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Contributions to this Issue:

This edition would not have been possible without the hard work of our dedicated editorial team. We would also like to thank Mr. Reeves and Dr. Griffin for their guidance and support for running the journal.

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Editors' Note

Young Scientists' Journal

ADVENT EDITION 2024

We are delighted to present to you the Advent 2024 edition of the LGS Young Scientists' Journal. Our journal aims to cultivate a passion for science, technology, engineering, and mathematics among students throughout the school.

We proudly provide a platform for students to exhibit their enthusiasm and excitement for research in various fields. This term's edition features a diverse array of articles on topics such as UFC injuries, human brain banks, supersonic planes, futuristic glasses, radiotherapy, and much more. We are amazed by the remarkable contributions this term, and we encourage even more students to participate in the next edition. We hope you enjoy the read!

Cover Images:

'UFC 229: Khabib v McGregor' by Christian Petersen/Zuffa LLC

'Human Brain in Brain Bank' by James King-Holmes

'Lung Cancer Radiotherapy' by SciencePhotoLibrary

"Soyuz Flyaround Imagery of STS-134 Endeavour Docked to the ISS' by NASA

Key word definitions are from the Cambridge and Oxford English Dictionaries.

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ADVENT 2024

Human Brain Banks

By Cunyi George Xu (Year 12)

Key Words:

Neurodegenerative: involving the nerves gradually stopping working

Neuroscience: the scientific study of the nervous system and the brain

Alzheimer's: a disease of the brain that results in the gradual loss of memory, speech, movement, and the ability to think clearly

What Are Human Brain Banks?

Human brain banks are non-profit organizations which collect and store donated brain tissues. They also provide researchers with the essential samples they need to study the brain. The brains in these banks come from both healthy individuals and people with neurodegenerative diseases, from a wide range of ages (sbb.neura.edu.au, n.d.). This offers valuable insights for scientific research.

In neuroscience, many big questions remain unanswered. Where does consciousness lie? Why do we need sleep? Can we cure neurodegenerative diseases? Human brain banks play a vital role in helping scientists tackle these mysteries (Science.org, 2021).

The Alzheimer's Disease Forum (Alzforum.org, 2015), established in 1996, is an organization focused on advancing research into Alzheimer's disease. It provides a global map of brain banks dedicated to studying neurodegenerative disease. This map shows 144 brain banks worldwide, including 81 in the United States, 16 in the United Kingdom, 10 in Australia, 6 in Germany, 3 in Canada, and 1 in the Netherlands (Alzforum.org, 2015).

Additionally, China has established 21 brain banks to date, which together form the China Human Brain Banking Consortium (Alzforum.org, 2015). These brain banks store large amounts of postmortem human brain tissue, which is essential for research. For example, the UK Brain Bank Network holds approximately 14,000 brain samples, the US National Alzheimer's Coordinating Center stores about 13,000, the NIH NeuroBioBank holds around 4,000, the Netherlands Brain Bank around 4000, Germany around 3000, the China Human Brain Banking Consortium around 2200, and the Sydney Brain Bank around 700 (Alzforum.org, 2015). The global distribution of brain banks and the corresponding number of stored brains are illustrated in Figure 1.

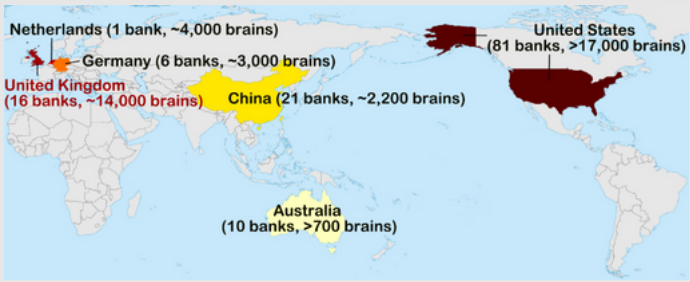

Figure 1: The global distribution of brain banks and the corresponding number of stored brain samples (Xu, 2024).

The UK Brain Bank Network, which was founded in 2009, is one of the most representative brain bank networks. It includes 10 brain banks and has offices in Swindon and London (Brainsfordementiaresearch.org, 2019). The network ensures that the brain tissues collected meet high standards by following strict procedures for collection and processing, keeping detailed clinical data records, sourcing from a wide range of donors, using advanced storage facilities, and conducting regular quality checks (Brainsfordementiaresearch.org, 2019).

Key Words:

Interdisciplinary: involving two or more different subjects or areas of knowledge

Parkinson's: a disease of the nervous system that makes the muscles become stiff and the body shake

Pathology: the medical characteristics of a disease

In recent years, countries around the world have increasingly recognised how important neuroscience and neurology are for human health. In 2013, the United States took the lead by announcing the BRAIN Initiative, which stands for the Brain Research through Advancing Innovative Neurotechnologies Initiative, which aims to transform our understanding of the brain, boost innovation in brain-related technology, and push forward progress in both science and industry (Nih.gov, 2024). In the same year, the European Union started the Human Brain Project, which focuses on using interdisciplinary research and technology to better understand the brain's complex structure and functions (www.humanbrainproject.eu, n.d.). Japan (2014), Australia (2016), and China (2016) have also subsequently launched their own Brain Projects to advance brain research (Nih.gov, 2024).

Why Are So Many Countries Keen On Establishing Human Brain Banks?

Advancing Neuroscience Research

The human brain, composed of the cerebrum, brainstem, and cerebellum, is often regarded as the most complex organ in nature, representing the peak of billions of years of evolutionary progress (Wikipedia Contributors, 2019). Its incredible complexity makes it a key focus of scientific research. By collecting brain tissues, brain banks provide essential materials for studying how the brain works, how neurals function, and what causes brain diseases, helping to speed up important discoveries in neuroscience (Alzforum.org, 2015).

Rising Cases of Neurological Diseases

As populations around the world age, the number of people affected by neurodegenerative diseases, such as Alzheimer's and Parkinson's Disease, is growing quickly (Jack et al., 2018). This rise puts a heavy burden on healthcare systems and economies. Brain research initiatives and brain banks are important for studying how these diseases develop, aiding in early diagnosis and discovery of more effective treatments (Alzforum.org, 2015).

Precision Diagnosis of Neurological Diseases

Over 110 years ago, Doctor Alois Alzheimer discovered Alzheimer's disease by combining clinical observations with pathological studies on brain tissue after death (Jack et al., 2018). Since then, the approach, linking postmortem brain analysis with symptoms observed in life, was proven effective for understanding the pathophysiology of neurological diseases (Jack et al., 2018). It has helped uncover conditions like prion diseases and Lewy body dementia (Jack et al., 2018). However, clinical diagnoses made while a person is alive can often miss underlying brain pathology, especially when multiple conditions are present, leading to misdiagnosis rates as high as 20-25% (Jack et al., 2018). Therefore, developing new diagnostic tools using brain bank samples is so important for accurately diagnosing neurological disorders.

Overcoming the Limitations of Animal Models

Although animal models are essential to neuroscience research, they have some inherent limitations. Compared to humans, animals possess thinner cerebral cortices, fewer cortical folds and smaller brain surface areas, leading to fewer neurons and reduced cognitive complexity (Wikipedia Contributors, 2019). These differences help explain why humans possess superior capabilities in areas such as problem-solving, emotional understanding, language, and social behaviours (Wikipedia Contributors, 2019). Animals have much shorter lives. For example,

mice live about 2 years, rats about 3 years, and non-human primates (rhesus monkeys) about 20 years (Wikipedia Contributors, 2019). These lifespan differences limit the ability of animal models to mimic the chronic progression of human diseases, particularly age-related neurodegenerative disorders (Wang & Feng, 2024). Ultimately, animal models cannot fully replicate the complexity of the human brain, making human brain banks invaluable, as they provide unique and valuable samples for directly studying human brain function and neurological diseases (Wang & Feng, 2024).

The Standard Procedure For Collecting Human Brain Tissues

The following text outlines the general principles and procedures for collecting human brain tissues, according to the NIH NeuroBioBank (United States), Netherlands Brain Bank (Netherlands), Sydney Brain Bank (Australia), and National Human Brain Bank for Development and Function (China), shown in Figure 2. After receiving the body, trained personnel obtain informed consent from the deceased's next of kin or legal representatives, and collect relevant medical records, questionnaires, and other pertinent information (Nih.gov, 2024). The brain is then removed from the skull, weighed, and photographed (Nih.gov, 2024). A detailed inspection of the brain follows, including checking for regional atrophy, visible lesions, and signs of blood vessels for vascular disease (Nih.gov, 2024). Additionally, other samples such as plasma, cerebrospinal fluid, and cervical spinal cord are collected (Bank, 2024). Usually, the right hemisphere of the brain is preserved in formalin for tissue characterization and histological studies, while the left hemisphere is frozen for studying proteins and genes (sbb.neura.edu.au, n.d.). The left hemisphere is sectioned into coronal slices, each approximately 0.5-1.0 cm thick, photographed, flash-frozen, and stored at -80°C (Bank, 2024). When researchers submit a request, specific brain regions like the hippocampus, substantia nigra, and amygdala are carefully dissected and preserved (Bank, 2024). In China's brain banks, the hippocampus is further divided into five separate regions for individual storage, including CA1 (cornu ammonis, CA), CA2, CA3, CA4 (containing the dentate gyrus), and the entorhinal cortex (Qiu et al., 2018). Finally, brain tissue samples are analysed using special staining techniques, including HE staining, ABC scoring, et al, to determine pathological changes and disease types (Qiu et al., 2019).

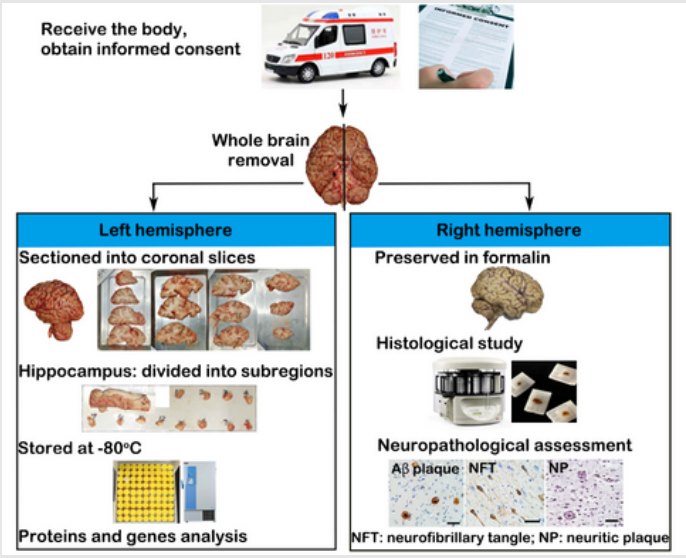

Figure 2. The process of human brain tissue collection (Xu, 2024).

Challenges And Opportunities Faced By Human Brain Banks

One of the main obstacles is the difficulty in encouraging brain donations (Wang & Feng, 2024). Despite the efforts of brain bank staff and neurologists, patients often misunderstand the concept, feeling uncomfortable or even resisting the idea (Wang & Feng, 2024). Chinese Prof. Duan once shared a compelling case involving a patient diagnosed with Huntington's disease - initially, after being persuaded by his doctor, the patient agreed to donate his brain for research upon his passing - however, unfortunately, he later changed his mind and decided not to donate (Wang & Feng, 2024). It wasn't until his child showed similar symptoms that the patient reconsidered (Wang & Feng,

2024). He came to realize that brain donation might help end the family's "curse" (Wang & Feng, 2024). The shortage of willing donors is a major challenge for brain banks globally (Wang & Feng, 2024).

Secondly, the key goal for brain banks is to have donors agree to join the donor cohort during their lifetime, allowing researchers to track their health over time (Wang & Feng, 2024). That is, there donors would undergo regular cognitive tests, brain imaging (like MRI scans), and blood tests, which provide valuable clinical data (Nih.gov, 2024). Then, when the donor passes away, they would donate their brain for further study, giving researchers both the detailed clinical information collected during life and the opportunity to examine brain tissue post-mortem (Wang & Feng, 2024). However, this process doesn't always go as planned. Some individuals, despite agreeing to participate and taking part in assessments, may decide not to donate their brain later on (Wang & Feng, 2024). Others donate their brain after death without having undergone the regular health assessments, which means researchers miss out on crucial clinical data (Wang & Feng, 2024). This gap between the ideal scenario and reality is another challenge brain banks face in developing comprehensive resources for research.

The announcement of the 2024 Nobel Prize marks the unstoppable era of Artificial Intelligence (AI). However, the understanding of the mechanisms of human brain is still far from even on very basic questions. Nevertheless, the deep problems of the human brain must ultimately be solved by the human brain itself. Human Brain banks will provide fundamental and essential support for the development of AI. Yet, no one truly knows what AI will bring to human being.

Key Words:

Huntington's disease: a rare genetic disease of the nervous system that causes uncontrollable physical movements and eventual dementia

AI (artificial intelligence): the use or study of computer systems or machines that have some of the qualities that the human brain has, such as the ability to interpret and produce language in a way that seems human, recognize or create images, solve problems, and learn from data supplied to them

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ADVENT 2024

Key Words:

Cosmos: the universe considered as a system with an order and pattern

Overpopulation: when there are too many people for the amount of food, materials, and space available

Galaxy: one of the independent groups of stars in the universe

Breakthrough: an important discovery or event that helps to improve a situation or provide an answer to a problem

Charting the Cosmos: 5 of the Greatest Discoveries in the 21st Century

By Yunus Hussein-Sheik (Year 8)

Humans have always been driven by curiosity, a trait that has shaped our history since the start of time. Initially, this curiosity led us to explore our own planet - from the Vikings' discovery of Greenland to Admiral Fabian Gottlieb von Bellingshausen's expedition to Antarctica. As we uncovered more of our world, some turned their attention to the depths of the ocean, while others sought out something even more vast and mysterious: the cosmos. In recent years, the fascination with space has intensified, driven in part by the growing challenges of overpopulation and environmental degradation on Earth. With this surge of interest, profound questions have emerged: Are we alone in the universe? Could another planet support life? Is the universe infinite? Do parallel universes exist? And what came before the universe itself? The recent discovery of the most distant rotating disk galaxy, REBELS-25, has sparked renewed enthusiasm and further inspired a list of the most significant breakthroughs in space exploration to date.

REBELS-25

The most recent out of the list, REBELS-25, was discovered in late September. We see this galaxy from when the universe was only 700 million years old! A mere 5% of how old it is today. What is so surprising is that the galaxy seems to be ordered compared to other galaxies at this time. Other galaxies that have been observed by scientists (at the time) seem to be clumpy and do not have a very defined formation. Galaxies at the time were expected to be small and very messy. This is because, over a long period of time, many of these galaxies merge and become much larger and more organised. REBELS-25 challenges that theory. This is due to its rotating disc, featuring spiral "arms" that curve outward from a dense central region, creating a structure similar to that of the Milky Way. Theories suggest that for a galaxy to have a similar structure to the Milky Way it would take billions of years of development. REBELS-25 challenges our knowledge of the universe at the time. If more evolved structures in this galaxy were to be found it would be one of the greatest breakthroughs in this field as it would be the most distant galaxy observed with this format (Astronomy News, 2024).

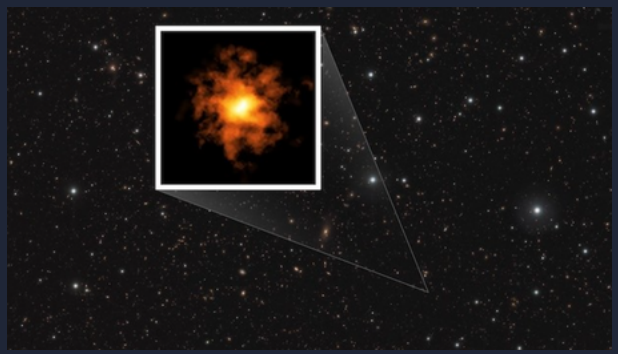

Figure 1. Distant galaxy observed through telescopic imaging (Sci News, 2024).

Mapping of the Milky Way

REBELS-25's look-alike was mapped in 3D by the European Space Agency's (ESA) Gaia mission. This included precise measurement of 1.7 billion stars and revealed images which were never seen before. It pins down the exact location of the stars and with much greater precision the earlier 3D maps. With Gaia's precision scientists have seen the motion of these stars within many global clusters. It was also able to pinpoint at least 14,000 asteroids. This data has been used to derive the orbits of countless global clusters and dwarf galaxies. Gaia is creating a 3D map of more than 2 billion objects right now, and is expected to make even more breakthroughs (ESA, 2018, 2024).

Figure 2. Gaia overview (ESA, 2018).

First Picture of the Supermassive Black Hole that Lies at the Centre of our Galaxy

We stay in the Milky Way with the image of Sagittarius A (a black hole) which, provided great evidence that the object which was in the centre of our galaxy was indeed a black hole. It yields valuable clues about how such giants work. These giants are thought to be in the centre of the majority of galaxies. For many years scientists have been seeing images of stars orbiting around something invisible in the centre of the universe. These findings backed the guess that this invisible, compact, and extremely large thing was a black hole. These images are the first look at this colossus. We cannot see the actual black hole in the image, but we can see the shape of it, through the matter and light that are being pulled into it with immense force (ESA/Webb, 2024).

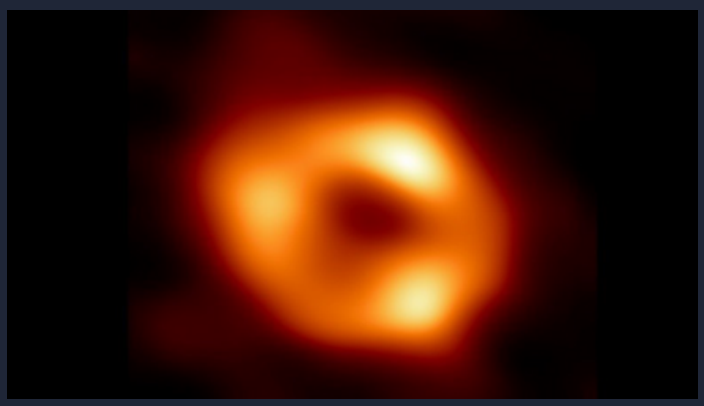

Figure 3. Scientists capture first-ever image of our galaxy's supermassive black hole (NOVA, PBS, 2024).

Kepler-186f

Kepler-186f, discovered in April of 2014, captured the imaginations of scientists and science fiction fans alike. This was because this planet was possibly habitable. It is 557.7 light years away from the Earth. To put that into perspective, it would take the fastest rocket, today, 12 million years to get there. Kepler-186f is just less than 10% larger than the Earth. It is one of 5 planets in its system and orbits about 32.5 million miles away from its star. It takes Kepler-186f 130 days to orbit its red dwarf star. Data suggests that Kepler-186f is in the Goldilocks zone of its star. A Goldilocks zone is somewhere not too far away or close to its host star for liquid water to exist. Liquid water is the foundation for life. Our planet is in the Goldilocks zone of our sun. This means that Kepler-186f could potentially have life. Maybe we are not alone after all? The other planets however, all took less than a month to orbit the red dwarf, meaning that they are all too hot to support life. What is so exciting about this planet is that it is the first Earth-sized planet that could host life. Astronomers have found other planets that are possibly habitable, but this planet was the first with a similar size to Earth. Its

Key Words:

Colossus: a person or thing of great size, influence, or ability

Light year: the distance that light travels in one year (about 9.5 trillion kilometres)

Atmosphere: the mixture of gases around the earth

Spectrometer: a piece of equipment that scientists use to record and measure spectra (the set of colours into which a beam of light can be separated, or a range of waves, such as light waves or radio waves)

Methane: a gas with no smell or colour, often used as a fuel

position and size mean that life could thrive, in theory. Kepler-186f is on the edge of the habitable zone but its larger size means that it could have a thicker atmosphere keeping the planet warm. However, scientists still cannot prove what its atmosphere consists of and there is no certainty that it has life. The star Kepler-186f orbits is much dimmer as well as cooler than our sun. Its star is half the mass of our sun (Space, 2014).

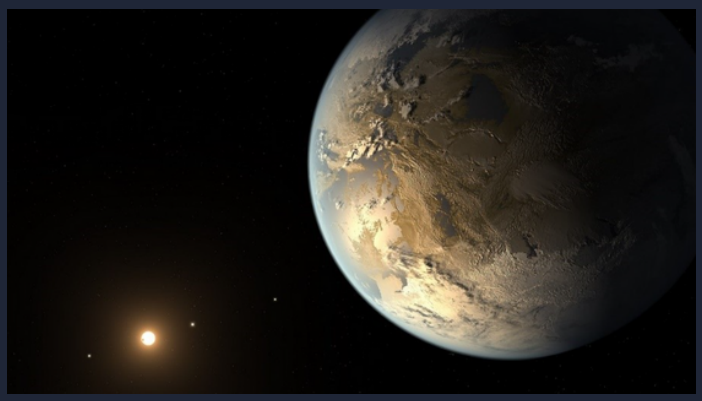

Figure 4. Kepler-186f (Wikipedia, 2024).

Methane on Mars

We stay in the field of life exploration with a mystery, which started in 2004 when the Mars Express orbiter with an instrument called the Planetary Fourier Spectrometer (an apparatus used to measure gases), measured the first presence of methane on Mars. The significance of this discovery is that methane may indicate bacterial life on Mars. The mystery surrounding this discovery however is that the Mars Express orbiter was unable to detect the methane again. Since 2012 the Curiosity Rover has constantly detected methane on Mars. However, the methane has been acting rather strangely as it only appears at night and fluctuates seasonally; it spikes 40 times more than usual sometimes. Scientists' hypothesis is that the heat weakens the ice which allows the methane to spew out from the ice at night. The surprising fact is that the methane is not in the atmosphere so how did the Mars Express orbiter detect methane? (Mars News, 2024) (Wikipedia, 2024) (Nasa.gov, (2024).

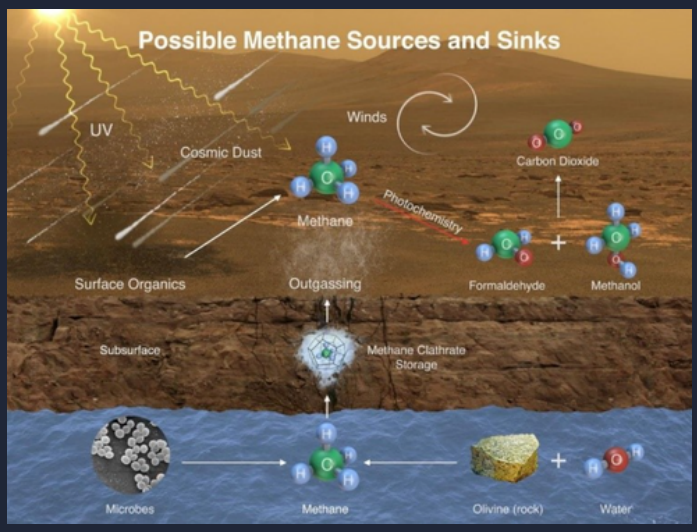

Figure 5. Mars surface with methane clouds (Space, 2024).

As humans we are always trying to make sense of the world around us. Without our curiosity, these discoveries that have paved the way for future missions would not have been made. Many of these discoveries challenge astronomers' knowledge of the cosmos - these are 5 of the most groundbreaking discoveries since 2000 as of December 2024.

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ADVENT 2024

The Human Touch: Can AI Replace Skilled Dentists?

By Ruby Patel (Year 11)

Key Words:

Diagnostics: identifying a particular illness using a combination of signs and symptoms

Orthodontics: the job or activity of correcting the position of teeth and dealing with and preventing problems of the teeth

Preliminary: coming before a more important action or event, especially introducing or preparing for it

Imagine a world where your dentist is a machine, capable of diagnosing oral health issues with near-perfect accuracy. While this may sound difficult to believe, it is quickly turning into a reality. AI is becoming increasingly used in dentistry to enhance diagnostics and plan treatments, making it one of the most transformative technologies in modern healthcare (Wood, 2022).

Artificial intelligence (AI) can now detect cavities on dental X-rays with an accuracy of over 90% in some cases, outperforming even skilled professionals (Nguyen et al., 2021). AI is also being used to create treatment plans, streamline administrative processes, and even make dentistry more accessible through tele-dentistry. But can machines really take over the role of a dentist, or is there something about the human connection that AI just can't replace?

The Power of AI in Dentistry

AI is revolutionising dental care in ways that would have been unthinkable a decade ago with its ability to improve precision and efficiency. With the help of AI, dental practices can provide better care for patients in less time. For example, AI technology can analyse dental scans much faster than humans, helping professionals identify dental problems before they become a major issue. This can improve the chances of successful treatment, but also reduce treatment time and cost (Schwendicke, Samek and Krois, 2020).

AI also plays a significant role in the advancement of orthodontics. Companies like Invisalign use AI-powered software to predict how a patient's teeth will move over time, making it easier to create treatment plans that fit their needs. By analysing thousands of data points, AI can predict tooth movements with amazing accuracy, allowing for the creation of more accurate aligners for a faster, more comfortable treatment (Schwendicke, Samek and Krois, 2020).

Furthermore, AI is being used to automate daily administrative tasks such as appointment scheduling, billing and even patient records, allowing dental practices to run more smoothly. A study by Chen, Stanley and Att (2020) found that implementing AI in dental practices increased administrative efficiency by 30%, allowing dentists to spend more time focusing on patient care.

AI is also breaking down barriers to access through tele-dentistry, which can be powered by AI to make dental care more accessible. Patients can upload photos of their teeth to receive preliminary diagnoses and advice without visiting a surgery. This is especially valuable for people who live in areas where access to dental care is limited.

A study by Wood (2022) highlighted that AI-powered tele-dentistry platforms reduced patient waiting times by 40% and increased the likelihood of early intervention.

The Limitations of AI

As impressive as AI is, it's far from perfect. AI systems are heavily dependent on high-quality data to function efficiently. For example, if the data used to train an AI model is biased or incomplete, the system might produce inaccurate results, leading to incorrect diagnoses and treatment plans. A study by Schwendicke, Samek and Krois (2020) found that while AI excels in tasks like detecting cavities or analysing X-rays, it struggles with nuanced clinical decision-making, such as considering a patient's overall health or unique circumstances when recommending a treatment.

AI's reliance on high-quality imaging and data also presents challenges in real-world settings. For example, in cases where X-rays are blurry or incomplete, AI systems could misinterpret the images, leading to false positives or negatives. This highlights the importance of human expertise in ensuring accurate diagnoses.

Why the Human Touch Matters

AI lacks emotional understanding and communication skills that are essential for providing personalised, empathetic care that no machine can replicate. Dentistry isn't just about diagnosing and treating teeth, it's about building trust and providing comfort and reassurance, especially since many people experience stress about dental visits. Studies have shown that around 36% of people have dental anxiety, and nearly 12% suffer from extreme dental fear (Appukuttan, 2016). In these situations, the reassuring presence of a dentist who can listen and adapt their approach is irreplaceable.

As much as AI can help with technical aspects, it is unable to replicate the 'human touch' which is an important part of what makes dentists valuable. Therefore, while AI is a very useful and powerful tool, it's clear that it cannot fully replace dentists. Rather, it should be seen as a tool that enhances their work, supporting them in delivering better care, but not taking over the vital human role. This was the conclusion drawn by both the researchers Schwendicke, Samek, Krois (2020) and the researcher Chen, (2020).

Key Words:

Cavity: a hole, or an empty space between two surfaces

Nuanced: made slightly different in appearance, meaning, sound, etc.

Empathy: the ability to share someone else's feelings or experiences by imagining what it would be like to be in that person's situation

The human touch: a friendly and pleasant way of treating other people that makes them feel relaxed:

The importance of the 'human touch' extends beyond emotional support. Dentists also excel at interpreting complex, real-world scenarios that require a deep understanding of context. A research study by Schwendicke, Samek and Krois (2020) highlights that while AI is excellent at identifying patterns in imaging, it cannot yet interpret these findings in the broader scope of a patient's overall health or lifestyle, which is important for creating long-term, sustainable treatment plans. A dentist's ability to consider multiple factors and form an accurate diagnosis is something that AI currently can't replicate.

Furthermore, communication is crucial in dentistry as dentists need to explain procedures, discuss options and address patient concerns in a caring, understanding manner and with consent. Machines, no matter how advanced, cannot replicate this human touch, which is important in quality dental care.

The Future of AI in Dentistry

Will robots be taking over dental surgeries anytime soon? Not likely. The future of AI in dentistry is not about replacing dentists but creating a partnership where human expertise and AI work together to deliver the best care possible. AI can manage repetitive, technical tasks like analysing X-rays or shaping treatment plans, while dentists focus on providing personalised care and addressing the human side of dentistry. Research by Schwendicke, Samek and Krois (2020) found that when AI and dentists worked together, diagnostic accuracy improved by 15%, emphasising how collaboration between AI and dentists leads to better outcomes than either could achieve alone.

Conclusion

AI is undoubtedly transforming the field of dentistry by enhancing accuracy, efficiency and accessibility. From diagnosing cavities to streamlining treatment plans, it's a powerful tool that supports modern dental practices. However, even the smartest machines can't replace the empathy, adaptability and critical thinking of a skilled dentist.

The future of dentistry is not about replacing humans with machines, but harnessing the best of both worlds. By combining the precision of AI with the compassion and care of the 'human touch', we can create a dental experience that is smarter, more efficient, and, perhaps, a little less intimidating for patients.

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Key Words:

Exhilarating: causing feelings of happiness or enthusiasm

Bullet train: a very fast train with a smooth, pointed shape, especially one used in Japan

Friction: the force that makes it difficult for one object to slide along the surface of another or to move through a liquid or gas

Hover: to stay in one place in the air, usually by moving the wings quickly

Gravitational: relating to gravity or gravitation (the force that attracts objects towards one another)

ADVENT 2024

Shinkansen – The Most Exhilarating Train on Earth?

By Gagan Kodivalasa (Year 8)

The Shinkansen is the world's most famous bullet train, topping at a speed of 200mph. That is so fast!

It was such a wonderful creation, however there was so much planning required to build the train.

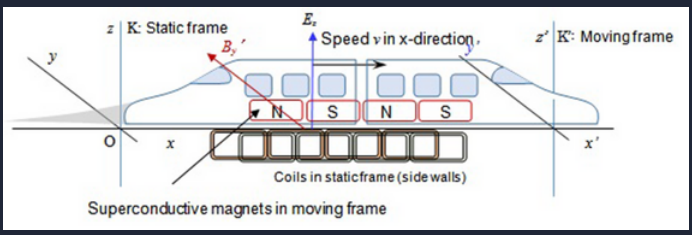

Figure 1. (City, 2020).

Just look at how complicated that plan is! I am sure the workers would have been excited but also confused! It is one of the most complex plans for bullet trains in the world. I mean, it did take 5 years to build the massive thing.

The Shinkansen train is in Japan, and it is so long that there are 1323 seats! I would want to travel by that train! Wouldn't you as well?

They have eliminated the force of friction by creating the bullet train as it hovers above the ground, but air resistance and gravitational force are still present during the journey, slowing the train down. The friction, however, I would say, is the most crucial force for both land and air vehicles.

Figure 2. (Davidson, 2010).

Personally, I think bullet trains are very interesting! How about you? Let's dive into Shinkansen more!

Figure 3. (Kenjo, 2017).

Key Words:

Maglev: short for magnetic levitation, an advanced type of transport system in which a train travels on a magnetic track, often at very high speeds

Levitate: to (cause to) rise and float in the air without any physical support

Half a century ago, on the 10th of October 1964, Tokyo held the Opening Ceremony for Japan's first-ever Olympic Games, which was conducted under an absolutely cloudless blue sky. A few days before that memorable event, another historical moment had been engraved in people's memories. On the 1st of October 1964, the world's first high-speed rail service, the Shinkansen, known as the "bullet train", had been launched between Tokyo and Osaka.

The idea of the Shinkansen was originally conceived to solve the problem of capacity shortage caused by the increasingly strong demand for rail travel in line with Japan's rapid economic growth. By the early 1960s, capacity on the Tokaido Main Line, which connected Osaka with Tokyo, had reached its limit. Every day a number of express trains ran between the two cities, and filling the intervals between them were numerous freight trains and local passenger trains.

The situation required a change, and the plan for change envisaged a new, separate track built to the international standard gauge dedicated to high-speed trains. This track would be the Shinkansen. The word "shinkansen" means "new mainline".

For fifty years, the Shinkansen has carried over 10 billion passengers with an impeccable safety record of "zero passenger fatalities". This safety record has never been blemished – not even when the devastating earthquake and tsunami hit the Tohoku region in March 2011. At the moment the disaster struck, 27 Shinkansen trains were in operation in the region, two of which were running at 168mph. However, due to the early earthquake detection system, trains were immediately and safely halted. Meanwhile, punctuality is another phenomenal feature of the Shinkansen. Despite the frequency of the services, the average delay per trip, including weather-related delays, is under one minute! Thus, the highest standards of safety and reliability are the hallmarks of Japan's high-speed railway system.

Here in the UK, the Shinkansen's technology and design can be discerned in the Hitachi-built "Javelin" trains, which during the London Olympics in 2012 swiftly carried hundreds of thousands of spectators from St Pancras International Train Station to the main site of the Olympic Games at Stratford. Hitachi is one of the most trusted companies involved in the construction of Shinkansen trains in Japan. Safety and reliability are thus assured for its Javelin trains. Japan's first knowledge of railways came from the UK about 150 years ago, and Japan's railways have developed from the roots of that transfer of knowledge. Today, the flow of knowledge and productive interaction between the two countries in this sector is still flourishing.

Coincidentally, on 17 October 2014, fifty years after the introduction of the bullet train, the Japanese Minister of Land, Infrastructure, Transport and Tourism approved plans for the construction of the Chuo Shinkansen between Tokyo (Shinagawa Station) and Nagoya, featuring for the first time the Superconducting Maglev.

This train uses innovative technology to levitate 10cm above the ground, reaching speeds of up to 311mph. In 2027, after the line's completion, passengers will be able to travel from Tokyo to

Nagoya in only forty minutes, compared to the present time of one hour and twenty-eight minutes.

High-speed rail in Japan has been a resounding success and has changed the way people live. Its 50th anniversary is a time for celebration during an ongoing journey. The Shinkansen will continue to go from strength to strength.

While the Shinkansen travels all over the country, you'll find that it runs between Osaka and Tokyo most of all. That's because this tends to be a hotspot zone for commuter traffic. It only takes ten minutes to load up and set a bullet train off to its next destination. You can travel as far as Hakata, from Japan's capital Tokyo, a distance 1100 km (680 miles), in less than five hours! To put it into perspective, the distance from London to Edinburgh is 640 km (400 miles), and a train journey takes 6 hours.

The nickname "Bullet Train" for the Shinkansen originated when the concept was first proposed in the 1930s. When the high-speed train started operating in 1964, it kind of resembled a bullet, so the name stuck. The fact that it could do 130 mph didn't hurt, either.

Shinkansen is now the second fastest train in the world, behind the Maglev. Even though there are faster trains than the Shinkansen, it still has its history written in golden words!

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ADVENT 2024

The Engineering Behind the Concorde: A Supersonic Marvel

By Deena Niran (Year 13)

Key Words:

Mach number: the ratio of an object's speed to the speed of sound

Wave drag: the resistance that an object faces caused by shock waves that form around it

Whitcomb's area rule: the square of the rate of change of a cross-sectional area is directly proportional to the wave drag

Critical Mach number: the lowest Mach number at which the airflow over any part of the aircraft reaches the sound of speed

The Concorde serves as one of the biggest legacies in aviation, symbolising the peak of supersonic commercial flight. With its ability to commute from London to New York in just under 3.5 hours, the Concorde travels at twice the sound of speed, Mach 2, where cutting-edge materials, powerful engines, innovative designs all were blended to push the barriers of commercial aviation. How was the Concorde's innovative engineering able to redefine the concept of air travel?

Aerodynamic Structure

The structure of the Concorde was designed with precision to withstand the extreme pressures and temperatures of supersonic flight with its sleek and clever designs.

Figure 1. Delta Wing Design (NOVA, 2004)

Delta Wing Design

The Concorde's delta wings played a major role in its supersonic ability to fly. When an aircraft exceeds Mach 1, it encounters several types of drag, predominantly wave drag, caused by shock waves that form around the aircraft, creating of high pressure.

Unlike conventional aircraft wings, which are generally more rectangular, delta wings are swept back and have a triangular shape, helping it to fly at supersonic speeds as it redirects airflow (NOVA, 2004). The sharply swept leading edges of the delta wing reduces the strength and size of the shockwaves created as the aircraft moves through the air. This is because the angle at which the air encounters the wings spreads the shockwave formation over a larger area, rather than concentrating it at a single point, reducing wave drag (HeritageConcorde, n/a).

The delta wing also has a minimised cross-sectional area. The flat and slender design of the delta wing reduces the cross-sectional area exposed to airflow, which is a key factor in reducing wave drag according to Whitcomb's Area Rule in aerodynamics, where the square of the rate of change of the cross-sectional area, is directly proportional to the wave drag. Concorde managed to keep its rate of change of cross-sectional area low using the delta wing design to minimise the intensity of wave drag, allowing it to fly at its supersonic speed (Skybrary, 2021).

Drooping Nose

The design of the drooping nose was cleverly balanced between aerodynamic efficiency and operational practicality. A pointed nose reduces the area over which the compression of the shockwave occurs, allowing it to form in a controlled manner, reducing its intensity and drag. This helped the Concorde transition smoothly through the Critical Mach Number (Skybrary, 2021). The nose of the Concorde also allowed it to delay the launch of full supersonic flow, with the help of the delta wing design. At lower speeds, a sharp pointed nose is impractical, as it obstructs the pilot's view. The drooping nose mechanism allowed us to solve this problem by tilting the nose down at low speeds by up to 12 degrees (HeritageConcorde, n.d.).

Engines

The Concorde was powered by four Rolls-Royce Snecma Olympus 593 engines, turbojet engines, which were specifically designed for the unique demands of flying above Mach 2.

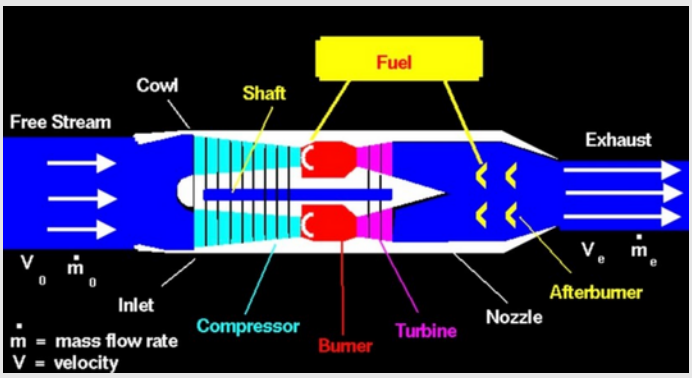

Figure 2. Afterburning Jet Thrust (Hall, 2021)

Afterburners

Afterburners are typically used in military aircraft; the Concorde was the first commercial aircraft to incorporate afterburners. Afterburners work by injecting additional fuel into the exhaust stream, igniting it, and producing additional thrust without a significant increase in weight (NASA, 2021). The burning of this extra fuel in the afterburner causes the exhaust gases to expand rapidly, exiting the engine at much higher speeds. This increased the thrust of the Concorde, allowing it to achieve speeds above Mach 2. The engines could generate approximately 720,000 newtons of thrust, allowing it to take off and cruise at much higher speeds than any conventional subsonic aircraft.

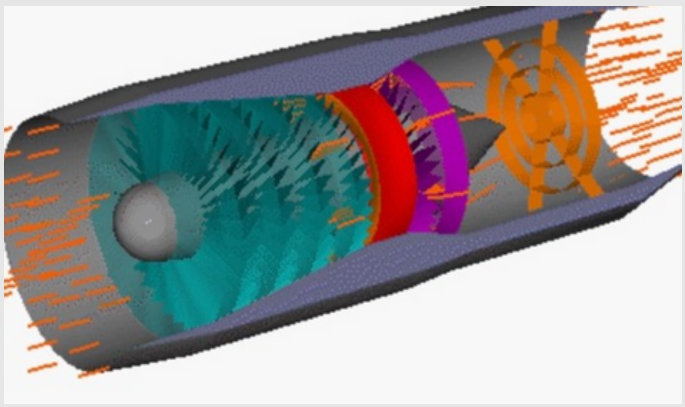

Figure 3. Afterburning Turbojet (Hall, 2023)

Variable Area Nozzles

The variable area nozzles are responsible for optimising the performance of the engine by adjusting the size of the exhaust nozzle, based on the speed of the aircraft. When the aircraft is flying at high speeds, a narrow nozzle helps increase the exhaust velocity, producing additional thrust (NASA, 2021).

Cooling Systems

Most of the cooling systems in the Concorde's Olympus 593 engines were achieved through air and oil cooling. This used air from the compressor stages to cool high temperature components, such as the turbine blades and afterburners, by heat transfer. The warm air transfers heat away from these engine parts with fins, by the means of convection This technique was critical to managing the temperatures in the engine's core, which would exceed 1500 degrees Celsius at supersonic speeds (NOVA, 2004). The Concorde also used oil cooling, where synthetic oils were used to cool these highly heated components. Oil is a good conductor, so it can absorb heat and carry it away to cooler regions of the engine. It is also a good lubricant, reducing friction between moving parts, such a bearings and shafts, reducing heat transfer. The use of these cooling systems was not specific to the Concorde, it is used in many supersonic aircraft, typically military aircraft (FAA, 2023).

Materials

The materials used in constructing the Concorde were crucial to its performance as a supersonic airliner. Many materials were selected based on their ability to withstand the extreme conditions of high-speed flight, such as high temperatures and pressure changes.

Titanium

Titanium played a crucial role in the Concorde's construction, due to its properties. It was used for a lot of the Concorde's structure, in the leading edges of the wings, the nose cone, engine components and fuselage, all components which are subject to extremely high temperatures during supersonic flight. Titanium was used in these areas as it can withstand temperatures above 1000 degrees Celsius, aerodynamic stress and oxidation. Without the use of titanium, the Concorde would not have been able to achieve the performance and durability (Carpenter Technology, 2024).

Aluminium Alloys

Aluminium alloys played a crucial role in the Concorde's design, especially in the fuselage, wings and control surfaces. Whilst titanium was used in areas exposed to the highest temperatures, aluminium alloys were chosen for most of the airframe, due to their lightweight nature and strength-to-weight ratio. Aluminium alloys were specifically chosen for their resistance to corrosion, as it could weaken the aircraft's structural integrity, especially during flights at high altitudes, where exposure to moisture and salt is a concern. These alloys have a naturally occurring oxide coating, which protects them from corrosion. The Concorde's outer skin expanded significantly during supersonic flight due to heat generated by friction. These alloys were chosen for their thermal expansion properties, allowing the skin to expand and contract without damaging the airframe. This was essential as the Concorde experienced an expansion of 25cm of its fuselage at Mach 2 speeds (Xometry, 2023).

Noise and Environmental Concerns

Alongside many other factors, such as high operating costs, limited passenger demand and competition, the environmental concerns and the noise pollution of the Concorde played an equally crucial factor in its retirement.

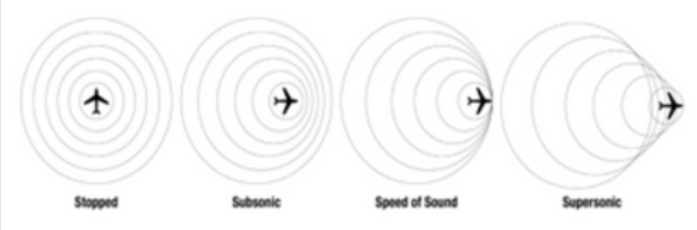

Figure 4. Pressure Waves of Air Flowing Off an Airplane (NASA, 2019).

Noise Pollution

A sonic boom is caused by the rapid compression of air as aircraft travels faster than sound, producing a shockwave that reaches the ground as a loud, explosive noise. The loudness is caused by the rapid change in atmospheric pressure This is not a one-time event, it is sustained as long as the aircraft is flying supersonically. It forms a 'boom carpet' a cone shaped region beneath the aircraft where the sound is experienced, producing a loud enough sound to startle people and cause minor structural damage (NASA, 2003).

Environmental Impact

Travelling at Mach 2 requires overcoming immense aerodynamic drag, meaning engines must operate at high thrust levels, burning significantly more fuel compared to subsonic aircraft. The Concorde burned 25,629 litres of fuel per hour at cruise speed, which is significantly more than subsonic aircraft. (HowStuffWorks, 1970). Surprisingly, the delta wing also contributed towards high fuel consumption, as whilst it was advantageous for supersonic ability, it resulted in a lower lift-to-drag ratio at subsonic speeds. This required more engine power and fuel. This releases a large amount of greenhouse gases, such as carbon dioxide and nitrogen, into the Earth's atmosphere.

Conclusion

The engineering behind the Concorde was a groundbreaking achievement that pushed the boundaries of aviation technology, from its iconic delta wing designs to the powerful Olympus engines and highly advanced materials. However, despite these innovative breakthroughs, the Concorde's high operational costs, environmental concerns and competition, ultimately led to its retirement. The legacy of the Concorde lives on and continues to influence and inspire the development of future supersonic aircraft.

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Key Words:

Trauma: physical injury, usually caused by an accident or attack, or a case of such injury happening

Physiological: relating to the way in which the bodies of living things work

ADVENT 2024

The Troubles of TMJD and Jaw Fractures in Athletes

By Amar Basra (Year 12)

Temporomandibular Joint Disorder is a disorder common in athletes, specifically in sports such as boxing, American football, UFC, and rugby. TMJD is quite prevalent, with up to 70% of the population experiencing pain related to it, yet many do not seek treatment due to a lack of awareness (Wiley Online Library, 2018). Temporomandibular joint disorders (TMJD) involve dysfunction of the jaw muscles, temporomandibular joints, and associated nerves, often resulting in chronic facial pain. This occurs when the system of muscles, bones, and joints fails to work in harmony (John Hopkins Medicine, 2024).

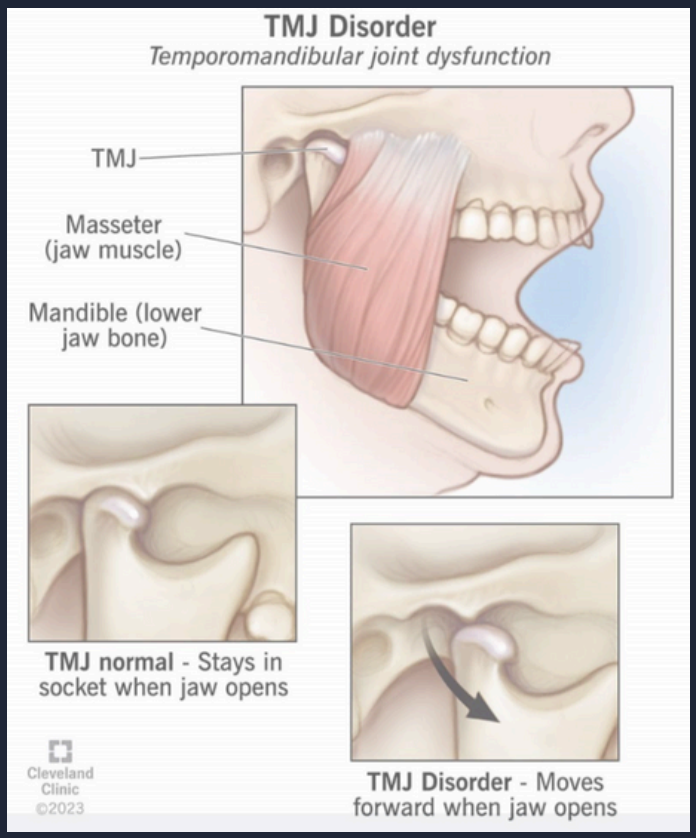

Figure 1. TMJD encompasses over 30 conditions affecting the jaw joint and surrounding muscles (Cleveland Clinic, 2020).

What are the Common Symptoms of TMJD?

Temporomandibular joint disorder has many painful symptoms, including:

- Pain or tenderness in the jaw
- Pain in one or both temporomandibular joints
- Aching pain in and around the ear
- Difficulty chewing or pain while chewing
- Aching facial pain
- Locking of the joint, which makes it difficult to open or close the mouth

Why are Athletes More Prone to TMJD?

Combat fighters are more likely to develop TMJD due to trauma from punches and impact. Additionally, overuse and muscle tension in sports requiring repetitive jaw motions, such as weightlifting, swimming, and martial arts, can exacerbate TMJD. Clenching and grinding (bruxism), often caused by physical exertion or stress, further contribute to the disorder.

Physiological stress is another major factor. Athletes under pressure may grind their teeth when nervous or anxious, placing stress on the jaw joint. For example, high-performing footballers in critical matches, like the Champions League, often exhibit these stress-related behaviours (Science Direct, 2006).

Key Words:

Debilitating: making someone or something physically weak

Mandibular: relating to the lower jaw

Fracture: a break or crack in something hard, especially a bone

Acute: severe conditions, illnesses, or injuries that need immediate care

Chronic: (especially of a disease) continuing for a long time

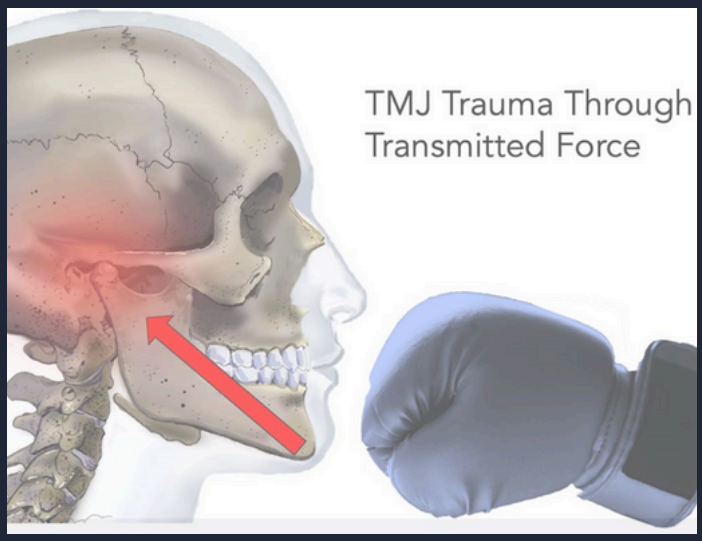

Figure 2. Sports dentistry treatments can help prevent TMJD damage (Orofacial Therapeutics, 2021).

Extreme Cases of Jaw Injuries

While TMJD can be debilitating, more severe injuries like mandibular fractures can lead to significant consequences. Treatment depends on severity, location, and the number of fractures.

Common treatments include:

- Jaw rest: Limiting jaw movements to soft foods and liquids.
- Jaw stabilisation: Wiring the mouth closed to allow healing.
- Surgery: Metal plates and screws stabilize the jawbone for severe breaks, often requiring a liquid diet (Colgate, 2023).

Early diagnosis is essential, as untreated fractures can worsen. Though recovery might take up to six weeks, proper treatment restores jaw function (Colgate, 2023).

Diagnoses for Mandibular Fracture

Diagnosing mandibular fractures involves radiographic imaging, including a mandibular series and CT scans.

Mandibular series imaging includes:

- An anteroposterior view, bilateral oblique views, and Towne view, which assesses the condyles and neck of the mandible.
- A dental panoramic view is ideal for evaluating the symphysis and body of the mandible.
- CT scans are indicated if facial fractures are suspected. A chest radiograph is also necessary for unconscious patients to rule out aspiration (National Library, 2023).

Case Studies of Severe Jaw Injuries

Muhammad Ali vs. Ken Norton (1973): Muhammad Ali's jaw was broken during a match when Norton landed a powerful punch. Dr. Gary Manchester, who performed the surgery, described the injury as severe, with jagged bone edges causing further damage (Wikipedia, 2024).

Darius Garland: The basketball player suffered a fractured jaw during a game against the Boston Celtics after colliding with Kristaps Porzingis. Garland's injury required surgery and a month-long liquid diet. He lost 12 pounds and had to rebuild his strength before returning to play (NBA, 2024; Bleacher Report, 2024).

Conclusion

Jaw injuries and temporomandibular joint disorder (TMJD) present significant challenges for athletes, especially in contact sports. TMJD results from acute trauma, chronic strain, and

physiological stress, leading to pain and limited jaw mobility that can hinder athletic performance. Preventative measures, such as protective gear and stress management, are critical for reducing these risks. Early diagnosis and appropriate treatment, including physical therapy, dental interventions, and surgery, are essential for optimal recovery and long-term oral health. Continued research and awareness will help better support athletes dealing with TMJD and jaw injuries.

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ADVENT 2024

Radiotherapy: The Invisible Force that Kills Cancer

By Eshay Chauhan (Year 11)

Key Words:

Radiotherapy: the use of controlled amounts of radiation (a form of energy) aimed at a particular part of the body, to treat disease

Mutation: the change that happens in an organism's genes which produces differences that are passed to new organisms by reproduction, or the process of this change

Understanding Cancer

Over the years, cancer has become an increasing concern for the public due to the uncontrollable nature of cell growth. In 2024, the NHS declared that patients diagnosed with cancer have risen by 5%, with an average of 950 new cases per day (Blood Cancer UK, 2024). Therefore, radiotherapy is crucial as it serves as a powerful tool in combatting this life-threatening condition.

Our cells typically divide through the process of mitosis, helping replace damaged cells or simply making new ones. Genetic mutations and disruptions in mitosis can lead to the uncontrollable growth of cells. (Cancer.gov, 2021). This eventually forms a tumour that may be cancerous. Cancerous tumours undergo the process of metastasis. As cancerous cells move away from the original tumour (Figure 1), they travel through the blood or lymph system (group of organs protecting you from infections) to a different part of the tissue. The metastatic tumour contains the same type of cancerous cells as the primary tumour. An example is breast cancer which could spread to the lungs, however these cancer cells are still breast cancer cells as they originated from the chest region. This tendency to break away from the original tumour allows cancerous cells to spread around the body causing damage to other important organs such as the brain, liver and lungs. Additionally, tumours are life threatening due to the immense pressure they exert on these vital organs. These Metastasis tumours are also commonly referred to as malignant cancer (Hematology.org, 2021). Alternatively, leukaemia is a common blood cancer usually affecting the amount of white blood cells found in the bone marrow. White blood cells are produced rapidly and fight infections that limit the amount the red blood cell to be produced in the bone marrow. With a lack of white blood cells, infections can target the amount of red blood cell production leading to fatigue and unexplained bleeding. Leukaemia can be described as either chronic (slow spread) or acute (fast spread) depending on the amount of white blood cells in the body.

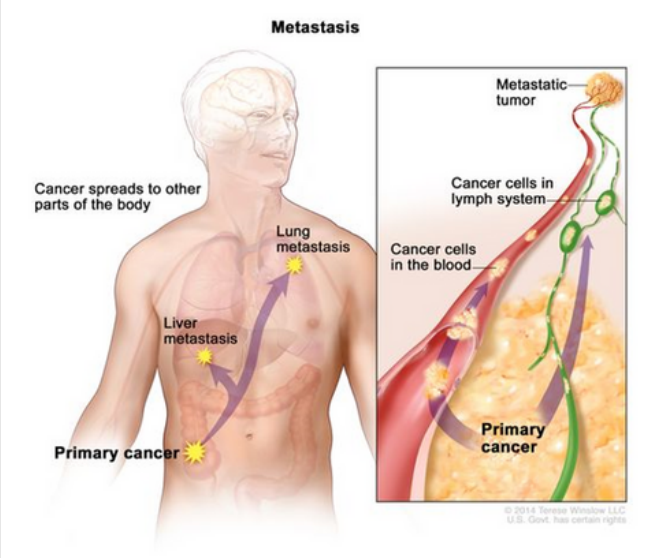

Figure 1. Process of Metastasis (U.S Department of Health, 2021)

What is Radiotherapy?

Luckily, Radiotherapy utilises the high penetrating powers of gamma-rays to treat cancerous cells. Radiotherapy can take different forms such as; brachytherapy or radioisotope therapy. In brachytherapy, small pieces of radioactive metals such as radium are ingested by the patient. The radioisotope must have a short half-life, so emits radiation over a small period. This radiation can be picked up by external devices. However, the more common method is using external beam radiation therapy. This treatment uses a large machine called a linear accelerator. Most of the time is prioritised aligning the patient in the necessary position to focus the electrons on the tumour. The penetrating beams destroy cancer cells by damaging the DNA. The cancerous cells are beyond repair and can no longer divide, as the DNA is not replicated. Radiation-induced damage leads to the death of cells through two mechanisms: apoptosis and necrosis. Apoptosis is the active process called cellular suicide. Conversely, necrosis is a passive process in which radiation injury results from cells containing unrepaired DNA with chromosomal aberrations as the number of chromosomes change (Science Direct, 1999), inhibiting the further production of these cancerous cells.

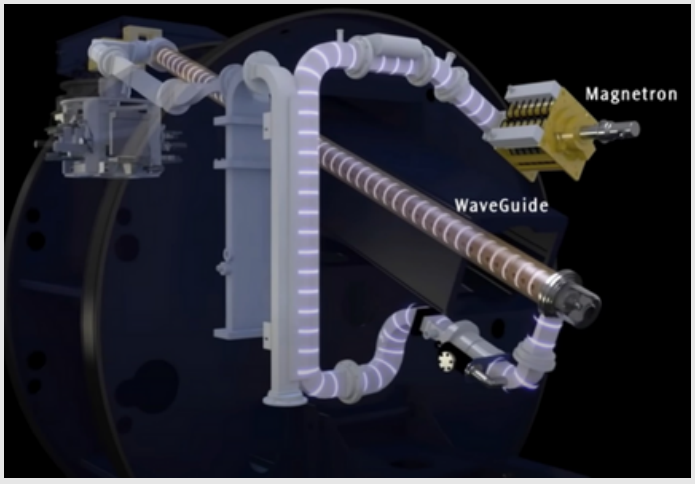

Figure 2. Linear Accelerator (Elekta, 2010)

How does the Linac work?

The linear accelerator (Linac) was first used in 1953 in London, marking the dawn of an exciting discovery into the treatment of cancers. In a full patient assessment, the oncologist will determine the frequency of the electromagnet waves and their direction of travel. Radio frequency waves are pulsed into the waveguide by the magnetron. Electrons are injected into the wave guide by an electron gun (Linac: Figure 2).These electrons are accelerated by the radio frequency waves at the speed of light. High energy electrons collide with an inner shelled electron, causing them to fly out to the tungsten target at the end of the wave guide. An electron on the outer shell is promoted to the inner shell and as a result, with a loss of energy, an X-ray Photon is emitted (Radiology: Figure 3). A primary collimator will help to shape the beam of radiation. It creates a cone shaped beam, which minimises leakage and absorbs any x-rays travelling to the lateral sides of the body. The cone shaped beam helps to concentrate more photons into the centre of the beam. This creates a concentrated X-ray beam with typical widths of 2mm - 7mm. The quality of the beam is controlled by an ionizing chamber which uses 7 electrodes to monitor the different sections of radiation. Furthermore, the oncologists ensure the dosage is appropriate by using a computer system. This single system controls the entire

Key Words:

Malignant: cancer or is related to cancer, and is likely to be harmful

Leukaemia: a serious disease in which the body produces too many white blood cells

Fatigue: extreme tiredness

Aberration: a temporary change from the typical or usual way of behaving

Oncologist: a doctor who studies and treats tumours (masses of cells, as in cancer) in the body

Collimator: a tube with a slit and lens used in a spectroscope to collect light and throw it upon a prism in parallel rays

Linac minimising communication delays but aiding efficient beam deliveries. All the radiation beams are grouped in calibration blocks. These blocks are used to adjust the dosage and intensity of the beam, ensuring the patient receives the correct amount of dosage. These values are stores on a hard disk found within the Linear Accelerator. (University of Virginia, n.d.)

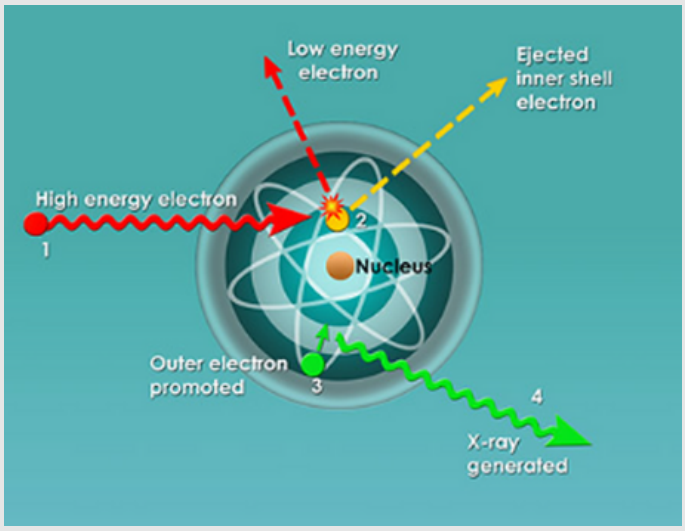

Figure 3. Diagram by Dr Graham Lloyd-Jones, Consultant Radiologist (Radiology Masterclass, 2016).

The Christie NHS Foundation Project

The Christie is a leading Cancer centre in Europe which have great ambitions for the future of radiotherapy (The Christie NHS Foundation Trust, 2024). As we move closer towards the NHS net-zero pledge, radiologists are concerned with the carbon footprint of radiotherapy. On average, 120,000 patients with cancer are treated with high energy radiation yearly. The Christie trust is aiming to improve the sustainability within radiotherapy, trying to minimise the carbon footprint of radiotherapy. The Christie strategy 2023-2028 aims to revolutionise cancer treatments with 4 key themes in mind: "Leading Cancer Care, The Christie experience, Local and specialist care and Best outcomes" (The Christie NHS Foundation Trust, 2024). The Christie will learn from every patient and develop clinical outcomes for patients using real-time clinical databases from every patient. By embedding data culture into their work, they can develop a framework for the advancements of future technologies and the possible use of Artificial intelligence. Currently, through academic investments, they have recruited experts in the filed of experimental cancer therapeutics and radiotherapy research, helping discover specific tumours such as lung and prostate. Lastly, the have supported international collaborations with Kenya, supporting a £2.8m NIHR grant to improve oesophageal cancer research in Kenya. Lastly, in 2014 the Christie joined a worldwide research constitution to develop MRI scans. In particular, the Elekta Unity MR-Linac is the first machine in the world, which combines the high-strength MR imaging with a linear accelerator.

Conclusion

To conclude, radiotherapy plays a vital role in fighting against cancer and serious medical conditions. The invisible forces holds immense power with the potential of improving the health of 7 million people yearly (NIH, David A Jaffray). The future of radiotherapy is promising with the influence of Artificial Intelligence and technological innovations, helping radiotherapy to be more efficient, precise and accessible.

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Key Words:

Augmented reality: images produced by a computer and used together with a view of the real world

Virtual reality: a set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in

GPS: global positioning system: a system that can show the exact position of a person or thing by using signals from satellites

ADVENT 2024

Glasses of the Future

By Nishanth Anbezhil (Year 10)

Augmented Reality Glasses

Augmented Reality (AR) glasses are a cutting-edge technology that combines digital elements with the real world. Unlike virtual reality, AR allows users to interact with both digital content and the physical surroundings simultaneously. AR glasses have the potential to create a whole new exciting dimension that has barely been explored, and thus opening a whole new aspect of uses in modern day society, from industry to everyday use. This is the future.

Figure 1. The future of wearable technology (Resco.net, 2022).

How AR Glasses Function

AR glasses basically work by overlaying digital information over the real world view. This can be fundamentally categorised into 3 stages: the input stage, processing stage, and output stage.

During the input stage, Leavitt (2023) explains that various sensors are used to interpret the user's surroundings. These include accelerometers (calculates head acceleration), gyroscopes (calculates head rotation), magnetometers (calculates the Earth's magnetic field) to determine the user's orientation. Cameras collect visual data of the surroundings, and depending on the quality of the AR glasses, depth sensors such as time-of-flight cameras (calculates how long it takes light to travel to and from the objects) may be included to provide the best immersive experience possible. Some AR glasses also include GPS systems to actively track user's location for navigation purposes. As for the gestures and voice commands that are used to operate AR glasses, some do it differently than others. NuEyes AR glasses use the already built-in sensors to also track unique hand gestures used as commands to operate the device. To be precise, NuEyes AR glasses can "recognize 21 points on the joints, six on the wrists and 3 for each finger" according to 'NuEyes AR glasses incorporate hand gesture recognition' (ServReality, n.d.). They also have in-built microphones to interpret voice commands. Unlike NuEyes AR glasses, according to Colin Hughes (2024), Orion by Meta uses a wristband that detects electrical impulses from the user's brain, and then translates these impulses to identifiable digital commands that the system can recognize. By having such a large array of inputs, AR glasses are able to fully understand the user's surroundings - crucial for augmented reality to function.

Key Words:

Algorithm: a set of mathematical instructions or rules that, especially if given to a computer, will help to calculate an answer to a problem

Eyestrain: tired or painful eyes as a result of too much reading, looking at a computer screen, etc.

In the processing stage, the input data is processed in order for the glasses to understand the user's visual surroundings and orientation, to produce the corresponding outputs. Some AR glasses feature a system-on-a-chip (SoC), which is a microchip that acts like a mini-computer as it contains all the components a computer has: a CPU, memory interface, I/O (input/output) interfaces, GPU, and can even run operating systems. It is the brain of the system and is used in many phones (Wikipedia, n.d.). According to Leavitt (2023), the SoC also has the responsibility of rendering graphics, textures, animations to create realistic 3D images, and to optimise a smooth operation without lag. It also runs key algorithms such as SLAM (Simultaneous Localisation And Mapping) which uses the input data to create a digital map of the user's environment, then overlay digital information on top and anchor it to certain landmarks of the environment. This ensures it is accurate and realistic, and it is essential in producing augmented reality. AI algorithms are also utilised to adapt to user's constantly changing surroundings. However, an integrated SoC may have limitations such as processing power, memory capacity, battery life and would result in heavier glasses if implemented. Baba (2023) explains that AR glasses are tethered to another device such as a smartphone via Wi-Fi or Bluetooth allowing the glasses to leverage the smartphone's SoC to processing. This significantly improves battery life, processing power, and makes it lighter and more conventional to wear; but it requires proximity to the device and a stable connection for it to function.

After processing the data, Leavitt (2023) describes that the AR glasses are then able to output digital information over real-world surroundings using a display system and an optical system. The display system often incorporates a liquid crystal display (LCD), which functions like a projector that enhanced image and colour quality. Alternatively, some display systems have an organic light-emitting diodes (OLEDs), similar to those in televisions. As the display system generates the 3D digital image, the optical system then is vital in focusing the light into the user's retina, creating the illusion of it floating in their field of view. Some use lenses or mirrors to refract or reflect the light; but in the latest models, waveguide optics utilize total internal reflection for precise focus of the light in the user's retina. Additionally, built-in speakers near the user's ears ensure the audio remains private. All of these components are meticulously engineered to deliver an immersive augmented reality where the digital information is seamlessly incorporated with the physical world.

Applications of AR Glasses

Figure 2. The top uses cases of AR glasses (INTUZ, 2021).

Due its many advantages, AR glasses are increasingly used in various cases. Law (2024) highlights the several applications in the industrial sector. Maintenance and repair technicians use AR glasses to have an overview

of the machinery being worked on and to have a contextual set of instructions to aid them with their work. Lockheed Martin, for example, uses AR to address complex issues in spacecraft and aircraft malfunctions. In businesses, AR technology boosts efficiency in warehouse management and is cost-effective as it reduces the need for a large number of technicians. It is also frequently used in employee training to create immersive work environments so that new employees can quickly understand the job. Engineers also use AR technologies to aid them in designing and prototyping as it enables to view 3D models in relation to their surroundings. With the addition of AI, it can inspire creativity and efficiency to access peak concentration levels to achieve the best products. Ford and Volkswagen already use AR for design reviews, and it reduces the need for physical prototypes. Furthermore, AR glasses are able to help collaboration remotely and experts can help on-site workers virtually.

Moreover, Adamska (2023) explains that it has various uses in other sectors as well such as healthcare. AR glasses assist surgeons by providing them real-time medical data, procedure instructions, and 3D models of the surgery. In education, AR glasses promote interactive learning experiences, helping students visualise complex ideas. Retailers like Coca-Cola and Pepsi are using AR glasses for 'virtual try-ons' to give consumers the chance to interact with their products before buying them. In the gaming industry, AR glasses provide a whole new authentic experience where the games are combined with reality. This is particularly effective for role-playing games such as Pokémon Go. In addition, it also could be for everyday-use to help multitasking and personal fitness. AR glasses could be a useful alternative to phones and it may reduce eye strain than staring at a phone. It also can boost wellbeing and helps users stay connected to the present by blending reality and digital interactions together in a balanced manner.

The Current State of AR Glasses

AR glasses are still in the early stages of development, and the platform for it is only just being built. Several early prototypes like Orion, Snapchat Spectacles, Microsoft HoloLens, Magic Leap are paving the way. Though AR glasses are evolving, it still has not yet reached its full potential. With the integration of AI to enhance its capabilities, AR glasses could potentially revolutionise how we think and work in the future. While still a work in progress, the future of AR glasses holds significant promise.

Figure 3. Meta's Orion AR Glasses (Cnet.com, 2024)

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ADVENT 2024

MS: Multiple Sclerosis or Moody Sister?

By Bahara Qalandari (Year 12)

Key Words:

Demyelinating disease: a disease that damages myelin (a white fatty substance that covers some nerves)

Central nervous system: the main system of nerve control in a living thing, consisting of the brain and the main nerves connected to it

Immune system: the cells and tissues in the body that make it able to protect itself against infection

Have you got a sister or brother, mother or father, who's known to be the "nag" of the family? Well, do you know why? Maybe your teenage sister has hormonal imbalances, or your parents are just tired of you. Or maybe, it's an undiagnosed case of multiple sclerosis.

Multiple (cerebro-spinal) Sclerosis is a chronic, demyelinating disease, that affects the CNS (Central Nervous System). But what does this mean? The name was given because of the multiple plaques (hardened tissue) that develop within the brain and spinal cord (CNS). MS brings about demyelination (loss of the myelin sheath) and plaques in the CNS because of focal inflammation (Rhesus Medicine, 2023).

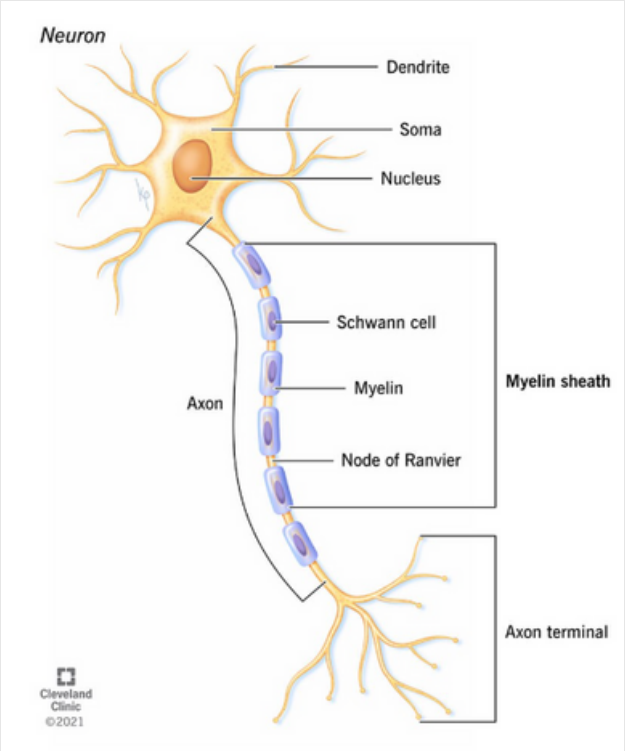

Figure 1. (Cleveland Clinic, 2022).

The myelin sheath is the insulating sheath that surrounds axons of neurons and increases the rate of electrical signals transmitted. In MS, this myelin is lost because of the immune mediated destruction of oligodendrocytes (myelin producing cells) (Rhesus Medicine, 2023).

This means that the immune system inappropriately attacks and destroys the myelin, which makes communication between neurons break down, ultimately leading to all sorts of sensory, motor and cognitive problems (Osmosis from Elsevier, 2017).

Symptoms begin to appear. However, demyelination is NOT constant - it's interrupted by periods of remyelination - this means that some of the myelin sheath is restored- but it's not completely rebuilt (Rhesus Medicine, 2023).

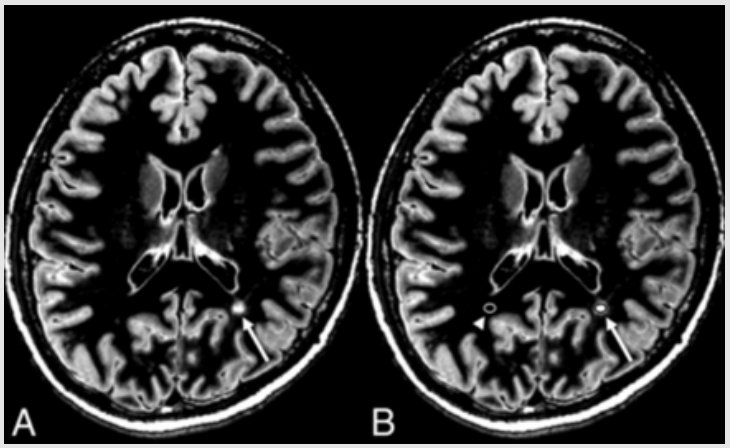

Figure 2. An MRI scan by Hagiwara et al (2016) shows the detection of multiple sclerosis plaques.

As this process of demyelination and remyelination is repeated, scar tissue forms and hardens, known as plaques . Plaque further impairs

impairs signalling and contributes to neuronal disfunction. They are mostly found in white matter, but primarily the CNS. Recently, it's been found out that grey matter could also be affected, and rarely, the peripheral nervous system (Rhesus Medicine, 2023).

Usually the blood-brain barrier prevents immune cells to reach the CNS. However, after infections, the blood-brain barrier can become injured, increasing the permeability of this barrier, allowing immune cells through - this is known as the "Outside In" hypothesis (Rhesus Medicine, 2023). Simply, certain cells create an immune response against myelin through cross reactivity. This leads to recruitment of other cells and development of an inflammatory reaction (Rhesus Medicine, 2023).

The causes for MS are unknown, but scientists assume it's linked to both genetic and environmental factors.

- Genetic risk factors include being a woman and having genes that encode a specific type of immune molecule (HLA-DR2), which identifies and binds to foreign molecules.

- Environmental risk factors may include getting certain infections as well as vitamin D deficiency - this could explain why MS cases are higher at the northern and southern poles compared to the equator (Rhesus Medicine, 2023). These genetic and environmental influences might lead to the body not killing off immune cells that target myelin.

But how do you know if you have multiple sclerosis? Symptoms tend to vary, depending on location of plaques. They usually affect 20-40-year-olds, worsening over weeks and lingering for months (Osmosis from Elsevier, 2017).

One common trio of MS symptoms is called Charcot's neurologic triad. This includes dysarthria (difficulty or unclear speech), nystagmus (involuntary rapid eye movements) and an intention tremor cord (Osmosis from Elsevier, 2017). Dysarthria is due to plaques in the brainstem that affect nerve fibres that control muscles in the mouth and throat, which affect unconscious and conscious movements, nystagmus is due to plaques around the nerves controlling eye movements and intention tremors can be caused by plaques along the motor pathways in the spiral cord (Osmosis from Elsevier, 2017).

Key Words:

Permeability: the ability of a substance to allow gases or liquids to go through it

Brainstem: the part of the brain that connects the spinal cord (the nerves inside the spine) to the forebrain (the front part of the brain)

Amygdala: one of two parts of the brain that affect how people feel emotions, especially fear and pleasure

Cerebrospinal fluid: a liquid that moves in and around the brain and spinal cord (the nerves inside the spine)

Remission: a period of time when an illness is less severe or is not affecting someone

MS patients may also be affected emotionally, causing outbursts and short-tempers due to plaques affecting the amygdala within the brain. This can cause the patient to seem fine at one point, then moody in just a matter of seconds.

If somebody is suspecting that they might have multiple sclerosis, they might have a preconceived notion that a definitive test might take place to diagnose multiple sclerosis (Rhesus Medicine, 2023). However, there is no single definitive test. To be diagnosed with MS, you must have dissemination in space (1+ areas of CNS affected), AND dissemination in time (damage at more than one point in time) (Rhesus

Medicine, 2023).

A doctor who specialises in this will order an MRI, examine the cerebrospinal fluid and visual evoked potential (Osmosis from Elsevier, 2017). If there is white matter (lots of myelin) plaques and high levels of antibodies found in your cerebrospinal fluid, this could mean you have MS (Osmosis from Elsevier, 2017).

If somebody is diagnosed with MS, unfortunately, there are no cures available for the condition - the overall aim is to reduce disability burden and help you in the long run (Rhesus Medicine, 2023).

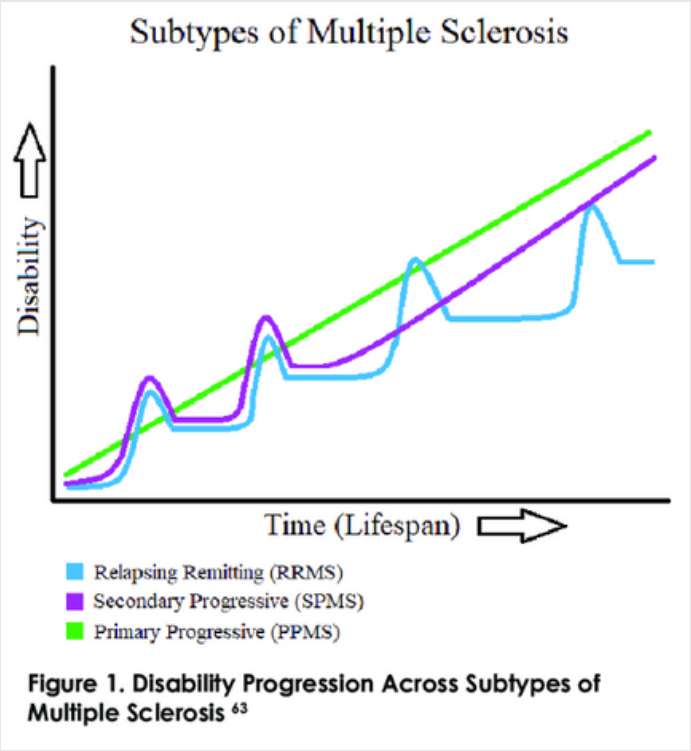

Figure 1. Disability Progression Across Subtypes of Multiple Sclerosis [63]

Figure 3. This graph by Bellman (2021) shows the disability progression across subtypes of multiple sclerosis.

Usually there is a period of remission (time) between the last remyelination and the next demyelination, which is known as a relapse. These relapses are unpredictable deteriorations in symptoms with extended periods with no new disease activity - this is known as relapsing remitting and occurs with 80% of undiagnosed MS patients. 20% of MS patients have primary progressive MS, where progressing deficits with minimal relapses or remission (Rhesus Medicine, 2023).

27-45 for every 100,000 members of the general population have secondary progressive MS (National Multiple Sclerosis Society, n.d.). This is where the periods of remission begin to have progression between relapses (Rhesus Medicine, 2023).

With the cause of MS being unknown, and with it being such a debilitating condition, lots of research is being done into MS. By researching to improve the qualities of lives for patients who have MS, and by researching to find a possible cure for the condition, we are developing our understanding of it - and as this research grows more extensive, we are closer to finding a cure for this every day.

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Key Words:

Celestial: of or from the sky or outside this world

Climate change: changes in the world's weather, the fact that it is believed to be getting warmer as a result of human activity increasing the level of carbon dioxide in the atmosphere

ADVENT 2024

Journey to the Red Planet

By Sayona Singh (Year 9)

Since Yuri Gagarin became the first man to leave the Earth's atmosphere, people have become more and more curious to explore the wonders of space. Our closest celestial neighbour, Mars, has become increasingly appealing with climate change threatening to reduce our Earth to a barren wasteland. Since 1965, when we had the first successful flyby of Mars, we have been researching the possibility of establishing civilisation on Mars (NASA, 2020).

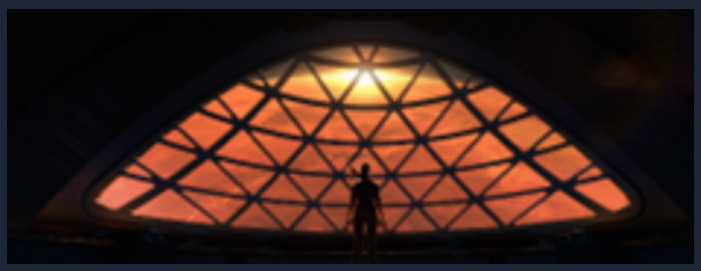

Figure 1. A visualisation of a Mars Mission (SpaceX, 2016)

Before considering establishing a Mars colony, we have to be able to transport humans safely to Mars and this is incredibly difficult. A manned mission to Mars is estimated to take around three years. Although it doesn't seem like much in the long term, three years of space travel can have extremely detrimental effects on astronaut's physical and mental health.

Physiological Health

Firstly, long term space travel is not medically feasible yet as we have already found many impacts of space travel that have affected astronauts on the ISS. These impacts include: increased muscle loss, loss of sleep, space blindness, etc. As well as this, there are many indirect cons of space travel such as lack of medical procedural capabilities, which increase the risk of space travel according to the NASA Office of Inspector General (2015).

These medical hazards were researched in the NASA Twins Study (Lewin, 2019), which was conducted from March 2015 to March 2016. This involved a pair of twins who were both astronauts – Mark and Scott Kelly – being monitored for any biological changes. Scott Kelly was placed on the ISS, while Mark stayed on Earth.

Figure 2. Scott and Mark Kelly (Yakima Town Hall, 2019)

The changes to their bodies were recorded and compared, and then categorised into 9 main groups:

- Telomeres
- Immunome
- Cognition
- Gene Expression
- Biochemical
- Microbiome
- Epigenomics
- Metabolomics
- Proteomics

Key Words:

Telomere: a structure at the end of a chromosome that protects it

Cognition: the use of conscious mental processes

Epigenomics: the study of the complete set of epigenetic modifications on the genetic material of a cell, known as the epigenome

I have chosen a few of these which I find interesting or worth taking note of.

Firstly, telomeres are found on the ends of DNA, and with cell replication, they become shorter according to Chadwick (2024). The rate of shortening is increased by age and environmental factors. Therefore, it was predicted that Scott Kelly's telomeres may shorten due to the harsh conditions in space. Surprisingly, they found out that his telomeres grew up to 14.5% longer in space. However, a few months after his return, most shortened to their normal length, but some shortened too much (Garrett-Bakelman et al., 2019). This makes DNA mutations more likely, which in turn makes apoptosis (self-cell death) more likely. Due to the increased chances of DNA mutations, telomere shortening also increases the risk of cancer.

Secondly, the mind is a very complicated and so research into cognition is essential. Scott Kelly's cognitive performance was similar to Mark Kelly's except for the changes that occurred due to the psychological impacts of long term space travel. Even six months after Scott Kelly's return to Earth, results still showed a reduction in his speed and accuracy according to Garrett-Bakelman et al. (2019). This is a big problem because the psychological impacts of being in unfamiliar territory can lead to the astronauts not being able to focus on their mission, having dangerous consequences. Therefore, providing astronauts with mental health support is crucial for ensuring the success and safety of their missions.

Furthermore, the NASA Twins study proved an extremely interesting theory about gene expression, which is how our physical features are expressed. Scott Kelly's DNA was tested before, during, and after his mission, and changes were found both during and after. The changes may have occurred due to radiation exposure; however the findings also show how the human body adapted to life in space after a year and then adapted back to life on Earth (Perez, 2019). This is important because it implies that the possibility that we may be able to adapt to living on Mars is growing to be more likely as we learn about the activity of genes and the environmental changes that may affect this.

Figure 3. Tracy Dyson on the ISS looking down at the Earth (NASA, 2010)

Additionally, epigenomics is how the environment can affect gene expression (National Human Genome Research Institute, 2016). Although Scott Kelly experienced epigenomic changes, most of these were of the same degree as Mark Kelly, and many reversed within a short time of him being on Earth. However, the most prominent of the changes were to Scott Kelly's white blood cells, which revealed the specific areas of the genome that were prone to DNA methylation (a type of epigenomic change) according to Garrett-Bakelman et al. (2019). This is important because sometimes these kinds of alterations can lead to a higher risk of cancer. In my opinion, for the Mars mission, NASA will have to conduct more research on epigenomics to find the extent of the changes that occur to fully understand the risks

and identify any countermeasures.

Finally, proteomics is the study of fluids and proteins in the body, such as in the eye (Beeton-Kempen, 2020). Many issues were discovered when it was researched and these issues must be solved before we plan any long term space travel. For example, we discovered the cause of space blindness through the research into proteomics in the NASA Twins study. In the Twins Study, this included monitoring the amounts of different proteins produced and the fluid shifts within Mark and Scott Kelly. They found that in Scott, there were increased levels of a protein that caused fluid to pool around the optic nerve (also worsened by the lack of gravity), putting pressure on it and degrading his vision according to Perez (2019). His vision did not return to how it was previous to the mission, however, it did repair slightly after his return to Earth. This is an extreme risk as astronauts must be able to see, and it only takes 6 months for the symptoms to set in, a mission to Mars will not be possible until this is solved. One way to solve this could be to simulate artificial gravity using centrifugal force, which would lessen the impact, but this would take several years to develop and implement (Man et al., 2022).

Psychological Health

As well as physical health, another main concern for long term space travel is the astronaut's mental health. Fortunately, we have found that a mission to Mars could be psychologically feasible.

In 2003, a study was begun to investigate the changes to several astronaut's mental health during the entire course of their missions according to NASA (2023). Between 2003 and 2016, 20 astronauts were asked to write a journal three times a week, their entries were analysed and then turned into quantitative data relating to how important a certain issue was to the astronaut. This systematic analysis helped greatly to develop new techniques and equipment that could help support the astronaut in the isolation and confinement of space. This is just one of the ways in which NASA is trying to ensure the safety of astronauts' mental health in space.

One consequence is that long term space travel can cause sleep loss. This can cause poor team cohesion and potentially even cognitive conditions as shown in the NASA Video (2018).

Furthermore, the crew members would have to be extremely adaptable as there would be days of heavy workload and stressful situations as well as days of extreme monotony. This also means that the longer the mission is, the worse their mental health would become and the more likely these behavioural conditions would become according to NASA Office of Inspector General (2015).

		Low Earth Orbit (6 months)	Low Earth Orbit (1 year)	Lunar Visit (1 year)	Asteroid (1 year)	Planetary (3 years)
Cognitive or Behavioral Conditions	In-Mission Risk	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Sleep Loss	In-Mission Risk	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Team Performance	In-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Accepted	Accepted

Source: Human System Risks Summary Charts, HMTA, January 2015.

Legend: High consequences | Low to medium consequences | Very low to low consequences

Figure 4. The Risks of Mental Health deterioration in Space (NASA Office of Inspector General, 2015)

There are many reasons for the worsening of mental health. Some include:

- A lack of privacy and space
- Isolation from familiar environments and friends and family
- Ill physical health from space travel

Furthermore, on the ISS, there is constant real-time communication and regular resupply missions according to NASA (2020). However, on a Mars mission, this wouldn't be possible as it can take up to 44 minutes to communicate between Earth and Mars, creating more risk.

Key Words:

Proteomics: the study of the proteome, which is the array of proteins an organism can produce

Monotony: a situation in which something stays the same and is therefore boring

Beneficence: generous giving, or the quality of being generous and doing good

Autonomy: the ability to make your own decisions without being controlled by anyone else

Fidelity: the state of remaining loyal to someone and keeping the promises you made to that person

Preventative: intended to stop something before it happens

Ethical Morality

Considering all the risks of a Mars mission, it is important to consider whether sending a crewed mission to Mars as soon as possible would be a good idea to learn more about interplanetary space travel, or to wait until we have minimised risks. In my opinion, it is not worth risking the lives of the talented and selfless astronauts who are chosen by sending them on an unnecessarily perilous mission before NASA can confirm that it would be beneficial enough to outweigh the risks.

This is why in NASA Office of Inspector General (2015), the OIG included the following principles required to conduct a mission ethically:

- Avoid harm – NASA needs to make sure they prevent as many risks as possible
- Beneficence – NASA must consider whether the mission will be useful
- Favourable balance of risk and benefit – benefits should outweigh the risks
- Respect for autonomy – astronauts must know the risks and benefits of the mission and have the right to determine which processes they may wish to exercise
- Fairness – NASA must make sure everyone is treated equally and given the same opportunities/protections
- Fidelity – after the mission, the sacrifices the astronauts have made must be respected by ensuring their protection for after their return (e.g. lifetime healthcare)

These 6 principles must be met when planning a mission, and if they are not, then the mission will not go ahead. Considering the dangers of a Mars mission and how long it may take to develop the technology, I believe it would not be ethical to launch a Mars mission too early (before 2030), and I am confident that NASA will certainly wait until they are certain they have taken as many risk preventative measures as possible (NASA Office of Inspector General 2015).

Figure 5. An artist's concept of a Mars base (NASA JPL, 2019)

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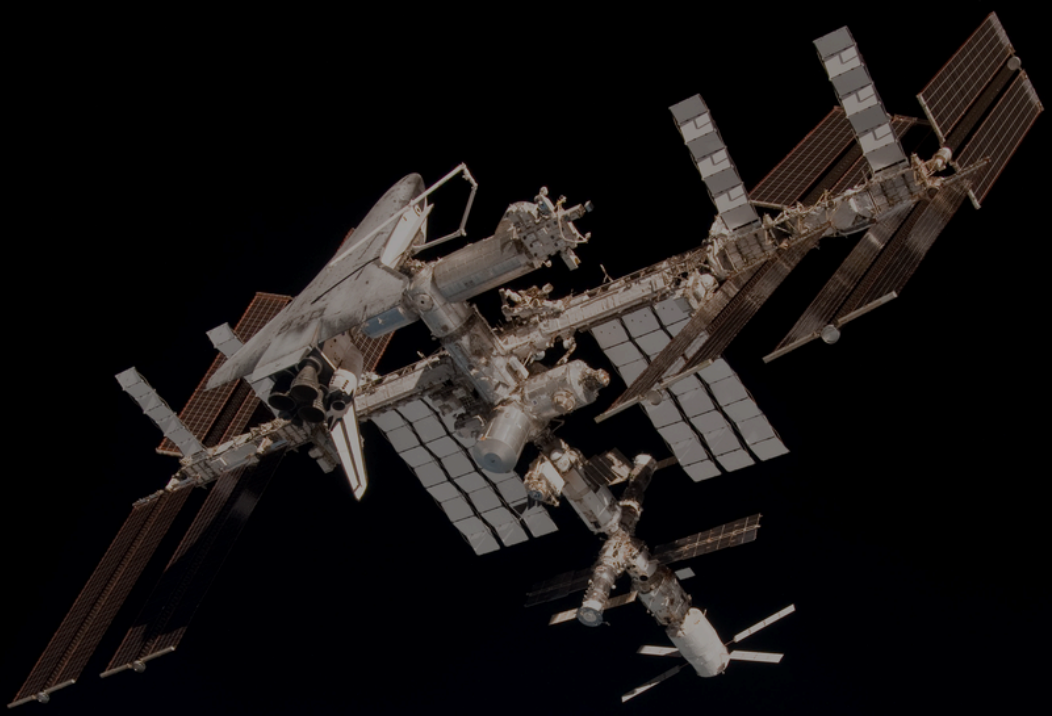

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