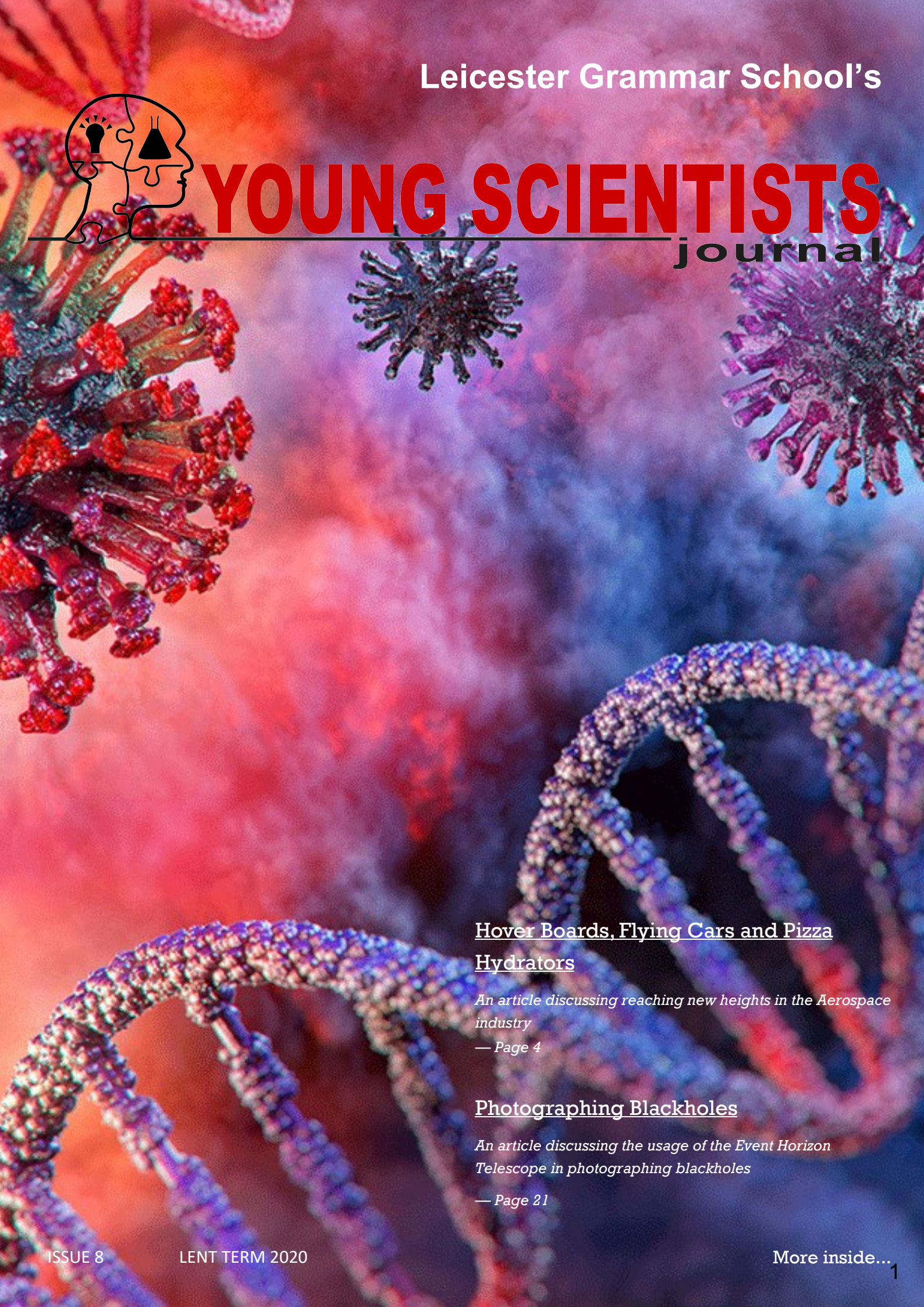
Leicester Grammar School's

YOUNG SCIENTISTS journal



ISSUE 8 LENT TERM 2020

More inside...

A Message from the Team:

“ This edition of the Young Science Journal comes at an opportune and timely moment. There is now a situation of great uncertainty and anxiety. This novel Coronavirus (COVID-19) has a widespread health, societal, and economical impact on the world. So much so, that all schools over the country, including ours, have closed. Now more than ever, the importance of dealing with infections such as COVID-19 by using scientific research and methods has been brought to the fore: governments are using scientific evidence and mathematical modelling to plan out responses, researchers are working hard to create vaccines. This is a race against time – will the scientific community create an effective vaccine before the virus ravages the entire world? Statistics and scientific methods are not only important for managing and treating the illness, but also to dispel the myths and misinformation surrounding this issue.

These times of lockdown are a perfect opportunity to spark curiosity and delve deeper into topics. It is important to inspire the next generations of young scientists to deal with such novel situations in the future. The journal strives to allow students to think laterally and deeply about topics in order to develop potential solutions, provide insight and suggest ideas. We hope our journal can act as a catalyst and a medium to inspire young curious minds and develop a fervor for the sciences.

We are often asked about what to write about – indeed, there is so much breadth in the field of science. The journal is based on the interests of students, so we encourage you to choose topics that you are fascinated by and are passionate about. Weirder topics usually prove most successful! If you would like to get involved either in writing an article or getting involved with the development, please get in touch with us by email.

This edition displays a variety of content from Aerospace to Phage therapy. We hope you enjoy the read.

We would like to acknowledge the following for their contribution:

The LGS Editorial Team:

Tejas Easwar/ Nazir Sirajudeen — Chief Editors

Writers:

Sarah Beadle

Lily Livermore

Karishma Gokani

Ahmed Hassan

Moritz Wagner-Tsukamoto

Oscar Schwabe

Rajan Bahra

Gabriel Samanta

Om Kela

Nazir Sirajudeen

Vlad Turapov

Annabelle Onions

Teachers:

Mr Reeves

Dr Griffin

Articles in this issue:

Who are We?

We are a collection of Leicester Grammar School students who have come together to produce a variety of pieces of writing about the world of STEM. As a school, we have become a hub for the Young Scientists Journal, an international peer-review written and edited entirely by young people.

Contact Us

Anyone interested in joining the YSJ to help to write, edit and publish is more than welcome to meet us at our meetings during lunchtimes (specific details will be in the daily notices). We welcome submissions from all year groups on any scientifically-related topic; so come along to a meeting or email us at:

lgsyoungscientists@gmail.com

See more of the Young Scientists Journal at:

ysjournal.com

Or follow us on social media:

@YSJournal

Young Scientists Journal

@LGS_Senior

Hover Boards, Flying Cars and Pizza Hydrators

Sarah Beadle discusses reaching new heights in the Aerospace Industry

In the 1980s the technology from Back to the Future could only be of fantasies. Unfortunately, Pizza hydrators are yet to reach the consumer market, and skate parks are not yet burdened by hovering youths. However, the technology that the aerospace industry has created would have impressed a time travelling Marty McFly.

Jet Suit Travel?

Does human flight have the same potential as conveyed in science fiction film and TV? Richard Browning the 'Real life ironman' and founder of Gravity Industries overtook his previous speed record in a jet suit of 32.02 mph in 2019, reaching 85.06 mph (Suggit, 2019). The suit is constructed with several miniature jet engines (Industries, 2020), and it is also a serious rival for Edward Scissorhands!

Flying Cars?

It is unlikely we will see jet suits become a common mode of transport, however flying cars may become more prominent. This image is the Aeromobil 5.0 VTOL, a 4 seat taxi aircraft/ car hybrid (Aeromobil, 2020). Aeromobil proposes this as a short-distance transport solution, consisting of two electrically driven rotors, encouraging environmentally friendly travel.

The Return of Supersonic Travel?

The creation of supersonic jets is back on the rise following the demise of Concorde, one of them including a commercial jet, the boom 'Overture' jet of the American company Boom Supersonic.

A Quick Break Down of the Sonic Boom phenomenon

'Mach' is the ratio of the speed of an object or aircraft and the speed of sound, and it is used to show a comparison between the two factors.

Mach number = Aircraft speed / Speed of sound

Pressure expands in a sphere, with the source producing vibrations travelling in all directions as waves of compressed air (Unknown, n.d.).

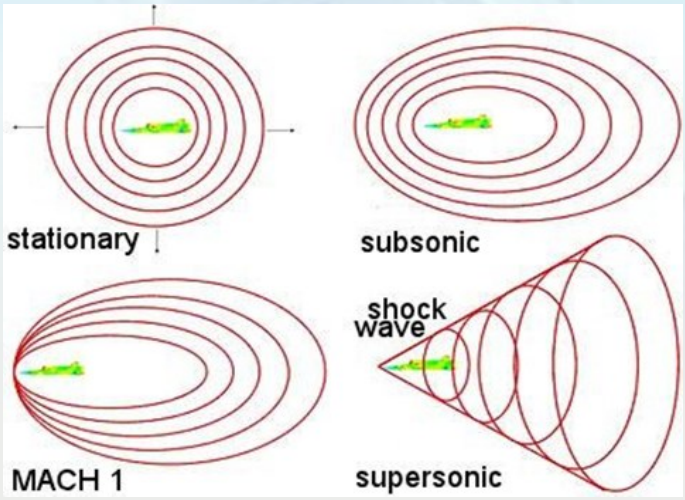
Imagine an aircraft…

Mach 1, When V (velocity) = C (Speed of sound) these pressure waves accumulate

(Unknown, n.d.), forming a front, which generates a large booming sound.

An object becomes supersonic when V > 2C - the waves accumulate such that a cone shape is formed (Unknown, n.d.), which then creates a percussion wave, causing a sharp sound to be heard by observers at the base of the cone (Gibbs, 2017).

The thunder like booms created can be responsible for building damage and large disturbance to inhabitants of the surrounding area, therefore restrictions on supersonic flight exist.



A comparison between the Concorde and the Boom 'Overture' jet.

The Concorde (first flight march 1969) is notorious for opening the possibility to a faster future in commercial flights, holding between 92 and 128 seats and equipped with four Rolls -Royce turbo jet engines. It was able to reach a top speed of 2,179 km/h (Mach 2.04) (Wikepedia, Last updated 2020).

The Overture jet tops the maximum speed of the Concorde with a greater speed of 2,335 (Mach 2.2) (Bremmer, 2020) - over twice the speed of sound. This means that it will be able to travel from London to New York in only 3:15h. Whilst it only has capacity for 55-75

passengers, the boom company proposes reduced CO_2 emissions (supersonic, 2020) and in contrast to the Concorde it possesses 3 turbofan engines. (supersonic, 2020)

Supersonic Flights Without the Boom?

The Lockheed Martin X-59 QueSST (in partnership with NASA), is an experimental jet which can travel at 937mph (Mach 1.42) (Bremmer, 2020) (Martin, 2020). This project is aimed to reduce noise whilst retaining the efficiency of supersonic speeds.

Currently the potential for aerospace technology is still endless, what may future transport look like? Will we achieve zero carbon emissions? And most importantly will we finally have pizza hydrators?

Sarah Beadle

BIBLIOGRAPHY

Aeromobil, 2020. *AeroMobil 5.0 VTOL.* [Online]
Available at: https://www.aeromobil.com/aeromobil-5_0-vtol/
[Accessed 14 April 2020].

Bremmer, C., 2020. *Boom times return for supersonic jets.* [Online]
Available at: https://www.thetimes.co.uk/article/boom-times-return-for-supersonic-jets-qzv7rr7pf
[Accessed 15 April 2020].

Gibbs, Y., 2017. *NASA Armstrong Fact Sheet: Sonic Booms.* [Online]
Available at: https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html
[Accessed 16 April 2020].

Industries, G., 2020. *Gravity.* [Online]
Available at: https://gravity.co/
[Accessed 14 April 2020].

Martin, L., 2020. *X-59 QueSST.* [Online]
Available at: https://www.lockheedmartin.com/en-us/products/quesst.html
[Accessed 16 April 2020].

Suggit, C., 2019. *guinessworldrecords.com.* [Online]
Available at: https://www.guinnessworldrecords.com/news/2019/11/real-life-iron-man-smashes-his-jet-powered-suit-record-by-flying-at-85-mph
[Accessed 14 April 2020].

supersonic, B., 2020. *Boom Supersonic - Overture.* [Online]
Available at: https://boomsupersonic.com/
[Accessed 15 April 2020].

supersonic, B., 2020. *Sustainability.* [Online]
Available at: https://boomsupersonic.com/sustainability
[Accessed 15 April 2020].

Unknown, n.d. *Sonic Boom Explained - How is it Created - Animated Graphics.* [Online]
Available at: https://www.youtube.com/watch?v=1pf-Is2S1_Q&t=272s
[Accessed 14 April 2020].

Wikepedia, Last updated 2020. *Concorde.* [Online]
Available at: https://en.wikipedia.org/wiki/Concorde
[Accessed 15 April 2020].

Acoustics and Architecture

Lily Livermore discusses how to improve architectural acoustics

Sound is a form of energy created when air is disturbed causing changes in air pressure that radiate from the source of the sound in waves.

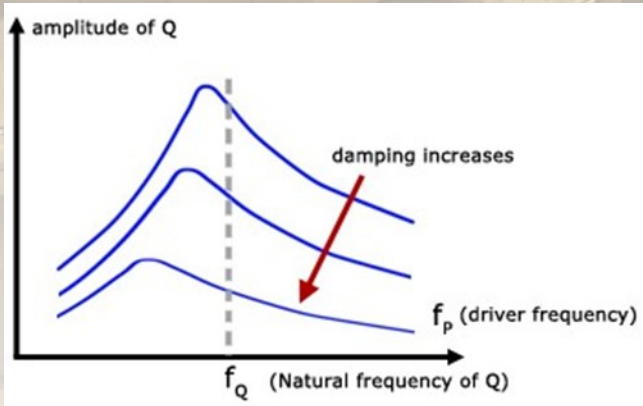
There are two categories to acoustics in architecture, soundproofing which is to create less noise and acoustical treatment is to improve the sound in these environments.

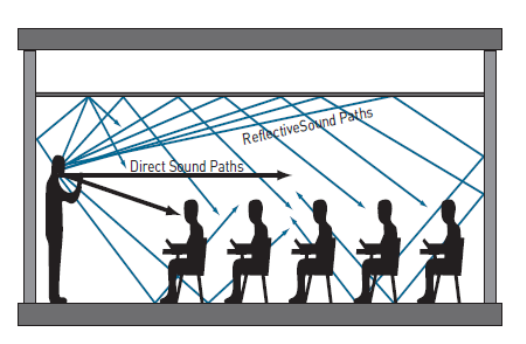
Soundproofing can be used in schools, construction sites and homes to decrease the noise that enters or escapes these places. To do this the walls should be solid and with no holes and structural mass of the walls, floor and ceilings should be increased and all sound outlets closed off.

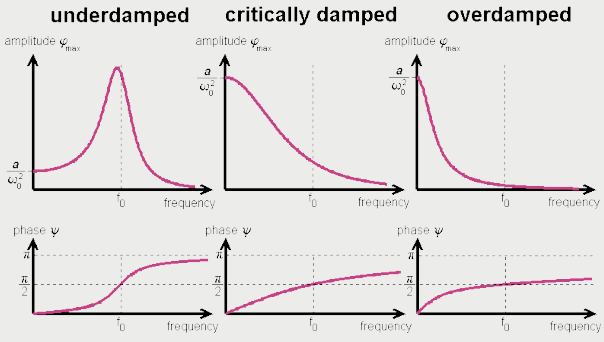
Acoustical treatment is the improvement of the sound quality in the space. When sounds are reflected they cause an increase in echo and resonance levels, when treating a room the aim is to reduce these two things by methods of sound absorption and diffusion and combining these two strategies creates the best results.

Sound absorption is where a material or structure takes in sound energy (incident sound) some of the wave is absorbed and some of the wave passes through and a small amount reflects back. The perfect material for absorption is one that creates a balance between absorption and reflection. This is like a window, the sound passes through and very little reflects back. For sound absorption to take place materials must be used that do not reflect the noise back into the space.

Resonance is when a sound is amplified and happens when the frequency of the sound is equal to the natural frequency of the object that the sound is travelling through or onto. When an abject resonates the amplitude of the oscillations increase, if the system isn't damped the amplitude of the oscillations will increase so much that the system will not work, for example the Royal Albert Hall has many musical instruments that need resonance in their bodies to produce louder notes, but too much resonance will undermine the aim of louder sound and this is when problems occur. Damping is when you reduce the maximum amplitude at resonance and therefore aims to create the balance of resonance needed for the desired object to work. As more damping is applied the amplitude of vibrations of the frequency decrease. The classic example of this is breaking a wine glass with sound at the precise resonant frequency of the glass.







There are three types of sound absorbing materials; porous absorbers, resonance absorbers and panel absorbers. Porous absorbers are made from porus materials- fibourous and open cell foam. Fibrous materials absorb the sound as the wave is able to penetrate it surface, then is damped and turns into heat energy. Converting the acoustic energy into heat energy is the main function and way of absorption.

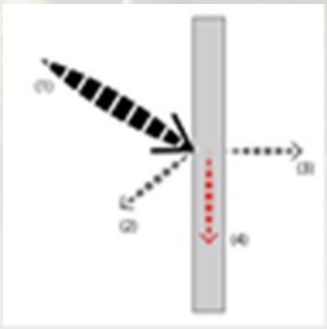
Open cell foam absorbs the sound by air movement of the sound into the material and by doing the sound is reduced

and again heat is generated.

Materials with low density and porous/fibrous characteristics are better at the absorption process as they are most successful at reducing sound of mid- range frequencies. Dense, hard and impenetrable materials such as metals reflect the sound and therefore are bad absorbers of sound.

Resonance absorbers contain mechanical oscillation systems with plates that contain air spaces, these plates are materials with holes or air openings. The openings trap the sound inside and contain the echo, absorbing it and reducing it. This type of absorber is the most successful with low frequencies.

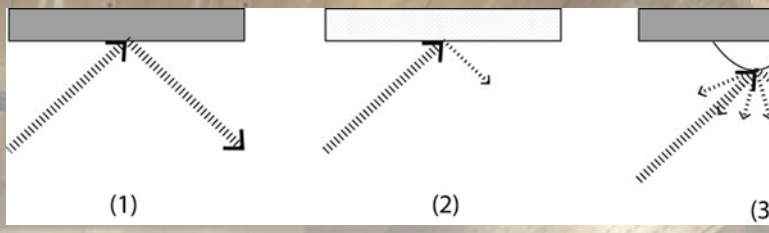
Panel absorbers are made from non- pours and non-ridged materials (membrane absorbers) that are common in our daily lives. Tables, chairs, windows and doors. They absorb best low frequencies.



1=incident sound, 2=reflected sound, 3=transmitted sound, 4=absorbed sound.

For different materials there is a different acoustic absorption that varies with frequency and density. As higher frequency sounds are easier to absorb because of their short wavelengths, meaning we can treat these rooms for high frequency absorption. The composition of a material determines its performances but we can use other factors to further improve the acoustics. - placing a pocket of air behind a ceiling or wall allows for an increased absorption

It is with a diffuser to improve the sound in a space allowing it to reach the desired areas. The reflected sound travels into the room by diffusion which reduces unwanted echo and resonance. The diffuser is a curved object covered with fabric which can be attached onto walls and ceilings, this allows for uniform spreading of reflections that otherwise on a flat wall would combine with the incident sound waves and create destructive interference. In a theatre hall these diffusion objects are used to improve the sound and therefore the balance between absorption and reflection is wanted, where as a restaurant is a place where most sounds are wanted to be absorbed.



1=reflective surface, 2=absorptive surface, 3=diffusive surface.

Fibrous materials absorb the sound most as when the sound reaches the material it absorbs them. The sound waves force the fibres to vibrate which causes heat due to friction and therefore sound absorption into materials occurs due from incident energy into heat conversion.

The diffusers and absorbers reduce the unwanted noise by decreasing the amount of resonance within the waves, so when noise levels are really high background noise that can come into play is dealt with. Spaces with proper acoustical treatment will use these techniques to reduce the build-up of the sound reflections and allow everything to be heard again.

A place with inadequate acoustics can make us feel uncomfortable and directly influence our behaviour, learning outcomes and productivity so when designing a project it is important to consider these elements to create a better experience for the person.

In concert halls the sound coming from the people on stage is spread throughout the hall by loudspeakers, some sound reflects off all the hard surfaces in the room such as the walls and ceilings, this causes the unwanted echo and resonance which distorts the original sound and could also result in places where the sound it not heard at all in the hall or areas where it is too loud.

Halls are designed to get rid of these unwanted reflections to maximise the quality of sound, this can be changed by engineering the shape of the walls and also using materials that absorb the sound. A good example is the Royal Albert Hall in London suffered from acoustical problems- an echo caused by the cove of the ceiling, the problem was fixed by introducing fiberglass acoustic diffusers from the auditorium ceiling. They were placed to the ceiling so that their convex shape reflected the rising sound back down to the viewers. This is also a form of using an object to damp the resonance.

.

Another example of acoustics is the Opera City Concert Hall in Tokyo, this opera house is quite different from others as it is characterised by the “shoebox” style, it has rectilinear and orthogonal lines with regular horizontal seats and rows of windows and glass walls. This is what creates the good sound experiences. The buildings different design and use of materials allowed the audio engineer to create the illusion that the hall is much larger than it is without the use of speakers. The use of solid oak ceilings and walls are designed with groves that are angled and that diffract and reflect the sound allowing the acoustics to bounce off the walls diffusing the high frequencies and minimising resonance.

Lily Livermore

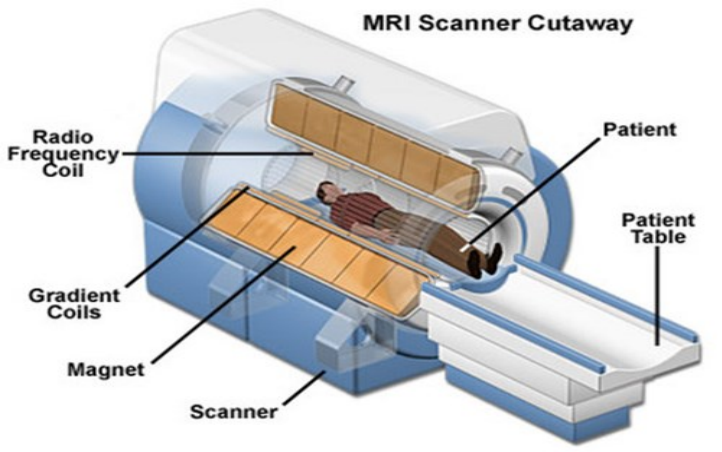
Magnetic Resonance Imaging

Karishma Gokani discusses the physics behind an MRI scanner

Magnetic Resonance Imaging is a non-invasive technique used to diagnose medical conditions. MRI allows the inside of the body to be viewed by using magnets and radiofrequency waves.

The average human adult's body consists of 60% water. This is crucial to MRI scans as they take advantage of the spin of the hydrogen-1 nuclei in water molecules.

Components of an MRI Scanner



An MRI machine consists of a superconducting magnet, a radiofrequency coil, gradient coils and a scanner. A superconducting magnet is used as they have no resistance, so they allow strong currents to flow without the material being heated. This allows a field that has a high magnetic flux density, usually 0.5T-3.0T to be created. A magnetic field of this flux density cannot be created using a copper electromagnet as the high resistance can lead to the coil melting when high currents are flowing. Liquid helium is used to 'trap' the current so that the electric supply initially providing the current can be unplugged. The current will remain the same as long as the temperature is cool enough.

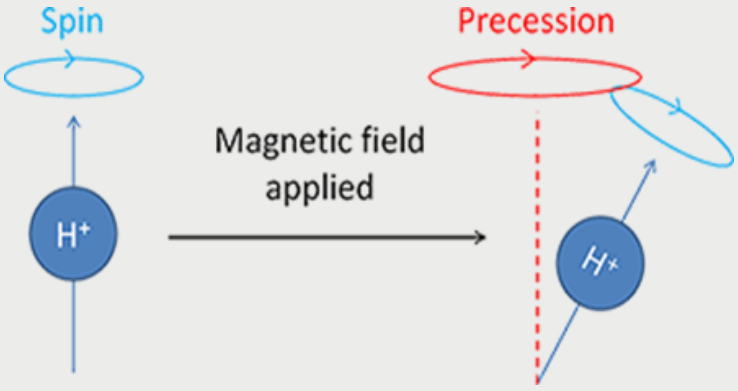
Radio frequency coils are used to create radio waves at different frequency. When radio frequency coils are used as transmitters, the coils generate an oscillating field. When the radio frequency coils are used as receivers, they detect the magnetic resonance signal. This changing magnetic flux is captured by the radiofrequency coil and an induced electric current is generated.

Gradient coils are loops of wire or thin conductive sheets. There are X coils, Y coils and Z coils. When a current passes through the gradient coils, a second magnetic field is created. This field alters the main magnetic field and makes the resonance frequency of the protons vary. Gradient coils are mainly used for spacial encoding but are also used in MRI angiography, diffusion and perfusion imaging. Gradient coils allow the scanner to view the image of a body in slices.

Principles of Magnetic Resonance

Spin is a fundamental property that is restricted to quantized values. These values of spin are multiples of □ (Planck's constant divided by 2π). Nuclei that have an odd number of nucleons have half-integer spin. Nuclei that have an odd number of protons and an odd number of neutrons have integer spin.

A hydrogen-1 nucleus, which is a proton, has the spin of ½. This spin gives the nuclei a magnetic moment. When an external uniform magnetic field, B_0 is applied in the z-axis (direction parallel to B_0), the protons will align with the field. As protons align with the field, they experience Larmor precession. The precessional frequency of a proton can be determined by the Larmor equation. The Larmor equation states that the precessional frequency is directly proportional to the magnetic flux density of the applied field, B_0. The constant is the gyromagnetic ratio and is unique for each nucleus, for hydrogen-1 it is 42.58MHz/T (for a magnetic flux density of 1T).



Most protons will precess aligned with B_0 (low energy

state) but some protons will precess in the other direction (high energy state). This creates net longitudinal magnetisation in the direction of the z-axis. Magnetisation in the direction of the magnetic field cannot be measured because of the magnitude B_0. So, the magnetisation must be transferred by an angle of 90° into the transverse plane. This happens by applying an oscillating magnetic field in the form of a radiofrequency pulse which has the Larmor frequency. This allows energy to be transferred to the protons efficiently and makes the precession angle spiral down to 90°, so a net transverse magnetisation is formed. When radiofrequency pulses are no longer applied, relaxation occurs. This is the process where the protons emit the energy they have absorbed and align in the z-axis direction. When this occurs, a signal is emitted. This signal will either be T1 (spin-lattice relaxation) or T2 (spin-spin relaxation).

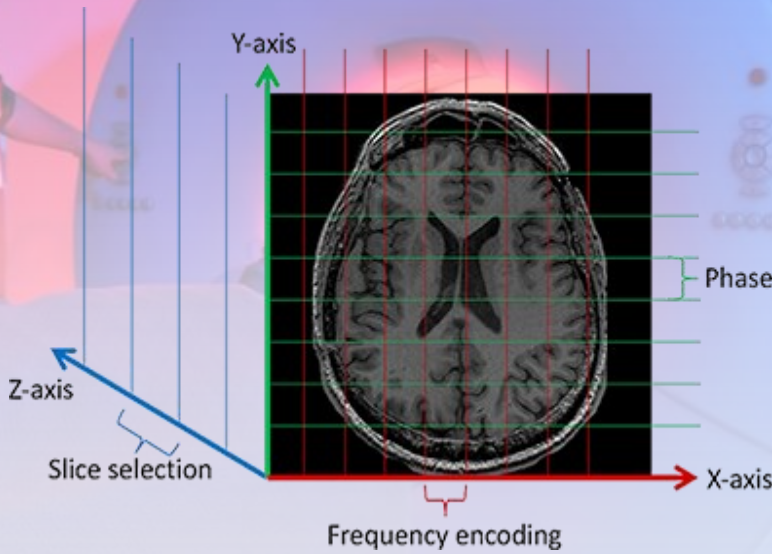
Spin-Lattice relaxation occurs when the protons in the transverse plane transfer their energy to surrounding molecules via collisions and electromagnetic interactions and they return to their longitudinal magnetisation exponentially. T1 is the time taken for the longitudinal magnetisation to return to 63% of its original value. It depends on the molecules surrounding the protons.

Spin-Spin relaxation occurs because after the radiofrequency pulse is turned off, all the spinning protons in the transverse direction are in phase. They quickly lose their coherence and the transverse magnetisation exponentially decays to zero. T2 is the time taken for the transverse magnetisation to decay to 37% of its original value. It depends on the magnetic field.

MRI scans can display more than 250 shades of grey. On a T1 weighted MRI, fat, blood, proteinaceous fluid and paramagnetic substances emit high signals (bright areas). Iron, water, most tumors and bone emit low signals (dark areas). On a T2 weighted MRI, water, edema, fat, blood and most tumors emit high signals (bright areas). Bone, hemosiderin, intracellular deoxyhemoglobin and methemoglobin emit low signals (dark areas).

Forming an Image

When an object is placed into a magnetic field, each area of the object has a specific signal strength. A magnetic gradient is applied by using the gradient coils so the protons in a specific area has a specific frequency. The signal that is detected is the combined signal from each specific area. A Fourier transformation splits each specific area up into their individual frequencies and amplitudes. The brightness of the pixels in the image is determined by the amplitude of the wave and the frequency of the signal determines where in the image the pixel is.

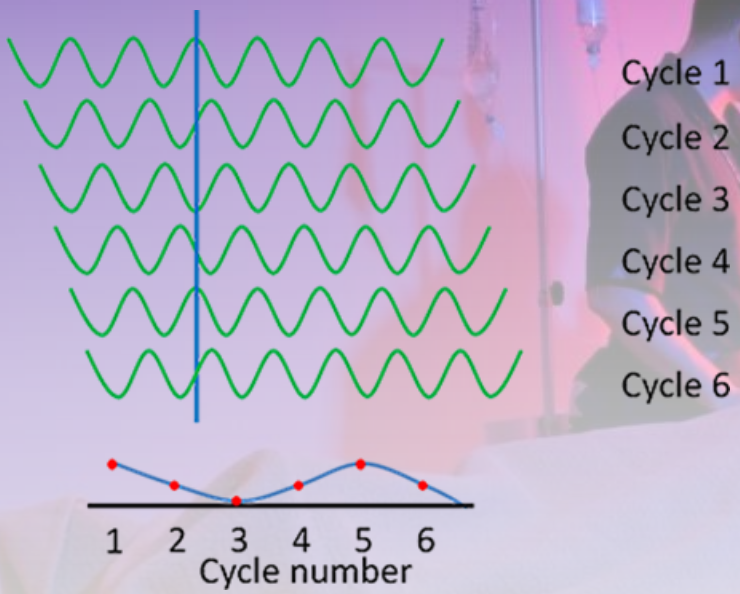


Slice selection is localising the position of the axial slice inside the image being formed. A magnetic field gradient is applied in the Z-axis direction and is superimposed on B_0. This allows different protons to have various Larmor frequencies. A radiofrequency pulse that matches the Larmor frequency of the protons in a desired area is applied. Since the Larmor frequency is different for each nucleus, their spin becomes out of phase. Reversing the gradient allows the phase to reset so all the nuclei spin are in phase again.

In the x-axis direction, nuclei in a slice will have different amplitudes but same frequency and will be in phase. The signals cannot simply be added together as this will only create on wave with the same frequency. To overcome this, a magnetic gradient is applied in the x-axis direction. The Larmor frequencies of the nuclei will change in the x-axis direction. Since the nuclei no longer have the same frequency, they no longer will be in phase. Combining the signal will now give a large signal at the start but the amplitude of the signal decreases as the number of nuclei in phase diverge. This gradient is known as the 'frequency encoding gradient'. As the signals go out of phase, the combined signal becomes very small, so there is a small amount of time when the desired signal can be measure.

A 'dephase' gradient is applied along the x-axis to rephase the magnetic resonance signals. A 'gradient echo' signal (which is a combination of the x-axis signals) is received. A

Fourier transfer is applied to the 'gradient echo' signal to separate each frequency and amplitude. This enables us to locate each signal on the x-axis.



A phase encoding gradient is applied in the direction of the y-axis. This makes the frequencies in each section of the column different. When the phase encoding gradient is turned off, the sections of the column return to having the same frequency, but now each section is out of phase. The phase-shift depends on the position along each column. The amplitude of the signals at certain points is plotted. If the phase encoding gradient is now turned back on with a different strength, the phase-shifts will be different. This process is repeated to produces a graph with a specific frequency. Each section of the column will have a different frequency dependent on its area on the y-axis. A Fourier transformation is applied to split these frequencies and place them in the correct position on the y-axis.

Karishma Gokani

BIBLIOGRAPHY

Coyne, K. (2020, April 6). *MRI: A Guided Tour* . Retrieved from Magnet Academy: https://nationalmaglab.org/education/magnet-academy/learn-the-basics/stories/mri-a-guided-tour

Gibbs, K. (2016). *The Physics of Magnetic Resonance Imaging* . Retrieved from Schoolphysics: http://www.schoolphysics.co.uk/age16-19/Medical%20physics/text/MRI/index.html

MedlinePlus. (2019, April 29). *MRI Scans*. Retrieved from MedlinePlus: https://medlineplus.gov/mriscans.html

MRI Questions. (2020). *NMR Phenomenon*. Retrieved from MRI Questions: http://mriquestions.com/hellipthe-nmr-phenomenon.html

Radiology Cafe. (n.d.). *MR imaging*. Retrieved from Radiology Cafe: https://www.radiologycafe.com/radiology-trainees/frcr-physics-notes/mr-imaging

Sheffield Hallam University. (n.d.). *Nuclear Magnetic Resonance Spectroscopy*. Retrieved from Sheffield Hallam University Web site: https://teaching.shu.ac.uk/hwb/chemistry/tutorials/molspec/nmr1.htm#

Smith, L. (2020, March 30). *Spin of Subatomic Particles* . Retrieved from Encyclopedia: https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/spin-subatomic-particles-0

Supraconductivite. (n.d.). *MRI Magentic Resonance Imagery*. Retrieved from Superconductivite: www.supraconductivite.fr/en/index.php?p=applications-medical-irm-more

The Antibiotic Crisis

Ahmed Hassan describes reasons for and how to combat antibiotic resistance

What are the Potential Solutions to the Antibiotic Resistance Crisis?

Perhaps when Sir Alexander Fleming discovered antibiotics in 1928[1], he never imagined that the word 'abuse' would be linked to antibiotics. His discovery of the first true antibiotic helped revolutionize medicine by saving millions of lives, particularly in developing countries; whereby antibiotics have helped offset the health problems caused by poor sanitation and help increased life expectancy. However, due to the evolutionary nature of bacteria, the benefits that antibiotics have bought about are in jeopardy. Since the widespread prescription of antibiotics in the early 1940s, bacteria have developed resistance to nearly all antibiotics that we have at our disposal today. Antibiotics deploy numerous ways in dealing with bacterial infection – interfering with the bacteria's metabolism thus reducing growth; targeting DNA to prevent replication while others use cytolysis. Nonetheless, bacteria are still spreading their immunity to other bacteria and even other types of bacteria. One of the ways that bacteria achieve this is through transformation – a process that harvests dead bacteria to accumulate DNA. Another method is called conjugation – whereby bacteria join to each other to pass on their resistive genes this allows resistant bacteria to proliferate. It is this increase in the rate of bacteria's immunity to antibiotics that have helped fuel this crisis by rendering more and more of our antibiotics obsolete.

The Epidemiology of the Antibiotic Resistance Crisis

The health burden that antimicrobial resistance (AMR) is thought to exceed that of other communicable diseases, with AMR surpassing Influenza and HIV (figure 1). It's expected that by 2050 that deaths associated with AMR will be more than the deaths caused by cancer. Its estimated that worldwide there will be an increase from more than 700,000 deaths due to AMR to 10 million annually by the year 2050[4]. Additionally, table 1 shoes the distribution of AMR deaths across the world, with the highest deaths in Asia and Africa. The report from the Food and Agriculture Organization (FAO) official released in 2018 supports the evidence from table 1. The FAO's Chief Veterinary Officer Juan Lubroth told Reuters that:" *Here in Southeast Asia…we consider it a hotspot for antibiotic abuse*'' [5].

The Social, Economic and Behavioral Factors of the Antibiotic Resistance Crisis

In the UK antibiotics aren't sold over the counter. Therefore, compared with the other countries where antibiotics can be accessed over the counter, the UK has a lower rate of AMR. Nevertheless, AMR should still be a cause of concern due to globalization over the past 25 years. The world has become a small village, with the International Air Transportation Authority (IATA) estimating that there were 37.8 million flights in 2018[6]. Therefore, an outbreak in AMR in one part of the world could easily spread globally in a relatively short period of time. It is prudent that scientists and doctors in the UK are prepared for an AMR pandemic.

Additionally, an economic factor that has made the antibiotic resistance crisis worse is that 15 of the 18 largest pharmaceutical companies have abandoned the antibiotic market completely[7]. The rationale behind such policies can be attributed to three reasons: (I) a low return on investment as new antibiotics that would be developed would have to be deployed sparingly for the most resistive of cases. (II) It would be counter-intuitive to mass produce newly developed antibiotics. Yes – it would increase pharmaceutical companies' revenue in turn increasing incentive for research development, but at the same time this would mean that bacteria would develop further resistance even sooner. (III) The very nature of drug development acts as a deterrent to pharmaceutical companies. The journey of an antibiotic from a lab to the shelf takes a lot of time and financial investment. It requires testing, trials, ethical evaluation, approval and licensing before it could be given to patients - a process that would take around 12 years and a cost of £1.15 billion approximately[8].

Moreover, the use of antibiotics given to livestock in the agricultural industry is regularly described as a significant contributor to the medical problem of AMR. Farmers often place livestock animals in congested and unhygienic places in order to save money. Disease thrives in these very places that these animals are kept

in, therefore farmers give multiple antibiotics to prevent death and maximize profit. China is one of the world's highest users of colistin (a 'last-ditch' antibiotic) in agriculture, especially in pig farms. Colistin is a cheap and old drug produced in 1959[9] - that's why its so widely used. China then discovered Colistin resistant E. Coli in 2013 in a pig farm nearby Shanghai[9]. This AMR bacteria could potentially spread to humans.

Furthermore, a behavioral factor that has worsened the antibiotic resistance crisis is the overuse of antibiotics. Today we take antibiotics for granted and so we use them inappropriately and indiscriminately. The World Health Organization (WHO) conducted a study that revealed a misunderstanding that people have towards antibiotics. Out of 10,000 people surveyed across 12 different countries, 64% of respondents believed that antibiotics should be used to treat colds and flus. [1°] The misuse of antibiotics is another contributing factor to increase AMR. People don't take antibiotics when they're prescribed, for instance missing doses, saving antibiotics for later use and sharing antibiotics with other people. These are common practices in low income countries whereby the misuse of antibiotics may also result from poor guidance about their safety and precautions from pharmacists. [11] Many low to middle income countries have taken the steps towards prohibiting the over the counter sales of antibiotics but unfortunately this isn't enforced enough by local authorities..

Combating the Antibiotic Resistance Crisis – Is there a cause for optimism?

The solution for AMR can be in research on how to develop new means of combating bacteria or raising awareness about AMR.

Research has shown that bacteriophages could potentially be good at combating AMR bacteria in the future, without affecting human cells. They are more specific than antibiotics since they don't kill the unharmful bacteria found in our body. Bacteriophages, or phages for short, have been discovered almost a 100 years ago and are very diverse and ubiquitous type of virus. However, there use in potentially treating diseases caused by superbugs have only been explored recently. From an evolutionary standpoint, bacteria and phages have been involved in arms race with each other for millions of years. If bacteria develop resistance to phages they would have to compromise on their resistance to antibiotics. [13] There is reason to be optimistic since phage therapy has resulted in life saving therapy in many clinical trials. In 2016 a woman named Steffanie Strathdee had her husband dying from an AMR bacterium. In a last-ditch effort they were successful in saving his life when using phage therapy[14]. Another instance was a patient who suffered from *Pseudomonas Aeruginosa* a multi-drug resistant (MDR) bacteria that had infected his chest cavity. After a month doctors decided to inject his chest cavity with thousands of phages in addition to antibiotics that the bacteria has proved to be resistant to. After a few weeks the man was cleared from *Pseudomonas Aeruginosa* and returned back to normal[13]. There's still a lot of regulatory hurdles that need to be overcome but phage therapy has come leaps and bounds in the last few years with more and more pharmaceutical companies increasingly becoming more willing to invest in its research.

Many low- and middle-income countries are beginning to prohibit the over the counter sale of antibiotics but this isn't enough as authorities in these countries need to move towards enforcing antibiotics being accessed through prescriptions only. This can be achieved by creating the infrastructure that registers medication that is being sold over the counter and to impose legal penalties to those who breach regulations which requires a lot of financial and resource investment. Raising awareness through campaigns and increased education about AMR is essential part of the solution. The World Antibiotic Awareness Week (18-22 November) is a good example of initiatives that help raise awareness. Despite these efforts it's still common practice worldwide for people to request antibiotics for colds and coughs showing there's a still long way to go. Antibiotics are treated as a commodity and so long that this perception continues there will be no improvement – so for this reason antibiotics should be taken as a last resort and not be used freely if we're to stand chance against AMR. A handful of countries shouldn't be the only countries dealing with this issue as a global problem requires a global solution.

Ahmed Hassan

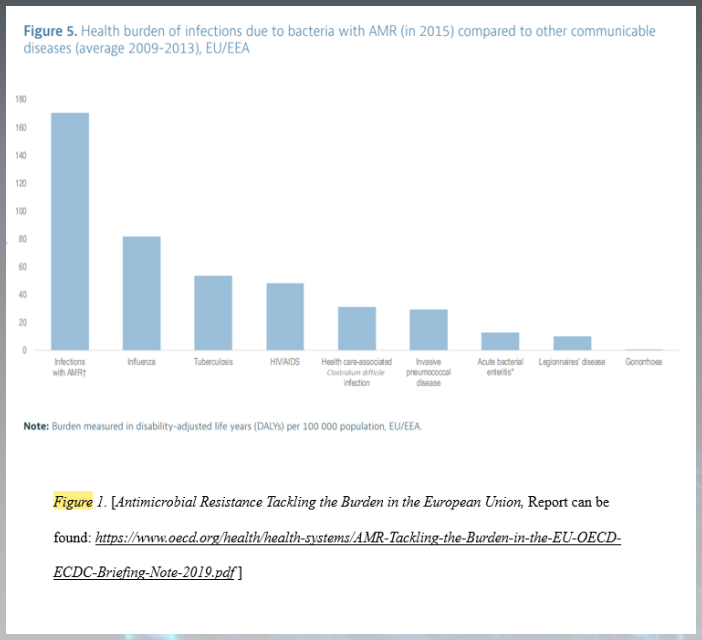


Figure 1. [*Antimicrobial Resistance Tackling the Burden in the European Union*, Report can be found: *https://www.oecd.org/health/health-systems/AMR-Tackling-the-Burden-in-the-EU-OECD-ECDC-Briefing-Note-2019.pdf*]

Tables

Table 1

The number of death due AMR

Continent	2016	2050
Africa	430,000	4,150,000
Asia	540,000	4,730,000
Europe	33,000	390,000
Latin America	29,000	392,000
North America	23,000	317,000
Oceania	3,900	22,000

Note: Table made from statistics gathered from the following sources:

- https://www.reuters.com/article/us-health-antibiotics/southeast-asia-a-hotspot-for-antibiotic-abuse-fao-official-says-idUSKBN1FK0OR
- https://ec.europa.eu/health/amr/antimicrobial-resistance_en
- https://www.cdc.gov/drugresistance/index.html

BIBLIOGRAPHY

https://www.sciencehistory.org/historical-profile/alexander-fleming

C. Lee Ventola, *Part 1 Causes and Threats of Antibiotic Resistance Crisis*, Pubmed

ttps://hygenica.com/amr/

https://amrreview.org/sites/default/files/AMR%20Review%20Paper%20-%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf

Amy Sawitta Lefevre, *Southeast Asia is a 'hotspot' for antibiotic abuse, FAO official says*, Reuters Health News, January 31 2018

https://www.statista.com/statistics/564769/airline-industry-number-of-flights/

Aaron E. Carroll, *We're losing the Race Against Antibiotic Resistance, but There's Also Reason for Hope*, The New York Times, March 7 2016

Ingrid Torjesen, *Drug Development: the journey of a medicine from lab to shelf*, The Pharmaceutical Journal, PJ March 2015 online, online | URI: 20068196

Maryn Mckenna, *Apocalypse Pig: The Last Antibiotic Begins to Fail*, National Geographic, Science November 21 2015.

World Health Organization, *WHO multicounty survey reveals widespread public misunderstanding about antibiotic resistance*, 16 November 2015.

Jacobs, T.G., Robertson, J., Ham, H.A. *et al.* Assessing the impact of law enforcement to reduce over-the-counter (OTC) sales of antibiotics in low- and middle-income countries; a systematic literature review. *BMC Health Serv Res* **19,** 536 (2019) doi:10.1186/s12913

Pires DP, Vilas Boas D, Sillankorva S, Azeredo J. 2015. Phage therapy: a step forward in the treatment of *Pseudomonas aeruginosa* infections. J Virol 89:7449–7456. doi:10.1128/JVI.00385-15.

Kurzgesagt, *The Deadliest being on Planet Earth – The Bacteriophage*, 10 Nov 2019 Video can be found : https://www.youtube.com/watch?v=YI3tsmFsrOg

Eric Boodman, *First phage therapy center in the U.S. signals growing acceptance,* STAT news, June 21 2018

The Post Antibiotic Era

Moritz Wagner-Tsukamoto discusses the alternatives to the post antibiotic era

Of all the medical advances in the 20th Century, the discovery of antibiotics was arguably the most impactful. However, now there is talk of a post-antibiotic era. An era in which bacterial infections, untreatable with existing antibiotics, kill thousands upon thousands of people (WHO, 2018). Who said this? The WHO (World Health Organisation). They stated in a report that antibiotic resistance is "no longer a prediction for the future, it is happening right now in every region of the world" (WHO, 2014). The US Centre of Disease Control and Prevention (CDC) also stated in a 2019 report that "Antibiotic resistance…is one of the greatest global health challenges of our time" (CDC, 2019).The post-antibiotic era is about to begin.

Discovered by Alexander Fleming in 1928 by accident, Penicillin was the first true antibiotic to hit the market in 1945, also because of the hard work of Howard Florey and Ernst Chain in the efficient purification of the drug and the vigorous testing they did during the Second World War (Adedeji, 2016; ReAct, n.d.). The three men were awarded a shared Nobel Prize for Physiology and Medicine for the discovery of penicillin in 1945. Fleming, in his award speech, issued a warning: "It is not difficult to make microbes resistant to penicillin…by exposing them to concentrations not sufficient to kill them… There is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant" (Fleming, 1945). Obviously, everyone listened to Fleming and lived happily ever after.

It was as early as 1947 that the first case of penicillin resistance was observed. Bacteria such as *Clostridium difficile* (often just called *C.diff*), which is resistant to most of the classes of antibiotics, including penicillins, and Methicillin resistant *Staphylococcus aureus* (MRSA), a very difficult to treat strain of *S.aureus* (or staph) bacteria (which cause staph infections – infections caused by staph bacteria) resistant to penicillin and methicillin (a penicillin-related antibiotic), appeared because of the overuse and misuse of antibiotics. (Castro, 2013) The name for such bacteria is a 'superbug' (NHS, 2019). Since it is the bacteria that becomes resistant to the antibiotic (and not the person receiving the treatment) these superbugs are able to spread just like 'normal' diseases. (WHO, 2018) Therefore, the solution would seem to be to develop new types of antibiotics that are able to treat these superbugs but also dramatically change the way we use them. There are some flaws with this approach.

Whilst the period from the 1940-1962 saw the vast majority of the antibiotic classes we use today be discovered, there has been a downward trend in the number of antibiotic discoveries being made since then (ReAct, n.d.). This is due, in no small part, to the change in how we use antibiotics. For longer than we like to admit, they were by health professionals (Adedeji, 2016). Whilst this was terrible for medicine, it was very profitable for the pharmaceutical companies. When antibiotic use switched to prescriptions that are perhaps only a few weeks long at most, mainly because of the increased concerns about bacteria developing antibiotic resistance, the pharmaceutical companies were not making as much profit, hence their interest in antibiotics started to dry up. (Conly & Johnston, 2005)

This profit-vs.-benefit paradox is dangerous, as it means that the more we try to save our precious antibiotics, the less likely we are to get new ones. Luckily enough, the WHO has realised this too, stating that if we continue walking down this path, fingers in our ears, refusing to listen to them, by 2050, an estimated 10 million people could die every year from drug-resistant diseases (WHO, 2019). The issue here also is that even if pharmaceutical companies were willing to invest in new antibiotics, it becomes harder to find a new way to destroy bacteria every time it develops a resistance to something (think of how it is now more difficult for pathogens to kill humans thanks to vaccines). More worryingly, even if we reserve the use of antibiotics for the most extreme cases, every time they are used, it gives the bacteria targeted an opportunity to mutate and become resistant. (WHO, 2018)

At this point, I want to introduce the alternative to this problem.

Phage therapy is the medical use of bacteriophages (or

phages), a type of virus that attacks bacteria and causes them to burst (lyse) and die, to treat bacterial infections. They are also one of the most abundant biological entity (viruses are the Pluto of the animal kingdom as they aren't technically alive but do share certain aspects of living organisms, such as reproduction, but they need a host in order to do this) on Earth (Lin, et al., 2017). They are found wherever there are bacteria that they can feed off. They are very specific phages were discovered independently in 1915 by English bacteriologist Frederick Twort and in 1917 by French microbiologist Félix d'Hérelle. (Srisuknimit, 2018)

Research into the medical use of bacteriophages began in the Soviet Union, Georgia and Poland in 1923, five years before Alexander Fleming changed the world. The complications, however in making phage therapy an easily available process stemmed from the fact that in the 1910s and 1920s very little was known at all about phages. It was not until the 1940s that the electron microscope finally enabled scientists to see what phages looked like. (Lin, et al., 2017) This does not mean that phage therapy did not see some early success. In fact, the Soviet Union was using phage therapy to treat its soldiers of serious bacterial conditions such as gangrene during the Second World War (Stone, 2002) (a benefit of their type of communism is the soldiers probably didn't have a choice).

By the time the war ended, antibiotics such as penicillin were already entering mass production in the West, making them a far more attractive proposition compared to the controversial, somewhat sketchy practice of phage therapy. As a result, phage therapy, as legitimate as it is, and as promising as it seemed, was, for the most part, forgotten about in the western world. (Hanlon, 2007)

Even today, almost a century since research began, it remains a very niche and rarely used form of treatment. Examples of it being used as a treatment are few but seem promising. In 2016 a team of scientists from University of California San Diego (UCSD), in collaboration with the US Navy Medical Research Centre and other institutions, used an experimental treatment using phages to treat colleague Thomas Patterson, PhD, infected with a multiple-drug-resistant strand of *Acientobacter baumanii* (an infectious bacteria that can cause pneumonia among other infections. In this case a pancreatic infection). UCSD has also successfully used phage therapy on five more patients, including the clearing of the chronic infection of one patient, allowing them to receive a life-saving heart transplant surgery. In May 2019, UK doctors from the Great Ormond Street Hospital (GOSH) worked with US scientists and successfully developed a cocktail, containing a combination of phages, for a girl, named Isabelle in the article, with cystic fibrosis, who was suffering from severe bacterial infections in her lungs, liver and skin after a double lung transplant which persisted despite several courses of strong antibiotics (NHS, 2019). From this it seems clear that phage therapy has much potential.

As with all treatments however, there is a downside here too. Phages are very specific in terms of what bacteria they will target, unlike antibiotics, whose effects are often broad aiming. Whilst this in and of itself is an advantage and means that they will only attack the bacteria they are meant to, like a hitman (unlike antibiotics, which could be compared to a hitman with an RPG), their area of attack is therefore very narrow and one type of phage will often only kill a certain strain of bacteria. As a result, a cocktail of a number of different phages is often used to broaden their usability (Chan, et al., 2013). This, at this experimental level especially, is time consuming and expensive. And whilst it is true that the specificity of phages could be a huge advantage, there simply is not enough information on phages in Western medicine to determine whether this is true yet. On the other hand though, experiments on hamsters infected with *C.diff*-induced ileocecitis (a disease of the valve that separates the small and large intestine (Pollard, et al., 2011)), found that eleven of the twelve survived when given a single dose of a phage able to attack *C.diff,* whereas the members of a control group infected with the same disease, and given clindamycin (a powerful antibiotic) all died within 96 hours. (Vijayashree, et al., 1999)

Resistance to phages is also a potential concern for scientists. However, as phages are viruses, and thus naturally occurring, it is possible that if a strand of bacteria evolves to avoid a phage, the phage may also evolve in order to overcome the resistance of the bacteria (Witzany, 2012). But here again, the information is scarce, and this assumption is just that, an assumption.

Another disadvantage is that despite success in research, a major adversity to the progress of phage therapy has been the problem of receiving approval for human trials from regulatory bodies such as the UK General Medical Council (GMC) or the US Food and Drug Administration (FDA). In the US, because phage therapy was considered experimental, it required emergency approval, which meant it was only to be used when all other options had

run dry (FDA, 2017). In 2019, however, the FDA approved a trial for intravenously administered (meaning administered into the body directly) phage therapy (Taylor, 2020). The achievement of such a major milestone is largely thanks to the efforts of UCSD, who has been at the forefront in research of phage therapy in the United States.

So, is phage therapy the future? Probably in a way, but antibiotics are still very capable in a given situation, although multidrug-resistant bacteria set to remove a further portion of their effectiveness. The issue here is the lack of information on the topic. And whilst it is incredibly interesting to see where we might be able to go with phages, the generally negative public opinion of viruses and the counterintuitive nature of a treatment that uses viruses to combat disease will no-doubt leave many people sceptical of it. There is no doubt in my mind, however. Phages have the ability to tackle some of the most difficult-to-deal-with superbugs, simply because the bacterium is their natural host. Yes, there are complication in making readily available cocktails, yes, they are a grey area but surely at this point, in the post-antibiotic-era, we should prioritise such a great potential.

Moritz Wagner-Tsukamoto

BIBLIOGRAPHY

Adedeji, W., 2016. *THE TREASURE CALLED ANTIBIOTICS.* [Online]
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5354621/
[Accessed 15 April 2020].

Castro, J., 2013. *What is MRSA?.* [Online]
Available at: https://www.livescience.com/40412-what-is-mrsa.html
[Accessed 16 April 2020].

CDC, 2019. *Antibiotic Resistance Threats in the United States,* Atlanta: U.S. Department of Health and Human Services.

Conly, J. & Johnston, B., 2005. *Where are all the new antibiotics? The new antibiotic paradox.* [Online]
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2095020/
[Accessed 15 April 2020].

Fleming, A., 1945. *Noble Lecture, December 11,1945.* Stockholm: s.n.

Lin, D. M., Koskella, B. & Lin, H. C., 2017. *Phage therapy: An alternative to antibiotics in the age of multi-drug resistance.* [Online]
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5547374/
[Accessed 10 April 2020].

NHS, 2019. *Antibiotic Resistance.* [Online]
Available at: https://www.nhs.uk/conditions/antibiotics/antibiotic-antimicrobial-resistance/
[Accessed 18 April 2020].

ReAct, n.d. *History of antibiotic development.* [Online]
Available at: https://www.reactgroup.org/toolbox/understand/antibiotics/development-of-antibiotics-as-medicines/
[Accessed 15 April 2020].

Srisuknimit, V. "., 2018. *Fighting Fire with Fire: Killing Bacteria with virus.* [Online]
Available at: http://sitn.hms.harvard.edu/flash/2018/bacteriophage-solution-antibiotics-problem/
[Accessed 18 April 2020].

Stone, R., 2002. Stalin's forgotten cure. *Science,* 298(5594), pp. 728-31.

WHO, 2014. *WHO's first global report on antibiotic resistance reveals serious, worldwide threat to public health.* [Online]
Available at: https://www.who.int/mediacentre/news/releases/2014/amr-report/en/
[Accessed 17 April 2020].

WHO, 2018. *Antibiotic Resistance.* [Online]
Available at: https://www.who.int/news-room/fact-sheets/detail/antibiotic-resistance
[Accessed 15 April 2020].

WHO, 2019. *New report calls for urgent action to avert antimicrobial resistance crisis.* [Online]
Available at: https://www.who.int/news-room/detail/29-04-2019-new-report-calls-for-urgent-action-to-avert-antimicrobial-resistance-crisis
[Accessed 18 April 2020].

Measuring Biomass from Space

Oscar Schwabe discusses the methods to measure biomass from space

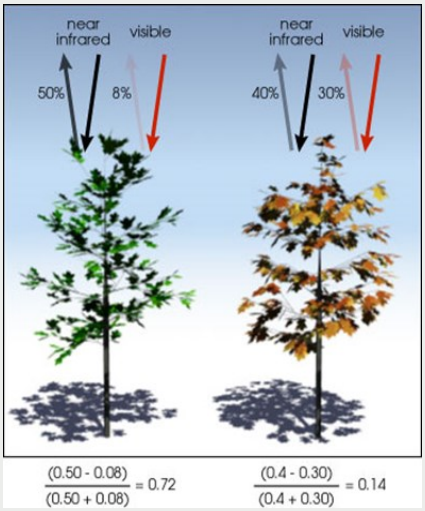
An accurate and efficient method to measure forest biomass is becoming increasingly important as we look to understand the global carbon cycle. Forests store large amounts of carbon, keeping it out of the atmosphere. As more forests are cut down, it is becoming more important to understand the effect that this will have on the climate. Measuring biomass by ground-based methods is not feasible for measuring biomass across huge areas of forest. Remote sensing using satellites as a way to measure forest biomass has been used since the late 20th century.

The current main method of measuring forest biomass is based on the NDVI or normalized difference vegetation index. (1) This is a measurement of the difference between the proportion of intensity reflected of near-infrared radiation (wavelength 0.7 - 1.1 μ m) and red light (wavelength 0.4 - 0.7 μ m). The equation for NDVI is as follows: (2)

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

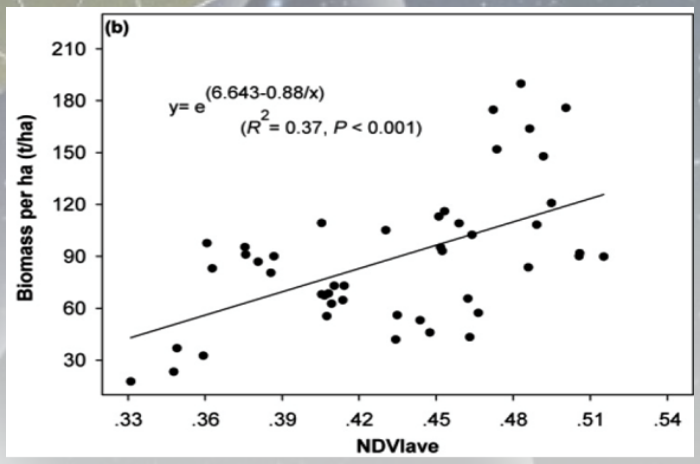
Vegetation strongly absorbs light in the red visible range for photosynthesis, whereas it strongly reflects light in the near infrared range.

This diagram (2) demonstrates that healthy vegetation has NDVI close to one, while sparse or unhealthy vegetation will have a lower NDVI value.



It is possible to calculate the NDVI for an area of land from a satellite in space, which has sensors to measure reflected light in the appropriate wavelength ranges.

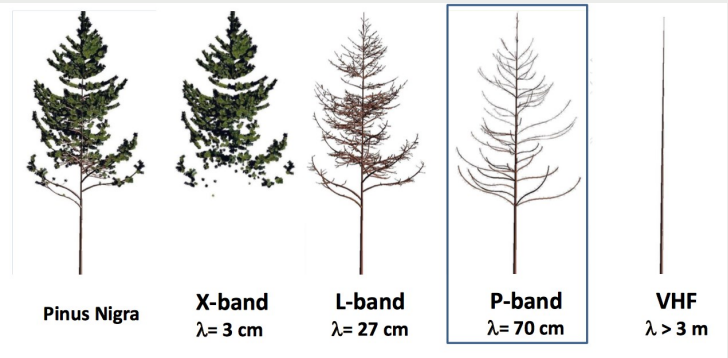
This graph (2) shows the relation between biomass per hectare



and the annual mean value of NDVI for different vegetation areas in northwest China. It is obvious from the graph that there is a weak positive correlation between NDVI and forest biomass. This means that this method has significant limitations and any results obtained will only be approximate. Another issue is cloud cover, which makes it impossible to take the required measurements.

In 2021 the European Space Agency plans to launch a new satellite; the Earth Explorer Biomass, which aims to provide better data for estimating forest biomass. The satellite will carry the first P-band synthetic aperture radar and will orbit in a sun-synchronous orbit approximately 660km from the surface of Earth. (3)

Radar imaging works by transmitting a microwave signal towards the area to be imaged, and then observes the strength and time delay of the returning signal. Unlike optical imaging, radar imaging is an active remote sensing system so it uses its own energy source to illuminate the area. (4)



P-band has the longest wavelength of the commonly used radar

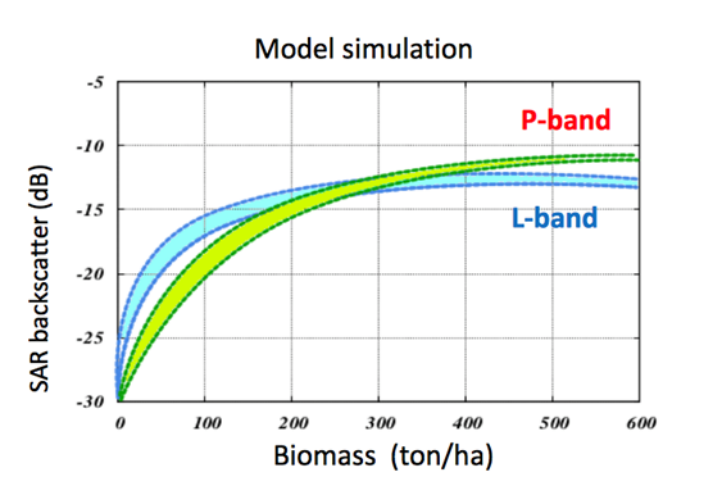
remote sensing bands. The wavelength is 30-100cm and frequency 1-0.3 GHz. The longer wavelength means it penetrates through the canopy so interacts with the trunk and thick branches of the tree; the parts with the greatest biomass. (4) In other words, P-band "sees" the woody parts of the tree whereas shorter wavelengths are obstructed by the leaves and canopy etc.

The detector on the satellite measures the backscatter; the radar signals that are reflected back. Backscatter occurs more from rough surfaces than smooth surfaces. Smooth surfaces reflect most of the signals away from the detector. The surface roughness can be quantified using the Rayleigh criterion; a surface is considered rough if:

$$h > \frac{\lambda}{8 \cos \theta}$$

where h is the mean height of surface variations, λ is the wavelength and θ is the angle of incidence. (5)

Forests with thick trunks act as a rough surface for the P-band radar, scattering the radar signals back to the satellite, which measures the backscatter. If the observation area has no vegetation cover, the ground will act as a smooth surface and reflect the signals away from the detector. If there is vegetation with little biomass, such as scrub or young trees, most of the radar will penetrate to the ground, which will act as a smooth surface, once again reflecting the signals away from the detector.



This graph (6) (based on computer simulation) shows the advantage of P-band over L-band for measuring biomass. The amount of backscatter for L-band levels off sooner, while the biomass is still increasing. This means that P-band has a significant advantage especially for obtaining accurate measurements for old forests with high biomass.

In order to obtain accurate estimates, many complicating factors have to be considered. These include the specific forest structure, the topography of the land, soil moisture, weather and the ionosphere. (6) The ionosphere is a layer of the Earth's atmosphere, which is impacted by solar and cosmic radiation, which has a significant effect on the data collected. (7) Another significant factor is the distribution of water in the tree, which changes throughout the day due to transpiration and water readily absorbs microwave radiation. (6)

Once these factors are accounted for, radar imaging can give much more accurate measurements of forest biomass and it is hoped that the Earth Explorer Biomass mission will contribute significantly to our understanding of the global carbon cycle.

Oscar Schwabe

BIBLIOGRAPHY

Shi, Lei & Liu, Shirong. (2017). Methods of Estimating Forest Biomass: A Review.

NASA Earth Observatory: Measuring Vegetation. https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php

ESA, Earth Online: Biomass https://earth.esa.int/web/guest/missions/esa-future-missions/biomass

Earth Imaging Journal: Discover the benefits of radar imaging http://eijournal.com/print/articles/discover-the-benefits-of-radar-imaging

ESA, Earth Online: Parameters affecting backscatter https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/ers/instruments/sar/applications/radar-courses/content-2/-/asset_publisher/qIBc6NYRXfnG/content/radar-course-2-parameters-affecting-radar-backscatter

ESA: The Biomass Mission. How it works, what it measures? http://seom.esa.int/polinsar-biomass2015/files/D2S1_Opening_3.pdf

University of Sheffield: How to weigh a forest from space https://www.sheffield.ac.uk/research/the-biomass-mission

Photographing Blackholes

Rajan Bahra discusses the usage of the Event Horizon Telescope in photographing blackholes

Recently researchers using the Event Horizon Telescope (EHT) released an image of a jet of gas emerging from a supermassive blackhole traveling near light speed. This comes one year after they released the first ever image of a blackhole. Although the name may suggest otherwise the EHT is not just a telescope, but instead a group of eight sets of radio telescopes across the planet all linked and sharing information creating a virtual Earth-sized telescope. The first image released is remarkably similar to the simulated image of the same blackhole giving very definitive evidence for the gravitational collapse first described by Karl Schwarzschild in 1916 using Einstein's General Relativity equations.

The international collaboration used existing radio telescopes to capture an image of something unseeable. Blackholes are the most extreme things within our universe due to their incredible amounts of mass within a theoretically infinitely small volume. They bend space-time such that nothing can escape, once within its event horizon. This means they do not emit anything that can be recorded by astronomers. Essentially they are left looking for the darkest object on a black background. Therefore, instead they look for the effects of the blackhole on its surroundings, specifically high energy electromagnetic waves (such as X-rays) emitted form super-heated infalling matter – its accretion disk. However, even though researchers have predicted that there at least ten million blackholes within our galaxy, none are large enough or have enough matter around them to be detected. If we look beyond our galaxy radio telescopes have only been able to find vague impressions of blackholes, which could all be explained by some other cosmic phenomenon. This doubt within the field is what slowed down many experiments, such as LIGO, into looing at blackholes and it has been only since 2000 that such research has been able to take place.

Now that projects such as the EHT have been funded, many developments have been made. The EHT uses a technique called 'very long baseline interferometry'. Interferometry uses multiple telescopes in different locations take measurements of the same object at the same time. In the simple case of two telescopes there is a focal point which can be adjusted based on the angle that they are pointing. The image produced of the object at this focal point has a much higher resolution than that of a single telescope but can only ever be of a single object, unlike those produced by the Hubble telescope for example. However, the maximum distance at which this can be used is much lower than a single telescope. When multiple telescopes are used the images produced have higher resolutions due to the varying distances between them. This means that not only is there a specific focal point but also a very wide array of radio signals can be recorded. The other advantages are that the focal point can be behind other objects and combining the data makes it easier to identify interference and remove it creating a much clearer image. Although this technique has been used for several decades it has never been done on such a scale. As mentioned, the EHT uses eight telescopes. The result is the ability to measure the most inner parts of distant galaxies, despite all the matter which shrouds them from the view of other telescopes. The first image the EHT

released is of a blackhole in the crowded galaxy, M87, 55 million light years away, a region of space which was previously impossible to see in such detail.

There are plans to expand the EHT project. The US National Science Foundation has decided to fund the next generation of the EHT. The goal is to have twice as many radio telescopes worldwide, therefore greatly increasing the capabilities of the EHT. One of the telescopes used currently is the Atacama Large Millimeter Array (ALMA). It is based in Chilli and consists of 66 antennae 5000 m above sea-level. Most of these dishes are 12 m in diameter and are spread over several kilometres. The project was an international effort and cost around $1.5 billion to fully find. This creates a huge economic problem for future expansion plans as the National science foundation does not have the resources to fund eight more of these state-of-the-art devises. Another of the major problems of interferometry at this is the processing speed of computers. In order to take an image all eight telescopes must be synchronised, taking images at the same time and all pointing at the exact same region of space. At these distances if the telescopes are half a degree out of alignment it will be pointing thousands of lightyears away from the intended target. Also, with every telescope added the amount of information being recorded and exchanged between sites increases greatly. These problems will all need to be tackled in order to move forward with the project.

Researchers hope to gain further understanding of the effects of blackholes through series of more detailed images and even real-time videos. With this they will be able to observe other features of blackholes such as their lensing effects and the jets produced by their accretion discs. One of the next targets for the EHT is Sagittarius A*, the supermassive blackhole at the centre of the Milky Way. Other than blackholes, researchers also want to investigate quasars and nebulas, giving us information on some of the largest structures within our universe. These improvements and expansions should lead to the development of powerful and useful technology as well as further insight on the most elusive yet violent structures within our universe.

Rajan Bahra

BIBLIOGRAPHY

Amos, J. (2020, 04 07). *Event Horizon Telescope: Black hole produces twisting jet*. Retrieved from BBC News: https://www.bbc.co.uk/news/science-environment-52204614

EHT Organisation. (2019). *Science | Event Horizon Telescope*. Retrieved from Event Horizon Telescope: https://eventhorizontelescope.org/science

ESO. (2020). *ALMA - Atacama Large Millimeter/submillimeter Array*. Retrieved from ESO: https://www.eso.org/public/unitedkingdom/teles-instr/alma/

NASA. (2020). *Black Holes | Science Mission Directorate*. Retrieved from NASA's Science Science Mission Directorate: https://science.nasa.gov/astrophysics/focus-areas/black-holes

Toscano, P. (2013, 03 13). *Meet ALMA, the $1.5 Billion 'Time Machine' in Chile - CNBC*. Retrieved from CNBC: https://www.cnbc.com/id/100548884

The COVID-19 Strategies

Gabriel Samanta discusses how effective country-based mitigation strategies have been during this global pandemic

The ongoing 2019-20 pandemic of COVID-19 concerns an infectious disease caused by the coronavirus. Whilst most people with COVID-19 are likely to experience mild to moderate symptoms of respiratory illness, those with severe disease have a poor prognosis. To date, 172,000 have died across the world.

The infection was first detected in Wuhan, China and since then has rapidly become a pandemic with 1.6 million active cases as of April 20 ("Snapshot," n.d.). The disease is thought to have an infection rate of 70%. Since there are several conflicting death rates circulating throughout the media, for example, in The Guardian ("UK will have Europe's worst coronavirus death toll" The Guardian 20 April, 2020) almost all countries have implemented mitigation strategies. This article considers the different approaches that are currently being used to try and reduce the effects of COVID-19 on health as well as on the economy.

A fundamental part of being prepared for a pandemic is to decide on the optimal approach to minimise deaths whilst safeguarding the economic impact on society. Achieving both to a satisfactory level may not be possible. The strategy chosen must be adaptable to change based on observable phenomena such as rates of infection, mortality, and morbidity. As expected, these approaches differ from country to country, and may well have different levels of success. To date, these have tended to fall into two main categories: non-pharmaceutical approaches (to diminish the effects of COVID-19) including cancellation of mass gatherings, social distancing and travel restrictions (as employed by China), and containment strategies such as isolation, as employed by South Korea. The initial choice of many countries was to follow containment measures as these had been used successfully in the previous SARS pandemic. This required self-isolation following symptom onset and contact tracing. It was also based on the belief that COVID-19 was not infectious prior to the onset of symptoms. Unfortunately, as published in 'Nature' it has now transpired that this is not the case (He et al., 2020). In fact infectivity occurs 2-3 days before the onset of symptoms, meaning that it resembles influenza A rather than SARS (Severe acute Respiratory Syndrome) in its infectivity profile. On this basis, experts predict that COVID-19 is likely to persist longer than seasonal influenza (Fraser et al., 2004) and with a much greater economic impact. Secondly, the effect of seasons on COVID-19 is unknown, although it is hoped that infectivity will decrease during the summer months in line with influenza. With pre-symptomatic transmission levels being as high as 48% isolation and contact tracing seem less and less feasible due to the COVID-19's 'effective reproduction number' of 2.5. This refers to the average number of secondary cases that occur following each primary case. To achieve outbreak control at least 80% of contacts need to be tracked as shown by research published in the Lancet (Hellewell et al., 2020). Achieving this would be very difficult as it is estimated that up to 80% of people infected with COVID-19 experience only mild symptoms. In fact, some people have no symptoms at all meaning that they are unlikely to realise they have been infected ("Q&A," n.d.). This means a shift from symptom-based control to mitigation measures is necessary with intense testing of people being a better mitigation strategy than quarantine alone (Piguillem and Shi, n.d.).

The main objectives of mitigation are to minimise morbidity, avoiding a surge of cases that could overwhelm the health services, and limiting detrimental effects on the economy. A further objective is to allow the population to gradually develop herd immunity. Herd immunity is achieved when a large percentage of the population have developed some level of immunity which then acts as indirect protection from the virus. However, to achieve all these objectives is difficult, if not impossible, as demonstrated by the depressed Chinese economy. Yet the Chinese did succeed in decreasing numbers of new cases since following stringent community-wide containment practices. By focusing on mitigation measures and accepting the inevitability of economic depression, lessons may well be learnt.

It is of course debatable whether the draconian measures

and infringements on personal liberty were reasonable. It is not up to debate that good contact tracking, prohibition of mass events, transportation restrictions, and the development of two major hospitals have dramatically decreased the number of new cases in Britain ("20200228-sitrep-39-covid-19.pdf," n.d.). As it seems unlikely that a vaccine will arrive very soon, due to the time it takes for manufacturers to respond as well as the need for safety trials, there is yet another confounding factor to consider: the ability of Covid-19 to mutate. This possibility means that persons who have survived the infection, and have some measure of immunity, may be re-infected by another strain ("Li et al. - COVID-19 Evolves in Human Hosts.pdf," n.d.). This is a terrifying problem because once quarantine has been lifted, there may well be a second phase of transmission. Mass testing and social distancing might therefore be a better mitigation strategy than mandatory quarantine as this will not only push the peak further into the future, reducing it with time and also allow time for effective treatments to be developed, like quarantine, but also to take a more aggressive stance allowing the identification of milder cases which comes with the benefit of reducing the death rate.

Some countries, such as South Korea and Germany, have ensured low death rates and a slower increase than other countries due to initial momentum rather than locking down entire cities as seen with China. Germany gained initial control using a combination of pro-active testing and recognition of the gravity of the threat in the early days. Even though Germany has one of the highest number of cases it has one of the lowest death rates. This is due to its aggressive testing strategy relative to the size of its population meaning that milder cases are more likely to be identified. With COVID-19 the more cases found with milder symptoms, the lower the death rate regardless of its population age. Nevertheless, Germany is also at an earlier stage than some of its neighbouring countries and even though at the moment it has a lower death rate, COVID-19 can have effects that last for weeks. This may mean that number of ICU beds may become a problem. It must also be remembered that because of Germany's testing they probably have fewer unidentified cases of COVID-19 compared to countries that do not have the same access to tests. South Korea, on the other hand, was hard hit initially by COVID-19 with 813 new cases on February 29 compared with 22 on the April 16 ("COVID-19 situation reports," n.d.). South Korea has decreased the number of new cases dramatically by investing in rigorous testing and contact tracking showing how important case isolation and diagnostic ability is for outbreak control. Unfortunately, South Korea's main focus has been on a large cluster of cases rather than multiple areas. They are now preparing for a resurgence of cases, and other countries should be aware of this possibility.

The UK has not had the same initial momentum as Germany and although it is increasing its spending on testing, this has not increased to the level of South Korea. Initially it advised self-isolation upon symptom onset, however, this had not taken into account the infectivity of COVID-19 before this time. As of last week, only 50,000 people in the UK had been tested for COVID-19. This sits us behind those countries who have been more successful in their testing strategies. The UK has implemented a lockdown which is a good measure to push the peak further away, however its potential is limited unless higher testing capabilities and better contact tracing is introduced. Once these have been implemented isolation guidelines could follow with more stringent guidelines for the elderly. At this point in time implementing the more successful strategies employed by other countries, seems to be the most sensible course of action rather than prolonged quarantine which brings the risk of another increase in COVID-19 once lockdown is relaxed.

Sweden is innovative case study of a western country going against the norm by choosing to follow the advice of its one of its top epidemiologists. Anders Tegnell suggested that Sweden leave its schools, gyms, bars, and restaurants open to the public, and leave its citizens to act responsibly in self-isolation and follow social distancing guidelines. Personal, rather than government action, in western democracies might be the most important issue, and it seems to be working in Sweden, with transport usage being down by 50%, early self-isolation, seeking medical advice remotely unless symptoms are severe, and social distancing. Tegnell's plan appears to be successful with predictions that the country has now passed the worst. However, of Sweden's 1,500 deaths, a third of these have occurred in retirement homes. This could be due to the plan being founded on the idea that COVID-19 is not infectious before the onset of symptoms which research ("He et al. - 2020 - Temporal dynamics in viral shedding and transmissi.pdf," n.d.) now points against. There seems to be some tension at the moment as retirement home workers are sometimes

not even required to wear gloves and many Swedish citizens like Magnus Bondesson ("Anger in Sweden as elderly pay price for COVID-19 strategy," 2020) have voiced concerns. Even Tegnell has admitted that the care home hit is worrying although he has ultimately rejected the criticism saying Sweden was on a different part of the curve and unfortunately already had a large spread of contagion in care homes for the elderly. Some have criticised this plan and are now saying that the elderly are paying for the potentially smaller economic hit that Sweden would experience if Tegnell is correct in thinking that the worst is now behind them.

In summation, the characteristics of COVID-19 mean that the strategies employed by governments for full quarantine are useful only if it exists as an aid to delay the inevitable so that contact tracking can be instigated at high levels and mass testing can be employed. However, with mass gathering 'super-spreading' events are inevitable and would likely overwhelm contact tracking. If there are no improvements in mitigation strategies upon the removal of quarantine there is a chance of COVID -19 cases resurging, as may potentially happen in South Korea. COVID-19 is now in such a state that it has outgrown containment plans and individual behaviour is more important than ever before. There are important decisions to be made on how to lessen the transmission of COVID-19 whilst still providing some support for impact on the economy. Future analysis will no doubt be instrumental in assessing which of the strategies was the most effective.

Gabriel Samanta

BIBLIOGRAPHY

Boseley, S., 2020. *Coronavirus: UK will have Europe's worst death toll, says study.* [Online]
Available at: https://www.theguardian.com/world/2020/apr/07/uk-will-be-europes-worst-hit-by-coronavirus-study-predicts
[Accessed 19 April 2020].

Fraser, C., Riley, S., Anderson, R. M. & Ferguson, N. M., 2004. *Factors that make an infectious disease outbreak controllable.* [Online]
Available at: https://www.pnas.org/content/101/16/6146
[Accessed 19 April 2020].

Hellewell, J. et al., 2020. *Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts.* [Online]
Available at: https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(20)30074-7/fulltext#seccestitle10
[Accessed 19 April 2020].

He, X. e. a., 2020. *Temporal dynamics in viral shedding and transmissibility of COVID-19.* [Online]
Available at: https://www.nature.com/articles/s41591-020-0869-5
[Accessed 19 April 2020].

Orange, R., 2020. *Anger in Sweden as elderly pay price for coronavirus strategy.* [Online]
Available at: https://www.theguardian.com/world/2020/apr/19/anger-in-sweden-as-elderly-pay-price-for-coronavirus-strategy
[Accessed 19 April 2020].

Piguillem, F., 2020. *The Optimal COVID-19 Quarantine and Testing Policies.* [Online]
Available at: https://www.researchgate.net/publication/340226829_The_Optimal_COVID-19_Quarantine_and_Testing_Policies
[Accessed 19 April 2020].

World Health Organisation, 2020. *Coronavirus disease (COVID-2019) situation reports.* [Online]
Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[Accessed 19 April 2020].

World Health Organisation, 2020. *Q&A: Similarities and differences – COVID-19 and influenza.* [Online]
Available at: https://www.who.int/news-room/q-a-detail/q-a-similarities-and-differences-covid-19-and-influenza
[Accessed 19 April 2020].

COVID-19 and the US healthcare system

Om Kela investigates the effectiveness of the US healthcare system, considering the effects of the COVID-19 Pandemic

To evaluate the effectiveness of the American healthcare system, it is essential to first understand its remarkably unique workings as thoroughly as possible. The Healthcare system in the US is a multi-payer system. This means that some will purchase private insurance, approximately 55%, and others will receive Government-funded, public healthcare, in this case, 35%. The insurance rate in the US is 91% with 28,264,700 uninsured Americans in the system. Of the 55% that opt for private insurance, 89% receive insurance from their employer (KFF's State Health Facts, 2018). This is unique to any Western country; America is the only country in the G20 to have a non-universal insurance system. America is also the only country in the G20 to have a non-universal healthcare system with the healthcare of 49% of the population tied to their employment. Soaring unemployment due to this pandemic has exposed some faults in the healthcare system of the US. One aspect to consider is the fact that the outbreak of COVID-19 is still current at the time of writing this article. This means no significant conclusions can be drawn about the lasting effects on the US healthcare system of COVID-19. However, this Global health crisis has highlighted some already present faults in this, as of 2018, $3.6 trillion industry (Centres for Medicare and Medicaid Services, 2019).

One key aspect of the current COVID-19 pandemic is that it has resulted in "a total of 22.2 million [Americans that have] …filed for unemployment benefits…since 14 March" (Dominic Rushe, 2020). This is hugely significant as it indicates three key pieces of information. Firstly, this unprecedented increase in unemployment for America indicates that it is currently undergoing an economic recession. The economy is operating below full capacity, and this leads to lower output, which is already clear from the crash of stock markets both in the US and globally. Secondly, the rise in unemployment and thus fall in output puts downward pressure on wages. Not only are there more unemployed due to the furloughs and lay-offs creating an increase in the supply of labour, but there is also now less income for households in the economy which reduces the demand for goods and services, from which the demand for labour is derived. A combination of these factors results in falling wages throughout the economy. This exacerbates the most significant problem in the US health care system, health care costs.

530,000 bankruptcies in 2019 were due to debt from medical illnesses in the US (David U. Himmelstein, 2019). This accounts for 68.6% of the 772,646 bankruptcies filed in 2019 (United States Courts, 2019). These statistics show that the costs of healthcare to households are extreme, even before the novel coronavirus outbreak.

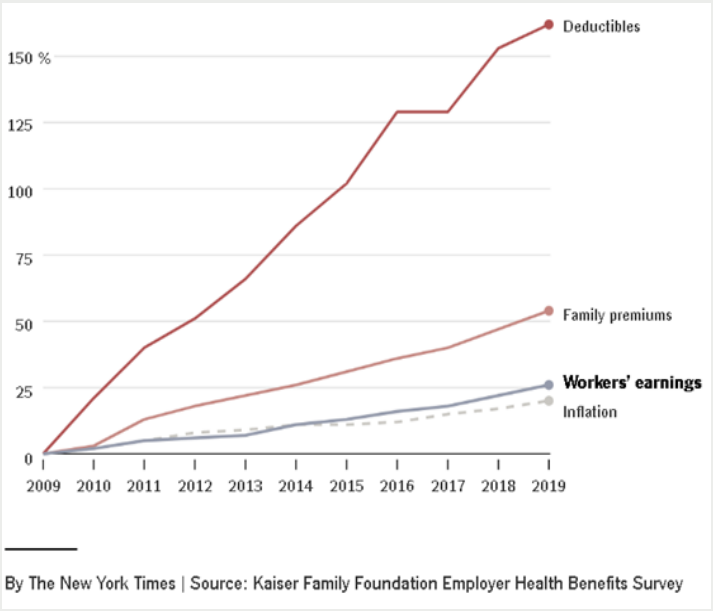


Figure 1 (Abelsen, 2019)

Figure 1 shows for the past decade family premiums

and deductibles have been rising faster than workers' earnings and inflation. Deductibles are the health care costs paid solely by the individual and family premiums are monthly costs incurred by households for access to insurance. The disparity between rising costs and comparatively stagnant wage growth causes financial woes for households in the US.

The most recent KFF Health Tracking Poll, by the Kaiser Family Foundation, finds that 34% of insured Americans find it difficult to pay their deductible, and 28% the cost of health insurance each month, i.e. the monthly premium (Ashley Kirzinger, 2019). This is only further worsened by the COVID-19 crisis during which, as aforementioned, wages are falling, and health problems are rising.

A report posted on the April 2nd 2020 by the Economic Policy Institute states that "3.5 million workers likely lost their employer-provided health insurance in the past two weeks" (Ben Zipperer, 2020). This adds to the tally of approximately 28 million uninsured Americans that have to now pay for not only all of the COVID-19 related costs they may incur but also any previous health care that they received.

This is before considering the government handling of the COVID-19 crisis; the possibility that people are putting off testing to avoid medical bills could greatly worsen the impact of the virus in the US. The reason for such high medical bills is the high prices charged by pharmaceutical companies and hospitals for therapies and drugs. In other developed nations this is not usually the case as the government negotiates with drug companies to secure lower prices. In the US, individual insurers have to negotiate prices for drugs which often leads them to be dramatically higher; the insurers have less bargaining power. The insurers will also then pass on any increases in prices by hospitals or drug companies to the individual consumer as healthcare is a necessity. This is even though the free-market approach is set up to encourage competition as employers often pick one insurer for all employees and remain with them for a long time.

High medical costs lead to a great number of significant issues in America. 51% of US adults say that "they or a family member put off or skipped some sort of health care in the past year because of cost" (Ashley Kirzinger, 2019). This number of Americans skipping healthcare will increase due to the stay at home order and so illnesses and conditions will further deteriorate, decreasing health outcomes for the population in general

However, there is a silver lining to high medical costs and prices for drugs and therapies. The US accounts for 57% of New Chemical Entity Output (Jha, 2017) globally. The US is definitively the leading innovator in medicine, which will prove to be extremely important in developing a vaccine to COVID-19. The fact is that other countries simply free ride off American healthcare innovation and the American public pay in high medical bills for expensive drugs.

An important point to address is that healthcare premiums act as a regressive tax as they are a monthly cost that both the C-suite and the entry-level workers will pay the same. This means those on lower incomes will be charged a larger proportion of their incomes, broadening inequality. Some middle-class workers are leaving their full-time jobs voluntarily to become eligible for Medicaid (Abelsen, 2019) and that is a huge detriment to the US economy as a whole, with unemployment rising even higher.

In conclusion, the American health care system is unique in its failings amongst all OECD, G20 and NATO countries. Despite having a non-universal healthcare system, the US still spent $11,172 per person on healthcare (Centres for Medicare and Medicaid Services, 2019), more than every other OECD country, in some cases even by close to double. The US also has the "lowest life expectancy and highest suicide rates in the OECD", the "highest number of hospitalizations from preventable causes and the highest rate of avoidable deaths" and the "highest chronic disease burden and an obesity rate double the OECD average" (Roosa Tikkanen, 2020). The US healthcare system has ballooning "administrative complexity", reaching $265.6 billion in 2019 (Shrank WH, 2019)and this is all to the detriment to the average consumer. By all means, the American

healthcare system is a boon to global healthcare innovation, however, it is off the backs of American people who have now much weaker health outcomes than their global counterparts.

Om Kela

BIBLIOGRAPHY

Abelsen, R. (2019, September 30). *Employer Health Insurance Is Increasingly Unaffordable, Study Finds*. Retrieved from The New York Times Web site: Health: https://www.nytimes.com/2019/09/25/health/employer-health-insurance-cost.html

Ashley Kirzinger, C. M. (2019, June 19). *Health Costs- Data Note: Americans' Challenges with Health Care Costs*. Retrieved from KFF Web site: https://www.kff.org/health-costs/issue-brief/data-note-americans-challenges-health-care-costs/

Ben Zipperer, J. B. (2020, April 2). *Working Economics Blog*. Retrieved from Economic Policy Institute Web site: https://www.epi.org/blog/3-5-million-workers-likely-lost-their-employer-provided-health-insurance-in-the-past-two-weeks/

Centres for Medicare and Medicaid Services. (2019, December 17). *National Health Expenditure Data: Historical*. Retrieved from Centres for Medicare and Medicaid Services Web site: https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsHistorical

David U. Himmelstein, R. M. (2019). Medical Bankruptcy: Still Common Despite the Affordable Care Act. *American Journal of Public Health 109*, 431-433. doi:10.2105/AJPH.2018.304901

Dominic Rushe, A. H. (2020, April 16). *'Hit by a hurricane': 22m out of work in US as coronavirus takes heavy economic toll*. Retrieved from The Guardian: https://www.theguardian.com/business/2020/apr/16/us-unemployment-coronavirus-economic-toll-jobless

Jha, A. (2017, September 18). *Judging Health Systems: Focusing on what Matters* . Retrieved from An Ounce of Evidence| Health Policy [Harvard T.H. Chan Web site]: https://blogs.sph.harvard.edu/ashish-jha/2017/09/18/judging-health-systems-focusing-on-what-matters/

Roosa Tikkanen, M. K. (2020, January 30). *U.S. Health Care from a Global Perspective, 2019: Higher Spending, Worse Outcomes?* Retrieved from The Commonwealth Fund Web site: https://www.commonwealthfund.org/publications/issue-briefs/2020/jan/us-health-care-global-perspective-2019

Shrank WH, R. T. (2019). Waste in the US Health Care System: Estimated Costs and Potential for Savings. *JAMA.*, 1501–1509.

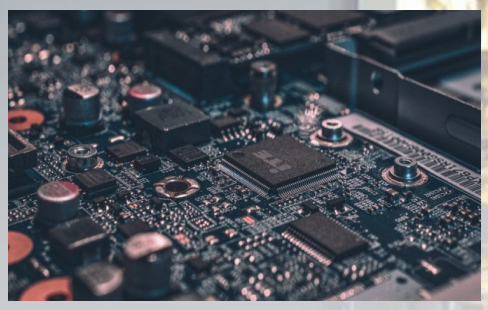
United States Courts. (2019, April 22). *Bankruptcy Filings Continue to Decline*. Retrieved from United States Courts Web site: https://www.uscourts.gov/news/2019/04/22/bankruptcy-filings-continue-decline

KFF's State Health Facts. Data Source: Census Bureau's American Community Survey, 2008-2018, "Health Insurance Coverage of the Total Population"

Quantum Computing

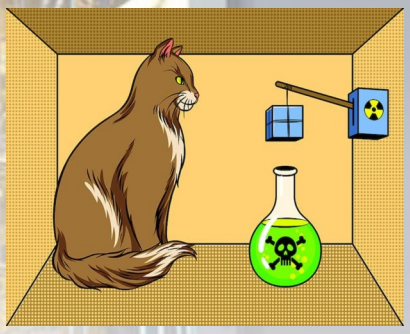
Nazir Sirajudeen discusses the physics behind quantum computing

In classical computing, transistors are required in order for the computer to work. These components are in one of two states, either open their gates to allow electrons to flow through ('on' state) or close them to prevent the movement of electrons ('off' state). The opening and closing of the transistor gates "determine which value a bit will have." (Tech Insights for Professionals, 2019) and forms the basis of classical computing. To improve the speed at which these computers can perform tasks, you would increase the number of transistors present in the components. Thus, there is a need to decrease the size of an individual transistor in order to cluster more of them to keep up with our ever-increasing demand of computing power. However, with our transistor sizes reaching "around 10-20 nanometres in scale" (Thompson, 2016), we are approaching the smallest viable size transistor that can be used in classical computing. After this limit, electrons can simply bypass the logic gate and so electrons can continuously flow, through a process called quantum tunnelling.



One solution to this problem is through the usage of quantum computers to further satisfy our technological advancements. Rather than using bits (1's or 0's) in classical computing, instead these quantum computers use qubits. Qubits are the basic unit of quantum information, and they are either set to one of two values, analogous to the 1's and 0's in classical computing. These are dependent on the quantum state of the object and "*These states are the undefined properties of an object before they've been detected, such as the spin of an electron or the polarisation of a photon" (Science Alert, 2019).* However, what distinguishes qubits from bits, is the ability for the qubit to be in both states simultaneously before being detected. This phenomenon is called superposition and is integral to both quantum mechanics and quantum computing.

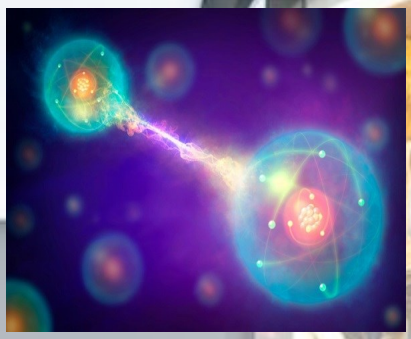
Quantum superposition is a fundamental principle to quantum mechanics and is "is essentially the ability of a quantum system to be in multiple states at the same time" (Institute for Quantum Computing, n.d.). This phenomenon only exists with matter and light on the atomic and subatomic scale (such as photons, electrons and protons). An example of superposition is the wave-particle duality of light (Light can act as waves in experiments such as Young's Double slit experiment or as a particle, a photon, in the photoelectric effect). A famous thought experiment by Erwin Schrödinger, an Austrian physicist, helps to correlate this phenomenon to an everyday scenario. He proposed this experiment where you would place a cat in a steel box with a Geiger counter, a vial of poison, a hammer and a radioactive substance. When the radioactive substance decays, the Geiger counter detects the count, causing the hammer to shatter the vial, exposing the cat to the poison. Until you open the box, you are unsure whether the cat remains dead or alive (as radioactive decay is a random process and you cannot predict when it would happen) and so *"as Schrödinger put it, be "living and dead ... in equal parts" until it is observed." (Kramer, 2013)*. This is analogous to the quantum states of particles mentioned previously, such as a photon having a vertical or horizontal polarisation, and it can be in any proportions of both states at a single time, before being observed.



This property of qubits exponentially increases the speed of computational power. In effect, when there's different routes or calculations to be taken by a computer, the effect of superposition allows the qubits to test all of the routes at the same time and "It can hold uncertainty in its head." (Katwala, 2020) reducing the time it takes to calculate a solution significantly. To give an example, if the task to be performed is asking a computer to work its way through a maze, the classical computer would try every single route one at a time, ruling each incorrect route individually before eventually finding the correct route. On the other hand, quantum computers would try each route at the same time, finding the correct route almost instantly. Currently one of the ways classical computers have used encryption is called RSA encryption. In this encryption, you would need to an RSA-2048 bit encryption key in order to access the message. One estimate has said that it would 'take a classical computer around 300 trillion years to break a RSA-2048 bit encryption key' (Baumhof, 2019). Yet with quantum computers, due to superposition of the qubits and an algorithm called Shor's Algorithm which 'uses quantum computing to find a period of a function, and then uses some more classical math to use that period to factor the modulus into two primes.' (Langkemper, 2017), this can significantly reduce the time it takes to calculate the RSA-2048 bit key, with one estimate claiming that a perfect quantum computer could break it within 10 seconds.

The other property that qubits possess is quantum entanglement, a phenomenon so strange that Albert Einstein once described it as 'Spooky action at a distance'. To put it simply, it is a phenomenon in which the quantum states of two or more particles cannot be described independently of each other, even if there is a spatial distance between them. Entanglement occurs in situations where we have partial knowledge of the state of two systems. This is due to the fundamental laws of conservation. One analogy used by Amar Vutha from the University of Toronto

was imagining ‘a pair of quantum particles (say atoms) that start off with a total of 100 units of energy’, (Vutha, 2019). If you and a friend decide to ‘share’ the units of energy, then by conservation of energy, you can determine the units of energy possessed by your friend, no matter how far you are away from each other. For example, if you possess 70 units of energy, then you can determine that your friend has 30 units of energy. The energy you get from sharing is not definite, for example, you could receive maybe 20 units or possibly 70 units, yet there still will be 100 units of energy in total.



This property of qubits can be used to realise certain protocols of quantum cryptography. One particular aspect of quantum cryptography where entanglement seems to be pivotal in is in ‘Quantum Key Distribution’. With quantum computers seemingly being able to break currently secure encryption methods, there is a need to implement secure encryption techniques that even quantum computers may still struggle break. Quantum Key Distribution (QKD) is one such technique and it allows the two communicators to detect anyone eavesdropping to gain knowledge of the encryption key. By using quantum entanglement, you can implement a system that transmits information using quantum states and communication can be implemented that can detect eavesdropping. If the eavesdropping of the communication is above a certain level, then a secure encryption key will not be produced resulting in the communication ceasing. Furthermore, due to the phenomenon of entanglement, if one particle changes its quantum state, then the other particle in the entangled pair will almost instantly change its state in response. This would result in a very rapid transfer in information which ‘appear[s] as if information can travel faster than the speed of light.’ (Gamble, 2019).

Currently, there are limitations for why quantum computers have not become mainstream. One such limitation is the fragile nature of the qubits. In order for certain qubits to remain stable, you will need a very low temperature, with one estimate putting this number to be ‘about 20 millikelvins—250 times colder than deep space’ (Greenemeier, 2018). Yet, once we overcome these limitations, we will be able to utilise this technology for a number of exciting prospects. From enhanced drug development to improved artificial intelligence, quantum computing has the potential to revolutionise the field of computing.

Nazir Sirajudeen

BIBLIOGRAPHY

Baumhof, A. (2019, June 13). *Breaking RSA Encryption – an Update on the State-of-the-Art*. Retrieved from Quintessence Labs: https://www.quintessencelabs.com/blog/breaking-rsa-encryption-update-state-art/

Gamble, S. (2019). *Quantum Computing: What It Is, Why We Want It, and How We're Trying to Get It*. Retrieved from NCBI: https://www.ncbi.nlm.nih.gov/books/NBK538701/

Greenemeier, L. (2018, May 30). *How Close Are We—Really—to Building a Quantum Computer?* . Retrieved from Scientific American: https://www.scientificamerican.com/article/how-close-are-we-really-to-building-a-quantum-computer/

Institute for Quantum Computing. (n.d.). *Quantum computing 101*. Retrieved from University of Waterloo: https://uwaterloo.ca/institute-for-quantum-computing/quantum-computing-101

Katwala, A. (2020, March 5). *Quantum computers will change the world (if they work)*. Retrieved from Wired: https://www.wired.co.uk/article/quantum-computing-explained

Kramer, M. (2013, August 14). *The Physics Behind Schrödinger's Cat Paradox*. Retrieved from National Geographic: https://www.nationalgeographic.com/news/2013/8/130812-physics-schrodinger-erwin-google-doodle-cat-paradox-science/

Langkemper, S. (2017, December 6). *Breaking cryptography using quantum computers*. Retrieved from Sjoerd Langkemper: https://www.sjoerdlangkemper.nl/2017/12/06/cryptography-and-quantum-computers/

Science Alert. (2019). *How Do Quantum Computers Work?* Retrieved from Science Alert: https://www.sciencealert.com/quantum-computers

Tech Insights for Professionals. (2019, February 14). *What is Quantum Computing (And Why Do We Need It)?* Retrieved from Insight for Professionals: https://www.insightsforprofessionals.com/it/leadership/what-is-quantum-computing

Thompson, A. (2016, October 12). *Scientists Have Made Transistors Smaller Than We Thought Possible*. Retrieved from Popular Mechanics: https://www.popularmechanics.com/technology/a23353/1nm-transistor-gate/

Vutha, A. (2019, May 17). *What is quantum entanglement?* Retrieved from Cosmos: https://cosmosmagazine.com/physics/what-is-quantum-entanglement

Latent Tuberculosis

Vlad Turapov discusses the effects and treatments for M. tuberculosis

Tuberculosis (TB) is a deadly and infectious disease caused by the pathogenic bacterium, *Mycobacterium tuberculosis*. In 2018, approximately 10 million people were infected with TB and 1.5 million people succumbed to it, making it one of the top ten causes of death in the world (WHO, 2019). The symptoms of TB include a constant cough for over three weeks which may produce blood, weight loss, night sweats and fever (NHS, 2019). Not all people who are infected with *M. tuberculosis* show these symptoms, and they are said to have latent tuberculosis.

Fashionable TB

In the 18th century, tuberculosis was considered fashionable. Many women would alter their appearance to have the thinness, paleness, 'rosy cheeks' and 'sparkling eyes' that were associated with sufferers of TB. (Meier et al., 2018)

M. tuberculosis enters the lungs by travelling in droplets that are inhaled. When reaching the alveoli, the bacteria are engulfed by alveolar macrophages (Davis and Ramakrishnan, 2009). Most bacteria are killed by the defence mechanisms of the macrophage; however, some can survive and replicate in the phagosome of the macrophage. These bacteria can alter the macrophage environment by preventing the fusion of the phagosome with lysosomes, resulting in an ideal pH for the *M. tuberculosis* bacteria to thrive. After multiplying several times, the *M. tuberculosis* cells kill their host macrophage and spread to other macrophages. The immune system responds by forming granulomas, localised areas of inflammation with a specific structure, to prevent the spread of the bacteria. This is the stage at which the immune system can contain the infection and an infected person develops latent tuberculosis. Most latently infected patients will never develop the active disease. If at any point the immune system becomes weakened, the granuloma may break, and the *M. tuberculosis* cells can become active again. They damage surrounding lung tissue and eventually form a cavity. This is characterised by the persistent, sometimes bloody cough. In some cases, millions of *M. tuberculosis* cells disseminate into the bloodstream and an extrapulmonary tuberculosis infection occurs.

Treatment depends on the type of tuberculosis infection a patient has; however, this usually involves a combination of several drugs to prevent the occurrence of drug resistance. Latent tuberculosis requires taking rifampicin and isoniazid for three months or taking isoniazid independently for six months (NHS, 2019). Rifampicin binds to and inactivates the enzyme RNA-polymerase, preventing the bacteria from reproducing and eventually causing it to die out. Isoniazid is thought to impair the metabolic function of *M. tuberculosis* by binding to an enzyme called NAD which is important for metabolism. It also prevents the production of mycolic acids, therefore damaging the cell wall (Horsburgh et al., 2015).

Pulmonary TB and extrapulmonary TB are both treated with pyrazinamide and ethambutol for two months, as well as the two drugs used for Latent tuberculosis for six months. The function of pyrazinamide and ethambutol is to kill as many tuberculosis cells as possible in the first two months. Rifampicin and isoniazid kill the remaining cells in the following four months. Extrapulmonary TB in vital areas, such as the brain, may also require a drug to reduce swelling (Horsburgh et al., 2015). The recovery process for TB requires heavy medication and is therefore a difficult and gruelling undertaking for most patients.

There are strains of *M. tuberculosis* that are resistant to multiple antibiotics. This means that some of the drugs previously mentioned may be ineffective. If the multidrug-resistant TB is latent, no treatment is carried out. If active, treatment over an extended period can be effective, however it is much harder to combat. A drug called bedaquiline is an example of a drug used specifically for multidrug-resistant TB (Andries et al., 2005). It was originally thought to bind to and inactivate the enzyme DNA gyrase in *M.*

tuberculosis, however this could not be proven. Instead, it was discovered that bedaquiline kills *M. tuberculosis* by binding to the enzyme ATP synthase. ATP synthase is necessary to produce Adenosine Triphosphate (ATP) and is almost identical in all life forms. ATP is the "energy currency" for all cells, it is vital for transferring energy within an organism and a lack of it will result in death (Lane, 2003). Therefore, a drug that disables ATP synthase generally causes more harm than good. However, after further inspection it was concluded that bedaquiline actually binds to a part of ATP synthase that is unique to the variant produced by *M. tuberculosis.* This means the drug can be used without posing a serious threat to the patient to treat both latent and active TB.

Despite various global efforts to cure TB, this ancient disease remains a massive threat to many lives. Therefore, the World Health Organisation has developed the End TB strategy to eradicate TB, with a vision to achieve "A world free of TB" by 2035 (WHO, 2015).

Vlad Turapov

BIBLIOGRAPHY

Andries K, Verhasselt P, Guillemont J, et al. (2005) A diarylquinoline drug active on the ATP synthase of Mycobacterium tuberculosis. *Science* 307(5707): 223–227.

Davis JM and Ramakrishnan L (2009) The role of the granuloma in expansion and dissemination of early tuberculous infection. *Cell* 136(1): 37–49.

Horsburgh CR Jr, Barry CE 3rd, Lange C.(2015) Treatment of Tuberculosis. N Engl J Med. 2015 Nov 26;373(22):2149-60

Lane N (2003) *Oxygen: The Molecule That Made the World*. Oxford University Press.

Meier A, Di Liscia V, Vartanian H, et al. (2018) How Tuberculosis Symptoms Became Ideals of Beauty in the 19th Century. Available at: https://hyperallergic.com/415421/consumptive-chic-a-history-of-beaty-fashion-disease/

NHS (n.d.) Tuberculosis (TB). Available at: https://www.nhs.uk/conditions/tuberculosis-tb/

WHO End TB Strategy 2015. Available at: https://www.who.int/tb/post2015_strategy/en/

WHO Tuberculosis Report 2019 (TB). Available at: https://www.who.int/news-room/fact-sheets/detail/tuberculosis

Did SpaceX get it wrong?

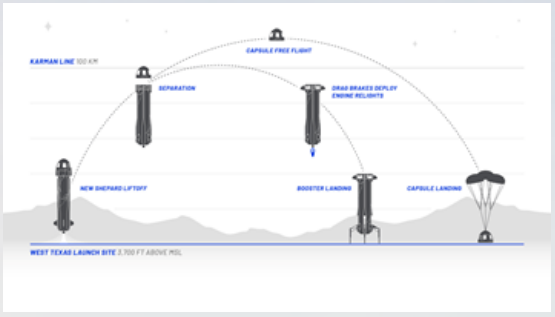
Annabelle Onions discusses whether the Falcon Heavy used the right method for rocket retrieval

In 2018, 113 rockets were launched worldwide and in recent years this number has only grown. As a result of this a growing issue within the industry is the cost of launching these rockets and many companies are now desperate to minimize this to create a much more sustainable industry. After all, if we look at the example of the Falcon 9 rocket developed by SpaceX, the cost of the fuel only contributed to around 0.4% of the actual launch cost. Of course, in the world of rockets, 0.4% is equal to a cost of around $200 000 but in the large scheme of things this is tiny. Thus, you can see the need for coming up with a way to reuse the rockets themselves.

No doubt many readers will have seen the launch of the Falcon Heavy (a new SpaceX rocket) in February 2018 and been amazed when they successfully managed to land 2 separated boosters on launch pads. This was an incredible feat and if you have not seen the video of the launch, I hugely recommend it. As well as recording an insanely progressive achievement, it's also set to Life on Mars by David Bowie which makes it the most stylish launch I've ever seen. Glorious test flight aside, the Falcon Heavy broadcast to the world the start of rocket recovery systems but I can't help wondering looking at all the factors whether the simultaneous booster landing was the right method to go for.

Obviously, the costs for making the Falcon Heavy were huge (as are the costs for anything in the space industry) and currently the starting price for such a rocket is $90 million (in case anyone was interested in buying one). None of this matter particularly as the reusability of the rocket makes it much more cost efficient than any others, however, something very important in terms of the method that was used to make the rocket reusable is the cost of fuel. It goes without saying that if you want to land boosters that are falling from thousands of meters above the earth then you need to slow them down. Now parachutes can be used for this but if you're looking for a controlled upright landing then you require a lot of fuel and all this fuel must be carried throughout the rocket launch. This means that not only do you need large amounts of extra fuel for the boosters, but you need more fuel for the launch as the mass of the rocket is heavier. Now indeed these costs are nothing compared to the cost of new rocket parts, but the increased amount of fuel does result in more carbon dioxide being released (a refined kerosene is used as fuel) and there are other methods out there.

There are various other private rocket companies in the world that are attempting to follow in the footsteps of SpaceX and use similar methods of rocket retrieval. For example, a company called Blue Origin have successfully conducted test flights which have got a capsule across the Kármán line (edge of space) for a short period of time (long enough for experiments to take place if they were on board). Following this they then managed to return both capsule and booster after an 11-minute flight. Though much the same method is used as SpaceX with fueled boosters the aim is slightly different looking into short trips into space which reusable rockets make much more possible. These rockets may well be the key to kickstarting the space tourism industry.



Despite the fact the methods of SpaceX and Blue Origin have proved successful, personally I am much more interested in current projects being conducted by Rocket Lab and the ULA. The approaches they are working on are much more sustainable and just as ingenious. Both companies are separately working on retrieval methods using large amounts of parachutes and parafoils to slow down boosters and helicopters. Initially this may sound a bit bizarre but the idea is that once a section of the rocket is reasonably slowed down, a helicopter with a huge hook attached to it will then swoop down and hook onto the falling part safely retrieving it and allowing it to be reused. With this

method no excess fuel needs to be carried in the rocket making the retrieval system much greener and it much simpler to execute once a few engineering issues have been solved (which ULA has already managed with their project 'Vulcan').

This is when I shall return to the title of this article: 'Did SpaceX get it wrong?'. Now what this company managed to achieve through the Falcon Heavy was incredible and revolutionary, but I can't help wondering whether further research into other methods of recovery would have been more profitable. For example, a system using the ideas of the ULA and Rocket Lab would have cost less money, both in terms of fuel and in terms of the $500 million that Elon Musk put into developing his system and rocket.

With all this being said, there are other factors in play. The goal of SpaceX from the start has always been to get man to Mars (or this is what I assume from their advertising and general announcements) and their recovery system is one that could be replicated on the 'red planet' maybe not so long from now. In addition, the re-use system will allow the company to increase their flight rates which will get them a greater income again bringing them closer to Mars. So, all in all, I would have to say no, SpaceX did not get it wrong. Yes, they have faults in their recovery system, yes, it looks like there could be better methods out there, but the success of their initial Falcon Heavy test flight was unprecedented. Elon Musk and his company managed to inspire many to start thinking about reusability and it is very possible that this technology could be used in the journey to Mars. Therefore, although it may not be the most cost effective or green way of reusing rockets, SpaceX were in no way wrong, it's just since the Falcon Heavy test flight other companies have come up with better ways. I do have to say, though, I doubt any of them will be quite as stylish.

Annabelle Onions

BIBLIOGRAPHY

SpaceX, 2018, Falcon Heavy, available from: https://www.spacex.com/falcon-heavy [30 March 2020].

Blue Origin, 2015, New Shepard, available from: https://www.blueorigin.com/new-shepard/ [30 March 2020].

Etherington, D, 2019, Rocket Lab's Electron Rocket Will Go Reusable, available from: https://techcrunch.com/2019/08/06/rocket-labs-electron-rocket-will-go-reusable-with-the-company-aiming-for-mid-air-helicopter-recovery/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAAyE4gyu2_pT52MSq_FJd0l8qSBiXRb3N1C01Z1sSb2rO6VSSPVjrUbyRi2vH5EVqGD-jg_f8CY_gGSvKfaAfIE_mAIr35ixhnulqNuuQqx4WU9qZljK-g5Q4jjvJ760XvL4L8zpEHgtnXFrdLhLG2qQctbO9P_A6rTgpZ14vDRi [30 March 2020].

ULA, 2015, ULA Innovation: SMART Reusability, available from: https://www.youtube.com/watch?v=lftGq6QVFFI&feature=youtu.be [30 March 2020].

NASA Spaceflight Forum, 2014, Speed and Altitude at First Stage Separation of Falcon Heavy, available from: https://www.youtube.com/watch?v=lftGq6QVFFI&feature=youtu.be [30 March 2020].

Rocket Lab, 2020, Electron, available from: https://www.rocketlabusa.com/electron/ [30 March 2020].