic diseases.

CRISPR

While shrinking the genome has its own advantages, changing the code itself is a rising possibility. While gene modification is something of the last millennium, the new CRISPR gene editing tool [2] can precisely amend certain parts of an organism's DNA. Scientists first discovered this revolutionary enzyme in certain bacteria that use it to protect themselves from viruses, since the bacterium redirects the CRISPR enzyme to correct certain parts of the DNA by cutting it up to make it non-functional. Some viruses insert their genetic material into the bacteria, and this can be very dangerous for bacteria. This acts as a sort immunological memory. It has evolved so that enzymes now scout the DNA for any viral genetics, and then "cut" it out. This has been adapted to use for humans. Scientists speculate that it can be used for editing people's genome when they have genetic conditions such as Huntingdon's. While research is afoot, it is predicted that it will be possible for us to eliminate/prevent genetic diseases soon.

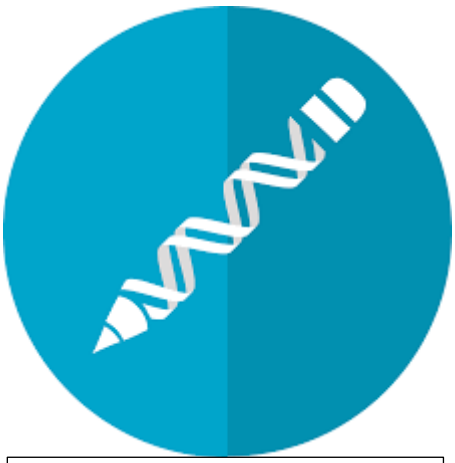


Figure 1 - What CRISPR does

Designer babies:

Some people argue that gene editing is playing with natural scheme of things, and some people fear that people will edit their embryos to make them more desirable. However, while this may been far fetched, current 'designer babies' are only to help and save someone's life. In Chicago 2006, a embryo's genome was selected since it was very similar to terminally ill Molly Nash's 3 genome. She was suffering from a disease where she couldn't produce sufficient blood cells due to an lack of stem cells. Doctors suggested the use of a new embryo which would have extra stem cells, that can be taken from its umbilical and transferred into Molly. This would cure her disease and not affect Adam (the embryo) at all. This may have been almost 13 years ago, the implications still echo with more news stories of life saving embryos. It, inevitably, raises ethical questions about it and a few people fear a new supreme race. While this is unlikely, it does highlight the dangers, possibly playing with life and death as philosophers might put it.

DNA tests:

Figure 2 - Leading genetic testing firm

Would you spit, rip out a hair and put in a few drops of your blood into some tubes and send it off, and believe the results you get? While it's all in the name of science, DNA tests are surprisingly accurate. With over 100 companies offering genealogy and health care information from these hairs, and them costing between £25 and £150, it's a rapidly growing market. Companies like "Ancestry DNA" and "23 and me" are expanding their genetic databases and as time grows, there will be more information available to anyone who send a sample of their skin through the post.

Left handedness:

Scientists have found genes dictating someone's handedness [4], something which was previously thought to be completely down to chance or environment. This is pushing the boundaries of science as we know it, and confronting our everyday beliefs. This study was however only conducted in Britain with a relatively small sample size. While this may challenge the validity of the study, it does lay down fundamental evidence for the cause of left-handedness.

With improvements in technology and measurements, and with greater availability of education, it's not long until what seems fantastical now becomes everyday tomorrow.

Edited by David Kuc

Diabetes and the Future of Treatment

by James Meehan (Y12)

An Introduction to Diabetes:

Diabetes mellitus develops in two forms, type 1 and type 2. Type 1 diabetes develops as a result of a misguided attack from the immune system of the individual, resulting in the destruction of [1]beta cells found in clusters called islets in the pancreas. However, type 2 diabetes develops as a dysfunction of beta cells within the pancreas resulting in the inability to use the insulin produced within the body – both processes result in hyperglycaemia (high blood glucose levels) and increased insulin resistance. As a result of these processes, the body is incapable of combatting episodes of hyperglycaemic phases.

The protein amyloid is a marker for beta cell dysfunction in type 2 diabetics. It building up in beta cells correlates to the decrease in beta cell mass and increase in alpha cell mass, resulting in hepatic glucose production (increased production of glucagon, which has an opposite function to insulin). This means that hyperglycaemia increases in severity for the affected individual.

The biological processes explained regarding type 2 diabetes come as a result of poor diet, such as intake of large carbohydrate foods and due to a lack of exercise. The combination of these mean that the pancreas' and livers' responses to intakes of carbohydrates is poorer and the production of hepatic glucose begins over time.

Unlike type 2 diabetes, the causes of type 1 diabetes are less well known. Studies hint that there may be a correlation between specific variants (HLA-DQA1, HLA-DQB1 and HLA-DRB1) of the HLA-DQ and HLA-DR genes and type 1 diabetes. These results suggest that 1 in 16 people are likely to develop the autoimmune disease if a [2]first degree relative possesses a larger number of these genes, compared to a 1 in 300 chance in the general population.

Diabetes Diagnosis, Glucose and Insulin Control:

After diagnosis, individuals will begin a regime of insulin and glucose control. This is important as insulin (which can no longer be supplied efficiently by the beta cells of the pancreas) is replaced, maintaining blood glucose levels at a target range of 4–7 mmol/L.

As insulin is crucial in decreasing blood glucose levels, a ratio is used to calculate how many units of insulin that must be taken after the consumption of carbohydrates. The ratio can be written as 1:10g, meaning that 1 unit of insulin must be taken per 10g of carbohydrates consumed. In addition to this, an insulin sensitivity ratio must also be calculated. This is important as it is used to reduce blood glucose levels when an individual may be outside of the target range. A ratio that is 1:3.5mmol/L essentially means that for each unit of insulin [3]injected subcutaneously, the blood glucose level will decrease by 3.5mmol/L. For example, if an individual were to have a hyperglycaemic phase and was at a level of 16mmol/L, (measured through a blood glucose meter) they would have to inject 3 units of insulin to

reduce their blood glucose level 10.5mmol/L, which would mean that in theory their new blood glucose level would be 5.5mmol/L. These ratios can be altered over time and are affected by many factors such as insulin resistance, illness or time of day. It is important to understand these ratios as they are essential in the use of insulin pumps, which secrete insulin during the consumption of carbohydrates.

Furthermore, diabetics can also undergo phases of hypoglycaemia, which occur when blood sugar levels are too low. The symptoms of this are shaking, dizziness, sweating, mood swings, extreme hunger, tiredness, paleness and weakness. In these instances, diabetics must decide on an appropriate amount of carbohydrates to consume, and the type of how fast or slow acting it is. Fast acting sugars are formed of short chains of glucose, which can be digested at a higher rate, and slow acting sugars are formed of long chains of glucose, which require longer periods of time to digest. It is thought that diabetics must make an average of 180 more decisions each day than an individual who is not diabetic, due to the constant variation in glucose levels and wellbeing.

Future Treatments:

Now that the basic understandings of diabetes have been explained, it will be easier to understand the new technologies and medications available to diabetics, and the ways in which they must work. In the UK alone, there are over 3 million diabetics and the demand for a successful development of a cure increases, as now it is predicted that 1 in 3 born after 2000 will develop one type of diabetes at some point in their lives.

For type 1 diabetics, future treatments could include:

Replacing missing cells with cell therapy—Replacing missing insulin producing beta cells could stimulate the recovery of cell function. This has been tested, but due to the weakened immune systems of diabetics, the transplants of cells have been rejected and the implanted cells have been destroyed. There is also a shortage in the number of possible donors, where tissue and blood types must be identical or similar enough to prevent rejection.

The Diabetes Research Institute are developing a bio-engineered organ that encapsulates insulin producing beta cells, to protect them from rejection or destruction by the recipient. In 2016, the first patient that had been tested in phase 1/2 no longer needed insulin therapy after a successful trial. Other methods of culturing cells from a patient's liver into pancreatic cells is also being tested to avoid complications due to donors and rejection of foreign cells. Large pharmaceutical companies are beginning to invest in encapsulation and stem cell technologies, but the extreme prices (some costing millions of pounds) mean that the first clinical trials are yet to come.

Attacking the origin with immunotherapy—Beta cells in the pancreas are progressively destroyed by the immune system of the individual, until the pancreas no longer functions. Early treatment can counteract this process and preserve cells, but also provide a cure. Bacteria are used to deliver two drugs that stimulate regulatory T cells and instruct the immune system not to attack the insulin producing cells. The process can be used to preserve remaining cells, after diagnosis of 6 months, up to 30% of cells are still producing insulin, and these can be protected through immunotherapy. Also, immunisations are being developed to inhibit the levels of inflammatory proteins that are involved in many autoimmune diseases.

Automated treatment with an artificial pancreas—For diabetics who have no cells to produce insulin, a pancreas can be integrated as an automated system that functions and secretes insulin into the bloodstream as a normally functioning pancreas would do.

Due to the unpredictable nature of blood glucose levels and insulin requirements in a daily diabetic's life, some sort of algorithm would need to be created to efficiently supply the correct insulin for the individual. The type of insulin required would have to act instantaneously to combat blood glucose changes and algorithms would have to become significantly better to efficiently calculate the exact insulin requirements of an individual.

For type 2 diabetics, treatments could include:

Stimulating insulin production—Glucagon-like peptide receptor agonists, which induce insulin production can suppress the secretion of glucagon, which could reduce the severity of a hyperglycaemic phase. This treatment could come in the form of an oral drug. Other drugs are being produced that reduce blood sugar levels and blood pressure, which is a risk factor for individuals who are obese. In addition to this, other drugs that can reduce insulin resistance, excessive eating, and fat deposition are being developed and are all close to the market, (in later phases of clinical trials).

Targeting the microbiome—Chronic illnesses such as diabetes are largely as a result of an unhealthy gut microbiome. An unbalanced microbiome composition has been found in many type 2 diabetics, whereas a more diverse microbiome has been found in healthy individuals. Microbiome transfers through faecal transplants can help to decrease insulin resistance in the short run.

The movement away from needles—The use of needles to measure blood glucose levels is becoming less and less common.

Sensors and continuous blood glucose monitors which use electromagnetic waves mean that blood can be measured without using invasive methods. This reduces the pain involved and needles necessary to supply insulin. Patches such as the FreeStyle Libre are being used which can be replaced each two weeks, and graphene patches are being developed so the accuracy of blood glucose results would be greater by taking samples from multiple hair follicles.

By 2025, the market for type 1 and 2 diabetes treatments will reach £85 billion and this means that new technologies will surely be implemented, such as nanotechnology: microchips and nano-robots may become influential in the development in diabetic technology.

On the other hand, it is important to understand the current practices of diabetics to reduce insulin resistance, reduce obesity (type 2), and improve pancreatic function. Dr. Bernstein's Diabetic Solution provides an apt and perfectly comprehensive guide to diabetes, which has been deemed as a "bible for diabetics". One of Bernstein's main practices is that of a low carbohydrate diet, where the intake of proteins is increased to account for the maximum of 50g of carbohydrates consumed daily. It aims to reduce the amount of insulin required by diabetics, with the aim that individuals can reduce insulin intake, as a small percentage of pancreatic function still remains.

Although there are many complicated processes that will take lots of testing and trials to overcome, an exciting new era in treatment is on the horizon for diabetics and their treatments.

Edited by Michael Lowe

Key Terms:

[1]**Beta cells:** Cells found in the pancreas which synthesise and secrete insulin (which is needed to control blood glucose levels) and amylin
[2]**First degree relative:** parent, sibling or child
[3]**Subcutaneous injection:** A injection administered as a bolus into the subcutis (the layer of skin directly below the dermis and epidermis)

The Science behind Memory by Ken Li (Y12)

Have you ever wondered what happens to allow you to learn information? Why certain people can remember things faster than others? Why some people are capable of learning vast volumes of information whereas others struggle to recall where they placed their glasses the previous evening? Memory is an abstract subject that had been investigated and debated for centuries by various scholars and philosophers alike. However, only now are we beginning to obtain a clearer picture of the true mechanics of human memory.

Memory, the ability to store and retrieve processed information, is integral to our existence; without it, we would not know who we were, or where we live, or what is safe and what is not. There would be no point reading this article, as its contents would be forgotten immediately after – that is if you remember what all these words mean.

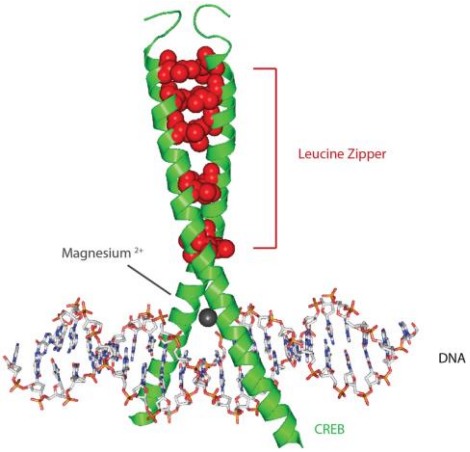
Throughout our lives, we collate a vast array of memories, most of which are formed from sensory stimuli – these are first stored, however, in unprocessed form within our sensory memory. Here, information is held for less than a second, as either iconic (visual) memory or echoic memory (auditory), before being transferred to our short term memory, depositing information for about half a minute.

How then, is the short term memory retained and transferred to our long term memory? One theory is that there are two systems within the brain that help to consolidate and associate the information so it can be stored and processed, to be forever retrievable as long term memory. The first is the **phonological loop**, a technique employed by the brain where it repeats spoken information, usually in the form of words, letters or numbers, to prevent it from fading into nothing. Unsurprisingly, this engages the Broca's and Wernicke's areas (located in the left frontal and left temporal lobes and associated with language mastery and production respectively), and likely plays an important role in language acquisition.

The other system is the **visuo-spatial sketchpad,** which helps to hold visual cues. For how it works, think of it this way: if you heard the word "plane", your mind would conjure up the picture of one, so that you could rotate it, zoom in and out to the wings and engines, and see all the detail there nearly as clearly as if there was one in front of you. Abstract nouns however, are less easy to visualise, and therefore abstract concepts may be harder to hold in short term memory. It's why people tend to learn better with diagrams and visual cues, as it is much easier to recall the diagram than the specific information.

Biologically, a lot more goes on to commit something to memory than one would imagine. It all depends on a feature of neurons known as **synaptic plasticity**, which is the variation of the strength of an impulse between two neighbouring neurons. When information is being committed to long term memory, a new connection of neurones in the brain is established; when the information is being recalled, an impulse is fired down this specific network of neurons, thus strengthening the pathway. This is due to the fact that when one neuron repeatedly fires the neighbouring neuron, chemical changes take place in both neurons that allow the neuron firing the impulse down the other to become more efficient to do so.

The change involves the activation of a certain protein, the **CREB (Cyclic Adenosine Monophosphate Response Element Binding protein)** which travels from the peripheral (outer) part of the neuron to the nucleus in the soma (cell body), and binds to specific genes in the DNA. A cascade of new gene activation continues, involving new protein formation, of which travel to the synapse of the neuron to grow new synaptic connections to the neighbouring neuron in that particular pathway. This makes the overall synaptic connection between the two neurons much stronger.



A specific type of synaptic plasticity, known as **Long Term Potentiation (LTP)** is particularly fundamental to long term memory in humans, and is applicable in just about any situation. Take learning how to drive for instance - initially, after the first lesson, the particular pathway of neurons used to recall the exact details and skills required will have just been established, with weak synaptic connections. However, continued firing of these neurons following subsequent driving lessons causes chemical and physical changes to said neurons, and synaptic connection is stronger, meaning the retrieval and application of the skills and knowledge is more readily available.

So what makes one person smarter than another, if the same chemical changes are occurring in both brains? Firstly, let us debunk the myth that a bigger brain means a higher IQ score. It doesn't, as Einstein kindly proved with his brain in an autopsy following his death. What he did have, however, was an abnormally large parietal lobe (the portion of the brain on the upper side of the temple). This was further attributed to larger neurons in this section of the brain, which could fire impulses at higher rates. He also had larger than normal dendrites which help to initiate impulses faster, meaning Einstein could intellectually make more connections in his mind to think unlike anyone else and come up with brighter ideas and propositions.

Studies have further shown that phenomenal memory and intelligence is attributed to genetics, more specifically the inheritance of two specific alleles of the gene BNDF (Brain derived neurotrophic factor), which helps the development of new neurons from stem cells.

Some may consider this unfair, for others to have boosted academic potential just because of hereditary factors out of their control. Do not be disheartened, however, as all hope is not lost; researchers say that genetic variation may provide an advantage in other biological processes. Better physical strength for example, which some seem to favour over academic excellence.

Edited by Ray Wang

Schizophrenia: The reality-altering disease of the mind

by Kevin Luo (Y12)

Is this a dagger which I see before me, the handle toward my hand?'. This line from Shakespeare's famous tragedy 'Macbeth' hints at the protagonist having a [(1)]psychosis—causing mental health disorder called schizophrenia. And, with roughly 1 in 100 people experiencing schizophrenia in their lifetime, there is a high chance you know someone who is experiencing or will go on to experience the same condition. Schizophrenia is a [(2)]neurodevelopmental disorder which involves a wide variety of symptoms which can vary between cases. Symptoms of schizophrenia include [(3)]positive symptoms, such as hallucinations and delusions, and [(4)]negative symptoms, such as social withdrawal and a lack of care for personal hygiene. Not all schizophrenics experience all the symptoms.

Causes:

The exact cause of schizophrenia is currently unknown. Research suggests that a combination of genetic and environmental factors may make a person more susceptible to developing the disorder. Neuroimaging studies of schizophrenics' brain structure and central nervous systems have revealed differences from a person who does not have schizophrenia indicating that schizophrenia is a brain disease.

As stressful or highly emotional life events can trigger schizophrenia, someone who would be otherwise healthy could develop this condition suddenly. Males and females are equally likely to develop the disease (although women tend to be diagnosed with schizophrenia slightly later in life than men). Drug misuse and birth complications also increase the risk. Schizophrenia diagnoses usually occur between a person's late teens to early 30s. These diagnoses are normally after puberty, as changes in the brain as it develops can trigger schizophrenia in people prone to the condition.

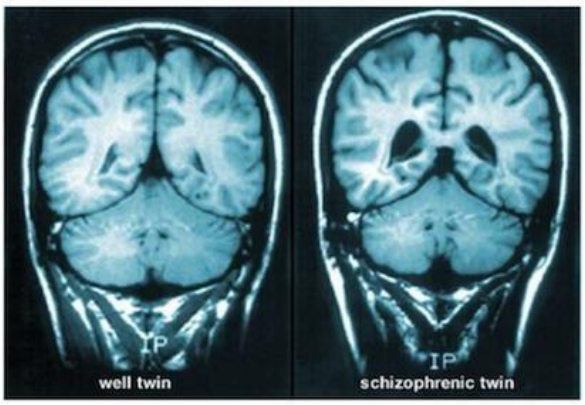
Life with Schizophrenia:

Most people diagnosed with schizophrenia recover from their condition, but many will continue to have occasional [(5)]relapses. These include symptoms such as insomnia, social withdrawal, concentration difficulties, lack of appetite and increased paranoia. The condition's effect on one's life, however, can be mitigated with self-care as well as professional support and treatment as they will reduce the severity of relapses and will help the schizophrenic make a quick recovery. As schizophrenia relapses can occur sporadically and suddenly, healthcare professionals will likely be in contact with patients regularly as to monitor how they are doing and for the patients to report any milder symptoms which they experience (as these show that they are having an [(6)]acute schizophrenic episode).

People with schizophrenia have problems organizing their thoughts and making logical connections and they may behave abnormally in situations, for example schizophrenics may talk and not make sense or make up words. They may have trouble keeping their house and/or themselves clean and they also may be agitated or expressionless. It has been shown that, schizophrenia, if left untreated can lead to many major complications.

These include:

- Suicidal thoughts/actions
- Self-harm
- Other psychological disorders (e.g. depression or OCD)
- Legal and financial problems
- Inability to work or attend school
- Social isolation
- Substance abuse



Source: Goldberg, 2016

Treatment:

Currently there is no known cure for schizophrenia but there are treatments which can reduce the symptoms. These treatments are lifelong (they need to be taken even when the symptoms subside) and include both therapy and medication. The treatment prescribed to a schizophrenic case is tailored towards the person and their needs as different antipsychotics (both [7]typical and [8]atypical) are prescribed and have varying side-effects. These antipsychotics work by blocking the effect of the neurotransmitters, dopamine and serotonin, on the brain. There are also different types of therapy available for a schizophrenic which help them cope with hallucinations and negative symptoms better. These include:

- Cognitive behavioural therapy (CBT), which aims to identify the thinking patterns which are causing them unwanted feelings and learning the replace these thoughts with more useful ones.
- Family therapy, as people with schizophrenia usually rely on their family for care and support in order to cope.
- Arts therapy, which promotes more creative expression.

Recently, it has been suggested that a [9]ketogenic diet may be used as treatment for schizophrenia as this has been shown to improve psychiatric symptoms as well as metabolic dysfunctions. This is because genetic data suggested that there is a [10]bioenergetics dysfunction characterized by abnormal glucose handling (diabetes) and mitochondrial dysfunctions resulting in impaired [11]synaptic communication in the brain of people with schizophrenia. This however has been said to need more clinical trials to show the [12]efficacy of a ketogenic diet.

Edited by Michael Lowe

Key Terms:

1. Psychosis – A mental health problem causing people to perceive/interpret things differently from those around them.
2. Neurodevelopmental -Related to the growth of the brain and/or central nervous system
3. Positive symptom – Any change in behaviour or thoughts
4. Negative symptom – A withdrawal or lack of function that you would not usually expect to see in a healthy person
5. Relapse - A deterioration in someone's state of health after a temporary improvement.
6. Acute – Severe but of short duration
7. Typical antipsychotic – The first generation of antipsychotics developed in the 1950s
8. Atypical antipsychotic – The newer generation of antipsychotics developed in the 1990s
9. Ketogenic diet – a high-fat, adequate-protein, low-carbohydrate diet
10. Bioenergetics – the transformation of energy in living organisms.
11. Synaptic – relating to a synapse or synapses (minute gaps between nerve cells which neurotransmitters diffuse across in order to pass an impulse) between nerve cells
12. Efficacy - The ability to produce a desired or intended result.

Dementia: Causes, Symptoms and Prevention

by Koushikk Ayyappan (Y12)

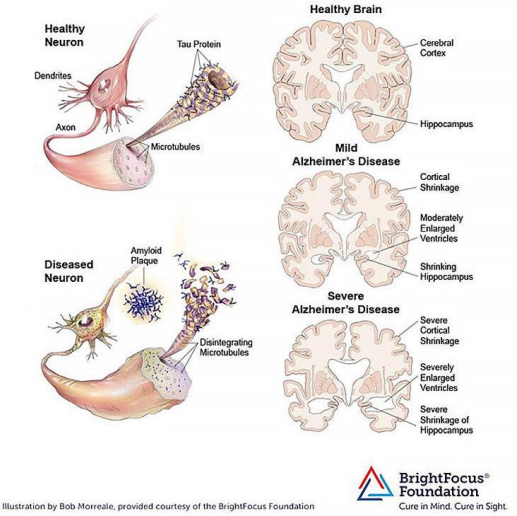
The word “dementia,” is well known for sparking fear and, in some cases, pity. This is arguably due to the stigma and lack of understanding about the condition, some of which I hope to diminish.

The natural starting point for anyone wishing to find out more about the condition is to investigate its biological basis and effects, before expanding research to encompass preventative and combative measures. This is invaluable information, especially within a nation such as the UK, where there are at least 850,000 people currently suffering from some form of dementia - a number that is predicted to 2,000,000 by 2050 due to our ageing population. Furthermore, it is anticipated that 1 in 3 people born this year will have dementia later in their lives, due to an increased proportion of people living longer, and the risk of dementia increasing with age. It is clear that dementia is becoming an increasing problem.

First of all, dementia is a collective term used to describe various symptoms of cognitive decline’[1], caused a range of progressive conditions. There are many subtypes – over 200, but the focus of this article will be upon the most common: Alzheimer’s and Vascular dementia, as well Young Onset Dementia, which may be more relevant to the typical *Intrigue* reader. Regardless of specificity, all of these sub types lead to cognitive decline and lead to symptoms of impairment in communication, memory and thinking. This is not a normal part of ageing, a widely held belief, although some symptoms of ageing may share mild similarities to early stages dementia.

Alzheimer’s:

Alzheimer’s, named after Alois Alzheimer, is responsible for more than 60% of dementia cases, thereby making it the most common form of dementia worldwide by far. It causes a physical change in the structure of the brain, predominantly due to two reasons. The first is, due to a build up of extracellular beta amyloid[2]. Normally, these protein fragments are broken down and destroyed by microglia and astrocytes - types of ‘glial[3]’ cells that remove waste products from neurones – but within the brain of anyone with Alzheimer’s, hard, insoluble plaques are formed between neurones, which in turn impede neural connections. As the glial cells accumulate, chemicals are released, causing chronic inflammation, further damaging neurones.

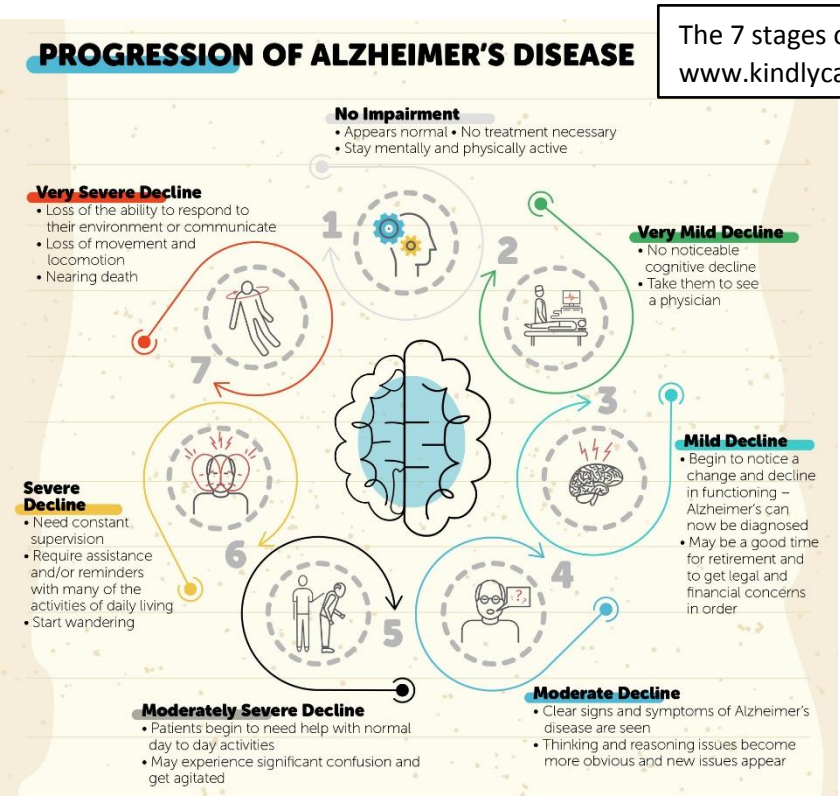


An illustration showing the physical change in brain structure due to Alzheimer’s[5] tissue

Moreover, neurofibrillary tangles of insoluble, twisted fibres will accumulate inside microtubules[4], and primarily contain the protein tau, which moderates the (physical) stability[5] of the brain. As a result of the beta amyloid and various chemical changes (due to tau kinase enzymes, and hyper-phosphorylation), tau detaches from the microtubules and sticks to other tau, forming threads and tangles (see image)- the other primary marker of Alzheimer's- and often causes the collapse of these microtubules after destabilisation (due to weakened neuronal transport systems), which further leads to weaker neural connections. Interestingly, these accumulate especially in the regions in the brain involved in memory.

Symptoms and Stages:

As the disease progresses, the brain tissue shrinks (brain atrophy) and up to 140g of tissue is lost if one has Alzheimer's[7], compared to a healthy brain, according to the #ShareTheOrange study (named as such due to 140g being commonly accepted as the average mass of an orange).



The 7 stages of Alzheimer's[6]
www.kindlycare.com

One of the earliest symptoms is short-term memory loss caused by the degeneration of the hippocampus in the mid cognitive impairment phase; many consider this to be the defining feature of dementia. This is accompanied by the (sometimes devastating) loss in ability to perform routine tasks. As the disease spreads to the cerebral cortex, judgement and command over language deteriorate, as well as emotional control. Later, the further neuronal degeneration occurs and changes in behaviour can be noticed such as agitation and wandering. In the final stages, the loss of the ability to speak, to recognise people and to self regulate will happen, with physical symptoms such as immobility and trouble swallowing food; constant care is often required.

Those with any type of dementia have a weakened immune system, which makes them especially susceptible to ailments and physical difficulties, especially during the later stages of their illness. However, all of these symptoms differ from person to person, as different brains will have slightly different physical changes and therefore each patient will experience varying symptoms.

Young Onset Dementia:

Although most cases of dementia happen in those over the age of 65, dementia can occur in those under 65, called young onset dementia, and poses many social challenges, the most common being employment issues and financial difficulties. 1 in 3 dementia cases are young onset, and are usually caused by genetic conditions such as Parkinson's or Huntington's disease, which lead to the rapid degeneration of neurones. Moreover, atypical variations of diseases, such as Alzheimer's, that cause symptoms of the later stages (such as sight problems) at a young age may be due to younger onset dementia. Symptoms vary just as widely as amongst older patients.

Vascular Dementia:

This type is caused by damage to the brain, often due to a lack of blood supply and oxygen. This kills neurones, and therefore impairs neuronal connections. It is linked with stroke and other cardiovascular conditions, as well as diabetes, so could be hereditary.

Furthermore, it is relatively common within younger people, as 15% of young onset dementia is vascular. Symptoms mostly include slower thinking and thought problems, with physical symptoms such as limb problems becoming especially likely to accompany strokes.

Treatments:

There have been many attempts at cures for Alzheimer's and other subtypes of dementia, with none being successful so far in reversing its physical effects on the brain – current treatments only aid with symptoms. Furthermore, although there have been antihypertensive drugs that can prevent vascular dementia, these do not cure the disease, so scientists have not been successful yet.

However, on 26 October 2019, a study has shown that the first drug has been created that can slow down Alzheimer's – a monoclonal antibody drug called Aducanumab[8], which targets and destroys amyloid, in order to prevent plaques forming. When tested in higher doses with patients with early Alzheimer's and data collected in a large dataset, it has been shown that clinical decline is slowed, and more of the memory is preserved. The drug is yet to fully clear clinical trials but plans to be launched in the US by 2020, with sights set on Europe as well.

Preventative Measures:

The prevention front of dementia is experiencing much more success – up to a third of risk factors are within our control. Diet plays a key role in delaying neurodegenerative diseases, and the Mediterranean-DASH Intervention for Neurodegenerative Delay Diet (also known as the MIND diet[5]) has been proven to be especially successful in this aspect, recommending green leafy vegetables, fruit, fish, beans, nuts, and minimising the intake of red meat, butter, fast food and sweets.

Omega fatty acids, primarily found in fish oil, such as DHA, (which leads to an increase in the LR11 protein) are significant in reducing the risk of dementia, as LR11 reduces the production of toxic amyloid, preventing the formation of plaques. DHA also minimises the number of active tau kinases, reducing tau build up and the formation of neurofibrillary tangles.

Vitamins and supplements have also been studied - we certainly need the essential B12, folic acid, E or D in preventing dementia, but other dietary additives are still being researched; a study in the Journal of the American Medical Association had warned us that many dietary supplements claiming to treat cognitive decline are not well supported by credible evidence.

Regular exercise, sleeping well, not smoking or drinking alcohol has also been proven to reduce the risk of vascular dementia. Keeping the brain active and well can prevent other forms of dementia – staying social, minimising depression and trying new activities are just a few examples of how this can be done.

Ultimately, these are physical diseases, terminal illnesses, which shorten our life, yet there is a lack of seriousness within the public. 49% of adults do not recognise that dementia leads to death, although it is the UK's current leading cause of death. However, all hope is not lost simply with the diagnosis - the patient can still live a perfectly content life, albeit later under constant care, such as with the SPECAL[9] method, which families and care homes can adopt, maximising communication with the patient, which leads to happier and longer lives, despite their illness.

Edited by Utkarsh Sinha

Notes:

1- according to https://www.medicalnewstoday.com/articles/142214.php

2 - Amyloid refers to small protein fragments. Beta amyloid is a fragment from an amyloid precursor protein (an integral membrane protein found concentrated at synapses of neurones).

3 - Microtubules are structures within neurones that transport mitochondria, vesicles and organelles.

4 - Abnormal tau proteins, that have an added phosphate group, normally stabilise these microtubules to form a cytoskeleton within neurones.

5 - Zoom in to see the diagram clearer

6 - This is a huge quantity of brain tissue; if someone had 75% of their leg, one might treat them better or help them out. However, this physical effect of dementia cannot be seen.

7 - $C_{6472}H_{10028}N_{1740}O_{2014}S_{46}$ is the formula if interested

8 - Contended Dementia - *Oliver James;* available in the school library. Alternatively, visit http://www.contenteddementiatrust.org/what-is-the-specal-method/

Oral Health: More Than Just Your Teeth

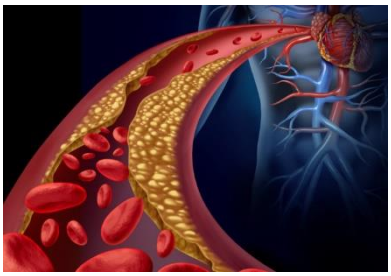
by Mohamed Ahmed (Y11)

You should probably take care of your teeth. I have heard that brushing tends to be a good idea, for a few more reasons than just chasing for those pearly whites, found in every commercial toothpaste known to man.

Your mouth is a web - it connects with different parts of your body in ways that most people do not expect. Because of that, consequences can arise in unforeseen places if you don't take care of your teeth.

When you think of poor oral hygiene, conditions such as dementia, stroke, respiratory infection, arthritis or Alzheimer's disease would not be the first to come to mind. I'm sure you would like to know more now. After all, what teenage boy does not take an active interest in their dental hygiene?

When your teeth are not brushed properly and often, plaque (a pale yellow substance) often builds up on them. This is because carbohydrates, sugars and fluids (such as saliva) encourage the growth of bacteria, which produce acids that damage your enamel (the outer layer of your teeth). As well as this, the bacteria present may infect the gum tissues and cause inflammation (referred to as gingivitis) which can cause many of the diseases and conditions mentioned above.



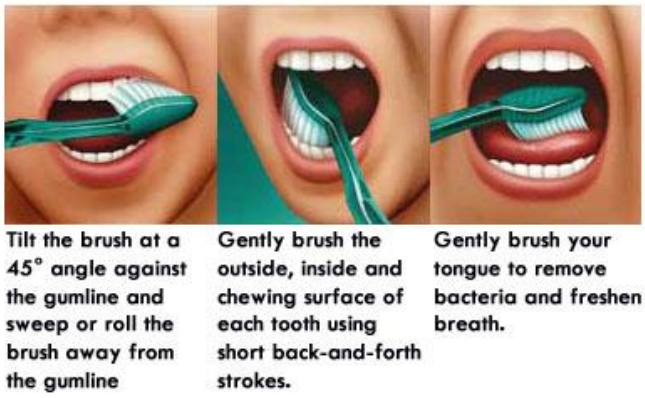
Gingivitis increases the risk of cardiovascular disease to an individual by around 20%, according to the Journal of Indian Society of Periodontology. The inflation of the gums can enable the bacteria to enter the bloodstream directly and may reach the coronary arteries. The consequent accumulation of plaques may lead to atherosclerosis (the hardening of artery walls), resulting in decreased blood flow to the myocardium, which increases the likelihood of heart attacks and strokes.

Furthermore, the bacteria present in the bloodstream may affect neurons in the brain causing dementia or Alzheimer's diseases. The mechanism underpinning this is unknown as of yet, and has only been proven by a study on Chinese Americans who were 60 years old or older (Chinese Americans were chosen due to their particularly low access to preventative oral health care). The study compared the relationship between their oral hygiene and their cognitive ability. It demonstrated that the decline of episodic memory and cognition were strongly correlated to poor dental hygiene, though correlation does not necessarily imply causation.

The bacteria in your mouth are what you take in with every breath and so can be invisible culprits of respiratory diseases such as pneumonia due to the inflammation of the alveoli within your lungs.

In addition, rheumatoid arthritis is caused by the immune system accidentally attacking the cells lining the joints, which are in the synovial membrane. Possible triggers for this immune response are citrullinated proteins. These proteins are found in high levels in saliva as a result of one particular strain of bacteria in the plaque - *Aggregatibacter actinomycetemcomitans*. However, these proteins are not the exclusive hallmark of rheumatoid arthritis, making their importance difficult to judge.

In any case, the message is quite clear: your body would appreciate good oral hygiene. So, perhaps take a bit of time when you next rush out of the house to properly brush your teeth. Brush at least twice a day (although 3 times - once after each meal - is preferable) with a fluoride tooth paste for 2 minutes. Clean no more than one tooth in a stroke (i.e. clean one tooth at a time) and don't wash your mouth out with water, as this dilutes the fluoride and decreases the likelihood that bacteria build up is countered. Instead, remove excess toothpaste from your mouth. It is also useful to clean between your teeth daily, with either interdental brushes or floss.



A useful guide of where to brush by Peach Tree Smiles Clinic

Edited by Neo Tang

Genetic Engineering: Society has a Bright Future

by Neel Patel (Y11)

Genetic engineering is the manipulation of an organism's genetic material to produce desirable characteristics or to eliminate undesirable characteristics.

There is no doubt that this new technology is extremely powerful and has the potential to greatly benefit society. At its current stage, however, there are some precautions that we must look into before using genetic engineering on humans.

In plants, genetic engineering is used heavily for a multitude of reasons, such as increasing the yield of a certain crop or to create resistance to a particular disease. It is also widely implemented in situations concerning bacterial organisms, helping increase outputs of vital hormones, such as insulin, to reduce problems associated with deficiency diseases.

However, after further advancements, some of the focus of this new technology has shifted to human applications—as altering the construction of genomes has the potential to end diseases caused by mutations of the DNA. The technology can be harnessed for genetic therapy, which corrects genetic defects and thereby removes the possibility of a gene weakness being transmitted to descendants.

On the other hand, various modern-day concerns pose a challenge to scientists hopeful to use genetic engineering to tackle genetic impairments. For instance, there are ethical constraints from certain groups; as well as harmful side-effects on humans in some cases; and modifying other organisms for human benefit can cause ecological imbalances if they escape into the wild. I am going to be discussing the possible benefits and drawbacks caused by each of these factors in turn and what effect they could have on the future of genetically engineering human beings.

Firstly, genetic engineering can greatly benefit mankind through its ability to help fight diseases such as cystic fibrosis[1] and diabetes. Diabetes mellitus is a disease caused by the deficiency of insulin or resistance to insulin (see James' article). This can lead to hyperglycaemia[2] which in turn can also have several negative repercussions.

The human gene for insulin production can be inserted into a plasmid of a bacterium using restriction enzymes. This is done on an industrial scale: the bacteria are fermented to produce huge volumes of insulin, which can then be used to treat diabetic patients.

Genetic engineering has already proved to be successful at tackling type 2 diabetes in mice, where researchers introduced a gene via a virus. The use of a therapeutic vector in mouse models without causing any long-term side effects. Perhaps, genetic engineering is the long-awaited solution to many diseases, including deficiency diseases, improving the quality of

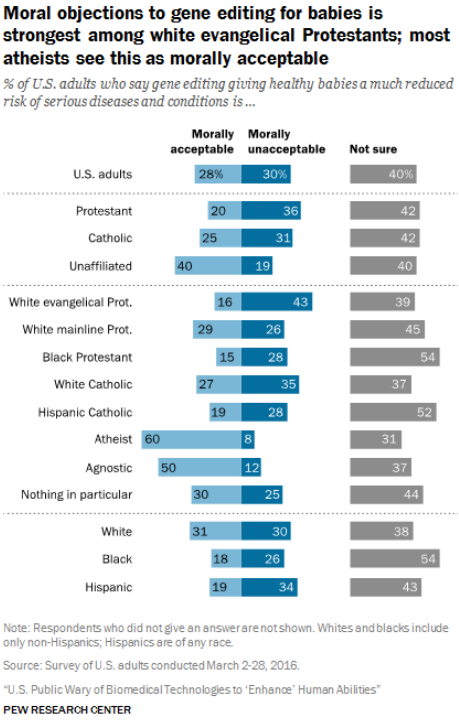
life for more than 2 billion people around the world who suffer from micronutrient deficiencies.

Likewise, we can eliminate the possibility of genetic limitations being passed on to offspring. This can be achieved through gene therapy. It can replace a dysfunctional gene that could cause a disease with a healthy, working copy of the gene. Gene therapy is also able to cease the activity of a mutated gene that is functioning improperly. We can also use gene therapy to insert a new gene into the body to combat a disease.

Despite these positive impacts, the possibility of human cloning is disliked by many due to its unethical nature.

In sport, trainers and athletes could ultimately abuse the technology to gain an unfair advantage if its prominence increases. In 1999, the International Olympic Committee created the World Anti-Doping Agency which forbids the use of drugs which enhance the performance of athletes. Perhaps this will one day be extended to genetic modification too? The possibility for human gene editing raises a lot of questions about what is "fair" in sports.

Moreover, religious groups such as the Roman Catholic Church oppose the use of genetic engineering on ecclesiastical grounds as they believe the destruction of embryos transgresses the sanctity of life[4]. The Roman Catholic Church teaches that "to legalise the use of the most vulnerable human being to cure is unworthy of man. To conceive a child to use him—even if it is to cure—is not respectful of his dignity." (Archbishop Pierre d'Ornellas of Rennes)



Genetic engineering uses a viral vector to carry the targeted gene into the human body. This could have several, undiscovered effects. It could even be the case that the targeted gene replaces an important gene rather than a dysfunctional gene, which can cause problems.

The benefits of genetic engineering on humans are limited by the reduction of genetic diversity, which is a consequence of human beings have similar or even identical genomes, and the therefore increased susceptibility to a communicable disease. If the technology is used too frequently, we could lose variation in the human population.

Genetic engineering has the capacity to better society, but only if we use it correctly. Not only can it be used to resolve genetic impairments and deficiency diseases, but it can improve the quality of life for many people globally. However, moral and religious issues mean that many people are unwilling to embrace this new technology and, as a result, (although the potential for this technology is huge) the impact may not be widespread.

Edited by Michael Lowe

Keywords:

Cystic Fibrosis [1] : A genetic disorder that affects mostly the lungs but also the pancreas, liver, kidneys, and intestine

Hyperglycemia [2] : A characteristic of diabetes where the blood glucose level is elevated due to the improper use or production of the hormone insulin.

Adenoviral Vectors [3] : These are the most commonly used vectors for gene therapy. They are nonenveloped, double-stranded DNA viral vectors

Sanctity of Life [4] : The Christian principle that every living organism should be treated with dignity and respect and should never be harmed

Trophic Cascade [5] : When a change at the top of a food chain restructures the whole ecosystem

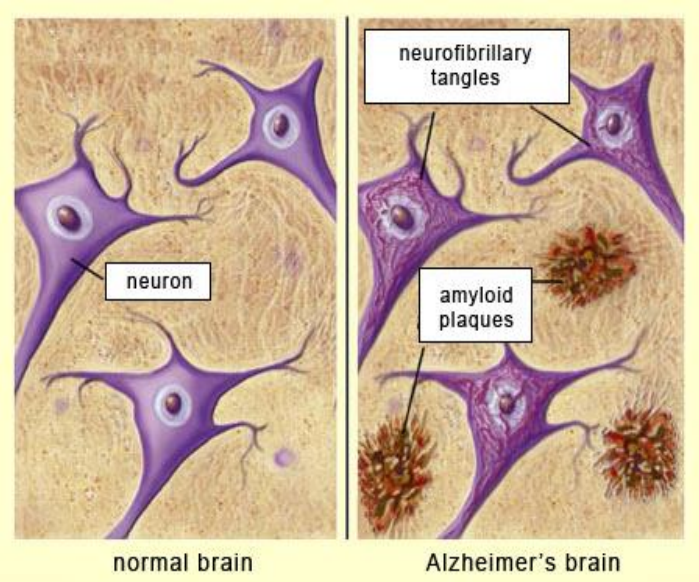
Alzheimer's Disease - What do I remember?

by Shivank Khare (Y12)

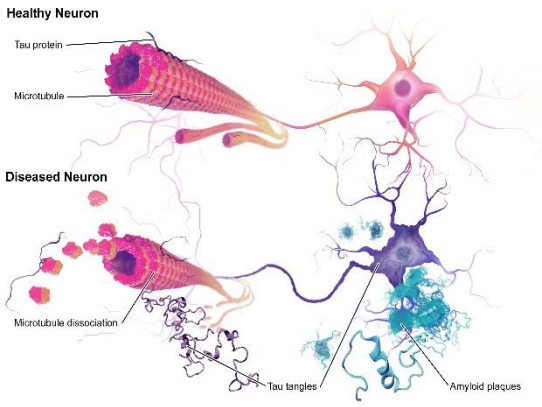
Alzheimer's disease is the main reason for the everlasting neurological disorder of Dementia. The condition progresses slowly over several years and the cause of Alzheimer's is still conclusively unknown. It is a **neurodegenerative**[1] disease supposedly caused by the build-up of **amyloid plaques**[2]**.**

How does Alzheimer's disease occur?

In our brain, we have millions of neurones that transmit impulses or information to many kinds of other cells. Between two neurones there is a synapse, where neurotransmitters are released from one neurone to another, allowing communication between the neurones. Alongside these chemical neurotransmitters, a peptide known as **amyloid beta**[3] is also released from the neurone - one of the believed causes of Alzheimer's. Usually, amyloid beta is cleared away from the synapses by the brain's "macrophage cells", called microglia - the brain's main immune defence against amyloid beta.



Over time, amyloid beta builds up, as it is released more quickly than it is cleared away by microglia. This can happen over a period of several years. Amyloid beta is quite sticky, in the sense that once enough has accumulated, it binds to itself to form amyloid plaques. After this build-up, microfibril can become activated and release chemicals that cause inflammation and further damage to the synapse. It is also thought that the synapses might be engulfed by the microglia. Eventually, a point is reached (usually around 65 years of age) where symptoms of memory loss begin to show such as asking oneself "Where did I keep my phone?", or possibly even the most basic things, such as "Did I brush my teeth?"



Another supposed source of Alzheimer's disease is from inside the neurone itself. A neurone is held together by its **cytoskeleton**[4] (partly made from microtubules). A special protein called tau stabilises these microtubules and allows impulses to be carried across. However, an enzyme called tau – protein kinase can cause the tau to become **hyperphosphorylated**[5]**.** This leads to the removal of **tau proteins**[6] from the microtubules, twisting themselves into "tangles", leading to restriction within the neurone. The restriction of impulses being sent due to this causes **apoptosis**[7] (cell death).

No matter the source, Alzheimer's disease leads to degradation in hearing and memory, worsening as time passes.

How can Alzheimer's be prevented?

Alzheimer's disease, as of now, has no cure. However, research into finding preventative medicines has been carried out - preventing the build-up of amyloid plaque in the first place, thus preventing Alzheimer's from occurring.

A drug called Aricept (donepezil) causes the balance of **acetylcholine**[8] which is a vital chemical for memory. However, there are many other drugs that do the same and yet no proven cure.

What are the risk factors?

- Age - People who are older tend to have more amyloid beta between the synapses, therefore leading to a greater chance of contracting Alzheimer's disease.
- DNA - There could be a rare genetic mutation in DNA which causes greater secretion of amyloid beta, leading to a higher chance of contracting Alzheimer's disease.
- Sleep - Research has shown that more sleep increases the chance of plaque in the synapse being removed.
- Cardiovascular disease - People with cardiovascular disease are more likely to contract Alzheimer's disease.

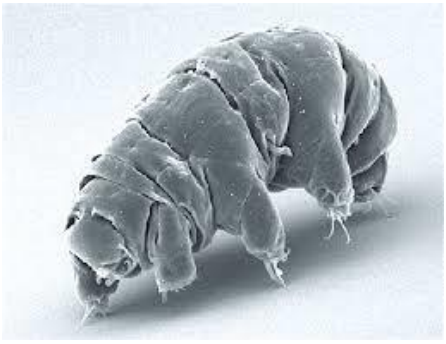
Edited by Neo Tang

Key Words:

1. Neurodegenerative – The neurones within the brain degrading or degenerating.
2. Amyloid plaques – The build-up of amyloid beta.
3. Amyloid beta – A peptide that is the main component in Alzheimer's disease.
4. Cytoskeleton – Gives the shape of the cell by protein filaments and tubules.
5. Hyperphosphorylated – The complete addition of phosphate to an organic compound. There are no more phosphorylation sites to react with phosphates.
6. Tau proteins – Proteins that stabilise microtubules.
7. Apoptosis – The death of cells as part of an organism's natural growth.
8. Acetylcholine – A neurotransmitter that carries signals.

Tardigrades – An Insider's Perspective by William Lu (Y11)

Tardigrades: Internet Phenomenon:

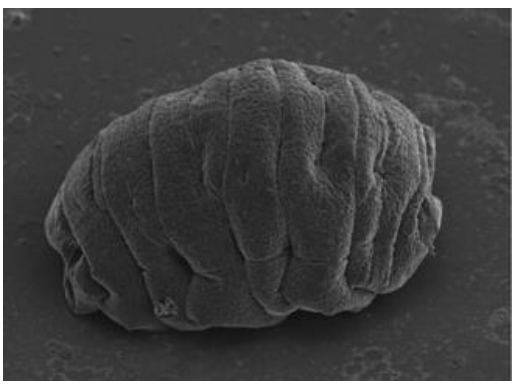


General Facts	
Size	0.05-1.2mm
Classification	phylum Tardigrada
Kingdom	Eukaryota
Domain	Animalia
Lifespan	3-4 months (2 years in some species) (Excluding dormant states)
Etymology	Tardigrada means 'slow stepper'

Tardigrades- commonly known as water bears or moss piglets- are microscopic, cute and one of nature's most bizarre organisms. They are renowned for their impressive arsenal of resistance capabilities and ability to undergo [2]**cryptobiosis.** It was even once a model organism for biological study prior to the round worm. These translucent piglets dwell in a range of snug habitats from moss, lichen to even freshwater or saltwater lakes, so moist environments in general hence the name 'water bears'.

Water bears are so firmly grounded in pop culture that they have even found their way into the Marvel Cinematic Universe. They appear in the twentieth instalment of the franchise, as Hank Pym traverses through the quantum realm. Although, this isn't biologically accurate as water bears can even sometimes be seen with the naked eye, albeit with the right lighting conditions. Thus, it is somewhat fantastical that they can dwell in a sub-atomic plane. Yet this is a universe with talking racoons, time travel and mind controlling sceptres so perhaps it is slightly unfair to question the scientific legitimacy of a superhero film.

Are Tardigrades extremophiles?



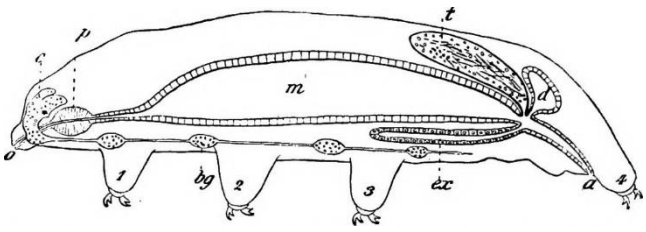
It is in fact a misconception that water bears are [3]**extremophiles**. Although they can withstand extreme conditions such as 0.5 Kelvin (by shrivelling up into a small shell known as a **tun** in which they lose 97% of their water and therefore are reduced to 1/3 of their already minute size during a form of cryptobiosis) So water bears must constantly have a layer of water around them to prevent turning into a tun and even in the vacuum of space, they are by no means adapted to live in such environments.

When water bears were launched into space by Kazakhstan in 2007[4] it was found that, although they didn't instantly decease when exposed to the lack of oxygen. After 10 days of exposure to space the scientists found that those that weren't protected from solar radiation actually perished. Yet scientists have found that tardigrades are in fact indomitable when it comes to extinction events, which would easily spell Armageddon for humans: meteor showers, gamma ray bursts and even a stray supernova blast! Furthermore, in 2011 tardigrades were placed aboard the US shuttle Endeavor as part of Project Biokis. Colonies were exposed to varying levels of ionizing radiation and their survival implies that moss piglets have the ability to effectively repair their DNA. Yet do not be fooled into thinking that they are invincible. Millions are slaughtered each day by a range of species such as insects, spiders, scorpions, mites, crabs, shrimps, worms, snails, slugs and even other water bears yes, some of the 1,000 species of tardigrades are cannibalistic!

Additionally, water bears have another state, asides from being active or slowing down their metabolic rates through cryptobiosis. In a situation where oxygen is in short supply, they undergo [4]**anoxybiosis** where their [5]**osmoregulation** fails, which causes the tardigrade to become turgid and swell up like a balloon. They are also known to be able to sustain another tun state called [6]**anhydrobiosis**, where the tardigrade is brought into suspended animation several times a year to bring about metabolic suspension. When rehydrated by dew or rain, the tardigrade can return to being active within mere minutes, but it can range up to a few hours.

The anatomy of Tardigrades:

Tardigrades have a relatively simple [7]**physiology**, which all have 4 pairs of legs. Six are situated at the sides of its body and the final pair is attached to the back of its body, which are used to help it slowly circumnavigate its surroundings by grabbing onto debris with its little claws and 'swimming' through its habitat.



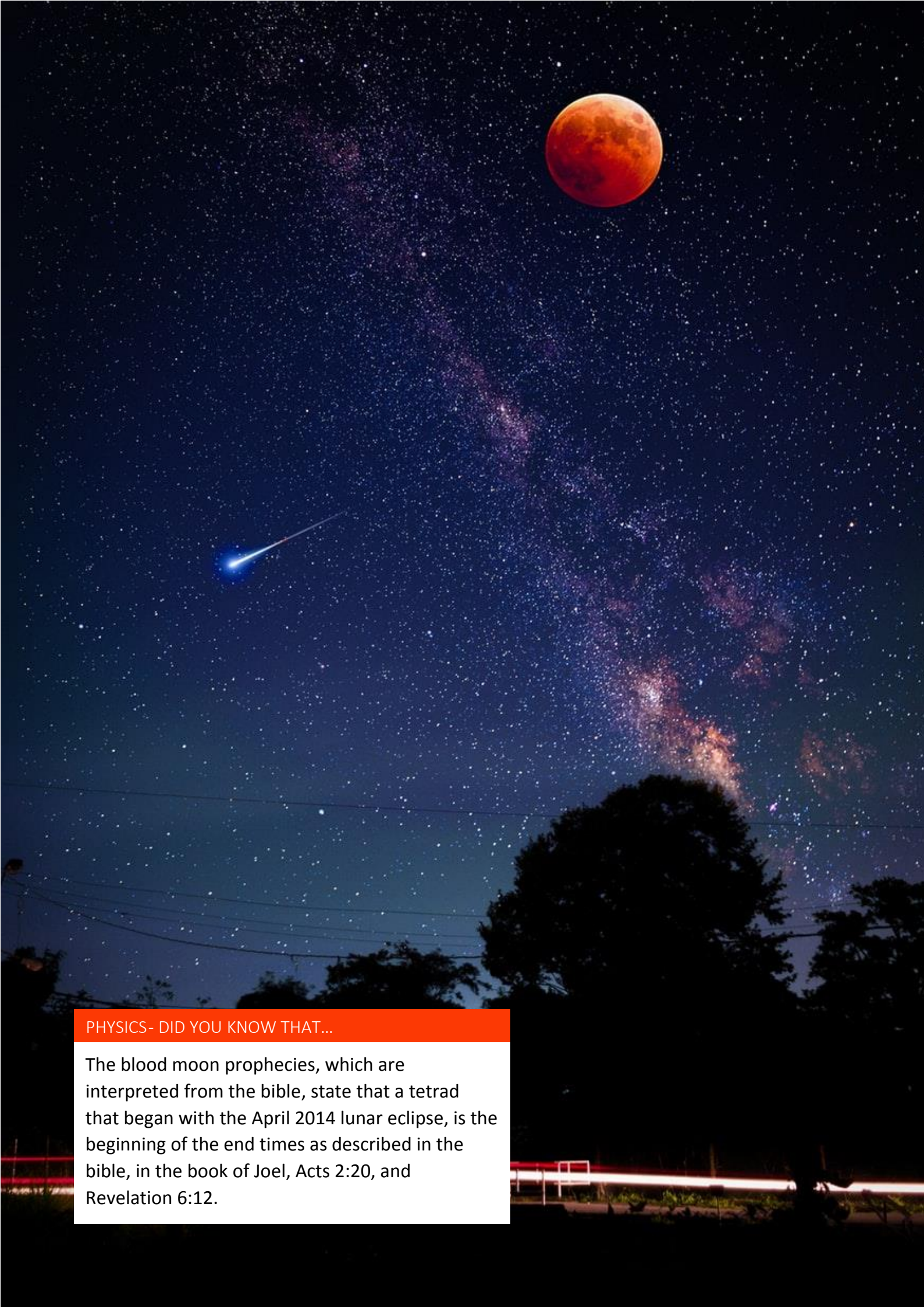
Water bears' lack of respiratory and circulatory systems are made up by having an open body cavity, which reaches each and every one of its cells, for efficient gas exchange and nutrition through a liquid known as [8]**haemolymph**. However, they do have nervous systems, which consist of a dorsal brain and a paired [9]**ventral nervous system**. Tardigrades have a fully-fledged digestive system which is rather impressive for such a diminutive organism. It has a [10]**stylet** for a mouth, which sharp telescope like mouth that has teeth to penetrate plant and body tissue, as tardigrades feed on juices from lichens algae and moss, hence their habitats.

Interestingly as well as having the typical reproductive glands such as the ovaries and testes, some species of Water bear are hermaphrodites, so have ovotestes, making them male and female at the same time![5]

Edited by Utkarsh Sinha

Key Terms:

[1]**Ethymology:** The study of the origin of words and the way in which their meanings have changed throughout history
[2]**Cryptobiosis:** A physiological state in which metabolic activity is reduced to an undetectable level without disappearing altogether
[3]**Extremophiles:** An organism that thrives in extreme environments
[4]**Tun:** A large marine mollusc which has a rounded shell with broad spirals
[5]**Anoxybiosis:** A biological response triggered by a lack of oxygen in which the organism takes in water and becomes turgid and immobile
[6]**Osmoregulation:** The maintenance of constant osmotic pressure in the fluids of an organism by the control of water and salt concentrations.
[7]**Anhydrobiosis:** A dormant state induced by drought in which an organism becomes almost completely dehydrated and reduces its metabolic activity to an imperceptible level
[8]**8Physiology:** The branch of biology that deals with the normal functions of living organisms and their parts.
[9]**Haemolymph:** The alternative to blood commonly found in insects
[10]**Ventral nervous system:** A part of the central nervous system found in invertebrates
[11]**Stylet:** A sharp mouth structure that pierces plant and body tissue so the contents can be sucked out



PHYSICS- DID YOU KNOW THAT…

The blood moon prophecies, which are interpreted from the bible, state that a tetrad that began with the April 2014 lunar eclipse, is the beginning of the end times as described in the bible, in the book of Joel, Acts 2:20, and Revelation 6:12.

How to Break Space-Time (Wormholes)

by Aditya Vishwanathan (Y12)

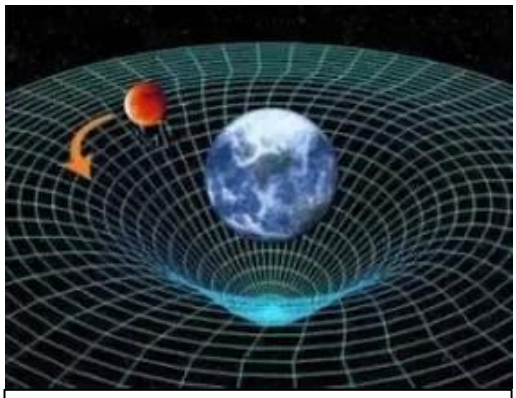
What are Wormholes?

Wormholes are complex physical phenomena which could exist theoretically but have never been observed. They were first theorised as a result of Einstein's theory of general relativity, and many top physicists have come up with ideas about wormholes but they remain a mystery to this day.

Wormholes are theoretical "short cut" connections between two points in space-time that are an immense distance apart. For now, they are only possible mathematically using Einstein's theory of general relativity. There are a few different types and they go by various names. In this article, you will find out more about one kind - Einstein-Rosen Bridge Wormholes.

General Relativity:

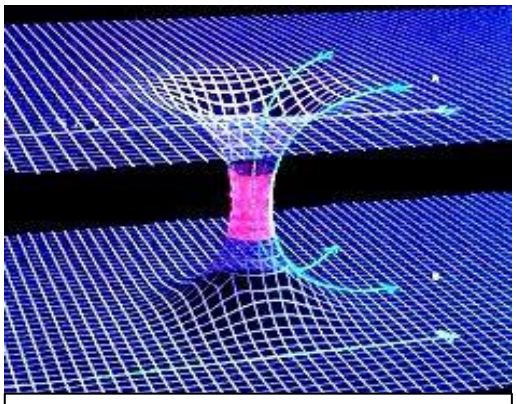
Einstein's famous theory of special and general relativity help to explain physical phenomena and the phenomenon of gravity. General relativity explains why we perceive a gravitational "force". The theory says that objects with mass warp space-time around them. Space-time is the four dimensions around you that you experience and are part of - the three planes of space (x, y and z axes) and time. Objects with mass warp space-time which causes gravity towards their centre. The greater the mass, the more space-time is warped.



The planet warps space time. As a result, the smaller object falls into a curved path around it - if it is not going fast enough it cannot overcome the gravity of the large planet and it will fall into an orbit

General Relativity and Wormholes

One way wormholes can exist is if the universe can be modelled accurately as flat with objects such as planets and stars scattered around - think of sheets of foam on top of each other with celestial bodies between the sheets. If two objects were on top of each other, had enough mass and were close enough to each other, it is possible that in warping space-time (deforming the foam sheets), the two sections of space-time (the deformed foam) meet. This would create a "tunnel" and theoretically enable passage between them. Since you are warping space-time, it is possible to therefore not only travel through space, but also, through time.



How Einstein-Rosen Bridge Wormholes might be visualised

The Austrian physicist Ludwig Flamm introduced the concept of a White Hole - the opposite of a Black Hole. A Black Hole does not let anything out once it has entered whereas a White Hole does not let anything get in - instead it spews out objects which are then free to interact with the universe. Einstein and Nathan Rosen developed this theory into the Einstein-Rosen Bridges. Einstein-Rosen Bridges are what most people mean by “wormhole” as a means of travelling vast distances quickly. They can achieve this, but even more phenomenal, they could achieve time travel. This is very theoretical and relies on many assumptions but it is possible - here is how. At very high speeds (upwards of 95% of the speed of light) time dilation occurs. This means time moves slower for you than for an observer - for every second that passes for you travelling close to the speed of light, more than a second passes for an observer. Imagine a wormhole with two ends, one end is at rest and the other is at a very high speed. The wormhole is traversable in both directions. If the “fast end” were to move for a few days for example, time dilation would make it appear as if that end had travelled a few days but the other end would have experienced weeks, months or years in the same period. Thus, from the fast end it would be possible to see or travel into the future relative to the observer at the fast end; someone at the stationary end would see the past relative to them.

Can they work?

Einstein-Rosen Bridges are very unstable - they do not stay open for even the time it takes a ray of light to travel through it. The only way to keep them stable for humans to travel through is by using exotic matter. The other issue is the way the bridge is built in the first place - humans can’t possibly survive the conditions in the black hole. Black holes have immense gravity that is so strong not even light can escape a black hole. Let’s say a human travels into a black hole head first. As they cross the event horizon, their head experiences stronger gravity and will be pulled towards the black hole faster than the person’s feet. As the head accelerates faster than the feet it will be stretched and eventually break off since humans are not very stretchable. The human, now in two parts will still be pulled by the black holes gravity, each part being stretched and stretched (and broken into more pieces) as it gets further into the black hole. The stretching is called “spaghettification” since your body will be stretched just like spaghetti due to the magnitude of the black hole’s gravity. As a result, humans would have no chance of surviving the journey making Einstein-Rosen Bridges useless for travel.

Exotic Matter:

Exotic Matter is, for now, only theoretical. Exotic Matter is particles that behave in highly unconventional and pretty strange ways. One example is a tachyon - a particle that only travels faster than the speed of light. For wormholes however, exotic matter with negative mass (not to be confused with dark energy or antimatter) could be used to counter the collapse of a black hole, keeping the “tunnel” open and enabling travel through the wormhole.

These particles with negative mass do exist and have been created here on Earth. However, wormholes would likely need huge amounts of exotic matter since they are already fragile so it is still unlikely humans will anytime soon travel intergalactic distances anywhere except in science fiction

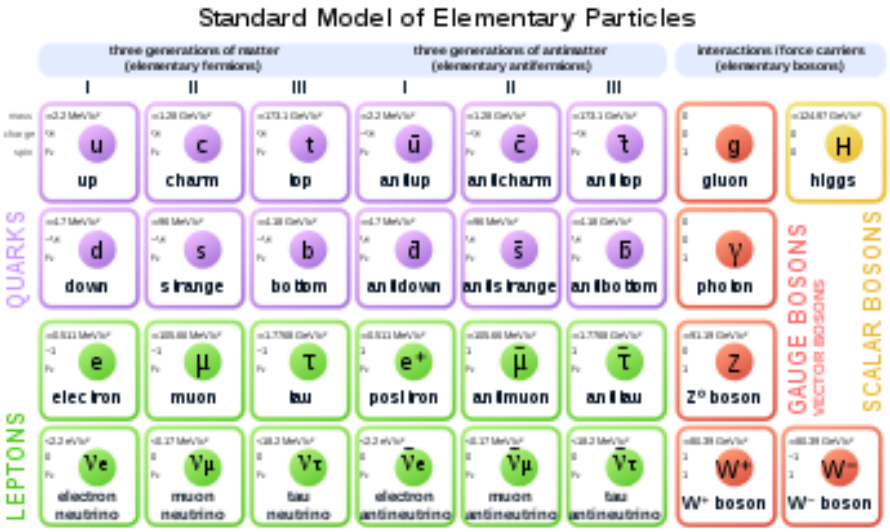
Edited by Neo Tang

The Tragedy of String Theory and Particle Physics

by Boyu Xiang (Y11)

String theory has become a rather famous scientific term used in pop culture; in films, books, TV shows, string theory has been (from my findings at least) represented as an esoteric scientific theory that no one understands. Consequentially, its use (or often misuse) as a plot device has become almost as pervasive as quantum theory, spearheading plot convenient discoveries. Whilst this can infuriate the scientifically inclined with this egregious misrepresentation, most can still reluctantly agree that no-one know with absolute certainty the viability and future of string theory as a tool to explain the universe. This article's role would be to hopefully inform those who read it of the truth behind this scientific idea so that you can have more respect for the brilliant minds behind it, or perhaps it could even inspire you to research it further yourself in the future.

String theory is the attempt to represent (or replace depending on the source) all matter and forces in the universe as/with tiny vibrating one dimensional strings. In layman's terms (as if the previous statement was not a gross oversimplification already), everything in the universe, be it forces, mass, matter, can be seen as the interactions of small string-like items. To understand this, we need to learn of its precursor, particle physics.



At GCSE level, we are told of atoms that make up all objects in the universe. Dark matter and other problems aside, we further learn that these atoms are composed of more miniscule items, electrons, protons, neutrons. However, beyond even these sub atomic particles, other smaller particles can be found in high speed collisions between atoms in places like the CERN research centre. This is in the realm of particle physics, representing these smallest particles as points ("point-like" to be pedantic), such as those on a graph. The standard model of particle physics (the most widely accepted model that explains the most) can explain three of the four fundamental forces (strong nuclear, weak nuclear, electromagnetic, gravity – *note that gravity is widely not considered a force anymore but is included here for a reason*) by representing them as particles, and even predicted a new type of boson particle as well as its properties: the Higgs boson. These successes lead it to

be a contender for the “Theory of everything” – a mathematical model that can explain and predict everything in the universe.

Unfortunately, with these successes comes a few setbacks, the aforementioned gravity, could not be explained by particle physics, being one of its most renown failures, the mass of a neutrino was also a mystery as it was predicted to be massless [(1)] in the standard model alongside the photon where experiments in hadron colliders. On the topic of gravity, graviton collisions [(2)] were predicted to yield infinite energy by the standard model, breaking down the mathematics. The strength of a theory is dependant on how well mathematical models according to the theory match experimental data, and with these deviations, the standard model is not the perfect solution to the theory of everything that scientists had hoped.

Returning to the definition of string theory, the major difference between particle physics and string theory is that rather than point-like particles, string theory represents everything as one-dimensional strings so small that they can be mistaken for points. Whilst this distinction seems abstruse, there are many differences in the two theories. In particle physics, the subatomic particles themselves have a set mass, a spin (which can determine magnetic charge among other things) as well as many other qualities that are unique to the type of particle that is being described. Conversely, in string theory, we had one-dimensional strings whose mass as well as other properties are defined by the vibrations and coalescence of the strings themselves as opposed to an inherent quality – *note that this is not ubiquitous for all variations of string theory where sometimes the vibrations are caused by the mass rather than the other way around.* As a result of this distinction, problems like graviton collisions become not an issue as the coiled string would rebound cleanly in an elastic collision.

This theory is most commonly applied to the aspects that particle physics finds hard to explain, such as in gravity. This is a subsection of the anti-de Sitter/conformal field theory (AdS/CFT correspondence), which integrated string theory into quantum gravity theory – an attempt to model gravity using the principles of quantum physics. An extension of string theory in this particular field is M-theory, a key difference is that standard string theory requires 10 dimensions to be congruent with other aspects, whilst M-theory requires 11. A theory, however, is less impressive without real-world applications, and an example of what the AdS/CFT correspondence has achieve would be partially solving the black hole information paradox [(4)]. If gravity were to be successfully explained in a manner that is congruent with the standard model, then we would have the theory of everything.

With a theory with such large prospects, there are quite a few criticisms – one of them would be the large dimension requirement. As alluded to earlier, String theory requires many dimensions for it to be mathematically viable; an estimated 10^{500} are needed to accommodate for macro measurements and results (low energy observations) as a result, many hypothesises are impossible to test, hence it being classed as a “pure mathematical theory”.

Some string theorist such as Leonard Susskind have argued that the dimensions may represent other universes within a larger multiverse, however other prominent theorists have argued otherwise. Woit argued that this is merely an excuse for being unable to predict anything with string theory [5].

If we were to discard all the technical and scientific aspects of string theory, it is a theory that tries to solve old (by modern standards) problems with newer method when older explanations fail to hold up to experimentation. Promising big and have outlandish methods have cast it into the spotlight, however a relative lack of progress has seen many scientists uncertain about their line of research. It could be the breakthrough needed to finally have the Theory of everything, or it could be a dead end amongst a graveyard of dead ends.

Edited by Utkarsh Sinha

Disclaimer: this article does not attempt to go too deep into every minutia of string theory, but merely wishes to explain the basics, the "facts" stated may not be absolute as it is still a newly emerging and vivacious field of study. This article does also neglect to go into much detail regarding some points of contention for risk of spreading misinformation. Please conduct further research if you have any questions or are intrigued by it.

Notes:

(1) https://t2k-experiment.org/neutrinos/in-the-standard-model/

(2) Gravitons are particles simulated by particle physics as to measure gravity it in any other way would require the measurement of distances, which is improbable according to the Heisenberg Uncertainty principle as the more we know about a particle's speed, the more imprecise our knowledge of its position https://www.space.com/17594-string-theory.html

(3) The discovery of Hawking radiation implied that information was destroyed

(4) "Speculative scientific ideas fail not just when they make incorrect predictions, but also when they turn out to be vacuous and incapable of predicting anything"

Chaos Theory by Leo Kavanagh (Y10)

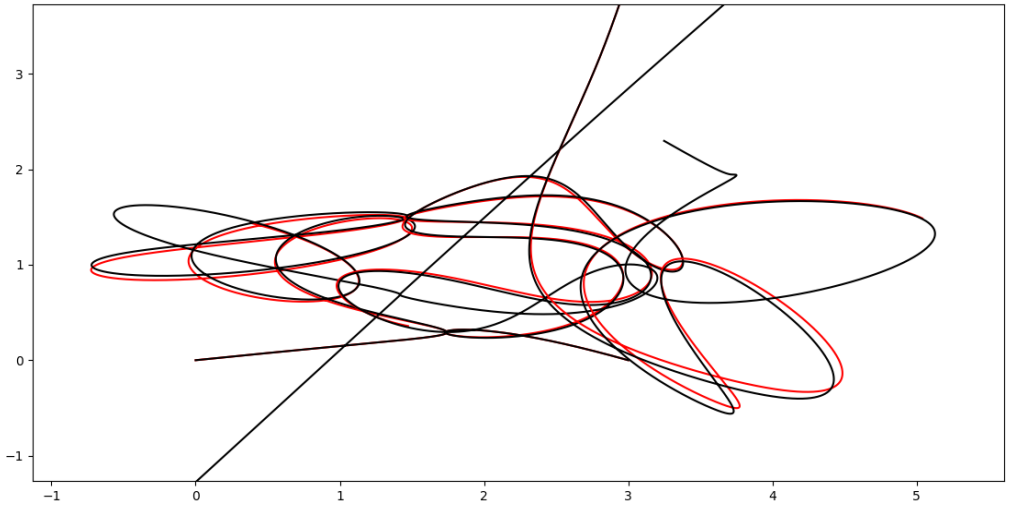
Every day, the Earth makes a full turn, spinning at nearly 1,000 Miles per hour. Every month, the moon goes around the Earth, travelling a distance of 1,423,000 miles. Every year, the Earth completes a full journey around the sun, hurtling through space at 30 kilometres per second. The motions of our home planet and the millions like it in the galaxy are governed by a deceptively simple set of rules of gravitation, describing the motion of three objects in space. Despite centuries of intensive research, the three body problem baffles physicists and mathematicians to this day.

Physically, this problem is simple to understand, there is nothing more to it than the simple forces of gravity that govern our lives on earth and that were discovered by Newton in the seventeenth century; objects that have mass attract each other, with a strength inversely proportional to the distance between the squared. First of all, imagine two objects (e.g. planets or asteroids) hanging in space, with no external forces acting upon them. With not much thought it is possible to predict that they will approach each other, accelerating until they collide and stay together. Now imagine doing this again, but with another, third object nearby. The two objects will be taken slightly of course by the gravitational attraction of the third, miss each other instead of colliding, and hurtle off into space, entering a chaotic orbit, destabilised by the presence of the third object. This is the behaviour that has confused the finest minds of many generations, and is still impossible to compute with perfect accuracy.

To begin to understand it, we first need to have some understanding of chaotic behaviour. Although the word chaos is often associated with randomness, the general definition has nothing to do with it. Instead, how chaotic a system is a measure of how sensitive it is to its initial conditions. This means that a tiny change to the way that the system starts out can have a huge impact later on.

An example of this might be someone running late for a flight abroad: as they are running to the catch the train to the airport, they stumble, slowing them down by a couple of seconds. This means that they just miss their train and have to wait 20 minutes for the next train, which arrives too late for their flight, causing them to have to wait a day for the next flight: ultimately, a tiny difference of a couple of seconds became amplified and led to a delay of 24 hours. This kind of behaviour can be observed everywhere in nature-its even behind the inaccuracy of longer term weather forecasts, where tiny inaccuracies in the data collected leads to huge inaccuracies in weather forecasts due to how chaotic and turbulent earth's atmosphere is.

So, now that we have an understanding of chaos, let's see how it affects our scenario with three objects. To do this we need a way of predicting how these three objects are going to move, to which end we can write a relatively simple computer simulation - all it needs to do is find the acceleration of the objects by using the inverse square gravity law, before adding this to their velocities and in turn adding the velocity to their positions to find how they move. Let's start out our simulation by placing all three objects on the vertices of a right angles triangle of side lengths (3,4,5 - there's no specific reason for this, the starting points are arbitrary). To measure how sensitive our system is to initial conditions, we're going to change the strength of gravity in each of our simulations, meaning that the force between the objects will also be changed, affecting their motion.



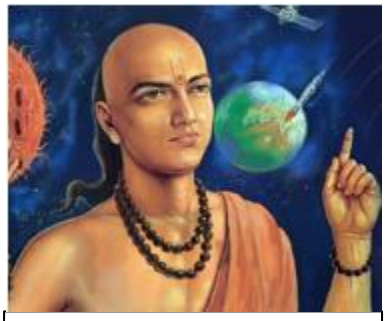
Here we see the paths of the three objects, under two different initial conditions, with the red path having higher gravity. It can clearly be seen that the small change in gravity affected the path of the objects, even during the very short 12 second simulation period. This shows that the system is sensitive to initial conditions, as we see a tiny change blowing up, which also means that we can definitively call the three body problem chaotic. This tells us why the three body problem the problem of finding how our three objects behave) is such a difficult one – its behaviour is enormously complex and sensitive, just like that of our own solar system – surely it is fascinating to think that had a tiny difference early on – maybe a stray asteroid passing through our solar system – could have rendered the solar system unrecognisable, and more importantly, impossible for humans to evolve in.

Edited by Utkarsh SInha

Why do we Havity Gravity? by Neo Tang (Y12)

Gravity – we all know and love it! It keeps us from slowly floating away from Earth to our inevitable doom, it ensures that the Earth orbits the Sun (enabling us to avoid freezing to death), and, perhaps most importantly, it literally facilitated the creation of the universe when gas and dust combined to form stars and planets all those billions of years ago. Without gravity, we simply could not exist. We experience the effects of gravity all the time, and so it only stands to reason that there have been many hypotheses as to the effects of gravity over the course of history.

The Investigation of the Effects of Gravity:

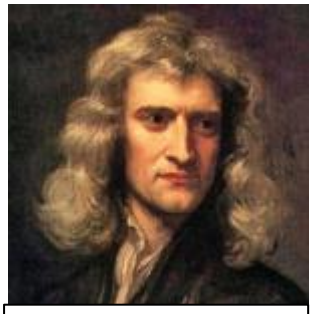


Aryabhata

The earliest of these investigations are thought to have occurred in the 5th and 6th centuries CE, by ancient Indian philosophers Aryabhata and Brahmagupta. The former identified gravity as the force which keeps objects attached to the Earth even as it spins, while the latter simply identified it as an attractive force. Brahmagupta actually referred to gravity as "gurutvākarṣaṇam".

The Leaning Tower of Pisa

Later on, in the 1500s, Italian philosopher Galileo purportedly carried out his famous experiment, in which he dropped balls of differing mass from the Leaning Tower of Pisa. From his results, he concluded that objects fall with the same acceleration, regardless of their mass, and that differences in this acceleration must be due to air resistance.



Issac Newton

More than a century later, the now-famous Isaac Newton analysed the effects of gravity. He is now often accredited by many as "the discoverer of gravity", with an apple-related physics legend to match. While it is perhaps untrue that he "discovered" gravity as much as anybody else, he does seem to be the first to have properly asserted that gravity is a universe-wide phenomenon.

He noted (as per the fruity fable) that there must be a force acting upon objects as they fall, as they accelerate from rest. He also realised that this same force must be keeping the moon in orbit of the Earth, as without a centripetal force (here, gravity) acting on the moon, it would shoot off into space. He did indeed identify this force as gravity, theorising that it exists universally, as well as creating the famous $F = G(\frac{m_1 m_2}{r^2})$ showing that the gravitational force between two bodies is proportional to their masses, and inversely proportional to the square of the distance between them.

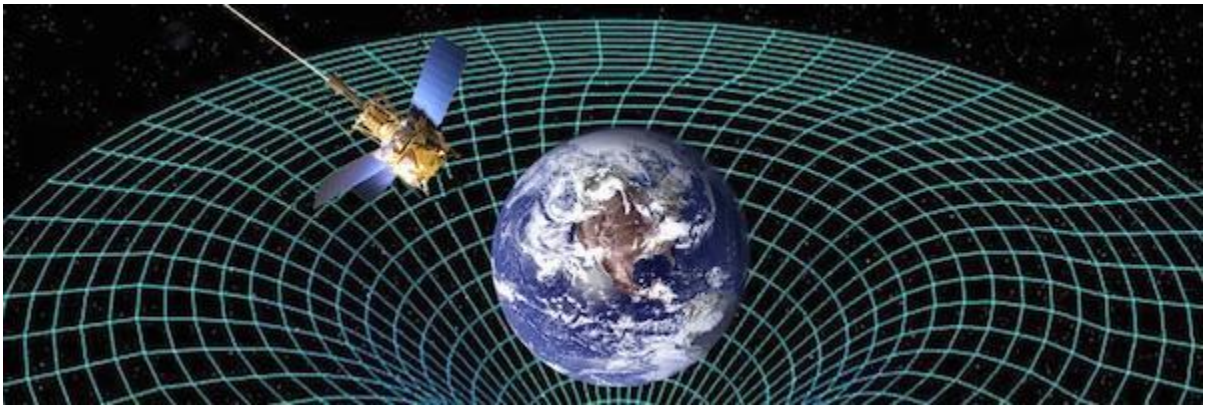
Johann Gottfried Galle

This relationship was eventually proven to be true in 1846, when Johann Gottfried Galle confirmed the existence of Neptune at the Berlin Observatory, utilising Urbain Le Verrier's prediction of Neptune's existence from Newton's formula.

So, it's clear that gravity is definitely real - tried and tested! But all of these investigations were about the *effects* of gravity. Even though Newton himself was a little miffed at his own lack of a hypothesis regarding the nature of gravity, a proper theory was not developed until the 20th century.

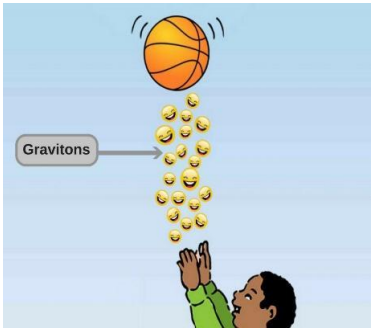
The Exploration of the Nature of Gravity – General Relativity:

Nearly 200 years later, Einstein introduced his theory of General Relativity. This was the first theory to address what gravity *actually* is, not just what its effects are. The main factor of his theory was this: if a person is in a freely falling elevator, then from their frame of reference, there is no force acting upon them. However, this is far from the case. The falling elevator is actually accelerating towards the Earth, with which collision would surely spell death for the unfortunate passenger. If the person is experiencing no resultant force, then they cannot be accelerating - but the fact is, that they are. Therefore, Einstein asserted that gravity must not be acting as a force. He postulated that objects with mass create curves in space-time, and moving along this curvature is what we perceive to be gravity. In modern physics, this is currently the best explanation for gravity. Unfortunately, however, there is a problem with this theory of gravitation when we consider quantum theory.



The Exploration of the Nature of Gravity – Quantum Field Theory and Gravitons:

Quantum physics deals with incredibly small particles - even smaller than subatomic particles such as protons and electrons – called fundamental particles. Unlike in classical physics, the interactions between these particles are caused by other particles, called bosons, being sent between them. There are four of these interactions: the electromagnetic force, the strong and weak nuclear forces, and the gravitation force. If the reception and emission of particles is required for these interactions, then the gravitation force must be facilitated by a kind of particle (clearly disagreeing with Einstein's space-time curvature from general relativity).



So, what particle is this? At the moment, it's a theoretical particle, dubbed the "graviton". Based on the effects of gravity which we can observe, some properties of gravitons can be predicted. For example, we know that gravity is a long range force according to Newton - every mass has a gravitational effect on another mass, no matter how far apart they are.

And so, it can be assumed that the gravitons would have to travel at the speed of light, and therefore would be a massless particle. This property is also apparent in photons - massless particles which are responsible for the electromagnetic force when transferred between fundamental particles.

If graviton transfer speed is at some point observed to be less than the speed of light, however, then it could be shown that gravitons actually do have mass (although unlikely). Unfortunately, gravitons are extremely unlikely to be detected any time soon (if at all). This is due in part to the gravitation interaction being extremely weak (~10^{36}x weaker than the electromagnetic force, for example).

So, why does it matter?

Previously, we had a great theory for gravity, General Relativity! But unfortunately, it does not agree with the new Quantum Field Theory, which can explain the three out of the four interactions - all but the gravitation force. If somehow gravity could be unified with Quantum Field Theory, we might have a "Theory of Everything" - a model which explains all physical aspects of the universe. It would open a new chapter of science for our planet, exploring even further - the efforts to solve this monumental challenge would finally be satisfied, and a thousand more amazing problems would be able to spring from it.

Edited by Devanandh Murugesan

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