

# The Scholar

Issue 10  
July 2018  
[thebrilliantclub.org](http://thebrilliantclub.org)

***What is Quantum Computing?***

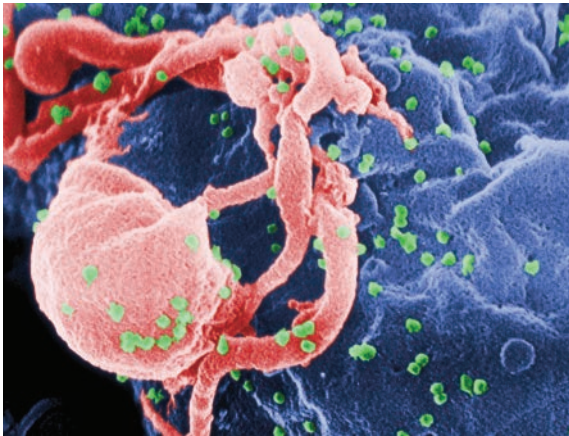
**+**

***Academic essays on  
Working With Nature,  
Driver Distraction and  
Climate Change from  
Brilliant Club scholars***



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The Brilliant Club

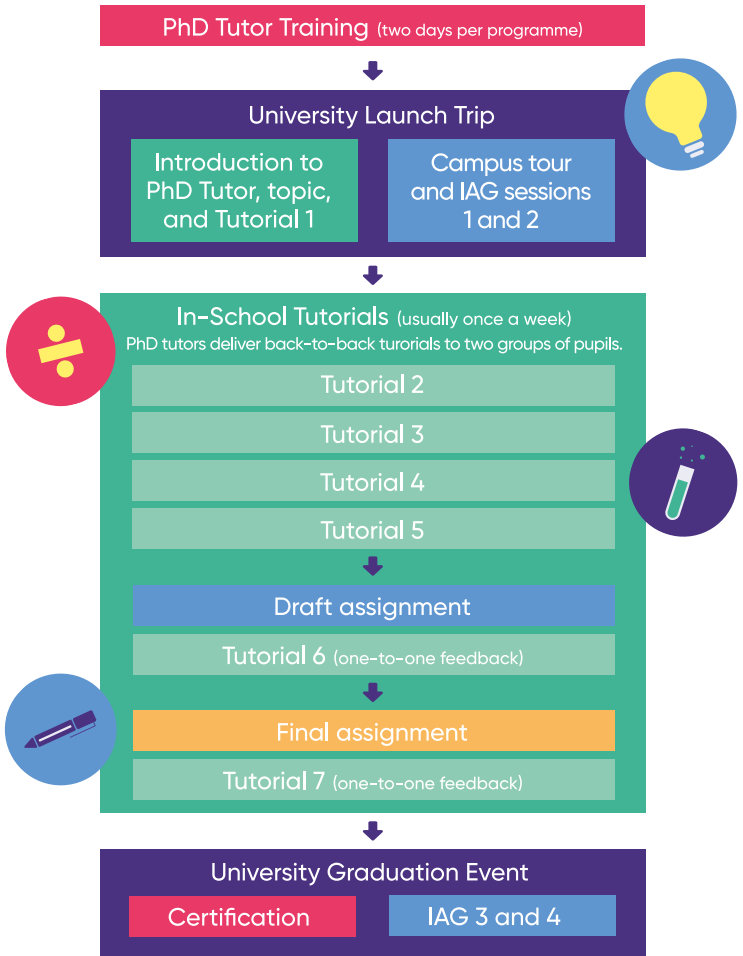
# What is The Brilliant Club?

The Brilliant Club is an award-winning charity that exists to widen access to highly-selective universities for under-represented pupils. We do this by mobilising researchers to bring their academic expertise into state schools through two core programmes: The Scholars Programme and Researchers in Schools.

The Scholars Programme trains PhD and postdoctoral researchers to deliver university-style courses with rigorous academic challenges to small groups of pupils. These courses begin and end with information, advice and guidance trips to highly-selective universities.

Researchers in Schools is a unique teacher training route, designed exclusively for PhD graduates. It provides the training necessary for PhD graduates to become excellent classroom teachers and university-access champions within their schools. Both programmes are designed to support pupils to develop the knowledge, skills and confidence necessary to secure places at highly-selective universities.

The Brilliant Club is building a national movement to mobilise PhD researchers to engage with state schools serving low HE-participation communities. At present, we are supporting over 500 PhD tutors from 30 universities to work with more than 11,000 pupils from over 600 schools across the UK. Through The Scholars Programme, our PhD tutors deliver courses of university-style learning to pupils from Year 5 through to Year 12. The courses they deliver focus on fascinating topics ranging from 'Are Some Infinities Bigger than Others?' to 'Making Maps, Constructing Worlds: Geopolitics and Geography'. As the diagram to the right shows, The Scholars Programme consists of trips to highly-selective universities, a series of tutorials and the completion of university-style assignments, as well as one-to-one feedback for pupils from their PhD tutors. It is the best of these university-style assignments that are debuted here, in *The Scholar*. We are delighted to showcase our pupils' work and celebrate their achievements in the country's only academic journal dedicated to publishing university-style assignments authored by school pupils. Publishing original work is an important component of academia and it is exciting for us to introduce our pupils not only to the world of research but also to the next stage of publishing in academic journals.



Updates

News from The Brilliant Club

Welcome to the latest edition of The Scholar!

We are delighted to be able to celebrate twenty three of the best assignments written by pupils on both The Scholars Programme and Uni Pathways here in The Scholar, Issue 10. The pupils featured come from schools across the UK and their work covers a vast array of fascinating topics, from advancements in the treatment of childhood cancers to quantum computers and the ethics of solitary confinement.

This edition of The Scholar features some of the most articulate and inspiring articles ever produced by pupils on The Scholars Programme and Uni Pathways. The university-style learning that pupils take part in on our programmes is designed to provide pupils with the freedom to develop their own ideas and approaches. We believe this is a crucial skill for all young people and, indeed, for society itself. As H. Duong so prudently states in his assignment (pp. 41 – 42), ‘the legacy of our world is at stake’ and young people can contribute to our collective future through their work, whether that be in the sciences, arts and humanities or the social sciences.

By supporting pupils to develop their critical thinking and independent study skills, university-style learning can empower young people to share their ideas and engage in the debates shaping our world, whether they concern medical ethics, the importance of the arts or the future of nuclear energy.

Furthermore, universities have long been engines of social change. They have been the home of scientific discoveries that have changed the lives of billions, they have seen student protests that have influenced policy makers, and they contribute to the landscape of their local communities in numerous ways. We believe all young people should have the opportunity to experience and contribute to university life.

The Brilliant Club is passionate about exposing pupils on our programmes to these important aspects of university and hope that their projects encourage them to dig a little deeper into subjects that matter to them and to seek opportunities to make their unique contributions to their fields. In doing so, pupils can change their own lives by enriching them with opportunities for learning and, as our guest editor Professor Jo Fox attests, change the world.



The map above shows the locations of all pupils featured.

We would like to say congratulations to the pupils published in this edition of The Scholar and to all pupils who completed The Scholars Programme and Uni Pathways. The programmes are designed to challenge and encourage you to take on new academic challenges, so all pupils who graduate from the programmes should be very proud of themselves!

On page 5 we share some exciting updates on our Annual Conference, MP visits to schools running The Scholars Programme and our Year 12 Information, Advice and Guidance Conferences.

If you are a teacher who would like to find out how your school can get involved with The Brilliant Club, we would love to hear from you! Please get in touch with the contact for your area below:

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Updates

News from The Brilliant Club



The Brilliant Club Conference 2018

Friday 13 July was a truly auspicious day for The Brilliant Club, despite the spooky date, as it saw the charity hold its fifth annual conference in Peterborough! The conference was titled ‘Measuring Up: Research, Evidence and Urgency in University Access and University Success’ and saw delegates from schools, universities, charities and beyond come together to share research and best practice. We were delighted to hear from Chris Millward, Director for Fair Access and Participation at the Office for Students, and to share interesting discussion on topics including ‘What Should University Access Look Like in Ten Years’ Time?’ and ‘Context Matters: Local and National Approaches to Improving University Access’. Our Research and Impact Department ran sessions on how to effectively measure intermediate and long-term outcomes and we heard research presentations from King’s College London on ‘Using Evidence to Change Institutions: Building Belongingness in King’s College London’ and from the National Foundation for Education Research on ‘What Influences a Pupil Premium Student’s Secondary Outcomes?’. We loved working with Nene Park Academy (part of Cambridge Meridian Academies Trust), who kindly hosted the event, as well as our national partners, King’s College London and Ormiston Academies Trust, and our regional partners, the University of Cambridge and the University of East Anglia. If you’d like to find out more, please see our website – we’ll be in touch about 2019!

MPs Visit Scholars Programme Schools!

Throughout the summer term, MPs from across the country have been visiting schools in their constituencies that have partnered with The Brilliant Club to deliver The Scholar Programme. So far 77 MPs have met with over 1000 pupils to discuss their research and aspirations to go to university.

We are delighted that our pupils have had the opportunity to meet their MPs and showcase the fantastic work they are doing!



B Festival

The Brilliant Club was honoured to be the charity of choice for B Festival 2018, an annual music festival held in Kent. Each year B Festival welcomes hundreds of guests to enjoy live music and to raise money for the year’s nominated charity. This year’s festival was held on Saturday 7th July and saw The Brilliant Club running games and painting faces, while providing more information on our programmes!

Year 12 Information, Advice and Guidance Conferences

On Wednesday 11 July and Tuesday 17 July, The Brilliant Club welcomed Year 12 students and teachers to university information, advice and guidance conferences in London and Sheffield.

Student sessions focused on getting in to university and making the most of university to prepare for life beyond. Students attended sessions led by Cambridge Assessment on preparing for admissions tests; Social Mobility Foundation on how to make an impression; the University of Bristol on the UCAS timeline and how to manage results day; The Brilliant Club on demonstrating subject passion; and Wadham College, University of Oxford on Oxbridge interviews, amongst others.

Teachers also had a programme of sessions to attend, which focused on supporting pupils with personal statements, admissions tests and information on the Sutton Trust US Programme from Fulbright.



Guest Article

# Imagine That You Can Change The World – And Then Do It

Professor Jo Fox

Professor of Modern History, Institute of Historical Research,  
School of Advanced Study, University of London

I like reading to my partner's daughter. She has imagination and spirit. Most importantly, she is determined and independent. We have been reading Goodnight Stories for Rebel Girls. The book contains stories about women who were told that they couldn't (or that they shouldn't even try to) change the world. These women are not Disney princesses – they are cyclists and aviators, scientists and musicians, campaigners and educators, doctors and authors, politicians and resisters.

They defied those negative voices – and change the world they did. My friend's little girl also loves this book, and she took it to school on World Book Day. When her classmates asked what 'rebel' meant, the teacher replied that it meant to be 'naughty'. I object to this definition, and I wondered whether the same descriptor would have been applied had the book been about men. These women are ambitious and daring, liberated and inspiring, creative and brave; but they are not 'naughty'.

I was fortunate in that I grew up in a home environment where I was constantly encouraged and given every opportunity to learn. My family told me that I could achieve whatever I set my mind to. It did not matter that I was female or that I attended an East London comprehensive school. Of course, it was not always easy to learn – being studious garnered the attention of bullies; our school had no real access to books (in an age before the widespread use of the internet); class sizes were large and resources few. But it turned out that I already had the one thing that I needed to succeed: curiosity. Curiosity is rarely examined, tested or measured in our education system; and yet, it is the single most important driver of knowledge and change.

All the women featured in Goodnight Stories for Rebel Girls are or were curious: Ann Makosinski, inventor of a flashlight powered by heat from the body bringing light to parts of the world without electricity, Emilia Earhart, the first woman to fly solo across the Atlantic, Ameenah Gurib-Fatkim, bio-scientist and later President of Mauritius, Grace Hopper, computer scientist, and Harriet Tubman, who rescued slaves from Maryland in the 19<sup>th</sup> century – all had the desire to push boundaries and imagine a world where things could be different, whether through scientific endeavour, social and political activism, or singular acts of courage and determination.

All saw their passions through to the end, despite the fact that, for some, this came at great personal cost.

Unfettered aspiration is critical to success. Young women should never feel or be defined or confined because of their sex. The circumstances in which we learn are not always easy, and there may be those who seek to pigeon-hole or constrain us due to our gender, our race, our sexuality, or our disabilities, sometimes in ways that limit our potential. Eleanor Roosevelt pertinently observed that 'no-one can make you feel inferior without your consent'. So, don't give your consent. Only by embracing curiosity, asking questions, and demanding answers will humankind progress, and it is only progress when we hear all voices and draw on our collective talents, wherever they reside. Like those rebel girls, imagine that you can change the world – and then do it.

*Jo Fox is Professor of Modern History, Institute of Historical Research, School of Advanced Study, University of London. She was the first female Professor of History at Durham University and its first female Head of Department. She is now the first female Director of the Institute of Historical Research, founded in 1921. The Institute of Historical Research's mission is to train the next generation of historians, to produce and facilitate ambitious and innovative historical research, and to foster public understanding of history and its social, cultural and economic benefits.*

Professor Jo Fox



## STEM

### What Will Hackers Target Next?

Year 9, Key Stage 4

B. Biju, Cardinal Heenan Catholic High School, Liverpool.

Supervised by L. Shore, Liverpool John Moores University.

#### Introduction

##### 1.1. What is the field of cyber security?

The field of cyber security is one that needs to be carefully monitored and developed continuously due to the rising threats of new malware programs. The important aims of cyber security include the need to ensure the uninterrupted provision of services and their resilience. [1] Cyber security seeks to protect various networks and data connected to the Internet of Things (IoT) from unauthorised access which can be granted to steal data. [2] The hackers involved in these activities are those planning to achieve a ransom by locking/stealing data and then using cryptocurrencies as the method of payment to gain money. Cryptocurrencies are ideal for hackers and cybercriminals as they are anonymous so they can steal the money and not be traced.

##### 1.2. Chosen Technology Topic

The topic that will be outlined in this final assignment is cryptocurrencies. The reason why this topic has been chosen is due to the rise of cryptocurrencies like Bitcoin. In the modern 21st century, it has hit a global market, consequently attracting more people to invest in it. Currently, it is regarded as the highest value and most widespread 'coin'. Experts predict in the future that cryptocurrencies like Bitcoin will replace traditional payment methods i.e. fiat money. Another factor that encourages people is that the pseudo-anonymous cryptocurrency is tax-free. As more money is invested, there are privacy and security issues that arise, making it the go-to method for criminals online. Larger sums of money result in more hackers attempting online robberies.

#### Literature Review

##### 2.1. Who will the hackers be?

With the rise in cryptocurrencies, hackers see an ideal platform for malicious activities in order to steal money. As the number of people using the blockchain increases, there is a higher threat of security issues associated with it. With new cryptocurrencies like Bitcoin entering the market, it is very vulnerable as it is not as robust as other programs that have been operational for many years. The majority of cybercriminals are likely to be civilians attempting to steal money from others. Another group that will attack cryptocurrencies are hackers that will capture devices in the Internet of Things (IoT) network, e.g. an electronic lock on a house. After successfully gaining access, they may demand money before giving back control. Hackers may use cryptocurrencies as the method of payment. Other groups of hackers that may target cryptocurrencies include both 'white hat hackers' and 'black hat hackers'. 'White hat hackers' will 'hack' in order to test the vulnerability of cryptocurrencies and to see if it is robust enough to withstand modern malware programs. 'Black hat hackers' will hack cryptocurrencies for personal gain.

##### 2.2. What will hackers do once they have hacked cryptocurrencies?

After successfully hacking into a cryptocurrency, hackers will try and steal money in a variety of possible ways. Hackers may mine money or directly make anonymous transactions. In theory, if a group of miners gets access to over half of the total network mining power, it can gain control over the system by validating or refusing transactions. [3]. If hackers

get full control over the system, technically they can do what they want by tampering with the transactions and making them unknown. Hackers will target objects connected to the Internet of Things (IoT), like heating systems that are connected, and take advantage of cryptocurrencies for their victims to pay the ransom. In the example of the heating systems, hackers may only give control back after the ransom has been paid. Once the hackers have gained unauthorised access to the cryptocurrency, they can access various parts of the cryptocurrency like the transactions and start tampering with them. After attacking one specific cryptocurrency, they may progress to another currency, making it a worldwide online cryptocurrency robbery which would cost billions of dollars in losses.

##### 2.3. Where will hackers choose to attack?

In geographical terms, hackers can strike anywhere in the world. Due to the lack of government control, some hackers and extortionists may be more advanced in terms of privacy and change various settings like IP address in order to fake a location. Another reason why cybercriminals use cryptocurrencies as the method of payment when they demand a ransom is that they cannot be traced to their illegal activities. In terms of coding, the hackers will attack where there is a flaw in the code. Hackers will run malicious programs to find these within the program code and then attack it. Additionally, hackers may send malicious emails and attachments which contain viruses that encrypt the files of a user, which then forces them to pay the ransom through a cryptocurrency. By tricking more users into clicking their website, more ransoms will be collected which means more money for the hackers.

##### 2.4. Why would a hacker choose cryptocurrency?

The simple and obvious reason why hackers will target cryptocurrencies is due to them being about money. Money has always caught the attention of many and will continue to do so in the future. With the rise in investments in cryptocurrencies like Bitcoin, hackers see potential and try to maximise their gain by hacking a currency with large amounts of money. The popularity of cryptocurrencies is increasing like no other, resulting in a higher usage of cryptocurrencies. In addition, hackers may target new cryptocurrencies as they are not as robust compared to other currencies, which are well established and therefore have tighter security measures in place to prevent theft of money and any violation of protocols. As more cryptocurrencies enter the market, members of the public are encouraged to purchase 'coins' and therefore invest in money which is appealing to the hackers who will gain more money by hacking into the currency. Some hackers may also find hacking cryptocurrencies a casual hobby which they enjoy. However, there are some hackers who hack cryptocurrencies like Bitcoin to create panic.

##### 2.5. When will a hacker target cryptocurrencies?

The attacks on cryptocurrencies are most likely to happen when the exchange rate is high which means each 'coin' is worth more. This is very beneficial for the hacker as they will be able to steal more money. For example, when the exchange rate is low each 'coin' maybe worth £200, but when the exchange rate is high it could be worth £12000 which is significantly more. Hackers may also strike on the cryptocurrency when there is a large number of users online and when they can steal more money from more users. Hackers may also perform a DDoS (Distributed Denial of Service) attack when the exchange rates are very high which causes the currency to crash and destroys the security barriers in place to prevent theft. A DDoS attack is an attempt to make an online service unavailable by overwhelming it with traffic from multiple sources [4]. Hackers may also hack cryptocurrencies when they discontinuously use the malicious subnet (turning on and off at phases during

the attack). [5]

### 2.6. How will a hacker target cryptocurrencies?

Hackers have got many different strategies for targeting cryptocurrencies, varying from simple malicious emails to large processors solving complex mathematical equations and cryptographic puzzles. The most common method for hackers to target cryptocurrencies is by sending malicious emails and attachments containing an undiscoverable virus embedded inside it which is known as Botnet. Botnets are networks made up of remote-controlled computers. Computers infected with the malware allows them to be remotely controlled [6]. When a user opens the attachments, different types of viruses are installed without the user's acknowledgment. With these software packages installed on a victim's computer, a hacker from the other side of the world can use the victim's processor to solve problems in order to mine coins which can be worth over billions. In most cases, the fact that you have an undiscoverable virus that is solving problems with your computer power is often gone unnoticed. Hackers can perform this on a mass scale consisting of thousands of computers. Cybercriminals may also then progress to hack cryptocurrencies by coordinating attacks in public Wi-Fi areas and steal coins. Beyond this, hackers can start spamming a cryptocurrency network like Bitcoin to create artificial congestion. [7]

### 3. Future Work

This is, comparatively, a small research project and if time and resources were infinite it would have been improved in many ways. Some of these ways may suggest future work:

**Better data:** In this study, the data given was at a basic level and the information on the internet was also limited.  
**More topics:** In this study, for simplicity, research was restricted to one topic which prevented further analysis.

To improve future work, the above strategies should be considered and there should be an expansion of the research idea by conducting a joint project with another researcher, whilst also rigorously testing the vulnerability of programs in a lab environment. Further progression in the assignment could lead to the conduction of surveys to the members of the public about their trust in cryptocurrencies in today's society.

### Conclusion

In conclusion, the technology of cryptocurrency could be useful in the future because it enables secure, tax-free transactions which cannot be counterfeited or reversed arbitrarily by the sender. However, there are risks involved, including the price of 'coins' fluctuating which means there is not a certain value for a 'coin'. Another risk is hackers installing malware programs on a user's computer without their knowledge or consent (Botnet). Without a user's consent, hackers can access private details on one's computer and have the control to encrypt files and only release them with a ransom. Hackers can also use powerful computers that can solve complex mathematical equations and cryptographic puzzles. A futher risk with cryptocurrencies is that, due to it being anonymous, no payments or transactions can be traced around the world which makes it harder to see where stolen money is being sent. Cybercriminals can take advantage of this for laundering money across the world. If there was a trace, it would help the police locate criminals. These risks can be reduced by regularly maintaining the program codes and always thoroughly testing the code. If the code that is built is robust, the chance of hackers gaining unauthorised access is very low, which consequently means less chance of an online robbery. Another strategy to combat these newly- emerging crimes is to enforce stricter government policies to discourage many to stop their criminal activities online. In addition, cryptocurrencies should be able to be regulated by governments around the world,

as well as banks. Additionally, creators should make sure there are no flaws in codes before releasing the program. To ensure there are no faults in the code before the release, they could ask a 'white hat hacker' to test the vulnerability of the program and perform the necessary actions upon the outcomes of the test. This conclusion is supported by a researcher named Dr. Catherine Mulligan who is the Co-Director of Imperial College Centre for Cryptocurrency Research.

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#### PhD Tutor's comment:

B. was a model student and a pleasure to teach. His studious nature and curiosity held him in good stead for the daunting task of a technical university style assignment. His achievement is doubly so given that the topic of cyber security is a very specific, somewhat alien subset of the already complex field of computer science. B. has certainly done an admirable job of picking a technology of his choice and reflecting on the security implications. As such, I'm confident that whatever path B. takes he will make a success of it!

## Working with nature to save nature: How should the UK government use biomass and biorenewable feedstocks to help meet revised targets as set by the Renewable Energy Directive?

### Year 9, Key Stage 4

**M. Elster-Jones, Ysgol y Preseli, Pembrokeshire.**  
**Supervised by S. Chapman, Aberystwyth University.**

### Introduction

Modern climate change, a 'large-scale, long-term shift in the planet's weather patterns or average temperatures'<sup>1</sup>, has been the cause for concerns amongst not only scientists, but the majority of the population. Around 97% of scientists believe modern climate change to be over 95% likely due to human activities<sup>1</sup>, most importantly anthropogenic greenhouse gas emissions, that are '... extremely likely to have been the dominant cause of the observed warming since the mid-20th century'<sup>2</sup>. Fossil fuel use by humans has been confirmed as responsible for the majority of anthropogenic GHG emissions<sup>3</sup>. As a result alternative sources of power and fuel are necessary to tackle climate change.

The RED, or the Renewable Energy Directive, is a policy set up by the EU. It's aim is to increase renewable energy usage, which can help reduce greenhouse gas emissions as they either produce energy without need for fuel, for example hydro energy etc. or - in the case of biomass - the CO<sub>2</sub> emitted is balanced by the crops taking up CO<sub>2</sub> when they grow. RED requires the EU to meet at least 20% of its energy needs from renewable sources by 2020, and a minimum of 10% of transport fuels must be renewable.<sup>4</sup> It is one of many national and

international governmental policies aimed at reducing greenhouse gas emissions.<sup>4</sup>

This essay will focus on biomass which is by far the most widely used renewable energy source. This is mainly because biomass is still used as a significant source of energy by people across the world in their homes, especially in poorer countries.<sup>3</sup> Another reason is that biomass can be used as a fuel within existing infrastructure and technology, for example, it is possible to burn biomass in power stations, in household stoves, and to convert it into liquid fuels that can be used by internal combustion engines<sup>3</sup>.

This essay will discuss first, second, third and fourth generation biofuels and their individual advantages and disadvantages. It will cover how each generation is an improvement from the last as research, experience and technology develops, and come to a conclusion about how the UK government should use biofuels to help meet the revised Renewable Energy Directive targets. It outlines that, whilst biofuels should be a significant part in reaching the RED targets, the UK government must take into account a number of important considerations. Firstly, concentrate resources on the most efficient biofuels. Secondly, consider all of the potential sustainability impacts related to different biofuels. Lastly, use biofuels as a short-term solution while zero-carbon technology and infrastructure is developed.

### First Generation Biofuels

When the RED was introduced, biofuels ('a liquid or gaseous fuel for transport produced from biomass'<sup>5</sup>) began to be used. The main types of biofuel are biodiesel, bioethanol and biogas. First generation (1G) biofuels are those that are generated directly from edible feedstock. In the UK, the main driver for the use of biofuels has been the Renewable Fuel Transport Obligation (RTFO) which came into effect in 2008.<sup>6,7</sup>

In 2009, around 70% of UK biofuels were reported to be sourced from three plant oils (soya, oilseed rape and palm oil). Eighty percent of bioethanol in the UK at that time was made from Brazilian sugar cane, with the rest made from sugar beet grown in the UK.<sup>7</sup> Producing biofuels from food crops had many benefits, including the fact that the technology needed to produce them already existed, and that they were already in production. This made them extremely easy to produce, and the use of first generation biofuels also meant that we could mitigate against climate change by growing fuel, instead of by prohibiting certain things (including fuel use).<sup>5,8</sup> Benefits also included the strengthening of rural economies.<sup>5</sup>

Despite this, the disadvantages of first generation biofuels have been proven to vastly outweigh the advantages. The main negative impact first generation biofuels have had on the economy is that, in order to grow feedstock, land previously used to produce food was converted into land used to grow first generation biofuels<sup>8</sup>. This meant that there was less food on the market, and an increase in global food prices was seen<sup>8</sup>. However, there were many other problems associated with first generation biofuels, including herbicide and pesticide leakage into the food chain, soil acidification and the indirect use of fossil fuels associated with artificial fertilisers<sup>8</sup>. In addition, in some cases the use of these fuels led to higher, not lower, carbon emissions<sup>8</sup>, along with biodiversity loss<sup>5</sup>, as deforestation not only harms flora and fauna, but forests can release '600 to 1000 tonnes [of CO<sub>2</sub>] per hectare if converted to energy crops'<sup>9</sup>, and the ploughing of fields similarly leads to CO<sub>2</sub> emissions.

The revised RED, second, third and fourth generation biofuels. The disadvantages of first generation biofuels led to revised Renewable Energy Directive targets to 'ensure that at least 27 percent of energy came from a renewable source by 2030', with the use of food-based biofuels reducing over time<sup>14,15</sup> and

the introduction of second generation (2G) biofuels. First and second generation biofuels are the same, only differing in the way that they are produced and the feedstock that produces them. Instead of being produced from food crops like first generation biofuels, second generation biofuels are produced from non-edible feedstock, including food waste, meaning that they are not taking up food crops. Third and fourth generation biofuels are also being introduced, with added improvements. Third generation biofuels concentrate on using crops that have higher yields and efficiency, such as algae. Fourth generation biofuels consist of the same procedures as third generation biofuels, but any carbon dioxide released during the production of fuel is captured and 'locked up' not by photosynthesis, but by artificial processes, such as oxy-fuel combustion. However, both third and especially fourth generation biofuels remain highly expensive to produce<sup>10</sup>.

The feedstocks used to produce second generation biofuels include:

- Willow, which can be easily grown in this country
- Micro-algae
- Miscanthus, which is widely regarded as one of most efficient second generation biofuels due to its high yield and other benefits
- Waste wood
- Food waste
- Forestry or agriculture by-products (also called residues or co-products) e.g. straw or waste wood

The development of second generation biofuels also involved the use of new production processes, including anaerobic digestion and biorefining<sup>3</sup>. Biorefining is of particular interest, as it can use several different feedstocks, employing a variety of processes to produce a wide range of products, including fuels, chemicals and pharmaceuticals. This integrated process is therefore analogous to that used by oil refineries and ensures that the whole feedstock is converted into products or energy, with no waste.<sup>16,17</sup>

### Advantages and Disadvantages of Second Generation Biofuels

Microalgae, just like plants, fix carbon dioxide in the Calvin Cycle through the process of photosynthesis. Microalgae are efficient at photosynthesis and at producing Tri Acyl – Glycerides, or TAG's, which are molecules rich in energy that can be extracted to be converted into biodiesel. Potentially, they could therefore produce more biofuel than plants. The large tanks that they are grown in can be situated anywhere with a supply of water and sunlight. Despite this, these processes are extremely expensive; concentrating a large enough amount of microalgae and extracting and converting the TAG's all costs large amounts of money.<sup>18,19</sup>

Biogas is produced through the process of anaerobic (without oxygen) digestion of biological material, such as waste biomass, crop material or anything organic. Sixty percent of the biogas produced from anaerobic digestion is methane, which is then used to produce electricity or heat. The digestate (the organic remains of biomass that is not converted to biofuel) produced can be used as a replacement to inorganic fertiliser. However, making sure that no methane leaks from the anaerobic digesters is highly expensive, and the consequences of any leakage would be disastrous as methane is twenty-five times more influential upon global warming than carbon dioxide. Obtaining planning permission for anaerobic digesters is difficult and heavily regulated, as methane is a poisonous gas with a pungent, highly unpleasant aroma.<sup>20,21</sup>

Miscanthus, also known as elephant grass, is a plant used to create bioethanol, but also many other products, such as bioconstruction materials (due to its thick, woody stem), biochemicals and biopharmaceuticals (medicine) by the process of biorefining. Its leaves can be anaerobically digested



and the stems can be pelleted for combustion. It has a lower water content and so combusts better than other bioenergy crops. Miscanthus is fast growing, highly efficient at photosynthesis, with a high yield and it has far lower input needs than other biorenewable feedstocks, meaning that it requires less fertiliser. The drawback of miscanthus is that the fermentable sugars are locked up in the cell walls along with chains of carbohydrates called cellulose, and long chains of proteins called lignin, making them very hard to digest into sugars to produce bioethanol. The crop can have high water demands due to its high growth rate and some species have the potential to be invasive<sup>22, 23, 24</sup>.

Other positive aspects of 2G biofuels include that they can be grown on marginal land, and the plants grown there can even make the land more fertile after a period of time. They can be made from organic waste and, unlike first generation biofuels, they seemingly do not interfere with the food supply.

However, many of the sustainability concerns associated with 1G biofuels also remain relevant for 2G biofuels. These include:<sup>11,12</sup>

- Concerns about the impacts on food security, for example, crop residues such as straw may be part of animal feed mixes
- Loss of jobs and food for the poor – although the marginal land on which second generation biofuels are produced may seem useless for anything else, the poor may rely on it for subsistence.
- Biodiversity and water may be impacted. If, for example, marginal land is used to grow biomass crops, biodiversity benefits could be affected. The use of water over the whole process of growing and refining biofuels can be significant. For example, 4 to 5 litres of water can be used to produce a litre of cellulosic ethanol biofuel.

Additional concerns regarding second generation biofuels are that, in some cases, they are not aesthetically pleasing, for example miscanthus grows extremely tall, and this could take away from the visual qualities of a location. This could affect tourism, in the long run reducing the income of small towns and villages, that rely mainly on this money.<sup>12</sup> Antibiotics can be needed when fermenting biofuel feedstocks and could potentially cause problems if the by-products of fermentation are fed to animals in the human food chain<sup>12</sup>.

### Conclusion: How the UK Government should use biomass and biorenewable feedstocks to meet Renewable Energy targets

This essay has discussed the advantages and disadvantages of modern biofuels. It is clear that these fuels have the potential to contribute to reductions in greenhouse gas emissions and deliver other benefits. They are also the only eco-friendly way possible to produce transport fuels, in order to meet one of the RED targets. It is therefore clear that biofuels are a necessary part of the UK governmental response to the RED targets. However, evidence suggests that there are three important considerations that the government should take into account whilst promoting the use of biofuels.

Firstly, it is imperative that only the most productive biorenewable feedstocks are used, providing the best possible range of benefits, for example miscanthus. Additionally, through the use of integrated biorefining, a maximum amount of energy and products can be produced from a feedstock, with no waste. To do this it is necessary to phase out the use of feedstocks and processes that do not have such benefits, in order to focus resources on developing the most productive and sustainable options. Biofuels are mainly very expensive to produce at present and therefore the money spent by the UK government should be channelled towards the most promising options available.

Secondly, it is important to take account of all the different types of potential sustainability considerations. Sustainability

is about thinking of environmental, social and economic issues together.<sup>12</sup> It is not enough to find the most efficient solutions in terms of greenhouse gas emissions, it is also necessary to consider how actions affect people, wildlife, water and ecosystems.<sup>11,12</sup> In doing so, the UK government should make use of EU Sustainability Criteria for biofuels and bioliquids:<sup>13</sup> To be considered sustainable, biofuels must achieve greenhouse gas savings of at least 35% in comparison to fossil fuels. This savings requirement rises to 50% in 2017. In 2018, it rises again to 60% but only for new production plants. All life cycle emissions are taken into account when calculating greenhouse gas savings. This includes emissions from cultivation, processing, and transport.

Biofuels cannot be grown in areas converted from land with previously high carbon stock such as wetlands or forests. Biofuels cannot be produced from raw materials obtained from land with high biodiversity such as primary forests or highly biodiverse grasslands.

Finally, biofuels should be thought of in the wider context of the transition to more fundamentally sustainable systems. Biofuels should be thought of as useful, but only as a transitional solution whilst the government completes the development of renewable energy that does not emit any greenhouse gasses (zero-carbon technology and infrastructure).

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### PhD Tutor's comment:

It was an absolute pleasure to work with M. during The Brilliant Club tutorials on the subject of biofuel production. I was particularly impressed with her outstanding level of engagement on the topic. Her excellent comprehension of a potentially challenging subject (one involving mathematics, biochemistry, plant physiology and ethics) was well matched with M.'s ability to concisely communicate this gained knowledge in her written work. I have absolutely no doubt that M. would be an invaluable presence on any undergraduate programme.

## An Introduction to BRCA2

### Year 9, Key Stage 4

**B. Harrison, Hayes School, Bromley.**  
**Supervised by S. Jugurnauth-Little, King's College London.**

### Introduction

Family history is the strongest predictor of a woman's chance of developing breast or ovarian cancer. As a result, research has focused on families with a high incidence of cancer in several generations to find specific inherited gene mutations that are passed from parents to offspring. In 1994, the first breast cancer gene was identified and named *BRCA1*. The second gene, *BRCA2* was found by researchers a year later in 1995.<sup>[14]</sup>

### The BRCA2 gene

*BRCA2* is a protein coding gene containing instructions for making a protein that acts as a tumour suppressor.<sup>[1]</sup> Tumour suppressor proteins help prevent cells from growing and dividing too rapidly or in an uncontrolled way.<sup>[2]</sup> Tumour suppressor genes, whose inactivation leads to tumour development, normally try to inhibit cell proliferation, an increase in the number of cells due to cell growth and division and tumour development.<sup>[3]</sup> In many tumours these genes are inactivated, therefore removing negative regulators of cell proliferation. This is linked to the activation of cellular oncogenes. Cellular oncogenes are genes that have one or more characteristics of cancer cells that represent one distinct type of genetic alteration that is involved in tumour development.<sup>[4]</sup>

*BRCA2* is involved in repairing damaged DNA and plays a critical role in maintaining the cell's genetic information. The *BRCA2* protein interacts with several other proteins to mend faults and breaks in the DNA. These breaks are caused by different types of natural and medical radiation or many other environmental exposures. The protein may also help to regulate cytokinesis, cytokinesis occurs when there is cell division in the cytoplasm that is usually followed by the division of cells in the nucleus<sup>[20]</sup>, supporting cells when they divide to form two separate cells.<sup>[5]</sup>

### Location

*BRCA2* is in the cytoskeleton. The cytoskeleton is the network of cells in the cytoplasm<sup>[21]</sup>, nucleus and cytosol, the liquid part of the cytoplasm<sup>[22]</sup>, of the cell as shown in the image below.

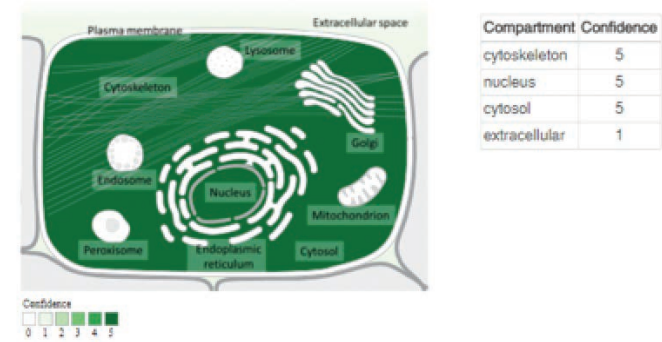


Image source: <http://www.genecards.org/cgi-bin/carddisp.pl?gene=BRCA2>

*BRCA2* is located in chromosome 13 at the position 13.1.<sup>[6]</sup>

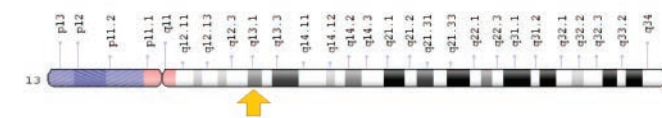


Image source: <https://www.ncbi.nlm.nih.gov/genome/tools/gdp>

### Diseases associated with BRCA2 mutations

*BRCA2* mutations reduce the tumour suppressing function of the protein and increase the risk of cancer. Individuals with harmful *BRCA2* mutations have an increased lifetime risk of developing cancer, as illustrated in the table below.

### What cancer risks are associated with *BRCA1* and *BRCA2*?

Gene	<i>BRCA1</i>	<i>BRCA2</i>
Breast cancer in unaffected women (up to age 80)	60–90%	45–85%
Women with breast cancer (unilateral)	50%	50%
Lifetime risk of a new cancer in the other breast	5 year risk of new breast cancer ~10%	5 year risk of developing a new breast cancer ~5–10%
Ovarian cancer, lifetime risk	40–60%	10–30%
	Risk increases from age 40	Risk increases from mid-late 40s
Male breast cancer, lifetime risk	0.1–1%	5–10%
Prostate cancer, lifetime risk	~10% Similar to population risk	20–25%

Image source Royal Marsden Hospital, beginners-guide-to-brca1-and-brca2: [https://shared-d7-royalmarsden-public.s3.amazonaws.com/files\\_trust/s3fs-public/beginners-guide-to-brca1-and-brca2.PDF](https://shared-d7-royalmarsden-public.s3.amazonaws.com/files_trust/s3fs-public/beginners-guide-to-brca1-and-brca2.PDF)

### Breast cancer

Breast cancer is the uncontrollable growth of malignant breast cells that multiply causing a tumour to form. Breast cancer kills over 500,000 people each year and is the most common cancer in women in both developed and undeveloped countries.<sup>[7]</sup> Women with *BRCA2* mutations are 3 to 7 times more likely to develop breast cancer than women without the mutation.<sup>[27]</sup> 5–10% of cancers are the result of inherited gene mutations and 85–90% of breast cancers are mutations caused by aging and other environmental factors.<sup>[8]</sup>

### Ovarian cancer

Ovarian cancer occurs when cells begin to multiply uncontrollably in the ovaries causing a tumour to form.<sup>[9]</sup> Ovarian cancer is one of the most common cancers that women develop. It can be hereditary and is normally seen in women who are over the age of 50.<sup>[10]</sup> In hereditary ovarian cancer, between 65–85% of the germline mutations are in the *BRCA1* or *BRCA2* gene. People with germline mutations, also known as hereditary mutations<sup>[19]</sup>, are affected by their environmental and lifestyle factors. These determine the likelihood of a woman developing ovarian cancer. The risk of a woman developing ovarian cancer because of *BRCA2* gene mutation is only 20 to 30 percent.<sup>[9]</sup>

### Prostate cancer

Prostate cancer is cancer in the prostate gland and is the most common cancer to occur in men. One in eight men develops prostate cancer, over the age of 50 in the UK. *BRCA2* gene mutations increase the risk of developing prostate cancer but it is unclear whether having a mutation of this protein coding gene is the cause of the disease.<sup>[11]</sup>

### Fanconi anemia

Fanconi anemia is a genetically inherited disease which affects the bone marrow in a person's body. It results in the decrease of blood cells. This disease is often diagnosed in children aged 2–15.<sup>[12]</sup> This disease occurs when a parent has the *BRCA2* gene in their body that is then is passed to their offspring. The offspring has an increased risk of developing a mutation of that gene causing Fanconi anemia.<sup>[13]</sup>



Mutation examples identified through genetic tests

*BRCA2* can be identified through SNP genotyping to determine the likelihood of a person developing cancers associated with this gene. SNP typing provides high coverage of coding regions such as mitochondria DNA and Y-chromosome DNA and structural variants of genes.

The example below is a SNP of DNA from a patient with *BRCA2*-mutated ovarian cancer.

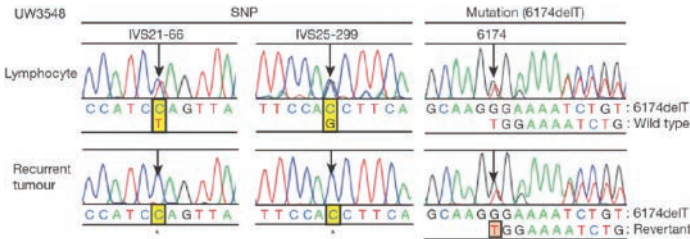


image source: [https://www.researchgate.net/figure/Genetic-reversion-of-BRCA2-in-platinum-resistant-recurrent-BRCA2-mutated-ovarian\\_fig4\\_5588208](https://www.researchgate.net/figure/Genetic-reversion-of-BRCA2-in-platinum-resistant-recurrent-BRCA2-mutated-ovarian_fig4_5588208)

Tests to diagnose mutations

Detecting mutation carriers in genes at an early stage can play an important role in its prevention. It is important because the disease is pervasive in the global population. Screening for mutations in predisposing genes, particularly for patients with a family history of illness, is vital for early diagnosis and treatment.

There are many types of testing to diagnose mutations – below I have described the most common tests for *BRCA2* gene.

Diagnostic testing

Diagnostic testing is a way of diagnosing a patient's disease by ruling out different chromosomes or genetic material in the DNA based on their physical signs and symptoms. Diagnostic testing can be performed at any time during a person's life, even before birth. However, it can only be used to find some genetic conditions and is not available for all genes. The results can affect the patient's choice of healthcare and how they live their life.<sup>[15]</sup>

Carrier testing

Carrier testing is used to identify patients who have a gene mutation that causes a genetic disorder. This type of testing is offered to those who have a family history of a genetic disorder. Usually couples who have a family history of genetic disorders will have this test to show the risk of them having a child with a genetic disorder.<sup>[15]</sup>

Predictive and presymptomatic testing

Predictive and presymptomatic types of testing are used to find gene mutations that are associated with disorders that appear after giving birth. These tests are helpful to people who have a family member with a genetic disorder but don't seem to have it themselves.<sup>[15]</sup>

Predictive testing is used to identify mutations in the patient's genes that increase their risk of developing a genetic disorder such as different types of cancer. Presymptomatic testing is used to find out whether a patient will develop a genetic disorder before they have any signs or symptoms of the disease. The result of these tests can determine whether a person will get a genetic disease and what medical care they need.<sup>[15]</sup>

Ethics of genetics screening

*BRCA* analysis is a genetic test that detects the presence of a *BRCA1* or *BRCA2* gene mutation. This test requires patients to have a blood test or oral rinse sample in order for doctors to determine whether they test positive or negative for the *BRCA1*

or *BRCA2* gene mutation. The results can help to detect cancer early and prevent it from spreading around the body.<sup>[16]</sup>

One of the issues of genetics screening is who controls the data collected. Firms offering to reveal your predisposition to certain diseases based on genetics charge for these services and then sell the data on to researchers and pharmaceutical companies. In the past, this has led to legal challenges being raised against companies performing genetics screening, such as Myriad Genetics. In February 2016, Myriad refused to provide benign *BRCA* variants back to patients on request which violates US government rules on medical records. As a result, many patients have raised legal challenges against Myriad Genetics stating the company refused to give them clear results from their tests.<sup>[17]</sup>

This has helped change the way we think about genetic testing. In February 2018, EncrypGen launched an online database where an individual can upload their digitised genome. It can then be left there until they want to show it to their doctor or they can opt into a service where their data can be sold to researchers. With this service, scientists searching the database will see anonymous profiles along with details such as their hair colour or medical condition. If they find a profile of interest, they can ask for access. Patients can then negotiate a price for handing over part or all of this genomic data. EncrypGen will take a cut of DNA sales and will charge pharmaceutical firms to access the database.<sup>[18]</sup>

To me this seems a much fairer way of managing genetic tests. It puts patients in control of their own data and ensures researchers have access to a wide range of results to continue genetic testing and analysis on cancer and its genetic history.

Conclusion: Impact for patients

*BRCA* gene mutations increase cancer risk not only for patients but also for their families and offspring. *BRCA* gene mutations are responsible for 5–10% of all breast cancer cases and 45% of all inherited breast cancer.<sup>[7]</sup> Researchers who have investigated the *BRCA1* and *BRCA2* gene have found that cancer-predisposing alleles of the *BRCA1* and *BRCA2* genes are autosomal dominant. This means that an individual who inherits a single defective copy will have an increased risk of developing cancer. However, both copies of the gene must be mutated for cancer to develop, which makes *BRCA*-associated cancer autosomal recessive.<sup>[25]</sup>

This can be explained using Alfred G Knudson's 'Two-Hit Hypothesis'. This hypothesis was published in 1971 to explain the relationship between hereditary and non-hereditary retinoblastoma, a rare form of cancer which affects 1 in 20,000 children. The hypothesis states that an individual will develop cancer of the retina if that person was to inherit one mutated gene and incur another one after conception. An individual will also develop this cancer if they were to incur two mutations after conception. Knudson's hypothesis also states that if one gene functions normally the cancer is suppressed. He called these genes "anti-oncogenes" although other scientists named these genes tumour suppressors.<sup>[26]</sup>

If a parent has a *BRCA1/2* gene mutation there is a 50% chance that they will pass it on to their offspring and if the child inherits the *BRCA2* gene mutation from both parents, then they will develop fanconi anaemia. This disorder can lead to many problems with the body such as: shorter growth, a smaller head and underdeveloped thumbs. Having fanconi anaemia will also put the child at a high risk of developing early childhood cancers such as leukaemia.<sup>[23]</sup>

Fanconi anemia has autosomal recessive patterns, which increases the risk of offspring inheriting the gene mutation if both parents are carriers.<sup>[24]</sup> This is illustrated in the diagram below.

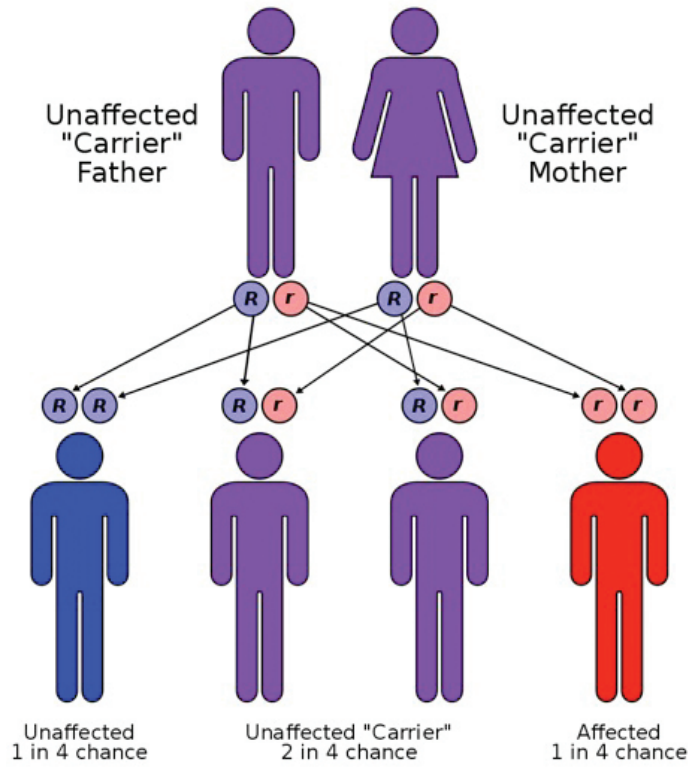


Image source: By entUser:Cburnett - Own work in Inkscape, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=1840082>

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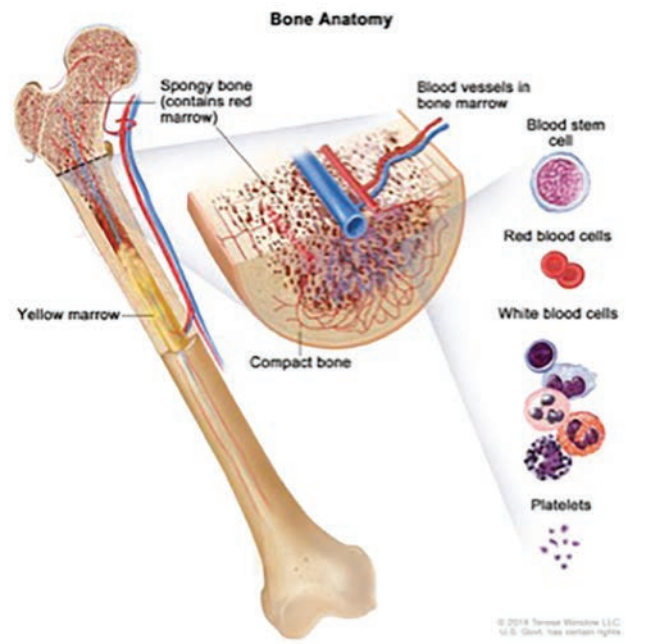


Image source <https://www.cancer.gov/types/leukemia/patient/child-all-treatment-pdq>

Childhood acute lymphoblastic leukaemia (ALL) occurs when the bone marrow in a child's body makes too many immature lymphocytes, a type of white blood cell. This type of cancer can cause death if it is not treated quickly.<sup>[2]</sup>

Bone marrow in children produces immature blood stem cells that will later become mature blood cells. Once these cells have matured they will develop into either a myeloid stem cell or a lymphoid stem cell.<sup>[2]</sup>

Lymphoid stem cells will become lymphoblast cells and then eventually become one of three types of lymphocytes:

- B lymphocytes, these make antibodies to help fight infection.
- T lymphocytes, these cells are used to help B lymphocytes make the antibodies that will help fight infections.
- Natural killer cells that attack different cancer cells and viruses.<sup>[2]</sup>

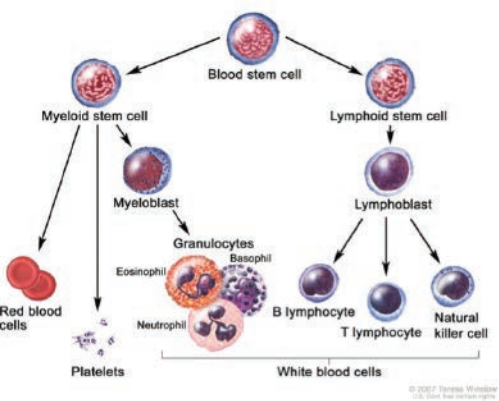


Image source <https://www.cancer.gov/types/leukemia/patient/child-all-treatment-pdq>

Lymphocytes in children with acute lymphoblastic leukaemia (ALL) are not fully developed and are not able to work properly. They were produced too quickly by the bone marrow and grow and divide too fast. The cells build up in the blood causing swelling in the bone marrow, lymph nodes or spleen and can spread into other parts of the body.<sup>[8]</sup>

An introduction to childhood acute lymphoblastic leukaemia

Leukaemia is a type of blood cancer which affects the white blood cells and bone marrow. People who have leukaemia accumulate large numbers of unnecessary white blood cells which take over the bone marrow in the body and, as a result, spill into the bloodstream causing a blood cancer called leukaemia.<sup>[1]</sup>



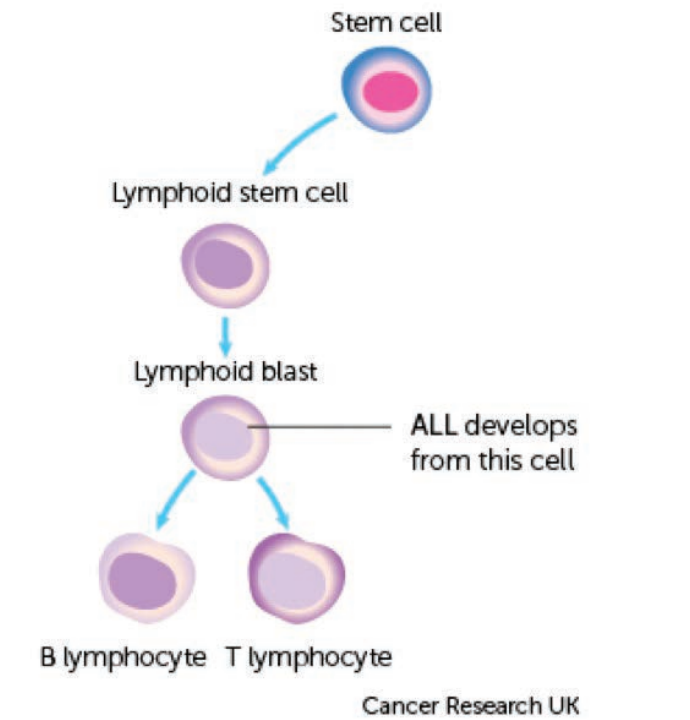


Image source: <http://www.cancerresearchuk.org/about-cancer/acute-lymphoblastic-leukaemia-all/about>

**Genetic history**

Acute lymphoblastic leukaemia (ALL) is the most common type of cancer in children.<sup>[3]</sup> In the UK around 760 people are diagnosed each year, with the highest occurrence in young children aged 0 – 4. <sup>[8]</sup> The causes of ALL are not well known, although some risk factors have been identified, including ionising radiation (the radiation of certain wavelengths that has enough energy to damage cells in the DNA and cause cancer<sup>[4]</sup> chemotherapeutic agents (chemotherapy drugs that have been linked to causing cancers such as myelodysplastic syndrome, acute myelogenous leukaemia and acute lymphoblastic leukaemia<sup>[5]</sup>) and specific genetic abnormalities.<sup>[6]</sup>

These risk factors explain only about 10% of the causes for acute lymphoblastic leukaemia as the other 90% is unknown. It is possible that the other genetic susceptibility factors are involved with the cause; these could be the effect of this alone or in conjunction with many different environmental factors.<sup>[6]</sup>

**Method by which the loci were found**  
**Genomic profiling**

Genomic profiling is a method used by scientists that enables us to learn about all of the genes in a person's body or in a specific gene type.<sup>[9]</sup> It can also enable us to learn about how a gene interacts with its environment and other genes in its genome. This has transformed our understanding of the genetic basis of acute lymphoblastic leukaemia. Recent discoveries have identified genetic variants that show susceptibility and the survival rate of childhood leukaemia can be inherited. Research and analysis has revealed a strong link between two common single nucleotide polymorphisms (SNPs) with susceptibility to not just acute lymphoblastic leukaemia but all types of leukaemia. <sup>[10]</sup>

Genome wide association studies (GWAS) have found that acute lymphoblastic leukaemia has a clear genetic cause from different enzymes and genes. Recent GWAS have identified that there are many genetic factors at many different gene locations in the body that are susceptible to acute lymphoblastic leukaemia such as the *ARID5B* protein coding gene and the *LHPP* gene.<sup>[7]</sup>

This diagram shows the location of the *ARID5B* protein coding gene and *LHPP* gene. It is mostly found in the nucleus of the cell where the cells genetic material is stored. To be more specific, the *ARID5B* and *LHPP* genes are found at the genetic reference point NC\_000010.11 NC\_018921.2.<sup>[11]</sup>

Red line indicates ARID5B localisation in chromosome 10.

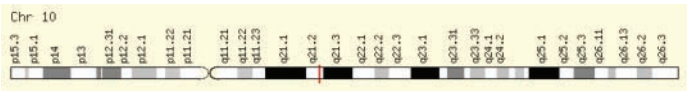
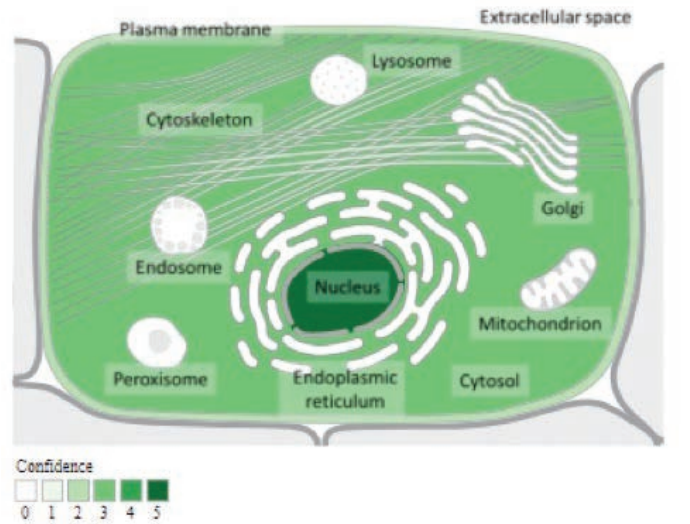


Image source <http://www.genecards.org/cgi-bin/carddisp.pl?gene=ARID5B#localization>



In this diagram, the red line indicates LHPP localisation in chromosome 10.

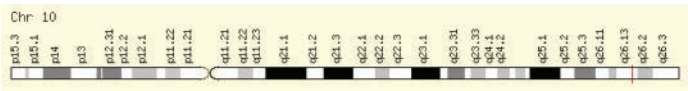


Image source: <http://www.genecards.org/cgi-bin/carddisp.pl?gene=LHPP&keywords=LHPP>

**Impact for patients and medical professionals**

Diagnosing patients in the early stages of their cancer can significantly increase survival rates. Cancer screening is one of the ways in which medical professionals can identify cancer in individuals who don't have symptoms but are at high genetic risk of developing leukaemia. <sup>[14]</sup> This usually takes the form of a blood test and may be followed by a bone marrow aspirate, where doctors take a sample of fluid from the bone marrow to identify the type of cancer. <sup>[15]</sup>

Treatment in the early stages of leukaemia means that around 70% of patients with leukaemia will survive more than five years after diagnosis. Early diagnosis for children, particularly those under the age of 14, can increase survival rates to more than 90% for five years after diagnosis. <sup>[16]</sup> Insight into genetic history of patients can determine the best treatment strategy for an individual.

Treatment for Acute Lymphoblastic Leukaemia depends on the type of genetic mutation and where it is located. Treatment can include one or more of the following<sup>[17]</sup>:

- Chemotherapy, a combination of anticancer drugs and agents
- Targeted therapy, drugs that target specific parts of cancer cells and have less side effects than chemotherapy
- Radiation therapy, the use of high-energy radiation to kill cancer cells (not typically used for ALL)
- A bone marrow transplant, which involves high doses of chemotherapy and potentially radiation, followed by a transplant of bone forming stem cells

**Conclusion**

Until the late 1960's, childhood acute lymphoblastic leukaemia was incurable.<sup>[18]</sup> Thanks to modern medicine patients with ALL now have a 90% chance of survival in certain countries.<sup>[19]</sup> This is largely due to an increased understanding of mutations in the human genome, their link to cancer development and how mutations can impact drug resistance to key treatments for acute lymphoblastic leukaemia.<sup>[3]</sup> Despite scientists' efforts, acute lymphoblastic leukaemia is still a leading cause of child cancer related deaths as it affects many people around the globe and there are many different variants that contribute to the cancer that a patient develops. In low income countries the survival rate is as low as 20%, often due to late diagnosis<sup>[19]</sup>

I believe that recent developments in ALL treatment are very important to people all around the world because it ensures that children with this illness have a chance at life. 25 years ago a child who was born with ALL would have had no chance of survival but if they were born now, children with ALL could be treated and have a chance to live. This is all thanks to our knowledge of the human genome and the process of genotyping in order for us to understand how we can work towards curing not just acute lymphoblastic leukaemia but curing all cancers in the future.

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**PhD Tutor's comment:**

B. excelled at The Scholars Programme, but for me what made her final assignment so exciting was the improvement she showed across the course. B. made enormous gains in confidence and applied it to her work. Drawing all the strands of independent research together to make this beautifully well-written piece of work will have taken her no small amount of effort but I know from speaking to B. that she enjoyed it. I am certain B. will continue to apply this enthusiasm and dedication to whatever field she chooses to study in the future.

**A Novel Vaccination Strategy for HIV**

**Year 9, Key Stage 4**

**K. Sewell, The Beacon School, Survey.**  
**Supervised by A. Dowling, Royal Veterinary College.**

**Introduction**

An essential asset to universal medicine, vaccinations are vital in aiding the eradication and control of harmful pathogens and their consequential life-threatening diseases. The efficacy of immunisation has proven to impact greatly on global health

statistics as vaccinations are now estimated to save two to three million lives annually (Bustreo & Kiény, 2016). Throughout this article, I aim to focus my discussions on the characteristics of the Human Immunodeficiency Virus (HIV), the successes and downfalls of the current control methods and how the HIV characteristics and global transmissions affects the stability of disease control. I will then go on to discuss my novel vaccination strategy for HIV in the areas of antigenic material, immune response, administration, target population and distribution aims, comparing it to previous HIV vaccine trials. I will end the article with a conclusion summarising the correlation of my vaccine to the future eradication of HIV.

**The pathogen and the disease**

HIV is a major pandemic pathogen that currently infects 36.7 million people world-wide ( U.S. Department of Health & Human Services, 2016). Classed under the Retroviridae family, this means that the HIV virus particle is composed of a single strand of ribonucleic acid (RNA) that is replicated by the enzyme “reverse transcriptase” to form DNA (International Partnership for Microbicides, 2018). When HIV enters the bloodstream, the virus bonds and breaks into CD4+ T-cells where copies of the viral DNA is produced within the host's organelles to infect and grow throughout the immune system (International Partnership for Microbicides, 2018) (Brown , 1997). The largest factor accountable for HIV transmission is unprotected sexual intercourse, where the pathogen is present in the semen, vaginal fluids and in other cases, the blood (U.S. Department of Health & Human Services , 2017). Variations in symptoms occur depending on the HIV strain and the disease progression.

Despite the prominence of HIV globally, the populations at highest risk of morbidity are those living in sub-Saharan Africa, with the HIV cases in this region accounting for two-thirds of international figures (World Health Organisation, 2016). I will further explain these trends in paragraph 3.1.

**The current methods for disease control**

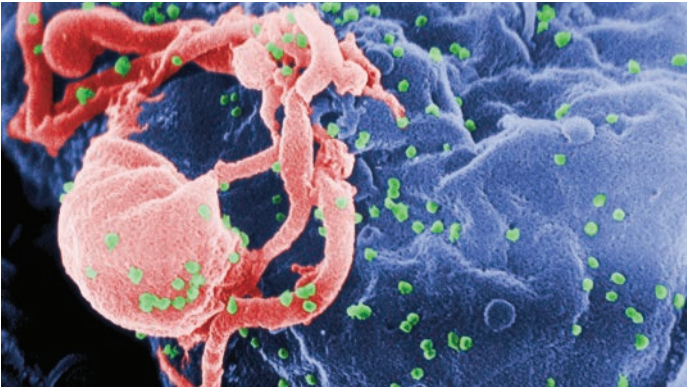
HIV is one of the most detrimental diseases to the socio-economic development of countries, with costs estimated at \$26.2 billion by 2020 (Avert, 2017). Therefore, it is essential that the pathogen is controlled.

Despite the positive relationship between HIV control and the previous methods, the common denominator hindering eradication is the absence of a vaccine. Although the previous controls prevent transmission in most developed countries, in sub-Saharan Africa, where the disease is most prevalent, these methods tend to be inaccessible or taboo. Thus, on a global scale, these methods will not achieve reduction from pandemic to endemic status. An appropriate vaccine would be more likely to do so, whilst being cost-effective and accessible via charitable aid. However, a universal vaccine has yet to have been developed due to many complications. The genetic diversity of the virus differs substantially across geographical regions, with over 60 separate strains and many more recombinants, all with varying virulence (Paddock, 2013).

This poses as an issue to HIV researchers because a singular vaccine would need to incorporate the correct balance of antigenic material for all strains to stimulate universal immunity. Moreover, a cell-mediated response would be needed to target intracellular infections within CD4 leukocytes. A difficulty here would be the potential of reluctance or rejection by healthy leukocytes to destroy similar immune cells.

Positively for HIV vaccine development, several studies of different recombinant vaccines on HIV-positive individuals have demonstrated recurring immunity to the pathogen when present. Although none have deemed entirely sufficient yet, an optimistic path for HIV eradication has been paved for the future.





Scanning electron micrograph of HIV-1 budding (in green) from cultured lymphocyte. This image has been colored to highlight important features; see PHIL 1197 for original black and white view of this image. Multiple round bumps on cell surface represent sites of assembly and budding of virions.

### Designing a Novel Vaccine

The aim in creating a successful vaccine is to have the ability to medically induce a controlled yet realistic immune response to a specific pathogen. When the vaccine is administered, dendritic cells should react to the pathogenic material and present it to T helper cells (Th), which will activate the adaptive production of cytotoxic T lymphocytes and/or immunoglobulins (Janeway CA Jr, 2001). These specialised, adapted cells will thereon be present within the immune system, preventing any further infection of the specific pathogen; an immunity is formed.

Since the discovery of HIV in 1984, very few vaccine candidates have demonstrated any optimistic signs of traditional protection (The History of Vaccines, 2018). Below, I will further explain the failures and accomplishments of a selection of previous trials (Table 3):

The research gathered from these trials suggests that a form of recombinant vaccine that utilises the gp120 Env protein, stimulating a strong CD4+ and CD8+ T cell-mediated response is a key correlate of protection to HIV (in most cases). Therefore, on this basis, I will now present my novel vaccine design for HIV, focusing on the antigenic material, immune response, administration, target population and distribution aims:

### The Antigen, Pathogen and Vaccine Composition

When HIV is contracted, the pathogen bonds to the CD4+ T lymphocytes and replicates the HIV RNA within. Reverse transcription ensues, and the virus particle is consequently transmitted across the immune system. For my vaccine, it is vital that an intracellular infection is prevented prior to this stage. This is because it becomes increasingly difficult to control the HIV virus particle once within several human cells.

I propose that an immunity is induced to neutralise the specific antigenic proteins that fuse to the CD4+ surface, all in a cell-mediated reaction. Under the sub-heading “Target Populations”, I will write a detailed explanation of my geographical reasonings behind selecting to target the potent HIV strains of sub-Saharan Africa. A 2001 study on the epidemiology of HIV-1 in this region concluded that, across three example countries (Cotonou, Yaoundé and Kisumu), the dominant HIV strain was Major Clade A, appearing in 70% of subjects. (Morison, et al., 2001). This is the strain that I will target to immunise.

In terms of genetic diversity, HIV consists of 9 genes (env, gag, pol, nef, tat, rev, vpr, vif, vpr), all of which can combine to code a variety of antigen-forming proteins (Idako & Isa, 2005). For a vaccine to be efficacious, it is important to understand which of these antigens will be required. My vaccine will be a recombinant sub-unit of the immunodominant antigen, glycoprotein (gp) 120. Although my vaccine is designed to be distributed for localised immunisation programs, it would be

immensely beneficial to stimulate immunity to the gp120 antigen as it is present diversely across numerous clades. The method which I will use to create such an immunity is neutralisation. Neutralisation is the process in which immunoglobulins mask the infecting site of a pathogen. Reflecting this onto the HIV vaccine, it is now evident that a cell-mediated and a humoral reaction is required of the stimulants as antibodies must be developed to neutralise the gp120 epitopes on the HIV membrane, which are responsible for HIV T-cell entry (Eggink, et al., 2010). For this, I would like to aptly name my method a “double-lock”. This is due to neutralisation primarily blocking the HIV fusion inhibitors and on a secondary basis, enhancing phagocytosis, the process in which the HIV virus particle would be engulfed and destroyed (Britannica Encyclopedia, 2018). Both “locks” prevent HIV entering a CD4+ cell prior to any form of replication.

Aside from my hypothesis, there is outstanding evidence for such a vaccine to be successful in real scenarios for clade A HIV. A research article published in 2004 reported that several neutralizing monoclonal antibodies neutralised four primary HIV clade A isolates, with a success rate higher than 99% (Kitabwalla, et al., 2003). Another optimistic study was published by the IAVI Neutralising Antibodies Centre (PhD Watkins, 2011). The research extracted antibody genes from the B-cells of HIV-positive individuals, all of which expressed a neutralisation of tier-1 HIV strains (PhD Watkins, 2011).

### The Immune Response

A key issue that has been observed when researching the immunology of HIV is the lack of a natural immune response to the virus upon infection. As previously discussed, the HIV virus particle replicates after creating an intracellular bond to CD4+ T cells, which may be the cause of reluctance to destroy the virus. Despite this, research from all three discussed trials, predominantly the RV-144, suggest that a strong cell-mediated response of the CD4+ and CD8+ T-cells correlate to the prevention of HIV contagion.

### Vaccine Administration

My administration programme is based upon the characteristics of a recombinant vaccine. As only the HIV antigens are within the vaccine, it will be injected into the deltoid muscle, much like the RV-144, because the intramuscular tissue has a good blood supply, meaning that it can easily absorb the vaccine (Weatherspoon & Cafasso, 2016). This is vital for the recombinant vaccine as there is a higher chance of the bloodstream directly intercepting the pathogenic material. It will be administered over a course of three doses to build a strong immunity to such a diverse virus, starting at 13, then 16 and finally as optional doses for sexual intercourse protection.

The regions in which I am targeting are the countries of sub-Saharan Africa. With poor medical infrastructure, the reasonable vaccine strategy would appear to be live attenuated as it could be administered via oral or mucosal inoculation with no medical assistance. However, I have chosen the recombinant because it is the safest, effective strategy for a virus that can so easily mutate.

### Target Populations

Reducing the pandemic status of HIV is indeed a difficult task. A vaccine would need to be distributed to all countries, reaching people in all areas. Nevertheless, with access to advanced medical treatments and education, developed countries tend to be at a lower risk of HIV contraction and are consequently less likely to transmit the disease. Developing low and middle-income countries, specifically those in sub-Saharan Africa, are where HIV morbidity rates are at their highest.

Data suggests that 15–34% of the African population carry the HIV virus in any one area. I aim to target my vaccine specifically

to these sub-Saharan countries. The benefit of targeting my HIV vaccine here would be eradicating the disease from the hotspot zones of transmission and mortality, where a risk of international transmission is highly probable. Whilst protecting other countries, immunisation of HIV in sub-Saharan Africa would simultaneously boost the economies of such developing countries by replenishing depleting workforces. With HIV commonly transmissible via unprotected sexual intercourse, it is vital that a person has developed an immunity before a sexual relationship is endeavoured. Accordingly, the vaccine will be mandatory for all those age thirteen and above. I have chosen this age group because the adolescent immune system is less susceptible to vaccine-induced infections and it allows a sufficient period of time for an immunity to develop prior to sexual intercourse.

### Distribution of the Vaccine

With sub-Saharan Africa as my target population, the distributions of my HIV vaccine will focus on this region. A large proportion of the countries in this particular expanse have a low socio-economic development due to several demographic and environmental factors, resulting in a poor medical infrastructure. Moreover, populations are distributed vastly across the landscape, lowering the possibility of a complete immunisation programme. Both aspects will require charitable aid and health organisations to vaccinate citizens independent of the government. The World Health Organisation and UNICEF have previously implemented such aid strategies, which could be applied to HIV vaccination programs. The Poliomyelitis Eradication Initiative is a prime example of independent clinical aid, in which medical volunteers visited high risk areas to immunise small populations, all building towards the bigger picture of eradication, which has now reduced cases by 99% (Polio Eradication, 2018) (Gates, 2012). The impact on HIV with a similar programme would be immensely positive, reflecting on the successful statistics of the polio initiative.

### Conclusion

In summary of this article, my vaccine would indeed be an improvement on current control methods. There is no commercial HIV vaccine available and the control methods currently used rely on a strong medical infrastructure and accessibility to be feasible. The vaccine that I have designed for HIV Clade A in sub-Saharan Africa neutralises the gp120 antigen, preventing an intracellular and potentially fatal infection. It overcomes the current limitations as it can be accessed via the aid of organisations such the World Health Organisation. Although my vaccine is specifically designed for sub-Saharan Africa, it will still have a positive impact on global biosecurity.

I believe that HIV eradication should be our future aim. For eradication to be successful, we must slowly eradicate HIV in the areas of highest morbidity, gradually reducing the global case numbers. The status of HIV must be reduced in sections, from pandemic to endemic, and from endemic to eradicated. My vaccine has been designed with this future in mind, leading us to HIV eradication!

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### PhD Tutor's comment:

I knew K's final assignment was going to be good because the homework that I had received from her throughout the course had been of a high standard and she was very interactive in tutorials. Nevertheless, when I came to mark K's final assignment I was stunned by how good it was. She achieved 77 out of 100 (a 1st), which means that she is already performing to an excellent standard at A-level. I have no doubt that K. is going to excel in any subject that she decides to continue with in the future.

## Is Nuclear Power Safe?

### Year 9, Key Stage 4

**S. Townley, Knutsford College, Cheshire.**

**Supervised by R. Worth, University of Manchester.**

Nuclear Power has been long debated about. Some people think it is dangerous, and some people believe it is completely safe. Nuclear power is a non-renewable power source, however, it is more eco-friendly than our current fossil fuels. Nuclear power currently accounts for 17% of the energy produced worldwide<sup>[1]</sup>, and there are currently 447 operating Nuclear power stations around the world today, with 61 already under construction<sup>[2]</sup>.

Most people believe that nuclear power is the most dangerous source of energy on our planet today; however fossil fuels do much more severe damage to our environment. Nuclear power plants are surprisingly eco-friendly, as they only release steam from the cooling towers, which is not radioactive, despite the myths surrounding it. One of the major problems with nuclear power is the radioactive waste which is produced. Nuclear power, like all other sources of power, does produce



waste; however unlike all other forms of energy generation, this waste is regulated and is therefore not allowed to cause any pollution. In most countries with nuclear power, radioactive waste from power plants accounts for a small proportion of the total hazardous waste produced. Radioactive waste is also produced by many other sources, including medicine, agriculture, research, manufacturing, non-destructive testing and minerals exploration <sup>[20]</sup>.

Most of the nuclear waste that is produced is defined as low-level waste (LLW). Low-level waste is the least radioactive and has only 1% of the overall radioactivity of radioactive waste. It accounts for 90% of the overall volume of radioactive waste. Intermediate-level waste (ILW) is more radioactive than LLW and has 4% of the total radioactivity found in radioactive waste. This type of waste takes up 7% of the overall radioactive waste produced.

The most dangerous type of radioactive waste is high-level waste (HLW). This waste is the most radioactive and accounts for 95% of the total radioactivity. However, HLW only accounts for 3% of the total waste produced <sup>[20]</sup>. A lot of people would argue that HLW is too dangerous and therefore we should stop producing it, however, because such a small amount of it is produced, we don't actually have to worry about it as much as people do.

Nuclear waste is considered a problem; however, over time radiation levels decrease and the danger of these materials also decrease. We have found ways to reprocess used fuels, by extracting fissile materials for recycling <sup>[21]</sup> and we treat and condition nuclear waste, in order to minimize the volume of waste which requires management via treatment processes and reduce the potential hazard of waste by conditioning it into a stable solid <sup>[22]</sup>. All of these methods are helping to make nuclear waste and nuclear power plants safer.

All of this information is reliable because it has come from an organisation that bases all of its work on nuclear power. This information will have been supplied by people who know a lot about nuclear power, because they work or run this organisation about nuclear power. I would consider most of this information to be correct and reliable, and to be a good source of information since it will probably have been checked by a nuclear specialist working for the organisation.

There are lots of different ways of producing power. We have hydro, wind, solar, geo-thermal, fossil fuels, and nuclear. All of these sources produce power but are not always as effective as a nuclear power station. A nuclear power station can produce power all the time and does not rely on the wind having to blow or the sun having to shine. This is what makes it really effective.

Nuclear power can also be located anywhere and does not have to be in a specific location, like hydro and geothermal. This means the power stations can be built away from people's homes and towns and in the countryside. The only other source of power that can do all these things is fossil fuels, as you only need the fuel, like nuclear power, to run. However, fossil fuels are far more dangerous than nuclear power.

For a start, coal power stations accounted for 43% of CO<sub>2</sub> emissions in 2012 <sup>[3]</sup>. The CO<sub>2</sub> is what is destroying our ozone layer. This information is reliable because it came from a nuclear-based project. This means that the organisation that wrote this piece of information would have been researching the advantages of nuclear power before they wrote the article.

Another reason that nuclear power is a safer alternate to fossil fuels is because for each person that dies because of a nuclear power station, 4,000 people die because of a coal power station <sup>[4]</sup>. This is a huge difference in deaths and this clearly

shows the difference in safety between a nuclear power station and a fossil fuel power station, especially coal power stations. However these figures might not be totally accurate because they came from an online news company that might exaggerate the information in order to get people to read it.

Most people would argue that nuclear power is not safe because of the devastation of a nuclear accident. Although nuclear accidents do have a devastating effect on the environment, they are also very, very rare. The UK's worst nuclear accident, Windscale Pile, and the world's worst nuclear accident, Chernobyl, were both more than thirty years ago, with Windscale pile being in 1957 <sup>[5]</sup> and Chernobyl in 1986 <sup>[6]</sup>. The longer we have had reactors, the less accidents that have occurred.

The information about Chernobyl is accurate because it is from a nuclear based organisation and is therefore reliable; however the source about Windscale Pile is not so reliable because it is from an online-based news company that write articles.

Windscale Pile was caused because of a fire that started in the reactor core. Although the fire was partially due to human error, it was mostly due to inadequate and faulty machinery. This is because, on the night of the fire, the workers who were on duty were superheating the core in order to prompt a winger release. The workers, who believed the winger release hadn't taken place properly, then superheated the core again, causing a fire to start in the reactor.

The workers, however, were oblivious to hotspots, which had developed in the reactor. These hotspots were the cause of the fire when the core was superheated for the second time. The reason the workers were oblivious was that the thermocouples that monitored the heat inside the core, failed to register the extreme heat of the hotspots purely because they weren't able to register such high temperatures.

The Windscale Pile accident was purely caused by inadequate machinery, which led the workers to make a decision, which, as a result of them being unaware of the dangers, led to a nuclear disaster <sup>[5]</sup>. The information about Windscale Pile is not completely reliable because it was part of an article written for an online news company. This means that the person that was writing this article could know a lot about nuclear power, however they might not know a lot about nuclear power, meaning that this source of information could be reliable, but it's hard to be totally sure.

Chernobyl was another example of a nuclear disaster caused by human error. However, in the Chernobyl disaster, the workers decisions caused the machinery to work inadequately, showing that the technology to control the reactors had improved, however our knowledge about them had not. This means that, following this theory that the safety is always improving, our reactors now should be a lot safer. Chernobyl was caused by human error during an experiment that was taking place at the Chernobyl plant. The explosion was caused because of an inadequate amount of control rods within the reactor core. On the night of the explosion, the workers had to lower the control rods in order to decrease the amount of fission taking place in the reactor, however the workers dropped all the control rods in, resulting in almost a complete shutdown. This was the first error they made.

The workers became concerned about instability and started raising control rods, however after the power output did not reach the desired 12%, the workers decided to disable the safety systems, which was their second mistake, and ultimately the most fatal of the two. The workers continued to raise rods, however at 1:23am, there was a sudden power surge and the reactor started to overheat. It is thought that there were only 6

control rods in the reactor at this time, with the safe operating minimum being 30.

Although the emergency shutdown button was pressed, the reactor continued to overheat. The control rods were lowered, however these only displaced the water, allowing more of it to turn to steam. The reactor started working at 100% more than its normal rate, and the fuel pellets got so hot, they exploded, killing 30 people <sup>[7]</sup>. This was all because of a mistake that the workers made, which was deciding to drop all the control rods, instead of a sensible amount like half or lower. The Chernobyl accident was rated at 7 on the INES scale.

This information is quite reliable because it came from the BBC, which is a well-established news organisation. This means that the BBC would probably have known a nuclear expert who would have written the article; however, because we can't be 100% certain, it might not be that reliable.

Since then, the only nuclear accident to happen has been Fukushima, which was caused by a tsunami, which is a natural occurrence and is not predictable <sup>[8]</sup>. This is also not an occurrence caused by humans or technology, which shows that firstly technology has advanced and is therefore a lot safer and far better at keeping reactors in a stable state. It also shows that humans have learnt how to control reactors better and this also means that nuclear power has become a lot safer.



Unit 4 after the hydrogen explosion. The bright yellow object is the lid of the Reactor Containment Vessel.

Fukushima was caused by a 15 metre tsunami that hit the Fukushima Daiichi reactors on the 11th March 2011. The tsunami followed an earthquake that hit Japan at 2:46pm. The eleven reactors that were operating at the four nuclear power stations shut down automatically when the earthquake hit and all sustained no significant damage. This shows that the technology has improved in the prevention of a nuclear accident in the case of an earthquake, however, the Fukushima Daiichi reactors were still vulnerable to the tsunami that followed.

When the tsunami hit, it took out twelve out of the thirteen generators at the Fukushima Daiichi power plant, leaving units 1, 2 and 3 without power. Eight out of the eleven reactors that were located across the four power plants had power from either the grid or onsite backup generators in order to run the residual heat removal system. This meant those eight reactors could be cooled, and this allowed for a complete 'cold shutdown' within 4 days after the earthquake hit.

The problem with units 1, 2 and 3 is that they had no working backup generators, as they had all been wiped out by the tsunami. This meant that these reactors did not have any

coolant circulating them, which meant the reactors could not be cooled. Although the reactors had no fission taking place, they were still producing heat due to the decay of the fission products. This heat turned the standing water inside the pressure vessels to steam, which reacted with the very hot cladding of the fuel to make hydrogen.

Even though they eventually managed to start manually pumping water back through the reactors, they had to vent the hydrogen and steam. The hydrogen that was released in units 1 and 3 caused an explosion when the hydrogen reacted with the oxygen in the air. There was also an explosion in unit 4, because the venting system was connected with unit 3 and some of the hydrogen was vented into the unit 4 building. The unit 2 building did not explode; however, the containment vessel of the reactor did rupture, leading to the release of lots of radioactive material. Unfortunately, nobody knows what caused the unit 2 pressure vessel to rupture <sup>[9]</sup>.

This information is reliable because it came from an organisation that specialises in nuclear power. This means that they will have nuclear specialists who know what they are talking about. The information is also reliable because the page and information have been updated recently, meaning that all the information is up to date.

Many power stations, especially ones in the UK, have responded to the events at other nuclear disasters, such as Fukushima, and have developed ways to stop this sort of a disaster happening again. This is really important because it shows how other nuclear power stations are responding to these sorts of events. It also means that nuclear disasters are becoming more and more unlikely because we are always finding new ways to stop them from occurring, and ways to minimise the damage they cause to their surroundings and the environment.

For example, nuclear power stations have responded to the events at Fukushima by undergoing 'stress tests'. These are tests that thoroughly scrutinise the safety of nuclear power stations, finding ways to prevent even the most unlikely of events. In the UK, nuclear power stations have increased the protection of their nuclear power plants by purchasing and installing new back up equipment, enhancing on-site resilience and improving emergency arrangements and ways to deal with severe accidents. <sup>[10]</sup>

The information here is also quite reliable because it has come directly from the energy company that runs the nuclear reactors. This means that they will know a lot about their reactors and will definitely have nuclear specialist who can check that all the information is correct. However, the energy company may lie slightly, in order to make themselves look good and safe to the public.

Another reason that nuclear power is safe is that since 1951, when the first ever nuclear reactor that produced energy was introduced <sup>[11]</sup>, there have been lots of changes to the reactors. The reactors we use now are a lot different to the reactors we used to use, in terms of safety and efficiency. Since the first generation of nuclear reactors, generation I, there has been four new generations, generation II, generation III, generation III+, and generation IV. Around the world we currently use generation II and generation III. Almost all of the generation I's have retired <sup>[12]</sup>.

The generation IV reactors are made up of 6 different prototype reactors, 3 thermal reactors and 3 fast reactors. These are experimental reactors that are currently being researched; however they are not expected to come into service until 2030. The 3 thermal reactors are Very-High-Temperature Reactors (VHTR), Supercritical-Water-Cooled



Reactors (SCWR) and Molten-Salt Reactors (MSR). A version of the VHTR is called the 'Next Generation Nuclear Plant' (NGNP). This design of a generation IV reactor is expected to be completed by 2021.

There are also three fast reactors which are proposed as part of the generation IV reactor designs. These are Gas-Cooled Fast reactors (GFR), Sodium-Cooled Fast Reactors (SFR), and Lead-Cooled Fast Reactors (LFR) <sup>[12]</sup>. France and Russia are currently developing Sodium-Cooled Fast Reactors (SFR) for near-term demonstration and Russia is expected to build a prototype Lead-Cooled Fast Reactor (LFR) around 2020 <sup>[13]</sup>. Generation IV reactors focus on providing sustainability, economics, safety and reliability. The most important thing that generation IV reactors will provide is improved safety. This backs up the point that reactor technology is always improving and that the reactors are always getting safer. Generation IV reactors are expected to excel in safety, due to new improvements to the overall safety of not only the reactor, but also the nuclear power station itself.

Generation IV reactors will provide more safety by having a very-low likelihood and degree of reactor core damage. This means that nuclear accidents due to core damage are a lot less likely. The generation IV reactors also improve in safety by eliminating the need for offsite emergency response. This means that generation IV reactors will have onsite emergency response, allowing for quicker response to an emergency. This can help prevent nuclear accidents <sup>[14]</sup>. All of the information about the generation IV reactors is reliable because it has come from an online forum that specialises in generation IV reactors. This means that all their information will be based around generation IV reactors and the organisation that run the forum will therefore have a good understanding, as well as good knowledge of, generation IV nuclear reactors.

Overall, nuclear power is an effective way of constantly producing safe power. Although nuclear accidents have happened in the past, we have developed our technologies and our understandings of nuclear energy, enabling us to have safe and sustainable use of nuclear power. Also, nuclear power is not harming the ozone layer, and is not polluting our atmosphere.

Nuclear power is not only more eco-friendly than fossil fuel power stations, but it is also safer. It also only accounts for 1% of the overall radiation dose we receive in our lives <sup>[15]</sup>. So, people might say that nuclear power is harming our planet, but it's not, and people might say that nuclear power releases harmful radiation, but it doesn't, so, as this report proves, nuclear power is a lot safer than we might believe!

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### PhD Tutor's comment:

Throughout the entire process of The Scholars Programme, S. has demonstrated a capability and enthusiasm to perform at a very high standard across all skills being assessed, immersing himself into the topic given, and going well beyond the minimum required. He has diligently responded to advice and criticisms offered throughout the programme, whilst also showing maturity in other valuable skills such as communication and organisation, resulting in the delivery of a thorough and well-presented piece of work which would be welcome on a university undergraduate programme. Well done S. Keep it up!

## The effectiveness of using preclinical models for studying angiogenesis in cancer

### Year 9, Key Stage 5

**G. Timbey, Ormiston Horizon Academy, Stoke-on-Trent. Supervised by S. Ashraf, University of Nottingham.**

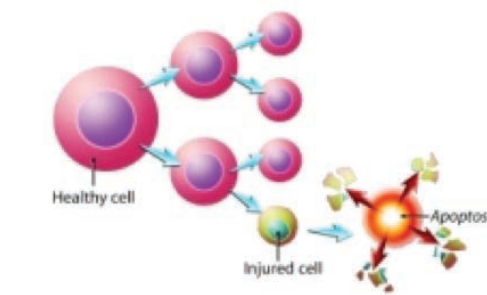
### Background to Cancer

Cancer is a disease in which angiogenesis occurs to the benefit of the disease and not the person. Cancer affects 14 million people worldwide annually and results in around 8.2 million deaths. The UK accounts for 163,444 of those deaths with 630 of them in the Staffordshire Moorlands alone. The statistics for cancer are more than just deaths, with a lifetime chance of cancer in the UK being 1 in 2 whilst survival rates have doubled in the last 40 years to 50%. This shows that almost everyone will know someone who has had cancer, and whilst survival rates have increased to 50%, there are still a significant number of deaths.

### Cancer and Angiogenesis

As shown in Figure 1, cancer is the uncontrolled division of the body's cells. This occurs when old or damaged cells live when they should die, where new cells are grown when or where they are not needed, when cells pass on faulty genetic information and when mutated cells divide uncontrollably creating tumours. When mutated cells grow bigger than a pin head they need a blood supply to continue growing. The cancer releases growth factor proteins; the most well-known is Vascular Endothelial Growth Factor (VEGF) of which there are many variants. These growth factor proteins trigger angiogenesis causing more blood vessels to form to provide nutrients and oxygen to the tumour, allowing it to grow. Normal formation of blood vessels is controlled using promoters such as VEGF. Inhibitors block the signalling of growth factors or the formation of endothelial cells to regulate the formation of blood vessels. A balance of pro-angiogenic and anti-angiogenic factors are essential to maintain healthy growth. But in the absence of inhibitors, promoters cause an abnormal chaotic and uncontrolled growth of blood vessels.

### Normal Cell Division



### Cancer Cell Division

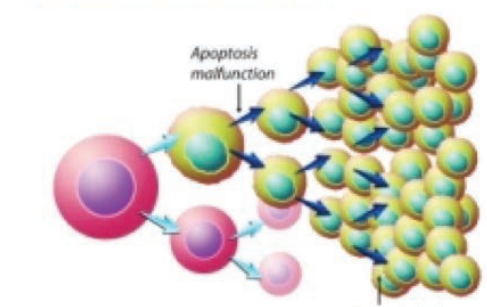


Figure 1: Normal cell division compared to Cancer cell division

VEGF is heavily involved in the growth of cancer tumours. For a tumour to gain a blood supply and grow it induces proteins to break down the extra cellular membrane, this provides a route for the endothelial cells to migrate forming more tubes and proliferating. As more pro-angiogenic factors like VEGF are released, they attach to the tyrosine kinase receptors, inducing angiogenesis. This in turn enhances the blood supply to the tumour allowing it to grow. In the absence of inhibitors provided by the body, chemical compounds in the form of drugs are introduced to the patient in an attempt to bring the rates of angiogenesis under control. Some inhibitors function by preventing VEGF from binding to the tyrosine kinase receptors reducing the effect of the VEGF released by the cancer, in turn slowing the rate of angiogenesis and therefore of tumour growth. Similarly, other drugs bind directly to the VEGF reducing their ability to connect with the tyrosine kinase receptors, this is highlighted in Figure 2. Examples of these drugs are Bevacizumab (Avastin) and Cetuximab (Erbix).

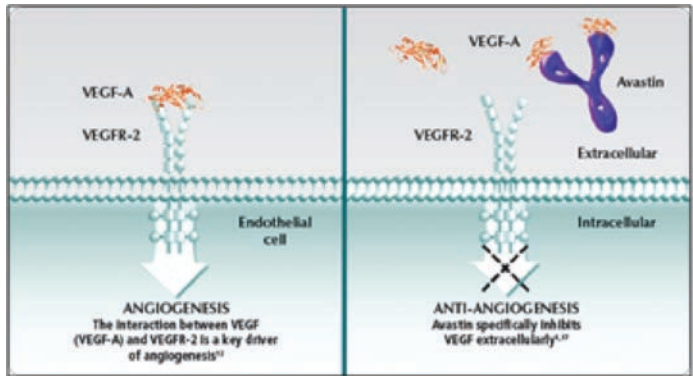


Figure 2: Illustration of the action of VEGF inhibiting drugs such as Bevacizumab (Avastin)

### Preclinical Techniques

There are two main types of preclinical models used to understand the role of angiogenesis in cancer. In vivo; studied in living organisms and in vitro; studies conducted in a laboratory with cells isolated from their normal host. Each has benefits and drawbacks.

In vitro techniques often use a commercially supplied gel matrix including endothelial cells and pro angiogenic factors to simulate conditions in the body. The studied compounds are introduced and the after incubation can be labelled with fluorescent dyes allowing a microscopic imager and data analyser to provide results. These machines process multiple assays at once.

In vivo techniques require the careful management of host organisms, which vary from zebrafish assays to rodents each requiring a different set of conditions. The in vivo assays require the introduction of the disease into the relevant cells. The studied compounds can be introduced, and their effects can be observed. Techniques involving transparent organs in hosts like the zebrafish or rodent corneas allow direct observation which can be performed non-invasively. And as the process uses living organisms it is difficult to automate.

In practice the study of cancer requires the combination of data from in vivo and in vitro techniques. The strengths of one help fill in gaps from the weaknesses of the other.

### Examples of Preclinical Techniques

An example of an in vivo technique is the zebrafish assay. This is where cancerous cells are introduced into a zebrafish. Zebrafish are a good host due to the early formation of a cardiovascular system in a transparent embryo. The advantages of a zebrafish assay are that they are a whole animal, and it is technically simple with many animals available. However, the respiratory system and cardiovascular system are not the same in the zebrafish as in a human, in other words they are non-mammalian, so the results may not be generalisable to humans. Also, the conditions required to maintain the animal are expensive.

An alternative in vivo assay is the Chorioallantoic Membrane (CAM). This is extra embryonic compared to the embryonic membrane in the zebrafish. This means that CAM can be used broadly to study angiogenesis because of its extensive vascularisation and easy accessibility. Similarly to zebrafish it allows non-invasive observation and is suitable for large scale screening. It also like the zebra fish has the weakness of being non-mammalian; therefore, the results may not be generalisable to humans.

An example of a mammalian assay is the corneal micro pocket. This can be undertaken in the cornea of mice, rats and rabbits. An advantage is that the cornea has no pre-existing blood vessels and the formation of blood vessels is caused by the introduction of pro-angiogenic factors rather than by natural processes. Because the cornea is transparent, a dye can be used to highlight the blood vessels for imaging to occur. A weakness includes the irritation of the cornea by the test substances which results in an inflammatory response complicating interpretation of the results. Compared to zebrafish and CAM the assay is more technically difficult due to the size of the eye, reducing in size from the rabbit to the mouse. Of course, the ethical considerations increase with these larger organisms.

An example of an in vitro assay is the tube formation assay. In this assay endothelial cells form tubes along an extra cellular matrix, allowing the introduction of test compounds to promote or inhibit tube formation. Tube formation is important in diseases like cancer where they form an important step in the growth of the lumen within the capillary, which will provide the blood supply to the tumour. In this assay tube formation is quantifiable by measuring parameters such as the number, length or area of the tubes, which can be undertaken, as shown in figure 3, with 2D microscope imagery and computerised image processing.



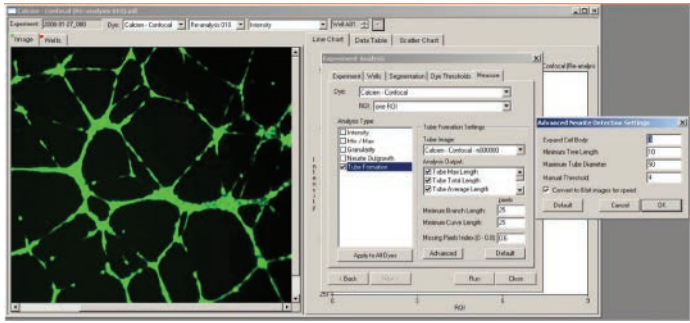


Figure 3: Imaging of Tube formation using automated microscopic imagery

The ease of setup and short culture period allow high throughput analysis. The disadvantage of this is the absence of other cell types that have a role in angiogenesis are not present such as fibroblasts, muscle cells or tumour cells. This means there is also a requirement to study in vivo. Another disadvantage is that tube formation may not represent true differentiation due to other non-endothelial cells demonstrating tube formation.

Another commonly used in vitro assay is the migration assay. This measures the growth and migratory response of endothelial cells in response to pro-angiogenic or anti-angiogenic factors. By introducing a scratch to the cell culture plate, the extent of cell migration is measured by the amount of closure within the wound (scratch). The benefit of this assay is that it is a cheap, repeatable and reliable way of measuring cell migration. A disadvantage is that prolonged studies are difficult because cells grow on their own, not just because of the angiogenic migration, as time progresses it is harder to see which has the greater effect.

### Ethical Considerations

Both in vitro and in vivo assays have ethical considerations which affect the choices made when experimenting. In vitro assays, whilst not a directly living organism, require the collection of tissues from living organisms, potentially in an inhumane manner. In vivo assays are directly linked to living organisms and the testing deliberately causes illness and potential distress, pain or irritation to the animal. Further testing at the clinical stage may use nonhuman animals with physiological similarities such as monkeys or dogs. The treatment of monkeys or dogs only must meet basic standards, but their fate is directly driven by the needs of the experiment rather than the animal's welfare. The level of interest in minimising this type of experimentation is especially high and results in greater numbers of in vitro testing and similarly to reduce the number of in vivo experiments.

### Improving in vitro testing

To improve the quality of results from in vitro tests alternatives have been sought to the existing 2D methods using flat glass petri dishes. One of these is the creation of a 3D cell culture where the previously mentioned limitation of in vitro tests is the lack of cell to cell interaction and presence of the ECM limits the relevance of the tests. The 3D hanging drop technique, shown in figure 4, allows a spherical micro tissue consisting of Endothelial cells, ECM, fibroblasts and tumour cells. In this environment artificial scaffolds are not required to generate micro tissues. This 3D environment more closely reflects the in vivo conditions. Previously with 2D methods endothelial cells had an apoptotic rate of 100%. Experimentation using the 3D method showed that in the culture with cancer cells and fibroblasts viability was still high after 10 days.

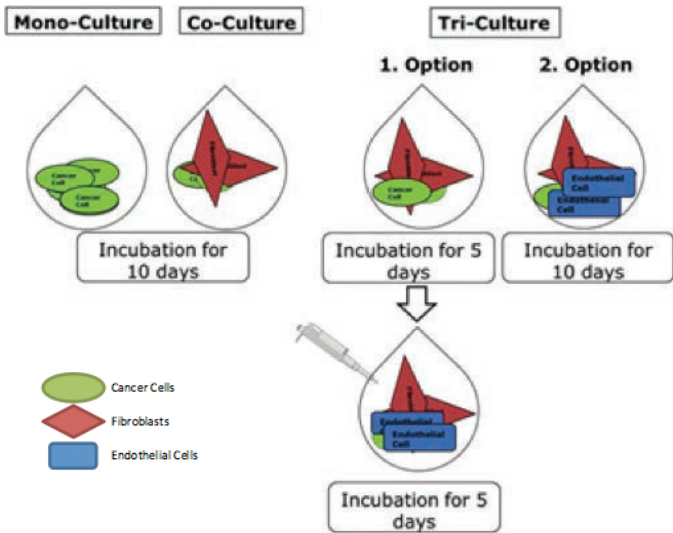


Figure 4: Diagram showing how a 3D Cell culture works

### Conclusion

In conclusion, in my opinion, cancer has a significant impact on the population and so the continued use of all available techniques to study the role angiogenesis plays in this disease is necessary. Testing on non-human animals such as monkeys is increasingly considered unethical. This has resulted in an increased burden on in vivo testing on smaller animals which aside from ethical considerations is not a perfect model either due to differences between the animals and humans. Increasingly additional testing is being performed at in vitro levels. It is also not a perfect model and the simplified nature of the testing fails to replicate in vivo or in use testing conditions. The development of 3D models to improve the applicability of the in vitro stage is important to give better results with higher validity so that the in vivo and in use testing can be minimised.

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### PhD Tutor's comment:

G. was a pleasure to teach. Her assignment was of a very high quality. I was impressed with her style of writing and the in-depth understanding of the subject studied. She constructed and developed a clear argument based on evidence. Her logically structured layout of the essay made it a pleasing read. Not only did G. show evidence of further reading, going beyond the material taught in the tutorials, but she displayed sparks of critical thinking, a highly valued skill to have in higher education.

## Can weathering be used as an effective carbon offsetting tool?



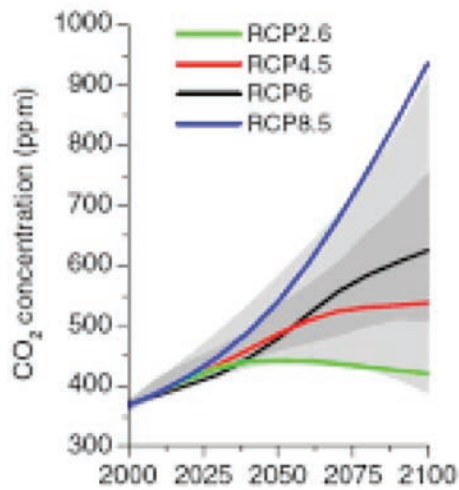
Year 10 Key Stage 4

D. Aref Al-kadi, Tapton School, Sheffield.  
Supervised by Dr R. Thorley, Tapton School.

**Abstract: What are the benefits of tree-planting? How can it offset CO2 emissions and what's the potential of tree planting for CO2 offsetting?**

### 1) Why are carbon offsetting schemes required?

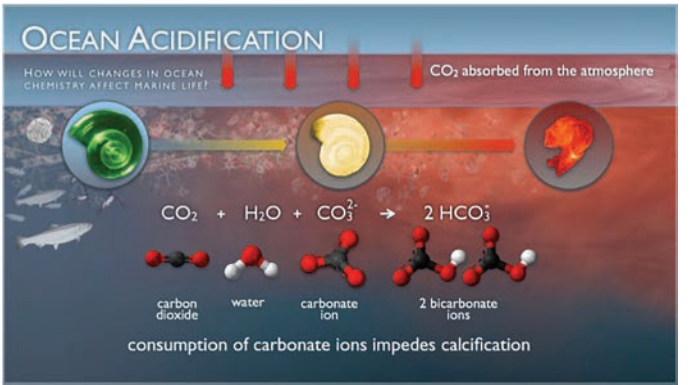
Carbon offset schemes allow people and companies to invest in environmental projects around the world in order to balance out their own carbon footprints. The projects are mostly designed to reduce future emissions but can also be based in developing countries. Clearly this CO2 concentration increase has been caused by the colossal amounts of CO2 that have been released into the atmosphere due to natural carbon sources such as respiration, natural gas, decomposition, and ocean release but mostly from human activity like deforestation, production of cement and plastic; and the burning of fossil fuels, coal oil and gas. Studies have shown that carbon dioxide concentrations are rapidly increasing, and predictions have been made using Representative Concentration Pathways (RCPs) and by creating graphs:



RCP 8.5 is known as the "business as usual" scenario, which assumes that across the globe, we continue to produce as much CO2 as we do at the moment. People make no extra effort to reduce emissions or take any CO2 out of the atmosphere. In this scenario the concentration of CO2 will increase profoundly throughout the 21st century and many livings will die due to global warming and ocean acidification. Where does all of this CO2 go?

### Ocean acidification

Well, 22 million tonnes of CO2 are released into the atmosphere every day! 30% of it goes into the ocean water causing ocean acidification and damaging effects on ocean species. Coral, oysters, clams and plankton are very important as they act as homes for many species and food for others. They are being dissolved because of the increasing acidity of the sea water.

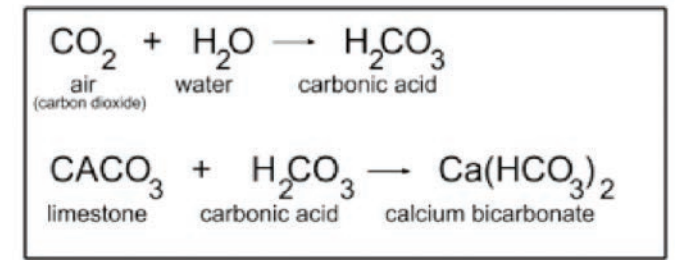


These species provide regular nutrition for fish and the rapid decrease in their numbers is causing fish to starve and die. This impacts us humans as many countries rely on fish a staple food, therefore this could cause famine to occur in these countries. People are working on sinks for carbon dioxide in order to stop this huge impact on the atmosphere such as artificially capturing and storing CO2 (which is used for producing products like soft drinks later on), as well as enhancing natural sequestration processes like oceans, plants and other organisms that remove CO2 from the atmosphere.

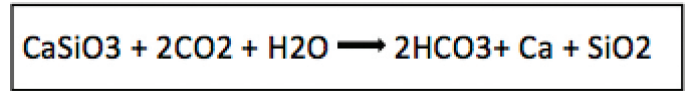
### 2) Rock weathering and mycorrhizal fungi

Rocks are made up of different minerals that contain chemical elements that plants need for growth. Chemical weathering of rocks uses up CO2 and releases minerals which can later be taken up by plants. Rock weathering is considered as a sink and one of the solutions to CO2 excess. The weathering of rocks by chemicals is called chemical weathering. Rainwater is naturally slightly acidic because CO2 from the air dissolves in it. Minerals in rocks may react with the rainwater, causing the rock to be weathered.

Some types of rock are easily weathered by chemicals. For example, limestone and chalk are made of a mineral called calcium carbonate. When acidic rainwater falls on limestone or chalk, a chemical reaction happens. New soluble substances are formed in the reaction. These are washed away and the rock is weathered. In carbonic rock weathering:



For every mole of CaCO3 weathered, 1 mole of CO2 is sequestered. Whereas in silicate rock weathering:



For every mole of CaSiO3 weathered, 2 moles of Co2 are sequestered.



### Why do mushrooms eat rocks?

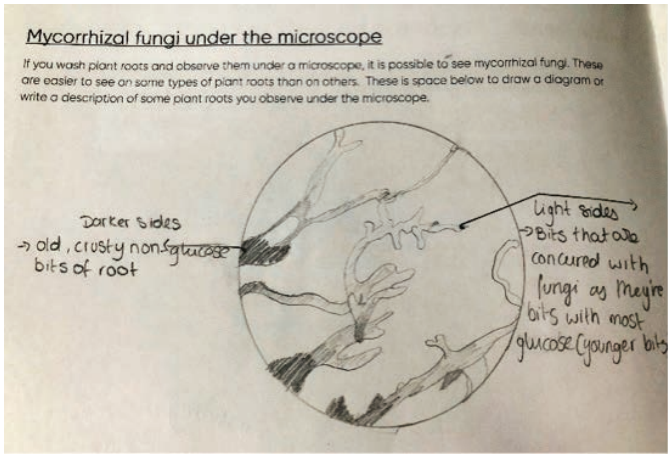
There are 200–600 km of mycorrhizal mycelium in every kilogram of soil.

Plants need mineral nutrients so they will exchange some of their glucose to the fungi and gain some minerals in return. Mycorrhizal fungi is one of the microorganisms that is provided nutrition by root secretions and is very good at taking up soil nutrients. Mycorrhizas increase the absorbent surface area of roots by 100 – 1000 times. Fungal hyphae (root-like structures) are narrower than roots, so they can get inside soil pores and cracks where roots cannot fit and access nutrients hidden there. Fungi can also increase the availability of soil nutrients by releasing secretions that increase the rock weathering. Mycorrhizae can secrete weak acids, chelating compounds and enzymes. In exchange for supplying mineral nutrients to plants, mycorrhizal fungi gain carbohydrates from their host plant roots. Plants give between 12–30% of the sugars they produce by photosynthesis to feed these fungi. To summarise, rock weathering breaks the rocks using CO<sub>2</sub>. Plants and fungi ‘attack’ rocks and gain all of the available nutrients; fungi grows on rocks and releases acids to dissolve the minerals in them and release nutrients. Let’s consider how the nutrients get to the plants.

Well, mycorrhizal fungus covers the roots, surrounding it with a process called symbiosis. This fungi is very good for the soil as it breaks down the rock, using citric acid or carbonic acid, which releases minerals. The fungi mostly coat the younger parts of the roots as they have the most glucose and that is where most of the exchanging of glucose from plants and mineral nutrients from fungi occur.

### Student observation

As we washed, dried and observed the plant roots under the microscope, they had an odd differentiation of colour from one side towards the other; there was a dark thin and crusty section where the root is most old with least glucose and as you go further away from the dark end, it gets lighter and lighter until it is a creamy white colour which is the younger region where the fungi has developed to extract the plant’s glucose, exchanging it for minerals.



D. Al-Kadi – diagram produced in class after observations.

### Mineral nutrients

Rocks store many essential nutrients that organisms need to grow. Phosphorus is one of the most important and used in many fertilisers. The chemical reactions that make rocks weather both sequester CO<sub>2</sub> and release mineral nutrients into solution. Mineral deficiency is the situation where a plant cannot get enough of a particular mineral from their soil for healthy growth.

Different minerals are needed for different reasons, so deficiency in each one causes different symptoms. Plants use phosphorus as it helps them in synthesis and maturity. Additionally it is also used in fertilisers. Phosphorus, potassium and magnesium are three essential plant nutrients. Plants and their mycorrhizal fungi increase rock weathering through producing a variety of chemical and enzymatic secretions. Rates of silicate and rock weathering are increased up to 10 times by plants and their fungi.

### Plant mineral nutrition

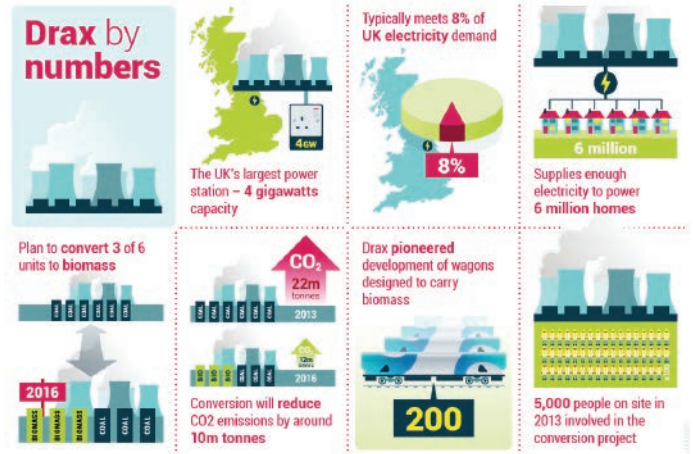
There are 17 nutrients that are essential for plant health. There are the primary Macronutrients, such as potassium and phosphorus, secondary Macronutrients, like sulphur and magnesium, Micronutrients, just as zinc, nickel, boron and iron, and finally non-mineral elements, like hydrogen, carbon and oxygen. Optimal yield can only be produced when all these nutrients are in proper supply. According to the law of minimum, if one or more nutrients is lacking in the soil, crop yields will be reduced, even though an adequate amount of other elements is available. Three other nutrients essential for plant health are:

- Nitrogen – as it is a major component of chlorophyll which plants use to convert sunlight energy to produce sugars from water and carbon dioxide (photosynthesis).
- Phosphorus – which is used in reactions within the plant to produce cell structural and storage components.
- Potassium – this nutrient will directly make plants susceptible to temperature changes.

### Drax power station

Drax is the UK’s largest power station, typically meeting 7–8% of the UK’s power needs. It is Europe’s largest decarbonisation project and the UK’s largest renewable electricity generator. Biomass is organic material obtained from living or recently living plant matter that can be burnt to produce energy. The materials that Drax uses include low grade wood, such as forest thinnings, tree tops and branches as well as sawmill residues, and to a lesser extent residual agricultural products, such as straw, sunflower seed husks and peanut husks.

Drax has already converted two generating units and with a third in the pipeline Drax will reduce its annual carbon emissions by around 12 million tonnes a year. This is equivalent to taking 3.3 million cars off the UK’s roads or making the UK’s entire industrial and manufacturing sector zero carbon – with sustainable biomass providing a carbon saving of approximately 86% compared to coal-fired generation.



As we know, weathering removes CO<sub>2</sub> from the atmosphere as the rocks are broken down by different acids using up CO<sub>2</sub> in order to exchange the minerals they gain for glucose so we want more weathering and more trees so that they can use up as much CO<sub>2</sub> as possible.

In my opinion, site A has the greatest potential for CO<sub>2</sub> sequestration at Drax because site A weathers more quickly at a speed of 1.03 mm/year, and planting trees increases uptake tenfold. The same area of trees can be planted in both areas A and B so it is more reasonable to therefore pick Site A as this would use up more CO<sub>2</sub>.

It would be ideal to plant the trees in a way that all of them receive sufficient amounts of sunlight and have enough space between them. As well as considering the tree type so that the trees that have the best fit for this process (amounts of glucose, amount of CO<sub>2</sub> exchanged) and mostly tree species that are fit for the weather and climate as well as the amount of gases and pollution released in that area.

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### PhD Tutor's comment:

It was a delight delivering the University Pathways course at Taptan School in Sheffield. I was really impressed with D’s engagement with this challenging interdisciplinary research topic, integrating elements of biology, chemistry, geology and maths. Her in-depth understanding of this complex science clearly comes through in her essay writing – congratulations D!

## Why should we study human reproductive biology?

### Year 10 Key Stage 4

**A. Christon, Cedar Mount Academy, Manchester.**  
**Supervised by A. Tomova, Manchester Metropolitan University.**

### Introduction

Improved and developed understanding and research of human reproductive biology has led to significant development of treatments regarding reproductive diseases, advancements in assisted reproductive technology (ART), new contraception methods, to mention but a few. This study and research has had remarkable and beneficial impacts on humanity. Though, there have been a few crucial impediments in this scientific process.

But what is human reproductive biology? This is the study of the sexual development and growth of humans. Through reproductive biology, we are able to have a wider understanding of how the reproductive system changes over time and the different phenomena that may affect it.

Human reproductive biology can further be divided into a various number of fields such as cell biology, fertilisation, reproduction, fertility medication, reproductive systems. To understand the importance of human reproductive biology, one must know the fundamental components of the subject.

### Cell biology

Cell biology is the study of the cell functions and structure. A cell is the smallest basic structural and functional unit of all living organisms. Knowing how cells function and what they are made up of is essential to all fields of biological science. During the cell division cycle, body cells in organisms divide to produce new daughter cells. In eukaryotes, there are two main types of cell division. The first type of cell division is mitosis. Organisms use mitosis to replace damaged cells and for growth. Before any cell divides, it has to undergo the interphase– the cell has to grow in order to increase the amount of subcellular structures. It then duplicates its DNA so there is one copy for each new cell. After the interphase, the cell can undergo mitosis which is divided into four phases; the first phase is prophase– the chromosomes condense and become smaller. The nucleus membrane breaks down and the chromosomes remain free in the cytoplasm.

The second phase is metaphase– the chromosomes line up in a straight line at the centre of the cell. The third phase is anaphase– the chromosomes are pulled apart by the cell fibres. The two arms of each chromosome move to opposite ends of the cell. The last phase is telophase– each of the sets of chromosomes form membranes. These become the nuclei of the two new cells. The cell membrane and cytoplasm will then divide to form two separate daughter cells, this is called cytokinesis. The cell has produced two genetically identical diploid cells because each cell has the exact same set of chromosomes as the parent cell <sup>[1]</sup>.

The second type of cell division is meiosis. In humans, meiosis only takes place in the reproductive organs to produce gametes for sexual reproduction. Meiosis is a lot like mitosis. The cell goes through similar stages however in meiosis, the cell has a more difficult task, it must separate the sister chromatids. There are two divisions in meiosis; homologue pairs separate in the first division, and the sister chromatids separate in the second division. In each division, the cells go through four phases; prophase, metaphase, anaphase and telophase. Before the first division, the interphase takes place. During prophase I, the chromosomes condense and pair up with their homologue partner to share their DNA. In metaphase I, the homologue pairs line up at the metaphase plate and get ready for separation. In anaphase I, the homologue pairs are pulled apart and move to opposite ends of the cell. The sister chromatids of each chromosome do not come apart. Finally, in telophase I the chromosomes are at opposite ends and nuclear membranes form around them forming two haploid daughter cells <sup>[2]</sup>.

In the second division, the interphase does not take place. During prophase II, the nuclear membrane breaks down and the chromosomes condense. In metaphase II, the chromosomes line up again individually on the metaphase plate. In anaphase II, the sister chromatids are separated and pulled to opposite ends of the cell. Finally, in telophase II, the chromosomes de-condense and nuclear membranes reform around them. Cytokinesis splits the sets of chromosomes into new cells forming four haploid daughter cells that are genetically different, in humans the product will be sperm or egg <sup>[2]</sup>.

### Fertilisation

Sexual reproduction requires the combination of genetic material from two parents to form a zygote. This occurs when two gametes (sperm and egg) fuse together. This process is called fertilisation. The zygote will inherit characteristics from both parents because it has received a mixture of genetic material and so it will be similar to its parents but not identical. Gametes contain only half the normal number of chromosomes, 23. When sperm and egg fuse together, the zygote that is produced will have the full set of chromosomes, 46 <sup>[3]</sup>.



In order for fertilisation to take place, sperm must go through capacitation in order to have the ability penetrate through the egg and have increased motility; the sperm must be able to swim through the environment of the vagina; ovulation in females has to occur and the egg has to move to the opening of the fallopian tube; sperm has to be ejaculated into the woman's vagina and swim to the opening of the fallopian tube in order to meet the egg <sup>[4]</sup>. Gametes have adaptations to increase the chances of fertilisation e.g. sperm are produced in large numbers, have a lot of mitochondria to provide enough energy, have a tail for increased motility etc. <sup>[5]</sup> while eggs contain the nutrients needed for mitosis after fertilisation, its membrane only allows one sperm to fertilise it etc. <sup>[6]</sup>

After fertilisation, the fertilised egg travels down to the uterine wall for implantation. The fertilised egg undergoes multiple cell divisions through mitosis. After the divisions, the zygote becomes a tiny ball of cells, which is a blastocyst embryo. The blastocyst may be able to successfully implant itself in the uterus although not all are able to. If the blastocyst is not able to implant itself or is not fertilised, the body sheds the uterus wall and blastocyst. This is known as a menstrual period. If a blastocyst does implant, a hormone called human chorionic gonadotropin (hCG) is produced in the uterus, it prevents the uterine lining from being shed so the woman does not have a period. <sup>[7]</sup>

The period between conception and birth in which the embryo develops is known as the gestation period. After eight weeks, the embryo is called a foetus. In humans, birth normally happens after about forty weeks. Child birth is the ending of a pregnancy when a baby leaves a woman's uterus.

### Infertility

Infertility is when a couple cannot get pregnant naturally despite having regular unprotected sex for over 12 months <sup>[8]</sup>. There are several factors that can affect fertility.

Female factor infertility: Most of the causes of infertility in women are caused by problems with ovulation, scarring from surgery: the fallopian tubes may get damaged or blocked after a pelvic surgery, premature ovarian failure, fibroids: these are non-cancerous growths that may block the fallopian tube <sup>[8]</sup>.

Male factor infertility: In men, the biggest factor of infertility is poor quality sperm, cancer or an infection in the testicles<sup>[8]</sup>.

Lifestyle and environment: In both genders, infertility can be caused by old age, being severely under or overweight, sexually transmitted diseases, smoking etc <sup>[8]</sup>.

### Fertility drugs

These are drugs which boost fertility levels by increasing the levels of certain hormones in the body, helping to mature and release eggs. Fertility drugs are used in ART treatments to improve the chances of a successful pregnancy and they can also be used if you ovulate irregularly. Some examples of commonly used fertility drugs for women are; clomiphene citrate (clomid)- is an oral tablet that blocks the effect of oestrogen at the hypothalamus, gonadotrophins-luteinising hormone (LH) and follicle-stimulating hormone (FSH) are types of gonadotrophins. LH and FSH stimulate ovaries to produce and mature eggs. They are usually given to women who have Polycystic ovary syndrome (PCOS), dopamine agonists-examples are bromocriptine and cabergoline. They are used to correct hormonal imbalances caused by high levels of prolactin, metformin hydrochloride- it makes the body more sensitive to insulin and it is particularly useful for women who are obese and have PCOS because they are more likely to have problems

with their insulin levels. Some fertility drugs can cause extreme side-effects e.g. abdominal pain, dehydration, headaches, ovarian hyper-stimulation syndrome (this is when fertility drugs overstimulate the ovaries, causing them to develop too many follicles; may cause ovaries to swell and become painful and may lead to extra fluid building up in the body) or high chances of multiple pregnancies <sup>[9]</sup>.

### The study of human reproductive biology is important and beneficial because;

It has led to advancements in ART, such as In Vitro Fertilisation (IVF), intracytoplasmic sperm injection (ICSI), fertility drugs etc. These advancements have been very effective in helping couples who may have infertility problems such as abnormal sperm morphology, asthenospermia, oligospermia or a physical disability or who are carries of a communicable disease. These couples are given the chance to be able to raise children of their own if the treatment is successful.

It has led to advancements in the microscope techniques and specialised micro tools used to view the sperm and egg which have helped to improve the techniques and therefore the success rates of ART e.g. with IVF. More recently, there have been improvements in time-lapse imaging (using a microscope and camera built into the incubator) which means that the growth of the embryo can be regularly monitored to help know which ones are more likely to result in a successful pregnancy <sup>[10]</sup>.

The causes, symptoms and treatments of some reproductive diseases have been discovered with research, and people with these diseases are able to get help and treatment.

It has led to new contraception methods being developed for couples who want to prevent pregnancy e.g. the use of oestrogen to prevent the release of an egg, use of progesterone to stimulate the production of thick cervical mucus, the use of barrier methods (e.g. diaphragms, condoms) etc. Couples therefore will not have to think about contraception every time they have sexual intercourse if they are using hormonal methods <sup>[11]</sup>.

### The study of human reproductive biology still has its disadvantages

A common issue with ART is the safety of the embryos if they are being handled outside of the body e.g. with IVF, if many embryos are removed, the ones that are unused may be destroyed (some people think it is unethical because each embryo is a potential human life)<sup>[10]</sup> or in some cases frozen and might not be very good for use in the future or with Intracytoplasmic sperm injection, the sperm that is used to fertilise the egg may not have otherwise been able to fertilise it which may result in abnormal growth of the embryo<sup>[12]</sup>.

The genetic testing of embryos before implantation raises ethical issues as some people think it could lead to selection of preferred characteristics e.g. eye colour, hair colour, gender etc <sup>[10]</sup>.

The use of the infertility treatments may give couples false hope because not all treatments are successful for every couple, some couples may have unexplained infertility. For example, the average success rate of IVF in the UK is low, 26%. This makes the process upsetting and stressful for some couples, especially if it results in multiple failures <sup>[10]</sup>. Clinics average only 20-40% live birth success rates. These success rates may be this high due to selective abortion which is an ethical problem or due to the implantation of multiple embryos, which could lead to multiple pregnancies<sup>[13]</sup>.

Reproductive treatments are very expensive e.g. one cycle of IVF treatment may cost up to £5,000 or more and these treatments do not guarantee that they will have a child <sup>[13]</sup>. This could also be very stressful for couples who are not financially stable.

As well as being emotionally stressed because of financial worries and low success rates, some women who use hormonal methods to treat infertility may be physically stressed if she has strong reactions to the fertility drugs used e.g. headaches, vomiting, abdominal pains, acne etc<sup>[10]</sup>.

### CONCLUSION

Reproductive biology is a significant importance to society and continues to help many couples and individuals as research and methods are developed. Although ethical issues may arise, they should be surpassed so that more improvements are made.

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### PhD Tutor's comment:

A. was a pleasure to work with. A. quickly grasped difficult scientific concepts and her work reflected this with each tutorial. Her tenacity and enthusiasm was refreshing and I cannot express how proud I am of her progress and hard work. I am certain A. will achieve all that she hopes to, she is a credit to her school and will be also to any university.

## Can a fish save the brain?

### Year 10 Key Stage 4

**S. Ezemuo, St Peter's RC High School, Manchester.**  
**Supervised by S. Crilly, University of Manchester.**

### Introduction

Throughout the past twenty five years, there has been commendable progress in neuroscience<sup>1</sup>; utilisation of animal models to study the pathophysiology of neurological disorders<sup>2</sup> has been fundamental in research efforts to further understanding of and improve prevention, diagnosis and treatment of neurological disorders<sup>3</sup>. Most of the over 600 known neurological diseases<sup>4</sup> however, remain incurable with treatment options being limited<sup>4</sup> and up to a billion sufferers around the world<sup>4</sup>. For more than a century, rodents have been the most prominently used animal models<sup>5</sup> and have been instrumental in the development of drugs for several neurological diseases<sup>5</sup>. Rodents have several shortcomings as animal models for diseases, sparking ethical conflict and are not the most economically efficient method of testing. Recently, other 'novel model organisms'<sup>6</sup> such as zebrafish have become an increasingly popular choice amongst researchers due to their numerous benefits and

surprisingly high degree of functional homology to humans<sup>7</sup>. There are already examples of zebrafish successfully aiding in the exploration of the underlying genetic mechanisms of epilepsy, Alzheimer's disease, schizophrenia, Parkinson's disease<sup>6</sup> (PD) and affective disorders, thus demonstrating their practicality as animal models of neurological diseases. This essay will, whilst considering their shortcomings, elucidate the numerous benefits zebrafish have to offer as animal models, using their contribution to Parkinson's disease as an example.

### Parkinson's Disease

Parkinson's Disease (PD) is the second most prevalent progressive neurodegenerative disorder, affecting approximately 1% of those over 60<sup>8</sup>. Around 15% of sufferers have a family history of PD however, most instances of PD are sporadic<sup>9</sup>. Investigations into hereditary PD alongside animal testing have led to five<sup>9</sup> mutated genes being associated with PD's pathogenesis: LRRK2, SNCU, PRKN, PINK1 and PARK7<sup>10</sup>.

PD's main histopathological hallmark is the loss<sup>11</sup> of dopaminergic neurons (DAn) within the substantia nigra pars compacta<sup>12</sup>. This induces PD's four cardinal symptoms: tremor, rigidity, bradykinesia and postural instability.<sup>12</sup> Lewy bodies (LBs), the cellular pathological hallmark of PD, are round eosinophilic intracytoplasmic inclusions<sup>12</sup>, located in neuron nuclei<sup>13</sup>. Large aggregates of the toxic<sup>14</sup> protein a-synuclein primarily comprise LBs.

Over the past several decades, various PD animal models have provided considerable insight into PD's elusive aetiology and pathophysiology<sup>15</sup>. Rat models of rotenone, for example, have displayed several features of PD, including intracellular inclusions that resemble LBs<sup>16</sup> and the main neuropathological hallmark: nigrostriatal dopamine depletion<sup>16</sup>(DA<sub>d</sub>). These rotenone experiments indicate that environmental neurotoxins are involved in the pathogenesis of PD<sup>9</sup>. Neurological and symptomatic treatments (i.e. physical therapy and deep brain stimulation) exist<sup>10</sup>, however there is currently no cure<sup>10</sup>. As PD can be debilitating<sup>17</sup> more research in hope of a cure is urgently required<sup>10</sup>.

### Zebrafish

#### General neurobiology and advantages

Although zebrafish are 'lower organisms'<sup>7</sup>, 47% of human genes have an exact zebrafish counterpart<sup>6</sup> and 84% of genes associated with human diseases have zebrafish counterparts<sup>18</sup>. Zebrafish are also quite physiologically similar to humans<sup>18</sup> (possessing intestines, kidneys, ears, muscle, cartilage etc.<sup>19</sup>), thus theoretically enabling scientists to model phenotypic expressions of diseases in humans.<sup>19</sup> Due to teleost-specific genome duplication<sup>6</sup> zebrafish possess several paralogous genes<sup>18</sup> which, depending on research purposes, may prove hindering or advantageous<sup>6</sup>; as duplicated genes may have different impacts on regulatory networks and output pathways, analyses of these genes can effectively evaluate whether functions are similar or not<sup>6</sup>. Experiments attempting to investigate a specific mammalian gene using zebrafish with the gene's paralogs, however, may prove unreliable.

Although zebrafish do not possess a mesencephalic region similar to that of the substantia nigra<sup>20</sup> (in which the degeneration of DAn results in PD<sup>15</sup>), zebrafish do display a similar cellular morphology and (general) macro-organisation of the brain to mammals. This allows for a relevant insight into the human brain to be gained from studies<sup>18</sup> e.g. the habenula in zebrafish regulates the release of dopamine and serotonin, thus is associated with fear responses<sup>6</sup> (which can be measured under correct laboratory circumstances<sup>21</sup>) and parallels the involvement of the amygdala in human brains<sup>20</sup>. Zebrafish also display functional neuroendocrine



systems, homologous to those in mammals<sup>18</sup>, allowing complex behavioural traits (i.e. memory aggression and anxiety) to be modelled<sup>6</sup>. These behaviours are characteristically altered in PD.

Zebrafish maintenance costs are extremely low as they are tiny, highly-socialable animals<sup>19</sup> and thus can be kept in high densities in relatively small tanks<sup>22</sup>.Their rapid breeding (200–300 eggs at a time<sup>7</sup>) is practical for researchers as experiments are often repeated several times for reliability<sup>19</sup>. In comparison, rodents are quite expensive to house as they are larger and produce only five to ten offspring per pairing<sup>7</sup>. Zebrafish embryos develop ex-utero and zebrafish display no parental attachment to their offspring<sup>6</sup>, mitigating potential ethical controversy about separating offspring from their parents and using them for research. Alternatively, this lack of parental concern may inhibit the study of certain CNS conditions i.e. separation anxiety<sup>6</sup>.

### 3Rs

Researchers are tasked with fulfilling the 3Rs<sup>22</sup> (replacement, refinement and reduction); principles that constitutionalise more humane usage of animals in scientific research<sup>23</sup>. Zebrafish, as both vertebrates (preserving a lot of the high physiological homology between vertebrate species) and less sentient organisms<sup>22</sup> somewhat fill the gap between cell culture and rodents<sup>6</sup>; allowing early in-vivo optimization of various ‘experimental protocols’<sup>6</sup>. They also pertain to (partial) replacement, as they are replacing the usage of more sentient beings and mammals (i.e. rodents)<sup>23</sup>. Alternatively, this pertains to reduction as the number of mammals used is reduced with the replacement of non-mammals<sup>22</sup>.

### Disadvantages

There are no existing ideal animal models thus zebrafish models indisputably have limitations, summarised in the words of George Box and Norman Drapr as, ‘essentially, all models are wrong, but some are useful’ (1987)<sup>10</sup>. Although pharmacological manipulations are easily executed, with chemicals simply being administered into the water, this also means that the absorbed drug dose cannot be fully controlled<sup>6</sup> entailing potentially inaccurate thus invalid results. Administrating drugs that are not water soluble can also pose a challenge, although use of special solvents may be able to circumvent the problem.<sup>6</sup> Current methods of measuring energy expenditure and food intake in zebrafish are not as refined as those of their rodent counterparts, meaning subtle metabolic phenotypes may be undetectable<sup>24</sup>. Although zebrafish can display aberrant swimming patterns, key motor symptoms that are observed through physiological structures in humans cannot be observed.

### Zebrafish in modelling PD

Despite some neuroanatomical differences between zebrafish and humans<sup>25</sup>, certain regions of the zebrafish brain appear to have been conserved in comparison to their human counterparts<sup>25</sup>; i.e. the zebrafish ventral telencephalon is seemingly homologous to the striatum in humans<sup>25</sup>. Additionally, anatomical studies of zebrafish’s dopaminergic system have revealed a cluster of DAn<sup>26</sup>, located in the posterior tuberculum of the ventral diencephalon<sup>25</sup> (vDC), that project to the ventral telencephalon thus are analogous to the elevating neurons of the nigrostriatal pathway in humans<sup>25</sup>. Several orthologs of genes found to be the causation of hereditary PD cases have been characterised in zebrafish: including PARKIN, PINK-1, PARK-7 and LRRK2<sup>10</sup>. This homology makes zebrafish relevant models of human PD thus zebrafish PD models have already been successfully utilised<sup>25</sup>.

### Genetic model

Parkin, the mutation of which is the most common cause of autosomal recessive early onset PD,<sup>9</sup> is an E3 ubiquitin ligase with integral involvement in the ubiquitin degradation system<sup>25</sup>. It also purportedly plays a role in mitochondrial

maintenance<sup>25</sup>. The zebrafish parkin gene functions quite similarly to human parkin; it encodes a highly conserved 458 amino acid protein between zebrafish and humans with up to 92% similarity in its ‘functional domains’<sup>25</sup>. In likeness to human parkin, zebrafish parkin is expressed ubiquitously throughout embryonic development and in adult tissues<sup>25</sup>. Parkin knock-down zebrafish however exhibit an increased susceptibility to 1-methyl-4-phenylpyridinium (MPP) and a 20% loss of DAn in the vDC<sup>25</sup>. These parkin deficient zebrafish do not display any mitochondrial morphological abnormalities, however activity of the mitochondrial respiratory chain complex is reduced by 45%<sup>25</sup>. In human sufferers of PD with Parkin mutations, this impairment of the mitochondrial respiratory chain complex is also found<sup>25</sup>, again displaying the relevance of zebrafish PD models to human cases. Most Parkin null mice (typically created by deletion at exon-2, 3, or 7<sup>27</sup>) however, do not display substantial DAd, or mitochondrial or behavioural abnormalities<sup>11</sup>. Some of these mice do display ‘slightly impaired dopaminergic release’, yet it is only Parkin-Q311X-DAT-BAC mice that display age-dependent dopaminergic neuron deterioration<sup>27</sup>. Additionally, recent overexpression of T240R-parkin and human WT parkin caused progressive, dose-dependent dopaminergic necrobiosis in rats<sup>27</sup>.

As with human Parkin, transcriptional upregulation of Parkin in zebrafish is used as a response to mitochondrial stress<sup>11</sup>. Also, overexpression of Parkin in transgenic zebrafish lines protects fish from necrobiosis induced by ‘proteotoxic stress’<sup>11</sup>, indicating a protective property of Parkin in-vivo. Collectively, this suggests a potential treatment of PD by a transcriptional upregulation of endogenous Parkin<sup>11</sup>.

### Neurotoxic model

1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) is highly lipophilic and easily crosses the blood brain barrier<sup>10</sup> (BBB), thus can be injected systemically. Initially, MPTP is not necessarily toxic<sup>10</sup>; once MPTP crosses the BBB and enters astrocytes in the brain, however, it is metabolised into its toxic metabolite MPP+ <sup>16</sup>. MPTP induces severe irreversible PD like syndrome when administered in non-human primates and humans alike<sup>10</sup>. The main pathological hallmarks of PD (including nigrostriatal dopamine degeneration and noradrenaline and serotonin changes observed in PD patients<sup>2</sup>) along with the main motor symptoms (except tremor at rest) are replicated with a high resemblance to idiopathic PD patients in non-human primate MPTP models. A downfall of this model is a lack of LBs<sup>15</sup>. Although difficult to replicate, some studies using MPTP have shown production of LB –like inclusions, suggesting that under the right circumstances all the major hallmarks of PD could be displayed<sup>16</sup>.

Using non-human primates is expensive, not compliant with any of the 3Rs and will, of course, spark ethical controversy. Interestingly, rats are highly resistant to MPTP neurotoxicity and only certain strains of mice display any susceptibility<sup>10</sup>. These mice can display motor impairments and olfactory and cognitive deficits reminiscent of PD<sup>13</sup>, however they don’t display according behavioural symptoms<sup>28</sup>.

MPTP induced zebrafish models display transient DAd, an aberrant swimming pattern<sup>22</sup> and behavioural defects<sup>11</sup>. These decreased dopamine levels after MPTP exposure correlate with findings in humans<sup>11</sup>, again emphasizing the relevance of zebrafish in neuroscientific studies. Prior studies using MPTP induced zebrafish larvae presented a significant loss of DAn in the vDC<sup>11</sup>. Further analyses suggested that different clusters of DAn in the vDC have different sensitivities to MPTP; those with ascending projections having a higher sensitivity to MPTP<sup>11</sup>.

### Genetic manipulation

Zebrafish have a high genetic tractability and there are several methods to manipulate their gene expression<sup>21</sup>,

including transgenic and knock-out methods via morpholino oligonucleotides (MOs) and Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR).

One of the most straightforward, economic experimental techniques, MOs (usually comprised of 25 bases and synthesized with morpholine rings instead of ribose<sup>29</sup>) can provide transient gene knock down by binding to their specific target mRNA and prohibiting protein synthesis<sup>29</sup>. Their hybridization to mRNA either blocks mRNA translation when injected near the initiation codon or inhibits splicing when targeted to ‘exon-intron boundaries.’<sup>11</sup> Both start-site and splice-site MOs ultimately hamper protein synthesis from zygotic transcripts.<sup>29</sup> As MOs targeting mRNAs are still highly functional 4 dpf<sup>29</sup>, MOs are commonly injected into the yolk sack of 1-2 cell(s) stage embryos, inducing transient knock-down gene effects for around 5 dpf<sup>21</sup>. Recent studies however, have revealed that an approximated 80% of morphant phenotypes in MO induced zebrafish were not successfully emulated in actual genetic mutants<sup>30</sup>.

CRISPR is a more recently developed technology with emerging utilisation.<sup>30</sup> Cas9, a DNA cutting protein is introduced to a target cell with guide RNA (gRNA).<sup>30</sup> Together, these molecules form a complex that can identify and cut specific sections of DNA.<sup>31</sup> The complex has to identify a common twenty nucleotide sequence in the DNA (PAM<sup>32</sup>), which it does using the gRNA, and then binds to it. The gRNA will only bind to a specific complementary DNA, thus it guides the complex to the desired genomic site. Once there, two endonuclease regions in the Cas9 protein each cut the DNA, causing a double strand break<sup>30</sup>. The cell will then attempt to repair the double strand break. As reparation is usually erroneous, however, mutations are often inadvertently produced as a result of insertion or deletion, thus inducing a frameshift and disabling the previous function of the gene<sup>30</sup>.

CRIPSR can also be used to knock-in genes by deactivating Cas9’s endonuclease regions, fusing the complex with a gene and then using the gRNA, as aforementioned, to guide the complex to a specific gene.<sup>31</sup> CRISPR could potentially be used to turn a ‘disease causing mutation into a healthy version of the gene’<sup>31</sup>, thus hereditary PD could conceivably be prevented from developing. Tools are increasingly being designed for a CRISPR/Cas9 system in zebrafish as, over the last decade, it has emerged as the most amenable approach to high throughput mutagenesis projects<sup>30</sup>. When first performed in zebrafish, gene knock-out via CRISPR/Cas9 technology mutagenesis rates ranged from 24–59%<sup>30</sup>.

### Concluding remarks

Zebrafish have already proved useful in modelling several complex neurological disorders such as PD and are rapidly emerging as key organisms in translational neuroscience and biopsychiatry research. Their affinity for high-throughput screening tests also makes them ideal for toxicology studies, thus possibly providing new treatments and even cures for several brain disorders in the future. Zebrafish have a surprising number of advantages for use which far outweigh their inevitable shortcomings as animal models. Although they are already being utilised, they still possess exciting potential to enable incremental neurological discovery in the future and thus, a fish could feasibly save the brain.

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### PhD Tutor’s comment:

S.’s submission for the assignment ‘Can a fish save the brain’ was outstanding and showed the extensive breadth of her own research into the topic and an accurate critique of the context that exceeds what is expected of a KS4 pupil. S.’s assignment received a high 1st class mark and I have been constantly impressed by the quality of her submitted homework and contribution to class throughout the course.



# What Can Different Brain Imaging Techniques Tell Us About Alzheimer's Disease?

Year 10 Key Stage 4

**G. Gorbould, The King Edward VI School, Morpeth.**  
**Supervised by J. Necus, Newcastle University.**

Alzheimer's Disease is a form of dementia affecting over 500,000 people in the U.K alone, according to the Alzheimer's Society<sup>[1]</sup>. It is a progressive mental deterioration of the brain<sup>[2]</sup>, that can have huge impacts upon an individual's way of life. Alzheimer's Disease is the most common form of dementia, accounting for up to 60-80% of dementia cases<sup>[3]</sup>. It is a generic diagnosis that covers gradual memory loss and the loss of other intellectual abilities, that as a result can inhibit daily activities with sometimes severe consequences. Although many symptoms of Alzheimer's are known, the exact cause is not, however age is suspected to be a factor of it. Different brain scans can tell us a lot about Alzheimer's, as they can compare images of a healthy brain to an unhealthy brain, identifying symptoms and patterns that have led to the discovery of medicines, that in some instances can slow down the extent of the deterioration. This essay will discuss the extent of what brain scans can tell us about Alzheimer's Disease and what could be developed in the future.

Structural imaging techniques, such as Magnetic Resonance Imaging (MRI) provide a detailed image of the structure of the brain, "providing information about the shape, position and volume of brain tissue<sup>[4]</sup>." MRI and Diffusion Tensor Imaging (DTI) are structural imaging techniques that can show radiographers the progression of Alzheimer's Disease and the varying symptoms that occur as a result. An MRI is a scan that uses magnetism and radio waves to produce those detailed images. MRI scanners contain very strong magnets, which cause the protons in our cells to line up in the same direction. Bursts of radio waves are sent to certain areas to knock the protons out of alignment. When the radio waves cease, the protons realign, releasing radio signals or electromagnetic waves<sup>[5]</sup>, which are collected to form images of the brain. MRI scans are non-invasive and produce very high-resolution images, however certain implants are not allowed near the scanner, for example: a pacemaker. If a patient has Alzheimer's, an MRI scan may detect larger ventricles and a decrease in the volume of cerebral cortex<sup>[6]</sup>. Where MRI scans create images of the tissues in the brain, DTI scans create images of the internal connections inside the brain. They register the diffusion of water along the directions of nerves, to produce images of individual fibres. If there is a problem or injury in the brain, the flow of water is usually disrupted. These scans can construct detailed images of the location of tears in white matter. They are non-invasive, however they have low spatial resolution and are extremely sensitive to movement, sometimes causing image distortion.

Alzheimer's is visible on a DTI scan, as there is evidence illustrating a breakdown in the number of connections in certain areas. This reduction is mostly found in posterior regions of the brain<sup>[7]</sup>. DTI scans can detect this as early as pre-clinical trials. They also detect anomalies in white matter: "These white-matter alterations on DTI are initially localised on the medical temporal limbic association tracts and tend to spread to the temporal and parietal white matter as the clinical disease progresses" [8]. More research has shown that DTI scans can identify structural changes in grey matter as well. Areas of grey matter are important for learning and memory, suggesting that DTI scanning

could, in the near future, be used to predict severe memory degeneration, with more accuracy than MRI scans. However more studies are required to prove this.

Functional imaging techniques, such as Functional Magnetic Resonance Imaging (fMRI), provide images that show changes in functions in certain areas of the brain. They can detect changes in the blood (for example oxygen levels), changes in metabolism and chemical composition. They can show how well cells in various areas are working by depicting how actively cells are using glucose or oxygen<sup>[9]</sup>. fMRI measures the changes in oxygen levels in the blood and the responses to neural activity. An MRI scanner is used during an fMRI scan, because the magnets allow the proton arrangement to become undifferentiated, thus measuring changes in blood flow<sup>[10]</sup>. fMRI scans have shown that during memory tasks, patients with Alzheimer's, present less activity in the occipital and temporal lobe. These scans are non-invasive, however they can be very expensive. On the other hand, Positron Emission Tomography scans use a radioactive tracer to bind to a specific antigen in the brain. The PET scanner then detects radiation given off by the tracer. It highlights the location of an illness or disease in the brain. Amyloid plaques can spread throughout the cerebral cortex if a patient has Alzheimer's. Radioactive tracers bind to the amyloid and positrons released by the tracer are detected by the scanner. If a patient has high levels of amyloid, it could suggest the person has Alzheimer's. PET scans also suggest that patients with Alzheimer's have reduced cell activity in certain areas of the brain<sup>[11]</sup>. For example, it has been deduced that Alzheimer's Disease could be linked to a reduction or insufficient use of glucose in areas that are important for memory, such as the hippocampus. This can also be seen using structural imaging techniques, for instance MRI. PET scans are highly effective; however they are invasive and expose the patient to radiation. They cannot be used during pregnancy for this reason.

In conclusion, Alzheimer's is a progressive disease that has a number of symptoms that are visible when using different scans. As Alzheimer's progresses the ventricles increase in size, while the cerebral cortex decreases in volume, as seen on an MRI scan. DTI scans show a decrease in the number of internal connections throughout the brain, and fMRI scans show a decrease in activity during memory tasks. In addition, PET scans illustrate an increase in amyloid plaques. Despite every scan presenting different symptoms, they all illustrate that Alzheimer's is a progressive illness, that can cause serious damage to the health of a person. Furthermore, they suggest that with more research, a cure could be found to successfully treat or limit the deterioration caused by Alzheimer's Disease, with significant effects. If the disease was diagnosed within the pre-clinical stages, it would have a greater chance of effectively and accurately limiting future damage to brain cells. However, the disadvantage of both pre-clinical scans and this potential cure would be the cost of the overall diagnosis and treatment, which as a result would limit the number of patients who would have access to it.

### What Can Scientists Tell From A Brain Scan?

Using different brain scans, scientists have been able to identify diseases and injuries in the brain, including the location and severity. However, scientists are now closer to working out how the brain functions, regarding personality and character traits of an individual. This essay will discuss how scientists have discovered the way emotions are shown to work in the brain, through different scans. It will also discuss future developments of science and the brain, and the impacts it would have upon our understanding.

In a recent study, research has shown an individual's brain activity to be as unique as a fingerprint<sup>[1]</sup>. In the study,

participants underwent six fMRI scans, four of which were taken when a patient was performing an intellectual task, the others when they were in a resting state. Brain activity was measured in 268 regions, showing the strength of internal connections and coordinated activity as well. After gathering this information, scientists could make predictions on how the participants would perform in other tasks. This then created a picture of the unique personality and intelligence of the individual. The research suggests that the stronger the internal connections in the brain, the more intelligent the participant. Despite more research being required, scientists believe that information like this could be useful in education or addiction rehabilitation centres, as it may eventually show the characteristics of an individual and therefore what learning environment would suit them best, for example. It has been suggested that data such as this could be useful for companies, schools, colleges and prisons; however it could lead to "neurodiscrimination", which would imply that companies were choosing an individual based solely on the results of their brain scans<sup>[2]</sup>, rather than documented evidence of their abilities. Nevertheless, research such as this could be beneficial in the treatment of mental disorders, such as schizophrenia or depression, as doctors would be able to decide which treatment would be best, due to information about the individual's personality. This would decrease the stress experienced by the patient.

In addition, further studies have shown that different emotions effect brain activity. A study undertaken by CMU's Dietrich College of Humanities and Social Sciences asked actors to bring themselves to a certain emotional state of mind [3]. Each actor then went through an fMRI scan, and the results were collected by a computer. As a result of the scans, the computer could correctly guess the emotion the actor was feeling. Further research inferred that each emotion had a different 'neural signature', that was similar for many cases. In addition, there were different levels of activity in different areas of the brain for both positive and negative emotions. This may benefit scientists in the future, as they would be able to tell what activity was occurring in certain areas of the brain, from different emotions, during an illness such as depression.

With the progression and advancement of technology, scientists have moved from MRI scans telling radiographers what sort of stimulus a person has been looking at, watching or thinking, to beginning to decipher the emotions experienced by an individual. More research is required to accurately interpret the subject's emotions, however after recent studies, patterns have begun to develop within data, that suggest what emotion is being experienced. Research has also shown that certain emotions are more closely linked than others. For example, "anxiety" is closer to "fear" than "happiness"<sup>[4]</sup>. There are diverse reactions to further development of this type of technology, as the negatives, in some cases, cause large social and ethical issues including "neurodiscrimination". On the other hand, developments such as this could increase scientists understanding of illnesses, such as depression or schizophrenia, as they would have more background knowledge of the emotions experienced by the individual, and what treatment would work more effectively, based up on this and other research.

In conclusion, scientists can deduce and interpret a growing amount of information from a brain scan, outside of the location and severity of an injury or illness. As science progresses, radiographers have begun to compare the human brain to those of other animals. Furthermore, they have begun to understand certain responses emitted through electrical signals, and in recent developments, emotions have begun to be deciphered through the use of brain scans and computer technology, increasing the

overall understanding of the brain and its functions, which in the future may enable scientists or radiographers, to determine information about a patient's state of mind when the individual is unable to communicate those things themselves. However, this will be subjected to and influenced by ethical debates.

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### PhD Tutor's comment:

I was very impressed with G.'s enthusiasm for the topic and her ability to pick up difficult concepts quickly. When approaching her final assignment, G. sourced a variety of extra material leaving her with almost too much of her own independent research to include! I am delighted that G.'s work is being showcased here in The Scholar as she deserves extra recognition for this fantastic achievement. I have no doubt that G. will continue to go on to perform to an extremely high standard at university whichever course she decides to pursue.

## What is Quantum Computing?



Year 10 Key Stage 4

**M. Soni, Weston Favell Academy, Northampton.**  
**Supervised by Dr T. Olupitan, Weston Favell Academy.**

Computer technology has come a long way since the 19th century and has developed and advanced further than we could have imagined. However, even the most modern computer could be viewed as a big nothing if we were to compare it to quantum computers. But what are quantum computers and how do they work? Quantum computers use subatomic particles, which exist in more than one state at a time, to do tasks much more quickly than standard computers we have currently. Not only can tasks be done at a faster rate, but they also use much less energy too. Quantum computing allows us to find answers and solutions to certain equations and calculations that modern computers can't even scratch the surface of. Additionally, quantum computers can carry out several operations and tasks all at once. This is because, while a standard computer would convert a task into a string of 0s and 1s (a bit), a quantum computer can turn a task into a string of 0s, 1s, and both 0s and 1s simultaneously. This is called a qubit, an abbreviation for Quantum Bit, and can store much more information than just 0 and 1 as they can exist in a superposition of these values. Imagine a sphere where a classical bit can exist in just two states that lie on the two opposite poles of the sphere, but a qubit can be any point on the sphere. Due to this, a quantum computer can store a lot more information whilst using less energy than a standard computer.

### Limitations of Standard Computers

Technology is improving at a rapid rate and soon even the most advanced standard computer we have currently just won't be enough. Why is this? This is because a modern



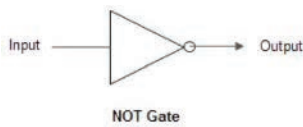
computer has certain limiting factors which disable it from enhancing further. For example, they can't think for themselves and therefore can't make decisions on their own because they are programed to carry out instructions by humans. Additionally in order to make decisions, computers would need the ability to judge and possess wisdom and knowledge. Standard computers rely completely on humans to produce algorithms and codes for the computer to follow and cannot do much on their own. A computer also has a limited memory/ storage capacity which cannot be extended. This could be limiting for people who require a lot of memory and storage on their computer, e.g. gamers.

How Qubits Were Made More Stable

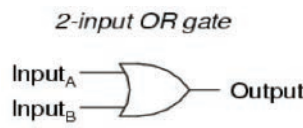
However, the road to the daily use of quantum computers is still quite long as there are a great number of obstacles that make it difficult to cross. Qubits are very unstable and cannot stay still or even exist for very long at all. But scientists at MIT have figured out a solution to this problem. They created a simple two-atom molecule out of sodium and potassium because molecules, unlike atoms, can vibrate, rotate, and strongly interact with each other. Atoms don't easily interact with each other; they have to be on top of each other almost, before they see that there's another atom there to interact with. Whereas molecules can see each other over relatively long distances. So, in order to make sure the qubits communicate with each other and perform calculations, molecules are the better option. After creating the molecules, the MIT team surrounded thousands of them in a microscopic cloud of gas which was then trapped in the intersection of two laser beams. Next the molecules were cooled down to a few ten-millionths of a degree above absolute zero. This meant that the molecules at the super cooled temperature were able to last longer than any previous attempts at keeping a qubit consistently stable. The qubits were able to remain stable for just one second but even though it may not seem like a great deal, it represents a major leap in the stability of quantum computers.

Companies such as Google and IBM (just to name a couple) are making big leaps in quantum computing with both of them producing higher and higher qubit processors. IBM had the previous record with a quantum computer capable of handling 50 qubits in 2017. But not long after, Google overtook IBM with a quantum computer that was able to handle 72 qubits! A higher number of qubits means that the quantum computer has better capacity, memory, and potential.

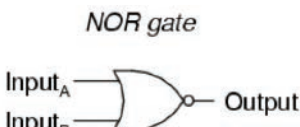
Logic gates are essential parts of all computer systems. They are electronic components of essential circuits used in processors, memory and almost all hardware components of a computer system. There are 7 logic gates: NOT gate, OR gate, NOR gate, AND gate, NAND gate, XOR gate, and XNOR gate. Apart from the NOT gate, all gates take two wires as input and output a single wire. A computer would not be a computer without these gates.



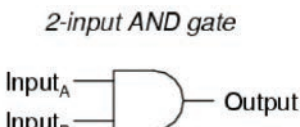
The NOT gate has a single input and a single output shown by the line that comes in on the left side and the line that comes out on the right. The output of this gate is always the opposite of the input. For example, if the input is 110, the output will be 001.



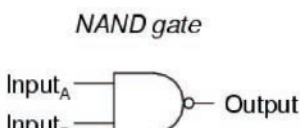
In the OR gate, at least one value of the input must be 1 for the output to be 1. If none of the values are 1, the output will be 0. For example, if the input is 001, the output will be 1. But if the input is 000, the output will be 0.



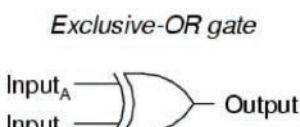
The input of the NOR gate has to have at least one 1 for the output to be 0. But if the whole input is just 0, the output will be 1. For example, if the input is 00, the output will be 1. But if the input is 01, the output will be 0.



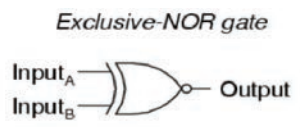
The output of the AND gate will only be 1 if all of the values of the input are 1. For example, if the input is 010, the output will be 0. But if the input is 111, the output will be 1.



The NAND gate only gives a value of 0 only if all the values of the input are 1. For example, if the input is 111, the output will be 0. But if the input is 100, the output will be 1.

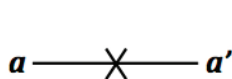


The output in a XOR gate will only be 1 if exactly one of the values of the input is 1. For example, if the input is 00, the output will be 0. If the input is 11, the output will also be 0. But if the input is 01, in output will be 1.

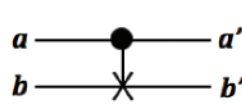


The output of the XNOR gate will be 1 if all of the values in the input are either 1 or 0. For example, if the input is 111 or 000, the output will be 1. But if the input is 010, the output will be 0.

Those were the logic gates for standard computers, but the quantum gates for a quantum computer are the NOT gate, the CNOT gate (also known as the Controlled NOT gate), and the TOFFOLI gate.

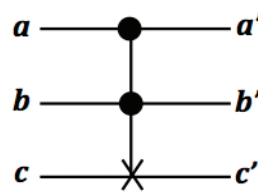


The NOT gate functions in the same way as the standard logic gate where the output is opposite to the input.



a	b	a'	b'
0	0	0	0
0	1	0	1
1	0	0	1
1	1	0	0

In a CNOT gate, the output is dependent on input 'a'. If input 'a' is 0, the input remains the same. But if input 'a' is 1, the NOT gate is applied.



This is a TOFFOLI gate. In this gate, the output will be determined by both of the first two inputs: 'a' and 'b'. This is where both of the first two inputs have to be a 1 in order for the NOT gate to be applied to all three values.

a	b	c	a'	b'	c'
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	0
0	1	1	0	1	1
1	0	0	1	0	0
1	0	1	1	0	1
1	1	0	0	0	1
1	1	1	0	0	0

Key Quantum Effects

Quantum effects are effects that cannot be explained with classical physics and requires quantum mechanics to be explained. The three key quantum effects are as follows:

*Observational Dependency* – This is where the direction in which you view a qubit will determine what you see.

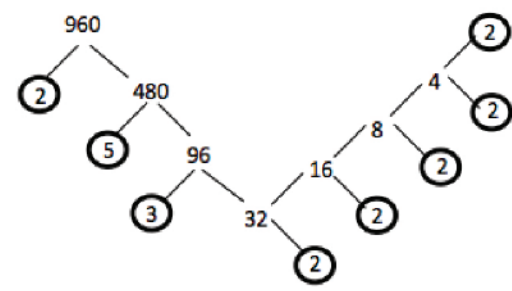
*Superposition* – This is where unless you look at the output, you will not know what the input is.

*Entanglement* – This is where observing one of two entangled qubits will directly affect the output of the other qubit.

Shor's Algorithm

Peter Shor formulated an algorithm which was later named Shor's Algorithm. The algorithm, which runs on a quantum computer, for integer factorisation solves the following problem of finding the prime factors of a given integer (n).

For example, if the integer (n) is 960, its prime factors would be 2<sup>6</sup> × 3 × 5. This is how you calculate this:



The Future of Quantum Computing

We, as a planet, produce more and more data every single day and soon enough we just won't be able to keep up. This is why the race to create the first ever, commercially available quantum computer is on. The introduction of quantum computing will affect a very wide range of areas. One area that could potentially be affected is Artificial Intelligence (AI). Experts, such as scientists and engineers working in Google, believe that AI is the next logical step for quantum computing. This is because quantum computers and AI have something in similar: exponential growth. Google's AutoML system produces a series of machine learning codes which are more efficient than the researchers themselves. It is capable of replicating Google's own programming and can do in hours what it takes the best human programmers weeks or months. This was proven as Google announced that AutoML has beaten the human AI engineers at their own game by building machine-learning software that's more efficient and powerful than the best human-designed systems.

Quantum computing could completely change Scientific Computing for the better in the future. Scientific Computing uses advanced computer simulation technologies to analyse complex problems in physics, biology, medicine, aerospace engineering and social sciences, etc. It is currently used to do countless things. Here are just some of them:

- To predict and improve the behaviour of new products such as diapers, vacuum cleaners, cars and aircrafts before the first sample is created.
- To allow analysis of large amounts of data and predict risks such as flood, weather, emergency evacuation planning, etc.

To provide better understanding and knowledge of theories and complex problems such as black holes and the nature of dark matter which cannot be experimented on.

If current computers are able to do this and much more, consider the endless possibilities and new doors that will open to all the fields and areas mentioned above. As we have learnt, quantum computers will be able to solve problems and find solutions to things that even a supercomputer of the 21st century cannot hope to do. So there will be a monumental benefit to Scientific Computing.

PhD Tutor's comment:

M. is such a delight to teach. She is a very keen student although she had very little interest in computing before embarking on the course. I am particularly impressed with her commitment to the course and independent learning which reflected in her essay. Her assignment brought together all the important basics of quantum computing in a distinctive way with lots of examples. Her explanation showed a good understanding of the subject. No doubt I look forward to continuing the Uni Pathways programme with her.

Plants And Their Own Photo Protective Properties



Year 10 Key Stage 4

L. Stephenson, George Abbot School, Guildford.  
Supervised by Dr L. Baker, George Abbot School.

In this review, the investigation of plants and their own method of photoprotection from harmful ultraviolet radiation will be discussed. We explore the photoprotective properties within plants by looking at the process of absorption of energy (in the form of light). Sinapoyl malate, a naturally occurring sunscreen molecule found in many plant leaves is presented as a case study. Such work may lead to the development of more efficient commercial sunscreens for human use.

Introduction

Ultraviolet radiation was a very important factor for early life evolving on Earth. It is the most energetic component of the solar spectrum that reaches Earth and can cause major damage to many biochemical processes of life, usually through the breaking of chemical bonds. Over billions of years, many living organisms have evolved and developed ways in which they can protect themselves from these strong ultraviolet rays, including plants with their own sunscreen molecule called sinapoyl malate. Humans are yet to develop such mechanisms that can protect us so efficiently but with our commercial sunscreens, we are able to avoid as much radiation as possible (how we do this will be discussed further in the rest of the article). Although too much ultraviolet radiation can be very harmful to



living organisms, as it can stop the essential process of photosynthesis in plants and can cause diseases like skin cancer in humans, some ultraviolet radiation is needed for good health, for example, in Vitamin D production. Too little UVR in extreme cases can cause rickets and fatigue in humans and can cause a loss of signal pathways in plants [1]. Therefore, exposure to UVR becomes a problem as there is a need to find an equilibrium of the so-called 'burden of disease'. Man-made sunscreens are a huge revolution in protection against the harmful radiation of ultraviolet light as UVR can cause great damage to all living organisms. It can cause damage in humans as it can hit and break bonds of DNA which can lead to many cancers but also, indirectly, it can damage molecules which later leads to damage of DNA [2]. Sunscreen works on the basis of absorption spectroscopy. Absorption of radiation occurs when an electron transitions between energy levels in an atom when it interacts with electromagnetic radiation. Typically, an electron will reside in the lowest energy level it can (this is known as the ground state) however, when this electron absorbs energy it can jump from the ground state to higher energy levels (known as excited states). In order to make this jump the energy gap between the start and end energy level must exactly match the energy of the photon [2]. Ultraviolet radiation consists of wavelengths less than 400 nm so a good absorption spectrum for a possible sun screening molecule should cover wavelengths of ~280 nm and 350 nm.

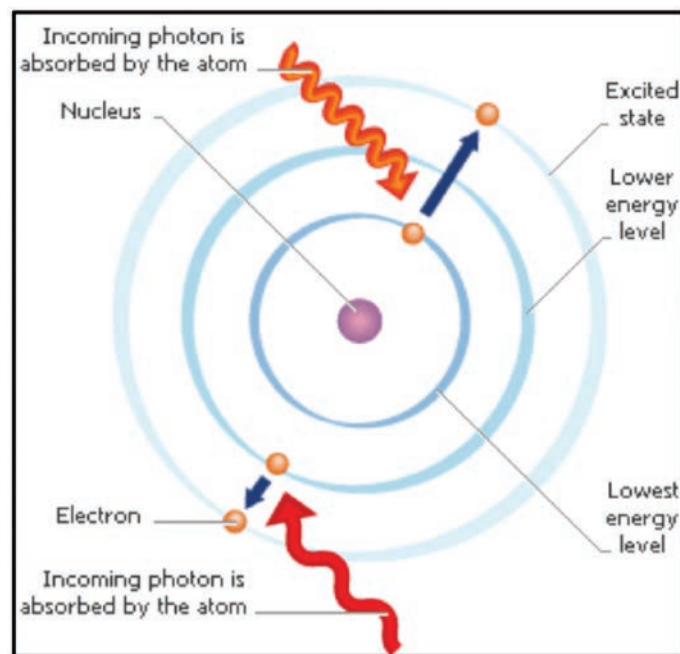


Figure 1. An overview of the process of absorption. Figure adapted from Ref. [3]

### Absorption spectroscopy

Absorption is a very important photochemical process for sunscreens as electrons absorb the energy/light that is put into the molecule, deactivating without emitting it back out (for example through internal conversion). This is important for sunscreens so you don't begin to glow from fluorescence or phosphorescence when you apply your sunscreen and go into the sun. Absorption spectroscopy is a good way to prove that sunscreens are doing their jobs. For absorption spectroscopy you need a light source, a sample (analyte) and a detector, see Figure 2. We created this simple experiment using a UV flashlight, a regular commercial sunscreen as the sample, and tonic water as our detector. We used tonic water as it contains a molecule called quinine which fluoresces blue under UV light [2]. The UV light from the flashlight causes fluorescence in the tonic water, the better the sunscreen works, the less fluorescence you should see in the tonic water. Using this experimental setup, we confirmed the effectiveness of a common commercial sunscreen product. This shows a fairly efficient sunscreen as the ultraviolet light is absorbed. However, there are more

factors to a 'good sunscreen'. To make a 'good sunscreen' it needs to not only absorb UV but be efficient, skin safe, easy to apply and aesthetically pleasing simply so people actually use the product.

An extension of absorption spectroscopy is a technique called transient absorption spectroscopy. This technique can be used to measure out *how fast* these sunscreens work. It works by using a laser probe and laser pump to cause absorption (excited state), and subsequently measure absorption and very specific time intervals, typically down to femtoseconds and picoseconds [5].

### Case study: Plant sunscreens

It has been discovered that plants do not get sunburn due to their own development of a photo-protection molecule within the leaves of the plant. This molecule is called sinapoyl malate. How this molecule works and how quickly it works can be investigated using a transient absorption spectroscopy. This spectroscopic technique uses equipment that is a lot more expensive and technical [5]. Although the actual use of each apparatus is rather simple, its timings and other small details must be so exact (like the probe). This equipment is only likely to be found in universities or places based on this scientific field [5].

In this experiment, it was discovered that when UV light hits this molecule, sinapoyl malate, it does what is called a trans-cis isomerization. An isomerization is a process by which one molecule is transformed into another molecule which has exactly the same atoms but the arrangement is different. This trans-cis isomerization is another way of letting electrons move down energy levels without emission of any light or radiation. It is in this way that stops the plants from burning in the UV light.

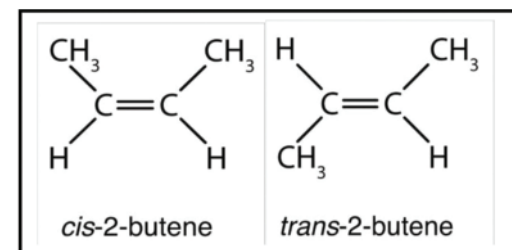


Figure 3. This is an example of the cis-trans isomerization [6].

### Conclusions

In conclusion, studying plants' own mechanisms to protect themselves from the harmful UV radiation that is all around us could possibly help scientists further understand how we humans can protect ourselves in commercial sunscreens and other products. Humans have not developed such an efficient capability to naturally protect ourselves, despite the fact we do have melanin, which means we are reliant on other methods such as commercial sunscreen products to safely enjoy the sun.

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- [5] L. A. Baker and V. G. Stavros. (2016) Sci. Prog. 99(3), 282-311.
- [6] [https://chem.libretexts.org/LibreTexts/University\\_of\\_South\\_Carolina/\\_Upstate/USC/\\_Upstate%3A\\_CHEM\\_U109%2C\\_Chemistry\\_of\\_Living\\_Things\\_\(Mueller\)/13%3A\\_Unsaturated\\_and\\_Aromatic\\_Hydrocarbons/13.2%3A\\_Cis-Trans\\_Isomers\\_\(Geometric\\_Isomers\)](https://chem.libretexts.org/LibreTexts/University_of_South_Carolina/_Upstate/USC/_Upstate%3A_CHEM_U109%2C_Chemistry_of_Living_Things_(Mueller)/13%3A_Unsaturated_and_Aromatic_Hydrocarbons/13.2%3A_Cis-Trans_Isomers_(Geometric_Isomers)) (accessed 30 April 2018).

### PhD Tutor's comment:

L's review article on the Uni Pathways course "*Why don't plants get sunburn?*" displays sophisticated thinking on advanced theoretical topics as well as a conscientious attitude towards engaging with scientific literature and academic writing. These are all hallmarks of a student who will go on to continually improve and develop their skills and knowledge, undoubtedly making them successful on any undergraduate degree programme.

## Skin highway: effective vehicles in the race for drug delivery

### Year 12 Key Stage 4

D. Akinsulire, Bishop Stopford's School, Enfield.

Supervised by F. Iliopoulos, University College London.

### Introduction

Pain relief in the form of gels and creams can be considered as one of the most renowned and favoured formulations in the medical industry. Not only is it socially suitable and typically painless for patients to use, but it has also been reported to be an efficacious treatment for various musculoskeletal conditions such as rheumatoid arthritis, osteoarthritis or chronic pain. Topical analgesics are applied on the skin and act on the painful site after they diffuse through the stratum corneum to reach the dermis and therefore the targeted cells within a short amount of time.

Ketoprofen is a non-steroidal anti-inflammatory drug (NSAID), available in the UK for the treatment of pain and mild inflammation in rheumatic disease, according to the ketoprofen monograph as described in the BNF. Carbopol® 980 gels containing various concentrations of Ketoprofen were formulated and designed as described in the application note: 50774 (Thermo Fisher Scientific Inc., 2007), taking many things into consideration.

### Routes Of Drug Administration: The Importance Of Topical Delivery

In terms of consideration of drug insertion methods, scientists have always accounted two factors, comfortability and efficiency. While patients will usually find that a drug is best delivered in the least painful way, some drugs are found to be better delivered either subcutaneously or orally. These decisions are often made by understanding the location of which the drug is intended to reach and the shortest pathway to that particular muscle or organ. Medications like Gaviscon for heartburn are administered orally and target heart burn by creating a barrier and increasing the pH value of stomach contents, thus providing relief of hyperacidity caused by the hydrochloric acid in the stomach (Gaviscon, et al., 2014). Oral administration of this drug is the shortest pathway as the drug would move from the mouth through the oesophagus and directly into the stomach where it would react. Diabetic patients will subcutaneously administer insulin into the blood vessels just beneath the skin, allowing it to immediately reach the bloodstream (Diabetes UK, et al., 2017). This is another example of drug administration where the drug is placed directly into the site of action in order to act very fast. While these drugs are convenient in terms of reaching the area, patients find the process of using subcutaneous methods inconvenient for social situations and some patients, particularly children in paediatrics, find oral drugs to be unpleasant to take making the patient adherence difficult. Gels and creams can usually improve the patient compliance and therefore are preferred in the medical industry for these reasons.

Pain relief gels containing NSAIDs are very efficient with pain relief for arthritis patients in terms of local pain. However, without the development of pain relief patches, gels can at times be quite redundant. Since arthritis is an auto-immune disease that attacks the body's joints (Cherney, et al., 2016), pains can occur in different areas of the body at different times meaning a patient may end up constantly applying relief gel to different areas as new pains spring up. Oral drugs allow pain relief for the entire body at once and last a very long time meaning the patient would only have to use the drug once to relief pain in all areas of the body.

Oral drugs have big advantages again pain relief gels in a sense that they relief pain throughout the body and don't run the risk of pains springing up in random places. However, they also have big disadvantages in terms of their effects on patients using them.

Oral drugs can have severe side effects. For example, NSAID drugs such as Ibuprofen and Ketoprofen can have detrimental effects on a patient with a stomach ulcer. Moreover, adverse side effects may occur when different drugs are co-administered, for example when NSAIDs are taken with some diuretics. The goal of topical delivery of NSAIDs, like ketoprofen, is to minimize the peripheral action of the drugs, thereby minimising systemic adverse effects. A letter published from Harvard Medical School published in January 2003 stated that 'oral nonsteroidal anti-inflammatory drugs (NSAIDs) are a common fix when you're suffering from osteoarthritis of the knees or hands. But applying NSAIDs directly to the skin (topically) can bring weeks of pain relief, and without the risks of oral NSAIDs, according to a new review by the Cochrane Collaboration, an international research organization.' (Harvard Medical School, et al., 2003). This view on the use of pain relief gels represents them as formulations that contain the same drugs as oral drugs but with an alternate pathway that prevents adverse effects in the body from their use.

With all of these factors taken into account, the implement of NSAIDs into more efficacious formulations in the future may make it possible to relief pain throughout the body (e.g. patches and body emollients) and prevent pains in different joints in the body causing constant reapplication of gel to different sites. Additionally, the concentrated local action of the drugs will protect the patient from major side effects to the body.

### Routes Of Permeation

When Ketoprofen is applied on the skin, it is expected to pass through the stratum corneum, (which is considered the non-viable epidermis as the cells it consists of are dead) and enter the stratum granulosum (the last viable part of the epidermis that shows increasing stages of keratinization and disintegration of the nuclei within cells (Moser et al., 2001.) before the stratum spinosum, the stratum basale (which contains Merkel cells and melanocytes responsible for the dispersion of melanin in the skin), the dermis and finally the hypodermis where it would diffuse through the blood vessels into the bloodstream. The stratum corneum is made up of desquamating corneocytes surrounded by lipids. The stratum granulosum marks the start of the viable epidermis contains compressed cells shaped like grains that slowly become flooded with lipids and proteins, preventing them from respiring and eventually killing them. The stratum spinosum contains star shaped keratinocytes, morphed from the original shape of basal keratinocytes as they are moved further away from the blood vessels and do not receive as many nutrients. This constant movement of the skin is caused by the proliferative layer of stratum basale that differentiates as it ascends. As the basal layer proliferates, the cells move upwards causing a gradual outward displacement of the cells towards the surface (Moser et al., 2001)

The dermis is the site of which transdermal drugs are transferred into the bloodstream, with the end point of the capillary plexi found within it. It contains nerve endings, blood vessels, sebaceous glands (oil glands) and sweat glands as well as collagen and elastin which supports the skin and allows it to stretch. The sebaceous glands constantly produce sebum which rises to the epidermis to keep the skin lubricated. The dermis is essential for thermoregulation and provides nutrients for skin cells (Moser et al., 2001).



The major route of permeation of any topical or transdermal drug is through the lipid matrix via the paracellular pathway. More specifically, the permeating molecule would freely diffuse around corneocytes and through the lipid bilayers present between each cell (Hadgraft et al., 2011). 0.1% of the drug would take an alternate route through sebaceous glands and hair follicles (Hadgraft, et al., 2011) found within the skin (the transappendageal route), taking the drug past the layers of the epidermis and into the dermis and hypodermis. The remaining drugs would travel in a straight line through both the cells and the lipids surrounding the cells (the transcellular pathway). When scientists are developing transdermal drugs, they develop formulations to make drugs pass through the lipid molecules in the epidermis to travel to the bloodstream while with topical drugs, scientists aim to make the drugs soluble with the lipids so that the drug will not push past the epidermis but settle in the skin to take effect on the cells within it.

### Factors Affecting The Rate Of Permeation

The rate of permeation is one of the factors that is prioritised in the process of creating a formulation. It can be determined by calculations made around the concentration of drug, its molarity, the rate at which it permeates and the thickness of the skin (subjective to the patient). Some compounds put into formulations of transdermal drugs are used to enhance the rate of permeation of drugs by interfering with the fatty acid chains within the mixture of epidermis lipids (containing ceramides, free fatty acid chains and cholesterol (Apostolos Pappas, et al., 2009). The molecule attaches to a lipid molecule and pushes the fatty acid chains away from each other, allowing drugs to pass through the channel in between. This increases the rate of permeation as the drug molecules can diffuse through channels created by the separated fatty acid chains instead of pushing pass the chains or being stopped by a blockade of lipids.

When considering what kind of permeation enhancer to apply, compatibility of compounds must be considered. While some compounds can clear a pathway for the drugs to permeate through the skin without interfering with other arrangements, some drugs can cause harm to the skin cells or enter the bloodstream and interfere with metabolic processes causing harm to patients using the drug. The compound could also react with the drugs in the formulation and create new compounds that may be dangerous or inhibit the main drug being applied. To avoid these things, scientists ensure that the permeation enhancers are unreactive against other chemicals in the formulation and are also safe to use on humans through clinical trials and animal testing.

In the development of Carpobol® 980 gels, the permeation enhancer, that is propylene glycol, was first diluted with distilled water and added to a mixture of ketoprofen and a co-solvent with triethanolamine before it was added to the mixture containing the ketoprofen. This process was completed ensuring that there were safe quantities of the permeating enhancers and contained a mixture of solvents that ensured that the solvent would travel through the skin into the blood vessels to reach the joints. (Thermo Fisher Scientific Inc., et al., 2007). Other examples of permeation enhancing compounds include ethanol, isopropyl alcohol and dipropylene glycol, which are all alcohols that react with the fatty acid chains and create spaces between them, increasing the diffusion and therefore the permeation rate.

### Conclusion

To conclude, pain relief gels are formulated to permeate through the skin transdermally from the stratum corneum, through the stratum granulosum, stratum spinosum,

stratum basal and into the dermis where it would enter the blood vessels and travel to the area where pain relief is required with permeating enhancers such as propylene glycol increasing the rate of permeation. It is a formulation that has a very short pathway and is relatively safe in comparison to orally administered drugs as it does not produce as many side effects or obstacles. Pain relief gels for arthritis patients in this current age is more suitable for patients who are on other medications which might interfere with oral drugs or have other ailments that oral drugs can cause further damage to. In the future, the development of patches of pain relief gel or emollients may reduce constant use of pain relief gels in different areas of the body as new pains rise. Transdermal drug delivery is an innovative method of administering drugs that carries high potential in drug development and will surely make good progress.

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#### PhD Tutor's comment:

My placement at Bishop Stopford's Enfield school was an invaluable experience. I met a team of respectful and self-motivated students, who were lively in every tutorial. From the very beginning, D. had an outstanding enthusiasm to learn even the most detailed areas of the subject. She has shown excellent academic potential and impressive capacity to understand and relate complex ideas to each other. D's essay is a testament to all the hard work put in by her throughout the placement, well done!

## Should we build a Quantum Computer?

Year 12, Key Stage 5

M. Alam, Stepney Green Maths, Computing and Science College, London. Supervised by M. Vasmer, University College London.

### Introduction

Alan Turing in 1936 thought of a hypothetical machine called the Turing machine which is made from a tape of infinite length which also consists of small boxes that can hold a symbol 0, 1 or can be blank. The machine uses a read-write head to retrieve the instruction from the tape and perform an action which essentially means that the machine can simulate any algorithm despite its complexity. [1][6]This is the idea on which classical computers were designed upon and although computing power has increased by a trillion fold from 1956 to 2015, the limitations of classical computing are becoming drastically apparent. Moore's Law states that computing power should double approximately every two years due to higher number of silicon transistors present in a processor. [2][8] What enabled this impressive leap in computing power was the shirking size of transistors. However, transistors can be only be made as small as after a specific length the transistors will no longer function as intended, as effects such as quantum tunnelling hinder its ability to act as a switch.

Scientist's class computational problems into two categories which are tractable problems and intractable problems. Tractable problems are those that can be solved by increasing the number of bits or the time and resource by a polynomial factor whereas intractable problems are those

which can be solved through exponential scaling of number of bits or the resource involved. This becomes a major issue for classical computers as we know from the law of exponentials that it becomes increasingly more difficult. [7] The simulation of nitrogen fixation is an example where the increasing the size of the molecule in simulation results in an exponential increase in the need for computational power as each of the electrostatic attraction of the addition of even a single electron must be accounted for in relation to all the other. [4] This is where quantum computers reign supreme over classical machines as, unlike a classical computer which utilises 0 or 1, a quantum machine uses a superposition of 0 and 1, where the information not exclusively 0 or 1 but can exist in all of the different states between 0 and 1. This means that where a traditional 2-bit register can store only one binary configuration at a given in comparison to a 2-bit quantum register can hold all of the four states as each quantum bit can represent two values. This capacity increase is exponential and what enables quantum computers to tackle problems through computational parallelism where multiple calculations can be tackled at once whereas a typical computer would perform tasks one at time. [1][9]

However, problems arise when you try to retrieve information from a superposition of all possibilities as once you try to make a measurement the wave function collapses, resulting in only one of two solutions which being 0 or 1. Scientists get around this issue by cleverly constructing algorithms which using this inherent randomness and add a phase to each state. This allows them to use interference to cancel out some of the answers and amplify others. This is a reason why quantum computers may never replace classical computation as not all tasks results in equal yield in performance. [1][10] It is also important to mention unlike most traditional computers which benefit greatly from the increase in bits i.e. transistors, quantum computers do not necessarily get more powerful when the more of qubits is increased as the error rate or the accuracy of operation must also be accounted for. Scientist use the term quantum volume to account for this two variables and it represents the number of superposition states that is available. For example, increasing the number of qubits by 100 without decreasing the error rate would result in no gain in quantum volume. However, instead of adding more qubits if the error rate was decreased by a factor of 10, quantum volume increases by 24 times hence it is also necessary to account for the error rate in order to explore a large space of quantum states.[10] Quantum computers have come a long way since its inception, as in 2017 IBM has unveiled the world's first quantum computer with 50 qubits at CES. However the quantum computer with the most qubits which is being tested currently in a lab is one which has 20 qubits. [5][3] In this essay, I will be discussing the applications of quantum computers, their advantages, disadvantages and the ethical concerns that follow the innovation of quantum computers.

Classical computers struggle to factor numbers due to the lack of the ability to tackle problems through computational parallelism and simply the lack of computational power. This fundamental idea is used as the basis of the encryption algorithm known as RSA. RSA is a type of asymmetric cryptography which relies on the generation of two keys – one which is public and the other which is private. The private is kept by the user whilst the public is available and shared with everyone. In order for RSA to work, you need to have two prime numbers which we can call p and q. These primes are then multiplied to form a new number, n. We also need the  $\phi(n)$  which can be calculated using  $(p-1) \times (q-1)$ . Next we need to find the exponent, e, which is a number between 1 and the  $\phi(n)$ . Finally – using all of these values – we can calculate d, our private value, using the formula  $e^{-1} \pmod{\phi(n)}$ . This results

in the creation of two keys where the private key= (d, n) and the public key = (e, n). In order to encrypt the data, the information is put into this formula, where x is the information being represented numerically:  $(x)^e \pmod{(n)}$ . In order to decrypt the data, you get the encrypted value we got earlier which is known as the cipher and apply the formula:  $\text{cipher}^d \pmod{(n)}$ . [15]

It becomes clear that only the private key holder who has the value of d can decrypt this data which can be worked out by factorising n however since n is usually a value of typically between 1024 to 2048 bits it becomes an issue, known as NP problem where the time and resources needed to find them is unrealistic. This is where quantum computers come in and Shor's algorithm can be used. Shor's algorithm has two essential parts. First the problem is turned into a problem of finding the period of a function and the second step is to use quantum Fourier transform to find the period which results in the requirement of a polynomial number of logic gates meaning the problem now becomes a tractable one. However, to this day the largest number factored using this algorithm is 21 and these were not a true implementation of this algorithm as in order to get the answer some prior knowledge of it was required but one of the largest number which was factorised is 56153 using a different method. [11][14]

Although quantum computers are far from achieving the computational power to decrypt RSA encryption, the idea that it can possibly do so raises concerns amongst the scientific community as it means that everything which uses not just RSA but any sort of cryptography where factorisation is the key part of it can be hacked. However this should not be a factor for not continuing to make progress in the field of quantum computing as there are already researchers seeking different methods of encryption post-quantum cryptography. Daniel J. Bernstein in his book *Post-Quantum Cryptography* discusses three viable encryption methods which are using a hash-based public-key signature system, a code-based public-key encryption system or using a multivariate-quadratic public-key signature system. Furthermore, discussed in the paper three criteria for any cryptography system to be successful are the efficiency, confidence and usability. Although the methods suggested in this paper is resistant to attacks by a large quantum computer, they are very inefficient and time consuming which becomes an issue for any large scale industry. [12]

Another possible application of quantum computers would be using it to simulate quantum and physical systems as with the example of nitrogen fixation which was briefly mentioned earlier. The Haber-Bosch process which is currently used by humans to produce ammonia commercially is energy as this process occurs under 200 to 400 atmospheric pressure and 400° to 650° C which is extremely energy intensive. [16] This can be achieved by many biological systems around room temperature and pressures through the use of the enzyme nitrogenase. Examples of such organisms include heterotrophic bacteria like azotobacter and cyanobacteria which is in a symbiotic relationship with the water fern Azolla. The simulation of this system through the use of quantum computers will provide researchers with better understanding on how nature's magic can be replicated in the lab. With increasing global populations and the increase in demand for food, it has become a race against time to reduce the cost of food and increase the efficiency of crop yields therefore one can imagine that with decreasing cost of ammonia production attributed by the better understanding of the role of enzyme nitrogenase in turning  $N_2$  into  $NH_3$ - the prices of fertilisers would also drop. [18] [7] [13] [17]

The simulation of quantum systems can also aid in the process of drug design. It has been estimated by DiMasi etal that it takes over 10 years and \$802 million for the research



and development of a new drug. Companies such as Accenture, in collaboration with Biogen and 1QBIT, are in process of simulating such systems and use quantum-enabled optimisation processes to reduce the time, cost and resources required for the discovery of a new drug. However, this source's credibility can be questioned as the success of these attempts could have been exaggerated to gain notoriety in the industry. [19][13]

Application of such simulation capability can even be applied to the field of genetics and epigenetics and a particularly good example of a use case would be through simulation of the effects of using gene editing tools like CRISPR. The possible uses of CRISPR are endless such as the removal of the parasite, Plasmodium falciparum, which causes malaria in mosquitos. This alone would change the world as in 2015 there were 212 million cases of malaria with 429,000 deaths according to the World Health organisation. [20] Moreover, a similar gene editing tool called TALEN was used on an infant in a desperate attempt by doctors to save her life from lymphoblastic leukaemia and one can only imagine the acceleration of cancer treatment and cure as such case with the child if quantum computers can truly achieve the level of simulation capability theorised today. [21]

However, the viability of gene editing tools achieved through quantum computers definitely raises some ethical concerns such as whether the benefits of the change outweigh risks of producing off target mutations. This can lead to health issues to the organism in question and also possible ecological disequilibrium where these off target mutations can cause negative traits to transfer to other species, not to mention annihilation of a certain species itself can lead to disruption of food webs causing a cascading effect on other species. [22] Although quantum computers are good at simulating, many-body systems are inefficient at other systems like when you would need to work in a 2<sup>n</sup> dimension Hilbert space which would require the need for an exponential number of quantum logic gates. [11]

The final application of quantum computing I would like to talk about is machine learning. Machine learning is a term given to a large class of algorithms which enable man made machines to learn from their environment through sensory apparatus, just like biological organism. In perpetual machine learning, it can be either supervised where it is programmed with certain initial parameters to improve performance whereas unsupervised learning, the machine has no prior data regarding its target, for example what features to look for when identifying a human face. This type of machine learning has multiple applications that are already in use today such as that in virtual assistants like Siri and Alexa, social media services suggesting people you may know, facial recognition, search engine optimisation and many more. [23][24]

The most appealing use of machine learning however is self-driving cars. Self-driving cars utilise many of the applications of machine learning which were listed above, but the most important one it achieves through machine learning is continuous rendering of the environment it is in. This includes the identification, detection and prediction of the movement of objects around it. Today this is achieved through the use of classical computers like that used in Google's self-driving cars. This process can be greatly accelerated through the use of quantum computers, as machine learning is essentially sorting and classifying data very quickly, which is usually stored in a form of vectors and tensor products. These can be easily and effectively manipulated by quantum computers in higher dimensional Hilbert spaces resulting in an exponential quantum speed up. [24] For example, using the HHL algorithm, calculations which would take classical

computers more than a hundred years can be performed within mere hours. However as enticing as machine learning may seem, machines can become racist or develop other social stigmas, for example a face recognition software made by a professor in the University of Virginia Vicente Ordóñez noticed that the guesses the software made suggested that it had become sexist. The actual issue lies with the engineers who program these machines as the initial set of data or input is often biased, which causes the machine to build up a model which too is inherently biased. [26] [23] Therefore, question arises whether or not humans can even program something without any biases. Ethical issues surrounding machine has caused the scientific community to be polarised. Many ask how one decides what is morally right or wrong and how we ensure machines evolve in their perception of what is socially accepted over time.

We already have built quantum computers such as IBM's 50 qubits quantum computer, but the question now becomes should we continue to innovate in the field of quantum computing? In my opinion, the answer is rather simple as I have demonstrated in the essay the quantum computers have the potential to the change way we interact with the world. They can speed up research enabling us to discover new cures, new drugs, new chemicals which would save billions of dollars in research and development, making it easier and potentially cheaper to save lives. Furthermore, better machine learning, enabled by quantum computers can revolutionise industries such as the self-driving car, and improved virtual assistance. The ability of quantum computers to handle massive amounts of data rapidly and efficiently also lends them to be used as optimisation tools and this has practically endless applications, such as the use of this in determining the right dosage of radiotherapy.

With every new technology there will be drawbacks and ethical issues however, I genuinely believe these are insignificant in comparison to the great benefits that will come through the innovation quantum computers. Some may argue that ethical and moral concerns like the trolley problem associated with any sentient machine will be a stumbling block for innovation, whilst others argue that quantum computers are going to make our current security systems trivial. Although these concerns are justified, quantum computers are merely tools, not inherently malicious as it humans who utilise and abuse this technology. Many concerns will lead to further innovation, such as the case with post quantum cryptography and hence nullify them completely. Therefore, I believe that innovation and support for quantum computers are a must in order for us to make a quantum leap to the future.

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#### PhD Tutor's comment:

I found working with M, and his fellow pupils to be a rewarding experience. The speed at which they absorbed new concepts and applied them to problems was significantly faster than I had expected. M.s final assignment is particularly impressive. His research went far beyond the topics we covered in the tutorials and his writing is expressive and clear. His explanation of the superior calculating power of quantum computers is truly exceptional, showing a rare talent for explaining subtle scientific concepts.

## Inflammation: the good, the bad and the ugly

### S2/3, Key Stage 3

**H. Singh, John Paul Academy, Glasgow.**  
**Supervised by C. Boz, University of Edinburgh.**

#### Introduction

Inflammation is mostly defined with words like pain, soreness and many related words. I will be discussing about the main components and factors in inflammation also what inflammation really is and its effect on our body. I will be doing this through looking at a fibrotic disease called IPF and an autoimmune disease called diabetes.

Inflammation is a large process of your body trying to treat a wound or an injury. Inflammation is triggered when noxious stimuli and other things like infections and tissue injury occur. If the problem is severe this may cause symptoms like feeling sick and getting exhausted, this shows that your immune system is very active and needs a lot of energy<sup>[1]</sup>. These symptoms were studied in Roman times and their names are in Latin. These are *rubbor*, which means redness, calor (hot), *dolor* (pain), *tumor* (swelling) and finally *functio laesa*, which conveys losing function in a part of your body. Your body tries to solve this by sending blood components to the problem. This is successful if the pathological agents are eliminated and your body repairs itself. This is all because of macrophages, which are white blood cells also known as leukocytes. Leukocytes are made in bone marrow and are found in the blood or lymph (a clear fluid that carries cells to help them fight infections<sup>[2]</sup>) tissue<sup>[3]</sup>.

The first cell that comes on the scene are the phagocytes. Phagocytes can pass through vessel walls to get to the pathogens or toxins easily<sup>[4]</sup>. They digest the pathogens, so they cannot cause more injury. They digest them by using their cytoplasm. They do this by extending their cytoplasm into pseudopods, surrounding the pathogen and creating a vacuole<sup>[5]</sup>. If the pathogen contains poison it cannot harm the phagocyte, but only if it remains in the vacuole<sup>[5]</sup>. Phagocytes enzymes are then released into the vacuole

and this is when digestion transpires<sup>[5]</sup>.

There are multiple types of these cells, but the tougher and bigger ones are macrophages. They come from monocytes which have left the blood stream. There are two main types of macrophages, there are the free types, they patrol the tissue and there's also fixed types. These are commonly attached to different organs and are incapable of moving. Monocytes can change into different macrophages depending on the signal your body gives, this is called polarization.

If IFN- $\gamma$  and LPS are present, then the macrophages are M1 which are pro inflammatory. If IL4 is instead present, then the macrophages change into M2; there are multiple types of M2. M2a are for host defence, these as their name suggest are a secondary defense. M2b perform immunoregulation; this means they check and see if everything is going smoothly. M2c are the ones who do tissue repair, they do this by recruiting fibroblasts. If an issue occurs, or your immune system isn't good fibrosis can occur which is the process of scarring. So, the process starts with M1 and then they activate and recruit M2 which then activate and recruit fibroblasts, which do tissue repair. If there is an imbalance of the amount of different types of M1 and M2, problems can occur. If there are too many M1 macrophages they will start attacking your own body. This causes more inflammation and a vicious cycle starts. There are two main things that keep repeating: these are that an injury keeps reoccurring and that inflammation starts again. As a result an autoimmune disease can form itself, such as diabetes and the result of scarring can cause a disease called IPF, idiopathic pulmonary fibrosis which can be triggered.

IPF is a fibrotic lung disease, in which tissue in your lungs becomes thick and stiff due to scarring (fibrosis). Because of this your lungs can't properly provide oxygen to your brain and many other organs<sup>[6]</sup>. IPF is serious and affects middle-aged people and it varies from person to person; in others the process can be slow while for someone else it could be faster<sup>[6]</sup>. IPF has no known causes and, therefore it is hard to find a cure or solution. If a person is diagnosed with IPF, they usually live 3 to 5 years<sup>[6]</sup>. Scarring starts in the air sac walls and the space around them<sup>[6]</sup>. The scarring makes the air sac walls thicker, this makes it harder for oxygen to pass through the walls and into the blood stream<sup>[6]</sup>.

A big risk factor of getting IPF is smoking. Researchers have found out that most people with IPF also have GERD, gastroesophageal reflux disease. This is when your stomach acid backs up into your throat<sup>[6]</sup>. Some symptoms may include shortness of breath, a dry cough, fatigue, aching, and finally digital clubbing, which is the widening and rounding of the finger or toes<sup>[6]</sup>. IPF can lead to collapsed lung, lung infections and lung cancer. Treating this is hard and doctors may prescribe things like oxygen therapy, pulmonary rehabilitation or lung transplant. But another way is by taking prednisone, which is an inflammatory drug. Because of the serious side effects your doctor may only prescribe it 3 to 6 months<sup>[6]</sup>.

Type 1 diabetes is an autoimmune disease which is caused when the pancreas is unable to make insulin, which is required to keep sugar levels safe. This occurs when your  $\beta$  cells are destroyed, due to inflammation. Some symptoms that may be present are increased thirst, frequent urination, extreme hunger and fatigue. If you have diabetes then your blood glucose levels can become low, medically termed hypoglycaemia<sup>[7]</sup>. This can be triggered either by a lack of constant sugar absorption from food or when insulin injected into your body breaks down too much of the glucose out of your blood stream too quickly<sup>[7]</sup>.



If you have high blood glucose levels, then hyperglycaemia can transpire, which if left untreated, can cause diabetic ketoacidosis<sup>[7]</sup>. Diabetic ketoacidosis is a serious issue which causes your body to break down fat and muscle to use as an alternative source of energy<sup>[7]</sup>. This leads to a build-up of acids in your blood, which then can cause vomiting or even death<sup>[7]</sup>.

Type 1 diabetes is usually diagnosed for a person when they're 4–7 or 10–14 years old. There is no solution for diabetes, but it can be controlled by managing blood glucose levels<sup>[8]</sup>. One way is by injecting insulin into your body<sup>[8]</sup>. A healthy lifestyle can reduce the risks of having serious issues when faced with diabetes. Things may include exercising, eating healthily, not smoking and generally staying healthy<sup>[9]</sup>.

Scientists can block, slowdown, negate effects and stop the production of specific cells and there are many helpful possibilities with such innovations. Reducing the collagen that the fibroblasts make could possibly reduce fibrosis; we could either do this by reducing the amount of fibroblasts produced or slowing them down. This could be done by destroying or reducing the production of the cells. This would work because fibrosis occurs when the fibroblasts fail, so such treatment could potentially take ensure fibroblasts can take their time and repair the body efficiently. This is all mediated by macrophages.

One of the ways in which scientists can research and find ways to solve problems is by making cells such as the beta cell. Human pluripotent stem cells – embryonic and induced – can help make cells and replace them<sup>[10]</sup>. This includes insulin producing beta cells. This can help with diabetes, but this may not cure diabetes. Another way to help with diabetes is by modifying insulin so that it can provide more energy. Enhancing beta cells could completely cure diabetes but again they could be reddestroyed. A fix to this could be by making these cells tougher and harder to destroy. Another idea we could implement is to stop the vicious cycle of inflammation by negating the effects of macrophages but the problem with this is that the pathogen may cause more harm. Trying to negate the effects of M2c's could possibly force them to work harder but then again, the same issue occurs as trying to negate the effects of general macrophages, except this time the wound or injury may even not repair properly at all.

### Conclusion

Inflammation is the body's response to a wound or injury. The body has specialised cells in order to tackle this issue and prevent infection. Immune diseases such as IPF and autoimmune diseases such as diabetes are both example diseases in which an inflammation response can be triggered. Scientific advances are attempting to find solutions to immune and autoimmune diseases as conditions such as diabetes can be difficult to manage and can lead to more deadly issues. Research has shown that we can modify the way cells work, like if modifying fibroblasts which could result in less fibrosis. Another example is in using human pluripotent stem cells we can make beta cells which can help to find a cure for diabetes.

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#### PhD Tutor's comment:

It was a pleasure to work with H. at John Paul Academy during The Scholars Programme tutorials. He has a very inquisitive mind that will take him far without a doubt! His essay was very well written. It showed not only a full understanding of the topic of inflammation and the cells involved, but also the ability to research the topic further and integrate the information appropriately. He was also a very proactive student during the tutorials, asking questions and sharing his ideas on the topic. I wish him the best of luck in the future!

# Arts and Humanities

## From “them, there, and then” to us, here and now: (why) are we responsible for climate change?

Year 9, Key Stage 4

H. Duong, Bradford Academy, Bradford.  
Supervised by K. Diprose, University of Leeds.

### United Nations Address (Part 1)

The legacy of our world is at stake. Centuries of tumult, of terror, of hardship, have set the foundations of our irrevocably interconnected modern society. We have been left a world with innovative means of instant communication between peoples. We have been left a world where democracy and fraternity are core tenets.

And yet, despite the world looking like utopia for any pair of eyes from centuries past, our world is as unjust as it ever has been. The axiom that the world is fair is criminally erroneous: we must banish the rose-tinted, nonchalant tunnel vision and finally face reality. While richer nations bask in wealth, poorer nations have had to pick up the check. Europe and the United States are unquestionably the biggest historical emitters of carbon dioxide (with China and India copying the roadmap), and yet bear virtually no vulnerability in the short term in comparison to Africa and south Asia.

It is a grave irony that the countries which founded many of the modern justice systems seem so blind to this serial injustice. The reckless actions of the past haunt us, yet we seem to simply turn our heads and pretend nothing happened: just because it wasn't on our shores. Rapid industrialisation caused climate change, which causes the destruction of the livelihoods of many people. But it doesn't matter; they are different to us. This attitude has been preserved over centuries of supposed superiority of the wealthy over the global poor. Colonialism may not be as conspicuous in today's world; there isn't a frenetic race for empires to annex unfound land any longer. Nonetheless, it has certainly not taken its leave. Climate change legislation has been clouded with the idea that it is a matter of the distant future. It is not. Purely based on the notion that Europe and America are apparently not directly susceptible, the problem is pushed further down the river. People are dying now, never mind decades from now. Frugality and caution went out of the window when quick profit through industrialisation came to fruition: anthropogenic climate change is the consequence. In legislation, corporate interests of profiteering and cost minimisation dominate the discussion: the rest of the world is purely an afterthought.

Despite ever-increasing awareness of the ramifications, a concerted effort to compromise with corporations over climate change still exists among politicians. Instead of change to renewables being immediately imperative, we have resorted to meek goals. Prosperity for all is not in the interest of corporations who thrive under the indifference and division. In making “goals”, we let culpable nations off the hook. Symbolic willingness to address the problem is – plain and simple – inadequate. The Paris Agreement is a gesture of goodwill from the world's governments, but no significant action has been taken, only baseless promises. “By 2050 we will...”, is just a sound bite. What about today? Are we really too scared to challenge the status quo and actually do something? History is an invaluable tool in highlighting the injustices of the world. Imperial powers cared little about the welfare of those they considered subordinate, so long as they

received a favourable short-term return on their risk in war. It is, however, also a damning polemic of our own shortfalls in the modern day. The Global North forged its affluence through unscrupulous energy consumption and exploitation of nature. In glorifying the success, consumer culture has become entrenched in society. We are as ethically complicit as our ancestors in our lethargy for action. Will we be another generation of people who devalue the world's future, or will we be the ones to finally make change? We need to wake up from this dream that we all have, of a better world in the future. The only way it can be attained is if we make it happen today.

### Critical Reflection (Part 2)

This essay reflects on the hypothetical United Nations address I wrote, where I explored the relationship between an indirect continuation of imperialism and inactivity in climate change legislation. Additionally, it looks at the price the affluent is morally obligated to pay, for the lack of frugality which has placed adversity upon the Global South.

The culture of creating “goals” for countries to attempt adherence towards removes the imperative for governments. The people affected worst are generally the ones who are least culpable: the Global South, predominantly Africa and south Asia (Samson, et al., 2011). Fundamentally, my argument revolves around the climate change problem arising due to the discernible lack of urgency among the political sphere to address it earlier. An embodiment of this lethargy is in the Paris Agreement. Lauded as a “victory for the multilateral system” (Kuylenstierna, 2016) and a “turning point” (Milman, 2016) by its architects, the climate accord of 2015 has – to date – made little ground in reducing emissions on a global scale. For all the rhetoric of historic international cooperation, minimal substantive action has been taken in combatting climate change. Article 6 of the Agreement effectively negates the purpose of the accord by recognising that international cooperation in implementing measures to cap emissions is on a strictly “voluntary basis” (United Nations, 2016), meaning the “targets” are exactly what the word implies – not imperative or urgent.

Barack Obama, one of the key proponents of the Agreement, recognises that Paris will only lead to “part of where we need to go” (Milman, 2016). In the eyes of many climate activists and critics, the deal was merely a “sham” (Friends of the Earth, 2015). The purportedly ambitious Intended Nationally Determined Contributions (INDCs), world governments' action plans attempting to reduce emissions, are meek at best. Government pledges to mitigate climate change would still cause 2.7°C of global warming by 2050 (Climate Action Tracker, 2015), still well above the maximum threshold the UN proposes (United Nations, 2016). Stephen Gardiner's theory of a moral storm suggests that the lack of urgency is due to an inability for decision-making to appropriately address the long-term future (Gardiner, 2006). This “theoretical storm” exhibits itself through complacency, leading to the problem being relegated; this informed my argument particularly towards the end, where the diplomats are faced with a choice to “finally make change”. Countries in the Organisation for Economic Co-operation and Development (OECD) report an overall confidence in government of just 37.6% (OECD, 2017), an unambiguous signal of the apathy the general population has towards their respective governments. Populations deride politicians, branding them unrepresentative, and yet continue to elect them to public office in the vain hope of change's spontaneous manifestation.

As apathy soars among the population, there is concurrently a belief that it is the role of the government to protect the environment in the Global North. INTERSECTION's survey on the British and Chinese public's view on who bears the responsibility of environmental protection conclusively



finds that the environment is seen as the responsibility of government (INTERSECTION, 2016) rather than themselves. Climate change will not be mitigated if consumers buy the same products, in the same culture of apathy, with the same short-term outcomes (Cuomo, 2011). The collective detachment impinges on any chance of a successful crusade against anthropogenic climate change. This detachment is mirrored in the political sphere. Many mainstream politicians are too scared to combat climate change as it could cause a short-term economic deficit.

The short-termism is seemingly illogical, but anything seen to have an immediate negative consequence – even for long-term prosperity – is vilified almost automatically by a media concentrated in the hands of corporations which thrive under the division (Barnett, 2010). Imperialism is viewed as an archaic issue among many in the Global North: its influence has, nonetheless persisted over centuries (Cuomo, 2011). Many of the affluent nations forged their wealth through the same short-termism, using unethical means of exploiting nature, subordinating people alleged to be “lamentably degenerate and base” (Select Committee on the Affairs of the East India Company, 1882), and therefore the foundations of society are entrenched in its colonial past. While empires did ultimately fall and grant colonies their independence, virtually nothing was the same after natural resources were ransacked and cultures were bulldozed by the occupiers. The exploited countries had lost control over their destinies; the colonists surged in capital. This newly-discovered prosperity coincided with industrialisation: profiteering and short-term gain rapidly became religion to opportunists (Cuomo, 2011).

The long-term repercussions of industrial revolutions are now being felt globally. Greenhouse gases remain in the atmosphere for up to two hundred years (Gardiner, 2006), and the problem has been further exacerbated by countries using unscrupulous means to follow the same blueprint. Nations such as China and India have a low historical record in terms of cumulative emissions (Hansen & Sato, 2016), in comparison with the United States, the United Kingdom, and other imperial superpowers. Their meteoric rise in recent years is a result of rapid industrialisation under poor living standards – a fast-tracked copy of the European model (Cuomo, 2011). The manner in which the problem is far from the front pages is testament to the failure of the former imperial powers to take responsibility for the mess they have created (Cuomo, 2011). If colonialism and industrialisation has become a precedent – a roadmap to riches – the same unethical nonchalance could govern as it had in Europe in centuries past. Critics of the Paris accord are generally in agreement that countries with more advanced economies are not taking their fair share of burden in the fight against global warming (Friends of the Earth, 2015). Given that these advanced economies are often also the forefathers of modern justice systems, it is highly hypocritical for these countries, which amassed their wealth on energy consumption, to bear little burden (Cuomo, 2011).

This “polluter pays principle” (Ward & Hicks, 2014) is supposed to be the hallmark of the climate change debate, as dictated by the Kyoto Protocol, which alludes to the idea that nations have “common but differentiated responsibilities”. However, when the UN itself resorts to “Sustainable Development Goals” instead of direct mandate (United Nations, 2016), governments are not compelled nor obliged to take necessary action. Surveys suggests that majority of people in affluent nations are aware of climate change (INTERSECTION, 2016) but believe the side-effects to be in the far distance, justifying the insouciance. While the findings of this survey are intriguing and play to the narrative of unconcern emanating, it offers a relatively small scope into the attitudes of only three cities. The world is increasingly interconnected through globalisation, which should extend the scope of care (Smith, 1998) but the re-emergence of nationalism, a remnant of

the colonial past, could be a major stumbling block for truly international resistance. Such perceived distance in time and space from the immediate after-effects handicaps the ability to move beyond indifference (Smith, 1998).

George Marshall argues that climate change is viewed as distant purely because of an ingrained notion that the “environment is in better condition in one’s own area”: an optimism bias (Marshall, 2014). The proposition that the general population has created an alternative truth makes sense, as it typifies the rose-tinted vision of a world striving for perfection when, in reality, it is embedded in depravity.

In conclusion, it would be fair to say we did not create the problem; we inherited it from an imperial past. That does not, however, exempt ourselves from the responsibility to atone for the errors of imperialism (Cuomo, 2011). Despite the impacts of climate change not yet being on our doorstep, nonchalance towards the issue will reap no rewards: the problem will not disappear. We need to breed a culture of activism to topple the current apathy, to hold governments accountable in the search for a prosperous future with an intact environment. In forcing governments to represent the people, we gain control over the world’s destiny. Therefore, we hold a responsibility for the world we live in, and thus additionally a responsibility for climate change.

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#### PhD Tutor's comment:

I was consistently impressed by all pupils at Bradford Academy, but H's excellent final essay stood out for a couple of reasons. Firstly, originality. The link between climate change and colonialism is not something we covered in our course handbook (on 'Space, Time and Climate Change: Exploring international and intergenerational responsibility'), but an idea he wanted to develop with some suggestions of additional reading. H. confidently tackles this complex subject and relates it to the core course material on global greenhouse gas emissions, vulnerability to climate change, and geographies of responsibility. Secondly, in its analysis of the Paris Agreement – something else that H. researched independently – his critical reflection shows how philosophical arguments have real-world applications. This link between theory and practice is a vital academic skill. It's fantastic to see pupils like H. unafraid of tackling big ideas and global challenges at this stage in their schooling.

## Analysis of the 'Vanishing Indian' trope in Sherman Alexie's *The Absolutely True Diary of a Part-Time Indian*

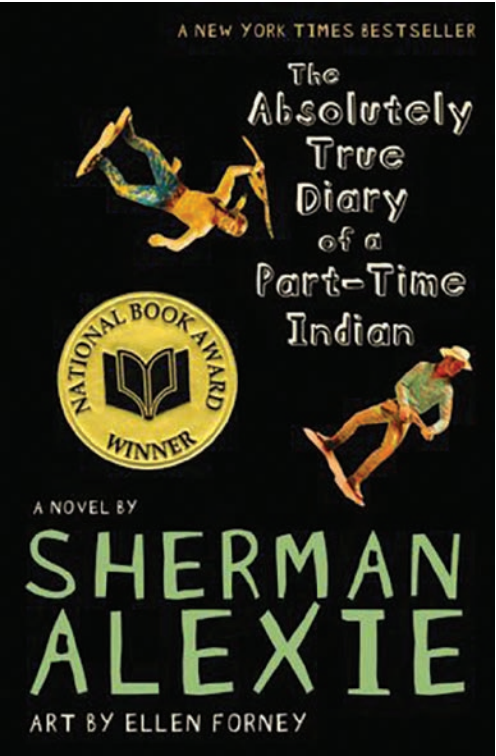
Year 10, Key Stage 4

C. Gibbs, Great Yarmouth Charter Academy, Norfolk.  
Supervised by A. Scullion, University of East Anglia.

Sherman Alexie (Spokane) is a Native American author who has written many works of literature that tackle the idea of the 'Vanishing Indian.' The theme is complex and covers many injustices within Native Americans' lives, including the contradictions in Post-Colonial Theory, which is the concept of the aftermath of settler colonialism in modern countries. *The Absolutely True Diary of a Part-Time Indian* is a semi-autobiographical work of young adult Native American literature, which draws from Alexie's experiences of growing up on a reservation. In this essay I hope to explore how Alexie uses literary techniques and cultural influences to challenge the 'Vanishing Indian,' and how he criticizes Post-Colonial Theory in his writing.

*The Absolutely True Diary of a Part-Time Indian* explores themes of alienation and objectification as felt by the Native American community through the character of Arnold, who is experiencing his first day at his new school, Reardan. From Arnold's arrival in the chapter entitled 'How to Fight Monsters,' Alexie begins to isolate Arnold from the rest of the school community, and allude to how cultural influences fuel these feelings of segregation. As soon as the white students begin to arrive, Arnold is "surrounded"; this verb emphasises the fact that Arnold is a minority in relation to the white students, and rather than being included, the connotations of the verb as a precursor to an attack suggest that Arnold is feeling threatened by the group. Alexie then proceeds to use the simile "like I was Bigfoot or a UFO" to show the lack of representation resulting from a general ignorance. The grouping of Native Americans with fictional races and species is commonplace in pop culture, which results in objectification; there are no popular, representative Indian people in current mainstream media that society would recognise, apart from stereotypical, dated characters such as Tonto from *The Lone Ranger*. Tonto is a recognisable creation, but is rife with fallacies and, as Adrienne Keene of Native Appropriations is quoted as having said in the *Indian Country Today* article 'The Real Problem With a Lone Ranger Movie? It's The Racism, Stupid,' published on July 8<sup>th</sup> 2013, "When a real group of people seem as real as, say, werewolves... it gets hard to pay attention to the real people who are alive today." Arnold encounters this misrepresentation at Reardan. Their mascot is a terribly stereotypical Indian warrior, playing on common conventions that make Arnold feel disheartened, insulted and separated from the school that fails to understand his race.

In the chapter 'Slouching Towards Thanksgiving,' Arnold's explanation of petrified wood is filled with stutters that clearly display feelings of genuine fear. The repetition of hesitation markers like "er" and "uh" show a fear of continuing and a panic to recall the correct information. In the context of the book, it shows Arnold's trepidation in drawing attention to himself, as he knows that one wrong step could mean he is judged by his ignorant white peers. However, in relationship to the 'Vanishing Indian,' it could be Alexie's way of showing how Native Americans in American society do not have a voice to speak for themselves and their rights.



This idea traces back to the earliest European settlers, and as they began to take more land as part of Westward Expansion, Native Americans began to lose control of land that wasn't meant to be owned by anyone. Indians used to lead nomadic lives, but this all changed with the advent of settler colonialism, and with such developments as the General Allotment Act of 1887, Native American people's traditional ways of life were soon constricted and confined. However, because of the settlers' belief in the concept of Manifest Destiny, which was the belief that Westward Expansion was always meant to occur by Divine Right, the opinions of the Native Americans were ignored and they were marginalised. The existence of Indian reservations and the alienation of the indigenous people of the United States of America as a result of Westward Expansion help realise the contradictions within post-colonial theory. Settler colonialism by its very nature cannot have an aftermath; its aim to create a permanent settlement away from the colonial metropole, as well as either replacing or coexisting with the native people, means that a country can never be 'post-colonial,' as the colonisers have become the dominant race! With this comes the problem of the marginalisation of the indigenous people. Native Americans are being ignored; after centuries of discrimination and forced segregation, even modern theories can fail to see the effects of the past on today.

Alexie displays the unfortunate effects of this stained history through capturing Arnold's loneliness in a nuanced way, which also acts as a powerful counterpoint to certain Native American stereotypes. As the title suggests, the book takes the form of a diary, which means that it is unlikely for anyone to be reading it. However, on page 83, Arnold explicitly addresses a reader in a way that suggests it is not himself:

"Now I know what you're thinking, "Okay, Mr Sad Sack, how many ways are you going to tell us how depressed you were?"

And, okay, maybe I'm overstating my case. Maybe I'm exaggerating."

His reference in this extract to the ambiguous personal



plural pronoun “us” suggest an audience he’s speaking to. In his imagination, Arnold has created an audience, perhaps as a coping mechanism for the alienation caused by the influence of harsh stereotypes and discrimination. However, Alexie may be trying to show something more positive by displaying Arnold’s passion for writing. In the story as a whole, Alexie wields language and structure to suggest the excitement of the fictional writer in his craft. On page 82, Arnold is overthinking a perfectly adequate zombie metaphor. His dedication to expressing his feelings in such an eloquent way presents him as an academic character. *The Absolutely True Diary of a Part-Time Indian* draws heavily from Alexie’s own experience, so as well as the story telling of the real author’s love for literature, it also gives Native Americans, especially children, a positive role model. To see a character of their race explore their talent despite social pressure is an encouraging message, and the intelligence of Arnold helps them realise that Native Americans, who have occasionally been portrayed as illiterate in the media, are not defined by stereotypes within society.

Arnold’s life isn’t simply imperfect due to the direct impact of his social exclusion from the school’s students; his home life is experiencing struggles as well. Arnold’s Dad is a recurring character in the novel’s narrative, and it is made clear that he is experiencing emotional difficulties. Evidently he has a drinking and gambling problem, as highlighted by Arnold on pages 55 (“...not stop in a bar and spend whatever money he had left”) and page 87 (“... stop at the rez casino and play slot machines first”). The specific reference to how his Dad would use his money in the casino as part of a regular routine that his son anticipates suggests that it is an addiction. This is reinforced by Arnold’s father being late to pick him up from school, which Arnold ties to his problems. Although it is never specifically stated what caused him to begin these habits, we can infer that it’s a coping mechanism; a way to drown out problems that may have resulted from the general struggles faced by Native American people. It has been suggested that twenty seven percent of all self-identified Native Americans and Alaskan Natives live in poverty, and forty percent of Native Americans who live on reservations reside in substandard housing. In relation to this, twenty two percent of Native American children have PTSD<sup>2</sup>. This is scratching the surface of the current political and social discrimination against Native Americans, which has stemmed from a history of oppression as a result of Westward Expansion, and objectification as a result of ignorance within the media. Arnold’s Dad’s alcoholism and addiction to gambling is Alexie’s method of highlighting urgent issues within the Native American community that must be dealt with in haste, before more injustice comes from delusion.

Mr Dodge and Arnold’s interaction’s in the chapter ‘Slouching Towards Thanksgiving’ is Alexie’s way of expressing his anger towards the ignorant part of non-Native American society that discriminates against his race. Mr Dodge, or Dodge as Arnold usually refers to him, showing a lack of respect, immediately takes a patronising tone when speaking to Arnold. His use of phrases like “if you’re so smart” and “if it’s not wood” shows how little he values Arnold’s voice and opinion, and has let his personal beliefs overtake his professional stature. Although only making this comment later within the diary, Arnold shows a clear understanding of Mr Dodge’s feelings towards him and his ethnic group, and uses it to secretly mock him. The repetition of “red” to describe Mr Dodge’s face, followed by the questioning of the term redskins as a description of Native American people, allows Arnold to express his amusement at the stupidity of the racism towards his people.

Although he may not have had the confidence to say it at the time, he does passionately feel that way. When Mr Dodge proceeds to say “We all know there’s so much amazing science on the reservation,” it only shows him to be less and less enlightened about Native American culture in today’s world, which relates to the creation of the ‘Vanishing Indian’ concept, which was born from society’s misinterpretation of modern Indians. Indians have kept up with the society in which they inhabit, but for those who look for traditional Native Americans plucked from the past, they do not see a developing people; they just see a dying race with little to contribute to the world. This is emphasised when it is revealed that Arnold was absolutely correct in his definition of petrified wood, and this allows Arnold to rip apart Dodge’s credibility. He repeats the concept of a “real science teacher” to show how clueless Mr Dodge is, and even goes as far as to call him a “fake” to truly undermine his knowledge and opinions. This entire interaction is arguably a metaphor created by Alexie to show what would happen if Native Americans were given the voice to express their feelings on the racism against their people, and how by letting them convey their concerns, we can build a more understanding, as well as inclusive, community.

In conclusion, Alexie both explicitly and subtly explores the theme of the ‘Vanishing Indian’ within *The Absolutely True Diary of a Part-Time Indian*. He draws from past injustices and modern grievances that his people have experienced to carefully portray an almost real-life Indian in a work of fiction, something that pop culture has failed to do since the dawn of cinema. Alexie is critical of the paradoxical Post-Colonial Theory, and develops situations that show the negative yet still relevant effects of settler colonialism. The book feels like its aim was to educate readers and support Native Americans through accurate representation, and its aim at young adults seems like Alexie taking his chance to make sure that the future is filled with a society that is inclusive and understanding of its important minorities.

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2 Figures taken from the Huffington Post article ‘13 Issues Facing Native People Beyond Mascots And Casinos’, written by Julian Brave NoiseCat and published on July 30th 2015.  
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#### PhD Tutor’s comment:

C. is an exceptional student and he has been a pleasure to work with throughout The Scholars Programme. The wonderful groups at Great Yarmouth Charter Academy studied a course called “‘Last of the Mohicans’?”, analysing contemporary Native American literature in relation to the challenging concepts of the ‘Vanishing Indian’ and settler colonialism. C. consistently made valuable contributions to seminars and pushed himself to produce work of the highest standard. This essay demonstrates his ability to think and write about literature and complex issues with sophistication and confidence. C. achieved a First in this essay, indicating that he is already working to an excellent standard at A-level. There is no doubt that C. would excel at university, in whichever course he chooses to pursue.

## ‘How we should interpret the work of a nineteenth century poetess’ Radio Script

Year 10, Key Stage 4

P. Henson, Litcham School.

Supervised by A. Flint, University of East Anglia.

<Music: 4-second poetry central theme tune>

**Person 1 (Jennifer Wood):** Good morning! Welcome all to *Poetry Central*. Today we are looking at how we should interpret the work of the nineteenth century poetess, Christina Rossetti. Rossetti wrote a variety of romantic, devotional and religious poetry, as well as poems for children. With Robin Cole, and another guest later on, we will be examining the existential conflict that Christina expressed in her poetry. She was a poet who questioned whether to celebrate or mourn death. We will see how this reflects her real-life conflict between her religious and secular obligations. We are going to examine two themes that dominate most of her writing: death and her religious beliefs. Robin, tell us about Rossetti.

**Person 2 (Robin Cole):** Well, Christina Rossetti is one of the most famous poets of the nineteenth century. Born in London, in 1830, to Gabriele and Frances Rossetti, she was the youngest of four children. They were an extremely talented family. Her siblings being Maria Francesca, then Gabriel Charles Dante, and the second youngest William Michael.



Christina Rossetti

All four Rossetti children developed artistic and literary skills. The most famous being her oldest brother Dante Gabriele, the pre-Raphaelite painter, who actually started the pre-Raphaelite brotherhood with his brother William. So we could say that Christina, she had a lot to live up to, being the youngest. She had many talented influences. In fact, she flourished during her childhood in London, a city in which the family had many visiting scholars, artists, authors, and political firebrands.

**Jennifer:** Of course. Her mother, though, was one of the biggest influences, I hear. They had a very strong relationship.

**Robin:** Indeed. Her Mother, Frances, was probably the biggest influence in her life. In fact, Christina’s first published poem was even called *To My Mother*. She wrote it at the tender age

of 11 years old. Her mother was also a devout Anglican and passed onto Christina her zeal for God. This can clearly be seen throughout a lot of her poetry. Rossetti’s religious faith was the core of her life and is a constant theme throughout a lot of her poetry.

**Jennifer:** I agree. I think that her faith was one of her main themes. More than half of her poetic output is devotional. Robin: We are now going to look at one of her poems that has religious symbolism, titled *A Birthday* written in 1857. This poem isn’t actually about a birthday celebration as we think of it, rather it suggests what can be achieved in the desired relationship with Christ. It is a poem of joy and can be viewed as a premonition of heaven.

**Jennifer:** Why is it called *A Birthday* then?

**Robin:** According to the author Erika Andersen’s [4] interpretation of *A Birthday*, the word ‘Birthday’ can be understood as a birth into a new life with the second coming of Christ, read from the study guide, she wrote...

*‘Rossetti frequently refers to the Second Coming of Christ as the ultimate “birthday” in her work. The Second Coming is central to the Christian faith, because it symbolizes the new kingdom replacing the old Earth.’ ([4] Anderson, Erika).* Here the poem is interpreted to be Rossetti expressing a great joy at Christ’s second coming, as though she was there in the moment. Andersen also mentions how it is the ‘birthday’ of her ‘love’ not a birthday of her own.

Though I can see this as a plausible interpretation, personally, I disagree with it. When the speaker says ‘my love is come to me’ I agree that it is likely she is writing about Christ rather than a man or lover, however I disagree that Rossetti’s poem is about Christ’s second coming. I also disagree with the view of the birthday belonging to her ‘love’, being Christ. Rather I think the ‘birthday’ is her own, made clear in the words – ‘the birthday of my life’ and that it refers to her death, rather than the second coming of Christ.

Therefore, could it be that Rossetti is referring to her ‘death-day’, as an unusual oxymoron, when she mentions a ‘birthday’ in this poem? I think this is very interesting and shows again the complexity you find in Christina Rossetti’s poems. However, I think that was the way Rossetti viewed death; she was not fearful of it, because she knew where she was going. I think that she viewed it as something inevitable and so chose to look forward to it as an ultimate point of destination. What most might consider as death Rossetti and many other Christians consider being a birth into new life. I see the poem *A Birthday* as an expression of how she thinks she’ll feel when she sees Jesus, at her death. Jesus being her ‘love’ when he comes to her and takes her to an eternal home in heaven.

**Jennifer:** Rossetti did write many poems about death and this related to her faith. Her poems on death and the attitudes she expresses, offer insights into her character. Samantha Brown, with us today, is a lecturer in English Literature. She’s here to help shed some light onto Rossetti’s view of death and how it helps us interpret her work.

**Person 3 (Samantha Brown):** Hi Jennifer, hi Robin. It is great to be here today... So, referring back to what I heard you say, Robin, about how Rossetti viewed death, I think that it was not quite as simple as you put it. It seems clear to me, that she had a turmoil within her, between religious desire to accept death sacrificially, despite her attachment to the world she was in, but then, on the contrary, having an actual desire to die.

Rossetti had bouts of serious illness throughout her life; her brother, William, insists in his memoir, which forewords *The*



*Poetical Works of Christina Georgina Rossetti* (from 1904) that you cannot understand Christina unless you recognize that she “was an almost constant and often a sadly-smitten invalid.” The morbidity that readers have so often noted in her poetry, William suggests, was attributable to Christina’s ill health and the ever-present prospect of early death rather than any innate disposition.” [6] The author Nesca Robb wrote that, “Christina is pursued, as she was all her days, by the thought of death” ( [1] *Four in exile, Christina Rossetti*, 1948). The American poet, Marya Zaturenska believes that Christina has been primarily “the poet of death, the poet of the death-wish” ( [2] *A Portrait With Background*, 1949 ). Let’s have a look at her poem A Better Resurrection. I think it is a beautiful poem. Within the second stanza, a solemn outlook to life is clearly identified...

My life is like a faded leaf,  
My harvest dwindled to a husk:  
Truly my life is void and brief  
And tedious in the barren dusk;  
My life is like a frozen thing,  
No bud nor greenness can I see:  
Yet rise it shall—the sap of Spring;  
O Jesus, rise in me.

This stanza, which started so glumly, rises towards the end. Christina Rossetti often adds a jubilation or a line of hope after morbid reflections, stating the hope she has in Christ and her afterlife.



Marya Zaturenska

Each stanza of *A Better Resurrection* has this rhythm, of stating the evil in the world or in her life and concluding with a prayer, or hope she has in Jesus.

Just like in her poem *A Birthday*, the mentioning of Jesus always reads positively – her use of words like ‘spring’ and ‘rise’ being good examples. Rossetti really did love her God, and poems of hers like this one, show how important, and how big a pillar, God was in her life. When looking at *A Better Resurrection*, Christina’s want for a superior life in heaven cannot be ignored. We find that, always being very matter-of-fact with the poems’ titles, she even called it ‘A Better Resurrection’. A new life into something greater, an ultimate destination.

**Robin:** Thank you Samantha, that was very interesting. However, a key aspect that must now be discussed, is that Christina Rossetti also felt distance between herself and God. Some also feel that her poetry indicates her religion being a burden. Rossetti is constantly referencing scripture in her poetry. As a professing Christian, I would hope to notice it when she does, but she knew the Bible very well and I often miss it. When reading the web article, discussing imagery and symbolism in *A Better Resurrection*, my attention was drawn to the line ‘My life is like a faded leaf’. The prophet Isaiah, in the old testament of the Bible, speaks of this image, ‘... we all do fade as a leaf; and our iniquities, like the wind, have taken us away.’ (Isaiah 64:6) ASV [8]. The article suggested two likely interpretations that Rossetti intended when comparing herself to a falling leaf. I agree with both of these. Allow me to read them to you now...

*“Read in the context of Isaiah, it would seem that she is claiming that her sins have created a barrier between her and God and that now she is falling away from the Christian hope that the Bible offers” “However, considering the refrain, ‘O Jesus, quicken me’ (line 8), her reference to being in the falling leaf could indicate both her willingness to let go of her earthly body, which is affected by decay and the fading of time and her openness to accept the new life that Christ offers.”, ( [5], ‘A Better Resurrection’ – Imagery, symbolism and themes, Dr. Elizabeth Ludlow, cross-ref it.info.)*

The second interpretation supports what you were discussing Samantha: that Christina really wanted to let go of her life in order to meet her maker. The first one, though, concludes how she felt distanced from God because of things she had done wrong. Many people think her regrets were because of her tumultuous manner as a young girl. I think it is more likely she regrets something that was more recent and prominent in her life: the matter of indulgence and her individual unworthiness.

Christina Rossetti felt strongly about this and she has written about it in her poetry many times. Probably her most famous poem, *Goblin Market*, has negative symbolism concerning indulgence, with the sister Laura indulging in the Goblins’ fruit and then consequently wasting away. She writes on the theme of indulgence in her other poems such as *‘Passing away, Saith the world’*, where the speaker says of how this world is “*passing away* ” and one should fix their eyes on God rather than the material things on Earth. Her feelings of individual unworthiness we’ve already seen in the poem *A Better Resurrection*. My opinion is that Christina was, throughout her life, feeling convicted.

Christianity was a massive part of peoples’ lives in the Victorian times, with most of the population attending church every Sunday. I think it is very likely she felt this conviction from the large amount of doctrines that taught against any indulgence in this present life, like Eve eating the forbidden fruit. When you read her poems for children, especially, you do see her love for nature and the seasons and material things in the world. Then, there are her poems on dreams being extinguished. Looking at her poetry, and her brother William’s points about her character, it seems to me that she saw and understood the beauty of this world, but had a religious guilt of finding peace in partaking in it. She had

restrained herself from society, thinking maybe that it made her more devoted to God.

In her brother William’s memoir, which forewords *The Poetical Works of Christina Georgina Rossetti* (from 1904) William speaks of the change in her high spirited character, I quote: “In innate character she was vivacious, and open to pleasurable impressions; and, during her girlhood, one might readily have supposed that she would develop into a woman of expansive heart, fond of society and diversions, and taking a part in them of more than average brilliancy. What came to pass was of course quite the contrary.” [7] ... You see... and then as an adult Christina was considered by many to be over scrupulous and very restrained. According to Georgina Battiscombe, one of the biographers of Christina’s life, William Rossetti said of her that “she was compelled, even if not naturally disposed, to regard this world as a ‘Valley of the shadow of death” ( [3] *Christina Rossetti*, 1965).

This valley of the shadow of death is spoken of in Psalm 23, which, if you read it, is a psalm of promise and protection. The ‘valley’ is considered as a trial or problem in one’s life. So, if what her brother said about her is correct then she viewed her whole life as a kind of trial. Without a doubt, we see she was occupied with the idea of death; more than a hundred of her poems seem to display her views on it. Whether you go with a close-reading approach through her poems, or you use context-based criticism to look at her work, you can find a constant obsession with death.

**Jennifer:** To interpret the work of this nineteenth century poetess, it is important to look for spiritual references, knowing she was greatly influenced by a devout Anglican mother, in an era which was predominantly religious. Without knowing about Rossetti’s background and her attitude to life, we are open to the mistake of viewing her work in a way she had not intended. A context-based criticism of her work creates a more accurate and rounded interpretation. Though we can never know exactly what Rossetti was thinking when she wrote her poetry, we can try to gain a new and fuller understanding of her work by knowing her character, her devotion to God and her turmoil with death.

Christina Rossetti’s work grows in popularity still, over one hundred years after her death. Her thought and her symbolism compacted into each carefully chosen word, each stanza containing great depth and insight that we have only been able to touch upon today. Samantha and Robin, thank you both, and thank you listeners. That’s all for now from *Poetry Central*. Have a nice day.

#### PhD Tutor’s comment:

P’s radio script on the relationship between Christina Rossetti’s portrayal of death and her religious beliefs is one of the most thoroughly researched, well-written and insightful assignments I have received at any level. It was awarded a distinction because it is of the standard I would expect from a first year undergraduate, and P. is just fifteen. As a doctoral student whose PhD thesis is on Christina Rossetti, I commend this assignment as a rigorous introduction to Rossetti’s religious verse. Few published critics approach Rossetti’s religious conflicts with such objectivity, and P. applies her knowledge of Christian doctrine with great precision and detail. I was highly impressed by all of my students at Litcham School—an outstanding group who were supported by their dedicated lead teacher, David Glenn.

## Social Sciences

### Magnetic Resonance Imaging

Year 9, Key Stage 4

C. Davis, Darrick Wood School, Orpington.  
Supervised by H. Rogers, UCL.

MRI (Magnetic Resonance Imaging) is a method of producing detailed images of the internal organs or tissues. It uses a very powerful magnet in order to detect radio waves, which then form an image. The image can be used to provide a diagnosis or search for a disease or injury. MRI is effective but also has potential issues that follow. Sending a child for an MRI scan would expand your knowledge of where the pain is coming from but in order to have a full understanding, the interpreter of the image must understand the principles of MRI.

MRI functions using the billions of hydrogen atoms that our bodies are made up of. The human body is made up of a large percentage of water. In children aged six months to eleven years the average water percentage is 53% to 63%. These hydrogen atoms that make up a large amount of our body weight, spin and move in a random formation, this process is called Brownian Motion. When a magnetic field



MRI machine

will be turned off and the atoms realign to their original form, emitting energy which is then converted to an image by a Fourier transform image (a mathematical formula). This image provides a complex image of the area scanned and it can then be examined by a doctor or researcher to seek a diagnosis if necessary.

During an MRI scan the patient will be asked to lay on the flat bed provided, which will then slide into the scanner. The scanner is controlled by a computer in a separate room so that it is not close to the magnetic field being produced. The MRI scanner is very loud so the patient will be given headphones and able to watch a film for a more comforting experience. In order to get the most accurate and precise results you have to be very still. Moving a significant amount during a scan can lead to ghosting and artefacts in the imaging. This is when reduplications of the image are produced. This results in light rings appearing on the image which may affect the readings. Correcting this is done by having sedation prior to the scan or by using motion correction algorithms on the images afterwards. MRI scans can take from around 15 to 90 minutes, the time it takes depends on how many images are being taken and the size of the body part being scanned.



The MRI scanner is able to take transverse, coronal and sagittal images of the body. A transverse image is when the body is scanned horizontally, splitting the body into two planes above the hips. A coronal image is when the scan is vertical and splits the body into two planes with the back and stomach. A sagittal image is when it is scanned through the middle of the body vertically, producing a left and right side. Having these different angles of the imaging helps to see all the parts of the organs and by taking several images at different planes, a 3D image can be formed.

MRI uses no radiation and is a completely painless procedure. The space for the scan is quite enclosed and may trigger claustrophobia, however patients can communicate with the radiologist, so this may reduce feelings of anxiety and claustrophobia. There have been large amounts of research done on whether the magnetic field can cause any potential harm to the human body, but no evidence has been found therefore Magnetic Resonance Imaging is one of the safest medical procedures we have. The magnetic field in an MRI scanner uses from 5,000 to 30,000 gauss, or 0.5 to 5 tesla range, in comparison to earth's 0.5 gauss magnetic field, this shows that in an MRI the magnet is extremely strong. As the MRI uses a magnetic field, no metal can be in the room of the scanning. If someone has any metal implants they are not compatible for an MRI scan. For medical safety laws and reasons, it is most likely you will be questioned more than once about the patient as it is important to be correct with the information and procedure. Clothing is also restricted and can have no metal qualities; buckles, jewellery, phones, bags, make up and nail polish cannot be worn in case of any metal particles within them. There have been some incidents of MRI going wrong. This includes a case where a 6 year old boy was killed by oxygen tank in MRI scanner that crushed his head. This happened as a result of the oxygen tank being too close to the scanner and therefore being drawn to the magnetic field that the MRI was producing. However, the source that described the story is an online reporting company, so the reliability of the source could be questionable. Incidents like these do happen, however the percentage of time that the MRI has been successful is significantly higher and the vast majority of the time MRI scans are completely safe. Only when the magnetic field is exposed to a metal item would it then become a risk, but hospitals and research clinics are very careful as it is a known danger. The number of times an MRI does work and causes no harm is way larger and eradicates the few risks that are unlikely to occur, as the results are regularly sufficient.

Diffusion Weighted Imaging (DWI), uses the movement of water particles (Brownian Motion) in order to get an Apparent Diffusion Coefficient (ADC) map. An ADC map shows the degree of diffusion of water particles within body tissues. This means that the image will show how much restricted diffusion there is through the different shades on the images. When water cannot move in a tumour this means it has restricted diffusion and a low ADC value. However, when water can move through a tumour then it has a high ADC value, this would appear bright on the ADC map and could possibly mean there is necrosis (dead cells), meaning the water could flow freely through the tumour. When using Diffusion MRI, the doctor or researcher can retrieve an image showing any tumours the patient may have, and it gives an important numeric value. Tumours can be either benign (a non-cancerous tumour) or malignant (a cancerous, fast-spreading tumour). Malignant and benign tumours will often have different ADC values, but they will not always differ 100% of the time. A malignant tumour would most likely have a lower ADC, as if the tumour is dense then water cannot move as freely.

Using a contrast agent in an MRI can enhance the quality of the images. Gadolinium is a contrast agent, sometimes used in MRI in order to improve the clarity of the images, it makes it easier to see the contrast between shades in the images, meaning that it would be easier to spot anything abnormal in the abdomen. Gadolinium is used in about 1 in 3 MRI scans. The radiologist will decide whether it would be beneficial to use gadolinium prior to the scan. Gadolinium is injected into the bloodstream and is disposed out of the body through the kidneys. If the patient had dysfunctional kidneys, then they would not be referred to have gadolinium. As do many medical substances, gadolinium has a few known side effects, these include nausea, vomiting, headaches, rashes and itching around where it was injected. Only 1 in 100 people say they received the vomiting and nausea symptoms after having a dosage of gadolinium. These are all short-term effects, a long term effect would be getting nephrogenic systemic fibrosis, a disease that affects the internal organs and skin. This would only occur if the kidneys were not functioning well enough to filter the contrast agent out of the blood, resulting in it being against the law to have an intake of gadolinium with an unhealthy kidney.

An alternative to having an MRI scan would be to have a computer tomography (CT) scan. CT scans are much quicker with a larger area surrounding the scanning table. Your whole body does not have to go in the tube, unlike an MRI, the area that goes into the tube depends on what are you are scanning. However, CT scans use x-ray radiation in order to produce an image. When overexposed to radiation, it can cause harm to the body. After a dosage of radiation, it can create molecules that can negatively impact the human body, these are called 'free radicals'. These alter the cells and can lead to a build-up of cancerous cells. One study shows that after a CT scan you are 24% more likely to develop cancer within the following 10 years.

Another alternative would be an abdominal ultrasound. An ultra sound uses very high frequency sound waves in order to produce an image. A lubricating jelly is spread on the abdomen and a sonographer will use an ultrasound transducer and run it over the abdomen. It can show the blood flow and structure of the organs in the abdomen. Ultra sounds have no risks, they do not use any radiation. This method avoids any issues with claustrophobia, but they do not get as clear an image.

Although these alternatives avoid feeling claustrophobic and are less time consuming, MRI provides a much clearer image that is easier to diagnose from. This provides less of a chance for incorrect diagnosis. MRI is more efficient and accurate and does not risk any exposure to radiation unlike CT. Under the NHS, all of these clinical methods are free, so having an MRI and getting the best results will not cost anything for the patient.

When children are having MRI scans, it is often recommended that they be sedated. This is because it will minimize the amount of movement of the child whilst in the scanner. It will also make it a more calming experience for the child, avoiding any panic or upset that the child may feel during the scan. Some common side effects of the medication used for the sedation include tiredness throughout the day and irritability. Sedation is a pain free option that allows the child to be much more relaxed, then able to avoid artefacts from sudden or large movements. When sedated, the patient's breathing slows. This is helpful because whilst scanning the abdomen, the lungs and diaphragm will be inflating at a slower rate, meaning there would be less motion that would interfere with the scanning and imaging.

In conclusion, sending a young child for an MRI scan is not really anything to be concerned about. MRI is very regularly used and successful images are acquired through the process. Although there are a few potential problems of having an MRI scan, for example claustrophobia or motion artefacts, MRI provides a very detailed image of the area that is in pain or has caused concern and from that you can seek further help if needed. There are other options as mentioned, CT and ultra sound, however these methods do not supply as clear an image as an MRI scan so it may be harder to spot any minor problems that could potentially grow to be something more major. The few problems with MRI scans are very minor compared to those with CT, therefore when weighing up the situation, MRI would be the best solution.

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PhD Tutor's comment:

It was fantastic working at Darrick Wood School! I was so impressed with C.'s work; she grasped a new and difficult topic very quickly and gave incredibly insightful comments. Her final assignment was written at such a high standard, it could have easily been from a university student! I wish her the best of luck for the future and know she will achieve great things.

To what extent is solitary confinement a good strategy for a prison?

Year 9, Key Stage 4

A. Pyathytska, Esher Church of England High School, Surrey. Supervised by M. Steinbrecher, Royal Holloway.

Solitary confinement, also known as segregation, sees prisoners locked up for a minimum of 22 hours per day and deprives them of meaningful human contact. According to Her Majesty's Inspectorate of Prisons' (HMIP) Annual Report 2012-2013, in segregation units '[a]part from a shower and a phone call, most prisoners remained locked in their cells nearly all day with nothing to do'. [1] Many people are critical of solitary confinement and whether the drawbacks outweigh the benefits; the Human Rights Court have described it as being 'imprisoned within the prison'. [2] In this essay, I will outline further what solitary confinement is like and the rules behind it and discuss what leads to the solitary confinement of prisoners. I will also explain the expectations of the Healthy Prison Test and evaluate the usefulness of segregation based on the test. Doing so will allow me to come to a justified conclusion on whether it is in

fact a good strategy for prisons to continue implementing or to begin using more frequently.



A report called 'Deep Custody' carried out by the Prison Reform Trust in 2015 revealed that prisoners who were confined participated in extremely low amounts of purposeful activity and experienced 'impoverished levels'. Those who were segregated were socially isolated, inactive and under strict control. The report discovered that troubled, challenging and vulnerable individuals were confined. A minimum of one night's segregation was experienced by almost one in ten of the prison population in the first three months of 2014. There was a total of 1,586 cells used for segregation purposes in January 2015. Although most prisoners (71%) were confined for less than a fortnight, a significant 20% were segregated for 14-42 days and 9% had a stay of longer than 84 days in solitary confinement. [3] However, prisons must adhere to segregation rules, falling under the following categories: removal from association, close supervision centres, disciplinary charges and governor's punishments. Under Prison Rule 45, segregation may be enforced if the prisoner is disruptive (for example disrespectful or getting into fights) or for their own protection. Under Rule 46, they can be placed in a close supervision centre (CSC) or in a designated CSC cell in the segregation unit of the prison. Rule 53(4) states that until the governor has carried out his first enquiry, a prisoner awaiting an adjudication hearing can be separated from other prisoners. According to Rule 55, prisoners can be 'awarded' cellular confinement as punishment for a disciplinary offence in prison. [4]

Solitary confinement can be used to punish prisoners who break prison rules, to detain potentially dangerous prisoners or to protect prisoners with a background of self-harm. It can prevent prisoners from scheming together before a criminal trial. [1] A maximum of three weeks of confinement can be given to adults as punishment. Breaking prison rules can lead to the solitary confinement of both teenagers and adults. Statistics show that one in three children will be segregated for a period of time during their imprisonment. [3] Appendix 5 is an extract from a recent High Court judgement, which ruled that the solitary confinement of a teenager in Feltham prison breached his human rights. Although this was the judgement, the actions of the teenager led to his confinement. He committed offences at Cookham Wood and was sentenced in January 2017. The judgement reveals these offenses to have been assault of a prison officer by 'biting him during the course of restraint' and another assault by 'punching him several times in the side of the head'. The attacks were a form of revenge, as the teenager felt 'disrespected'. Much of his time in Cookham Wood Young Offenders Institution (YOI) was spent in segregation and on '3-officer unlock' (when the prisoner must have three officers present when let out



of their cell). When the teenager was placed at Feltham YOI, he was on ‘single unlock’ immediately, which works just like removal from association. [5] The source implies that prisons implement solitary confinement regardless of the age and background of prisoners. Despite him being ‘psychologically vulnerable’ and diagnosed with post-traumatic stress disorder (PTSD), conduct disorder and attention deficit hyperactivity disorder (ADHD), his violent and inappropriate behaviour led to him being placed in segregation. This does not support the safety component of the Healthy Prison Test, since the teenager needed encouragement to behave positively and access to help from the prison as well as family members.

The Healthy Prison Test consists of four tests to ensure that despite being confined to life in prison, prisoners are treated like humans. It makes it clear that prisoners should be supported in preparation for leaving prison and they should retain their right to pursue ordinary human lives once released. [6] It is carried out by Her Majesty’s Inspectorate (HMI), an ‘independent inspectorate which reports on conditions for and treatment of those in prison, young offender institutions and immigration detention facilities.’ [7] The four sections of the Healthy Prison Test are: safety, respect, purposeful activity and resettlement. [6] HMI has high expectations, so inspections of conditions and treatment of prisoners is thorough. HMI encourages prison staff to work effectively to provide prisoners with the necessary support to not reoffend and help them accomplish things as individuals. [8] To meet safety expectations, prisons are expected to keep all prisoners safe, particularly those who are emotionally vulnerable. Positive behaviour needs to be encouraged and suicide and self-harm prevention should be prioritised by giving prisoners access to a ‘multidisciplinary team’ and ‘unhindered access to help, including from their families’.

Next, the test for respect requires staff and prisoners to have positive relationships to maintain dignity and equality within the prison. Allowing prisoners to have a say in decisions regarding services, routines and prison facilities is expected. Purposeful activity is another component of the Healthy Prison Test, requiring prisoners to have ‘regular and predictable time out of cell which is sufficient to promote rehabilitation and mental well-being’ and it should help them gain skills and ‘benefit from good quality teaching’. Finally, rehabilitation and release planning focus on ensuring prisoners do not lose contact with the outside world during their imprisonment and get useful advice from prison staff on having things like ‘suitable accommodation on release’. [9] Segregation falls under the ‘safety’ criteria of the Healthy Prison Test and it’s stated that prisoners should be segregated for as little time as possible and have their individual needs ‘recognised and given proper attention’ whilst in confinement. Furthermore, prison staff are supposed to encourage segregated prisoners to ‘access an equitable range of purposeful activities’.

Based on the Healthy Prison Test, solitary confinement is not particularly useful – it is more detrimental to the wellbeing and rehabilitation of individuals. Although the safety component calls for prisoners to be segregated for the shortest period, in January 2015, 9% of prisoners were segregated for more than 84 days and 20% stayed in confinement between 14–42 days. [3] These are significant time periods, and the prolonged isolation would have deteriorated mental health. More than 50% of the prisoners interviewed by the Prison Reform Trust reported a minimum of three of the following because of solitary confinement: anxiety, depression, anger, difficulty in concentration, insomnia and an increased risk of self-harm. [3]

The source therefore implies that solitary confinement is a detrimental strategy more than it is an effective one, especially since the safety element of the Healthy Prison Test calls for suicide and self-harm prevention. Since prisoners were isolated from the rest of the prison population, they did not get to practice behaving positively in the community. Segregation doesn’t improve cohesion within the prison because it simply removes individuals from the community, making it harder to re-integrate later on.

Purposeful activity is important for resettlement because it provides prisoners with key skills needed for both time in custody and once released. Participating in work activities and having access to education develops prisoners’ ability to progress as individuals. However, prisoners in solitary confinement don’t get the education and work opportunities they deserve. Since a minimum of 22 hours of their day is spent in their cell, there is little to no time left for learning. Purposeful activity also concerns activities, exercise and regime. However, segregated prisoners are deprived of adequate opportunities to benefit from all three. The Prison Reform Trust’s report revealed that ‘regimes in segregation units were impoverished’ as prisoners only had time for a quick shower, a short period of exercise and their meals. Some segregation unites forced prisoners to choose between having a shower, a phone call or exercise, making these units appear far from the ‘healthy establishments’ they are supposed to be. Most units allowed 20–30 minute periods of exercise, significantly lower than stated in the European Prison Rules and the United Nations Standard Minimum Rules for the Treatment of Prisoners (the Mandela Rules). [3] The report presents segregation negatively and diminishing the quality of life of prisoners.

When the resettlement element of the Healthy Prison Test is compared to the life of segregated prisoners, it is evident segregation is far from useful or beneficial. Prisons are expected to assist prisoners with resettlement and this includes helping prisoners to ‘re-establish or maintain relationships with their children and families’ through phone and mail communication and regular visits. However, when prisoners are locked up in their cells and left with no meaningful human contact, their mental state is likely to deteriorate and communicating easily and openly with family and friends will prove a challenge once they are eventually released from prison. It is not useful for prisoners to be left alone with no one but their thoughts to turn to – potentially, they may begin to consider reoffending due to no release planning or support for progression. Moreover, the fact that they spend 22 or more hours alone means they cannot get help from rehabilitation services and therefore, they cannot prepare to move on from their prison life.

The Healthy Prison Test advocates the important of human rights and requires prison staff to treat prisoners in a fair and humane manner. In some ways, segregation isn’t useful for improving respect in prisons. Prisoners who are segregated are not able to ‘take an active role in influencing decisions about services, routines and facilities in the prison and managing day to day life.’ [9] This means that it denies them all control and authority over their lives and could potentially make them feel inferior to others. However, there is evidence that staff and prisoner relationships don’t suffer – in fact, they remain good. According to the Prison Reform Trust’s report, ‘prisoner-staff relationships were a key strength of many of the segregation units.’ A staggering 89% of prisoners living in confinement revealed that they got along well with some of the officers. Also, 57% thought that the officers were supportive, meaning prison officers were willing to put time and effort into maintaining good terms with prisoners despite them being isolated potentially for extremely aggressive behaviour. [10]

From my point of view, solitary confinement isn’t a good strategy for prisons because it makes it far more challenging for prisons to meet the expectations of the Healthy Prison Test. It can also make vulnerable individuals even more vulnerable than before. In order for prisons to be effective establishments, I think it’s necessary for them to reduce the likelihood of prisoners reoffending and also prepare them for life outside prison. However, solitary confinement simply isolates prisoners and prevents them learning new skills and how to interact and communicate with others in a non-aggressive and respectful manner. I believe that the background of prisoners plays a particularly heavy role in whether solitary confinement should be permitted, let alone considered a good strategy. In Appendix 5, solitary confinement was considered a breach of the teenager’s rights because he had childhood adversity and had pre-existing mental health conditions. [5] It’s very likely that people who break the law and are sentenced have experienced similar things in life and their human rights should also not be breached through segregation.

In conclusion, I believe solitary confinement is not a good strategy for prisons. Prisoners have a poor quality of life confined to their cells for a minimum of 22 hours per day. More than half of prisoners blame solitary confinement for the development of conditions such as anxiety and depression. They get inadequate physical activity; most prisons allow only 20–30 minutes per day. [3] Both physical and mental health is harmed through segregation. Also, segregation denies prisoners of their human rights and according to Anita Dockley, research director at the Howard League for Penal Reform, is ‘a troubling indictment of a broken system.’ The prisoners put into confinement are the ones who require the most support. Being shut off denies prisoners of any incentive to reform. [11] Segregation is not effective or useful in terms of meeting the expectations of the Healthy Prison Test. The amount of time allocated for purposeful activity is practically non-existent and no preparation for rehabilitation takes place during solitary confinement. The benefits of segregation, like protecting other prisoners and retaining prison discipline, can be achieved through a normal prison sentence instead.

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### PhD Tutor’s comment:

I enjoyed every tutorial at Esher High School. Although the general level of students’ research and writing was high, A. stood out. Her understanding of the material and application to such a challenging issue demonstrated her maturity. She is already capable of working at university level and I am confident that she can achieve whatever she sets out to do.

## How Can we Encourage Young People to be more Involved in Decisions about Their Health?

Year 10, Key Stage 4

Z. Morgan, Ysgol Abersychan, Pontypool.  
Supervised by A. Jordan, Cardiff University.

This study will focus on asthma and how young people with the chronic illness can be encouraged to take a more focal role in their own health decisions. Asthma is the most common long-term illness in children, with 1.1 million children in the UK affected by it (National Institute for Health and Care Excellence 2013). This study will particularly concentrate on adolescents, as this is the age group that begins to take more control of their health needs and, arguably, find it hardest due to life choices (for example health risk behaviours that could worsen their condition) plus social and psychological influences at their age. With many other adolescents trying things such as smoking and alcohol misuse, adolescents with chronic illnesses are also likely to do similarly. Sawyer et al., (2008) shows that adolescents with chronic illnesses are more likely to engage in health risk behaviours than healthy adolescents. This shows that more must be done to raise awareness of how detrimental these acts can be to young people’s health, especially those with chronic illnesses.

Perhaps, the most effective option to combat the antecedent problems is shared decision making (SDM). SDM relies on a good relationship between the patient and healthcare professional. Patients are given support through the sharing of information to aid them in making decisions towards resolutions for their health problems. To support this, Elwyn (2012) suggested a model of how to successfully carry out SDM formed on three main factors: *choice (1), option (2) and decision talk (3)*. The model has three procedures: 1) introducing choice to the patient, 2) describing options to create a resolution to the choice(s) that suits the wishes of the individual, whilst also benefitting and attempting to improve the patient’s condition or making a decision that the healthcare professional also feels is most suitable, and 3) helping the patients to explore their own personal preferences and make decisions.



Regarding long-term (chronic) health conditions, the policy in England explicitly advocates actively engaging individuals in the management of their condition and helping to improve the patient’s overall experience of the services (Department of Health (DH) 2007,2010). According to the World Health Organisation (2002), it is fundamental to the future of healthcare delivery for empowering



individuals to take control of their own condition. This is embedded within a programme in the UK called ‘The Expert Patient Programme’ (DH 2001).

At a young age, children diagnosed with chronic conditions have very little responsibility in managing their condition (i.e. taking their medication and so on). The parents/carers of the patient have greater control over the patient's health. As the patient ages, the control over their own health increases and the pendulum of responsibility is then passed on to the now more mature patients. The Orell-Valiente et al., (2008) asthma management responsibility study found that as the patient ages, they have greater control over their medication. The study shows that by age seven, children had, on average, almost 20% responsibility for taking their medication; by age 11, this had increased to 50%; by age 15, this had increased even higher at 75%; and by age 19, they had assumed complete control and were entirely independent. Although adolescents take more control of their medication, they often however don't have much of a say in treatment options and this is dominated by the healthcare professional.

Thus, my study and proposed intervention sought to:

1. Persuade adolescents with chronic illnesses, specifically asthma in this study, to have a greater role in SDM.
2. Raise awareness of the affects of health risk behaviours, especially to those that have chronic illnesses.
3. Improve the effectiveness of the intervention through feedback from the interviewees.

The Biopsychosocial model (Engell, 1977) replaced the biomedical model. The latter equated health as absence of illness and led to a limited understanding and narrow view of what health actually is. The Biopsychosocial model shows that health is “a complete state of physical, mental and social well-being, and not merely the absence of disease or infirmity” (World Health Organisation, 1984). This increased our knowledge and has shaped how we now view health. It is used to raise awareness of physical, mental and social wellbeing, as all of these need equal recognition. We can use it to understand the overall health of the target audience. Adolescence is a testing developmental stage, which can become more challenging if a teenager has a chronic condition (Luyckx et al., 2008)- striving for normality, dealing with family conflicts, seeking peer acceptance and the emotional as well as physical burden of living with a chronic illness (Jayarajah, 2016)

## Methods

I have proposed an application for my intervention. I felt that this was the best option as technology is becoming increasingly prevalent for the younger generation and could be used to actively track progress of the patient; the patient could use it to track how they are feeling. They could use their Peak Flow Meter and record their results on the app to show their healthcare professional the progress they have made (positive or negative) and can continuously contact the healthcare professional if they feel any improvements need to be made. The app, which would be called, ‘My Health, My Decisions’, would allow the patient to take control of their health, with the aid of notifications that remind the patient to take medication or other factors set by the healthcare professional. The patient could log how they are feeling on a day-to-day basis in order to help the doctor understand any improvements or otherwise.

Another aspect to the app would be to educate the patients of the increased risk of health risk behaviours, as outlined above in the Sawyer et al., (2008) study due to their condition. I developed the app using the COM-B

model (Michie et al., 2011). The model coveys that behaviour is influenced by three main constructs- ‘Capability’, ‘Opportunity’ and ‘Motivation’.

The app aims to make the patient feel capable of changing their mindset towards taking a leading role in their medical decisions. The app would include confidence building to improve the mindset of the patient so that they feel that they can take on the responsibility of controlling their own future. The app removes any restrictions (i.e. not being in close contact with their healthcare professional) and there is no physical boundaries- they are able to be in command at the touch of a button. The app would also feature stories from people who decided to take part in the decision making of their health, showing new patients that it is possible, with the help of doctors and the app, that you can make the right decision.

The app educates them on options available and the advantages and disadvantages, giving them the opportunity to make an informed decision. The opportunity is presented, giving the patients the incentive to be in the centre of the SDM process, due to the app's ease of use, educational features and ability to contact the healthcare professionals.

The motivation is provided through notifications each morning. To increase the capacity of the lungs, the app will encourage these adolescents to do more exercise. We could supply them with exercises, which would change each week to add variation and keep the adolescents motivated. With funding, gyms that can be used by patients for free to improve their condition could be set up. Another aspect of the app to keep the patient motivated would be to add quotations from others that have decided to take part in SDM and how it has helped them (giving the patient inspiration to do the same), and statements that motivate the patient to continue, making sure that they know that their decision is the most valuable because they know *their* bodies better than anyone else can.

It is hoped that the app will be recommended by healthcare professionals around Britain, and will be available to download from the ‘App Store’ or ‘Google Play’ for free. Patients would be given a code, personal to them. This allows the patient to have a personalized experience and contact the healthcare professional(s) that they are treated by.

I have completed a series of interviews presenting the proposed intervention and gathered feedback accordingly.

## Sample and study design

A mixture of a qualitative and quantitative design was used to obtain the results. A qualitative approach was used in the questionnaire to help improve the intervention. Asking such open questions allowed me to collect personal opinions in regard to how to improve the app, with suggestions I had not considered. It also helped obtain the participants’ experiences from their own perspective (Speziale and Carpenter, 2007). The quantitative aspect was used to collect results for precise answers, to create a ‘snapshot’ set of results. I could then collect the results and put them into a table (figure 1) to find out whether the intervention would be effective, in the eyes of the participants. The study was conducted in a school environment and the interview was carried out ‘face-to-face’ and recorded ready to be transcribed. To be interviewed the participant had to meet the following inclusion criteria: teenager aged 11-16, in mainstream education. The mainstream education inclusion was created as it can cause complications in terms of taking medication and the patients must be fully independent. This was one of the factors that influenced

the transfer of responsibility for asthma from parents to adolescents (Newbould, 2008).

## Data collection

Data was collected through an audio-recorded individual interview that was structured based on the predicted effectiveness of the proposed app. The use of open-ended style interview questions ensured complete flexibility with the questions, and to allow freedom of speech, allowing the participant to give us their opinions and experiences as the responses were not “black or white” and required a much broader description. Thus, qualitative best suited the needs of the study. The quantitative style was only useful for ease of analysis of the effectiveness of the intervention, though was extremely successful at this. The conversations lasted around 5-10 minutes and were conducted in a friendly, natural environment with no distractions.

## Ethical considerations

The parents and the participants granted ethical approval. Five days of ‘reflection period’ was given so that if they no longer wanted to be a part of the study they had adequate time to retract from the agreement to participate if they so wished. Parents were not present as gaining the view of adolescents was the priority of the study.

## Data analysis

I analysed the data myself. The interview was recorded literatim. I then identified and selected the key points. I used an inductive approach, as I wasn't sure how the participants would react to my intervention, to be able to make a hypothesis.

## Sample demographics

10 teenagers were interviewed. Of the 10, 7 were male and 3 were female. Not all had been diagnosed with a chronic illness: asthma (n=5), diabetes (n=1) and no diagnosis (n=4). A small sample group from a South Wales valley town participated.

		Number	Percentage
Gender	Male	7	70%
	Female	3	30%
Age (11-16 years)	11-12 years	0	0%
	13-14 years	4	40%
	15-16 years	6	60%
Diagnosis (chronic illness)	No diagnosis	4	40%
	Asthma	5	50%
	Diabetes	1	10%

Figure 1

## Results

The intervention would be “easy to use” (A6) and would be accessible for “almost everyone in this day and age”(A3). Overall, most participants approved the intervention proposal. 90% said that it would be effective and influence adolescents to take a substantial role in SDM. Its main advantages were its ease of use, accessibility through technology, encouragement and provides a “detailed, educational experience that is easy to understand and more effective than having a healthcare professional talk to you about it”(A7). It appeals to the younger generation, who are the target audience. One of the interviewees stated that the incorporation of notifications would be a feature that he would “benefit from hugely” due to his “forgetful nature” (A10). Participant A1 agreed, voicing that the notifications would also help her to stay motivated and she thinks that if she had a chronic illness it would help her to feel capable of “taking a stand” in the SDM process. All of the participants relayed that the tracking characteristic of the app was a benefit. Being able to input your results for the Peak Flow Meter and how you feel would allow the doctor make an informed assessment of the patient's health status.

However, feedback also showed some negatives to the concept. As one participant pointed out, although many adolescents have at least one form of technology that the application would be compatible with, this is not the case for everyone. There is no way to rectify this, unfortunately. An improvement recommended through the interviews was the addition of a feature that allowed you to FaceTime your doctor. This would be used if the doctor was concerned about anything or patients had any queries/ had a problem that was asthma related and would help reduce the need to travelling to a local GP.

## Limitations

Unfortunately, there were some limitations to the study. I was only able to interview ten participants. This gave me a small focus group, not allowing me to see other perspectives or opinions that I may have discovered, had I questioned a larger group of people. The study's participants were also very male dominated. To gain a better understanding I would need to pose the questions to a more even amount of adolescents from each gender. One gender may prefer the app to the other and so may highlight more strengths/weaknesses. I had to use a convenience sample, which was not ideal. This sample was not a robust representation of the target audience because only six had been diagnosed with a chronic illness (only five of which had the specific illness- asthma). I plan to conduct another study in the future to gather a wider range of results and opinions so that I know the app will be successful to enable me to release it. In this study I will improve on the limitations mentioned previously- using a more diverse geographical sample group.

## Conclusion

Due to the feedback I received, I can conclude that adolescents feel that the intervention I have proposed will be effective and change their behavioural attitude towards SDM. It would help people to feel motivated by setting challenges to improve their own condition- allowing them to feel as if they are taking a lead role in the process. By allowing them to choose the exercises they do that benefit their condition, they feel more motivated as they are doing something they enjoy. The app inspires them, making them feel capable of making the correct decision and the detailed description of each option gives them the opportunity to know that they are making an educated decision.

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Adolescents’ responses are referred to as A1 to A10 for anonymity.



**PhD Tutor Comment:**

Z. went above and beyond on all his homework assignments, including full transcriptions of his qualitative interviews. In this assignment he thoughtfully defends the importance of engaging young people with long-term conditions in shared decision-making. He has designed an interesting idea for an intervention for behaviour change, which was justified effectively utilising relevant models, and user tested using a mixed-methods approach. Z. examined the limitations of the study in depth, and from this made insightful recommendations for future research. The quality of his work demonstrates his capacity to succeed at whatever future endeavors he chooses to pursue.

## Driver Distraction

**Year 10, Key Stage 4**

**K. Smith, Ormiston Sir Stanley Matthews Academy, Stoke-on-Trent. Supervised by L. Savigar, Keele University.**

Driver distraction is regarded as one of the leading causes of fatalities and injuries on British roads. In fact, out of 1445 fatal crashes that were recorded by the British police, a total of 395 incidents were identified as having the contributory factor of ‘failure to look’ and a further 140 incidents with the contributory factors of in-vehicle driver distractions, distractions outside of the vehicle and phone use [1]. To drive a vehicle, the occupant’s attention must be on the road at all times, although concentration is often impaired by three types of distraction: visual, when a driver’s focus deviates from the driving task at hand, wondering towards objects and scenery that are part of the surroundings; cognitive, which is when the drivers brain function is hindered as their attention strays away from the road; and biomechanical, which occurs when the driver is doing something physical that distracts them or causes them to take their hands of the wheel , for example, reaching for something out of the driver position or holding an item, such as food or a mobile phone [2]. Mobile phone use while driving is a major concern, with as many as 85% of the estimated 100 million phone users regularly talking on their phones while driving [3]. One study even found that driving and talking on a mobile phone at the same time quadruples the risk of crashing [4]. The government strived to tackle this problem by introducing legislation which prohibits handheld mobile phone use while driving.

By prohibiting handheld mobile phone use and encouraging the use of hands-free mobile devices while driving, the government aimed to remove the biomechanical factor of holding the mobile phone. The driver is not able to pick it up or operate it even momentarily while the engine of the car is still turned on. Any hands-free device should be prepared while the vehicle is stationary and the engine turned off to avoid the possibility of offending while driving, although the police still maintain the authority stop the driver if they believe the mobile device is a distraction [5]. Removing the biomechanical factor should theoretically reduce the risk of crashing, and therefore the amount of injuries and fatalities on roads, however the legislation proved to be somewhat ineffective and did not have the effect the government had hoped for. Despite the removal of biomechanical distraction, the driver’s brain function is still hindered by cognitive distraction, which often stems from hands-free phone calls that are initiated and received. In addition to this, drivers using hands-free mobile devices have the tendency to “look at” but not “see” objects, with estimates indicating that they dismiss up to 50% of the information in their driving environment [6]. When this happens, drivers are not aware of the filtered information and cannot act upon it. They are looking out of the windshield, but fail to process the necessary information to effectively monitor

their surroundings, restricted from seeking and identifying potential hazards and responding to unexpected situations [7]. Numerous studies have also shown delayed responses and reaction times as a result of conversing on a hands-free mobile device, with the probability of crashing rapidly increasing, along with the chances of fatalities and injuries [8].

In addition to the legislation preventing handheld mobile phone use while driving, the government have also introduced a variety of general laws that require drivers to become more attentive while on the roads [9]. However, these laws do not directly tackle the issue of mobile phone use while driving. If the occupant of a vehicle is caught participating in a distracting activity, they could be charged with a range of offences, including Dangerous Driving, Careless and Inconsiderate Driving, Failure to Be in Proper Control of the Vehicle or Driving without Due Care and Attention, depending on how badly their driving was affected [10]. Many of these charges carry penalties of either disqualification, between 3 and 9 points on a driver’s license or a fine of up to £2,500, depending on the nature of the incident [11]. The penalties are not always set in stone as prosecutors are reminded that each individual case must be considered on its own facts and merits, applying the Full Code, as contained in the Code for Crown Prosecutors. The Full Code has two stages. The first stage is the consideration of whether there is sufficient enough evidence available to charge the suspect (the evidential stage). If there is sufficient enough evidence, the prosecutor must then continue to the second stage, which is whether the prosecution is in the interest of the public (the public interest stage) [10]. The sanctions of these charges are much harsher than the penalties for mobile phone use while driving, despite them having been increased.



From 1st March 2017, those who are caught using their mobile phones while driving receive 6 points on their license and a £200 fine, twice the amount of the previous penalty [10]. These increased sanctions are said to be aimed at repeat offenders who are consistent in using their mobile devices while driving, as well as young and newly qualified drivers, who have been highlighted as the most common offenders. Newly qualified drivers have a limit of six points for their first two years on the road, meaning they could immediately lose their licenses if they are caught [11]. Although the improved penalties are effective in that drivers may realise the significant legal consequences of their actions, thereby reducing the chances of repeat offending, the government should be doing more to ensure the penalties are enforced. This could include increasing the budget of the police force to allow more crackdowns on mobile phone use, which would drastically increase the chances of drivers being caught.

Law enforcement plays a significant part in improving

road safety for drivers, passengers and pedestrians. In 2017, despite the repeated warnings about the dangers of phone use at the wheel, the police in Britain penalised almost 6,000 motorists for the offence, equivalent to one every seven minutes [12]. These punishments took place directly after the introduction of harsher sanctions, a time consisting of multiple crackdowns to test the effectiveness of the new penalties. Since then, however, there has been a fall in the number of drivers who receive fines. This is due to the reduction in the number of full-time road policing officers, despite the new figures calling for more investment in traffic policing to compliment the tougher penalties [13]. The British police force only have a limited budget provided by the government, forcing them to reduce the amount of crackdowns, as well as the number of road traffic officers. Furthermore, results from a recent survey revealed that for two thirds of motorists, it would actually take having an accident, a threat to losing their job, and national awareness campaigns to get them to change their attitudes towards mobile phone use. Of those surveyed, 50% said that the threat of punishment could possibly deter them, therefore emphasising the role of road officers and the need for more of them [14].

Moreover, it is arguable that the development of mobile phones throughout the years has resulted in a variety of additional contributory factors that were not considered when the laws were devised. From the 1990’s to 2003, mobile phones had less chance of distracting drivers, due to the phones only possessing low quality features such as a game, the ability to initiate and receive calls, as well as message people, and in the later years, a camera on the back of the phone to take pictures. However, as technology has advanced, mobile phones have too. In recent years, mobile phones have become an increasing problem for those policing the roads, as their increasing functionality means more and more reasons someone could be paying attention to a screen rather than the road in front of them [15]. Many new mobile phone features have been introduced to the world, for example, the ability to access the internet and social media. In society today, social media is a popular trend, with people frequently seeking opportunities to update their accounts and catch up on the latest news, even if they have to do so while driving.

Research by Aviva reveals that an alarming number of people admitted to using social media on the roads, the younger generation being the worst offenders with 34% of 18-34 year olds using Facebook while driving, compared to only 3% of over 55’s [16]. Accessing social media while driving is often associated with the ‘fear of missing out’, with drivers experiencing a strong desire to stay continually connected to what others are doing and being afraid to miss out on the latest news [17]. The government should be attempting to tackle this problem as their ban against mobile phone use while driving is ineffective when some drivers believe they are doing nothing wrong by accessing social media, as they are not using the mobile device as a ‘phone’ (not receiving or initiating calls). It is the government’s duty to educate drivers and ensure awareness of the laws that they have enforced; otherwise, the pieces of legislation are simply futile.

Laws that are introduced by the government aren’t always effective, but not through the government’s fault. In 2017, the RAC Foundation described the increased penalties as “a start”, but warned figures for March suggested that “the key message still isn’t sinking in”[18], with drivers still ignoring repeated warnings about the dangers of using a mobile phone at the wheel [19]. This is due to the attitude of the drivers. Despite multiple laws being put into place to reduce driver distraction through phone use, their effectiveness is determined by the driver and their road manner. It is the

government’s duty to identify and reduce the risk as much as they can, and that means forming a piece of legislation. However, once this process has been completed, it is the driver’s responsibility to abide by the law that has been devised. If drivers do not acknowledge or accept the piece of legislation, then the safety of the roads will not be improved, and the law will prove ineffective.

The government has attempted to increase the effectiveness of legislation surrounding driver distraction through methods such as mandatory educational courses and distracted driving campaigns, both of which aim to educate drivers, teaching them about the laws and consequences relating to driver distraction and mobile phone use at the wheel. However, yet again, no matter how educated the driver of the vehicle is, it is their manner and attitude on the roads that will determine whether or not the legislation is effective. The government cannot do much more than creating the guidelines for drivers to abide by; whether drivers decide to follow them is their choice, but they will have to reap the consequences if they decide not to. A recent article in *The Mirror* newspaper revealed the details concerning a tragic road incident, involving a heavy goods vehicle driver and a 43 year old pregnant woman, which resulted in the death of an unborn baby. The 43 year old pregnant woman spent 11 and a half weeks in hospital suffering through 13 operations and eventually lost her unborn baby, after a lorry driver became distracted from the road due to sending text messages [20]. His criminal behaviour resulted in a forty month prison sentence, as well as a six year driving ban. This is a striking example of how a moment’s thoughtlessness can result in death and a lifetime of unnecessary suffering, as a result of a driver disregarding the law and their obligation to their fellow road users.

In the past, there has been strong resistance towards the introduction of new legislation and the change in driving attitudes that would be associated with it. For example, the compulsory wearing of seatbelts was met with great reluctance at the time of its introduction [21]. It was only with the combination of legislation and the gradual change in attitudes that wearing them is now the norm. Similarly, campaigns to stop drink driving were only met with success after the introduction of the Road Safety Act in 1967, which set out guidelines for the maximum legal blood alcohol limit. Before this, society had adopted a rather flippant attitude towards drink driving, with the change in attitude occurring gradually alongside the introduction of legislation and education for the public. It seems that legislation surrounding mobile phone use while driving is often still resisted by drivers, as well as the public, with the government only hoping that gradual compliance can be achieved as they continue to work towards making the roadways safer.

To conclude, every driver should be aware of the existing laws surrounding mobile phone use while driving. Each and every time they drive, they make a conscious decision to abide (or not) by the law, embracing the responsibility that is placed upon them to keep themselves, as well as other road users, safe. In my opinion, the government implemented a sufficient amount of laws to tackle the issue of mobile phone use while driving, however there are a variety of contributory factors that impact their effectiveness. The United Kingdom has one of the best road safety records in the world [22], however it is public knowledge that there is still much to be done. Each and every fatality and injury caused by the inappropriate use of mobile phones could have been prevented. Several improvements need to be made with regards to the flaws identified in the legislation, as well as the driver’s skills, knowledge and attitudes towards their responsibilities [23]. Said improvements could be made through a variety of methods, such as



utilising the advances in technology to render the mobile device less of a risk, or reducing the cognitive workload that is placed upon the driver, thereby reducing chances of distraction, and therefore collision. Although the roads have been made somewhat safer since the introduction of legislation regarding mobile phone use while driving, many improvements could still be made concerning how the laws are implemented in a way that will make them effective.

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# Critically evaluate an approach to developing a working relationship with young people who are in the youth justice system

Year 12, Key Stage 5

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Supervised by A. Booth, University of Nottingham.

In this essay I will examine details of the young person's life, and use social theory to explain how these past events could have led to the young person displaying the behaviour they did. I will address why it is important to establish professional, instrumental relationships with a young person when working to rehabilitate them after a crime. I will also assess some of the barriers present themselves in establishing relationships, and how I as a social worker could address these barriers whilst instigating positive interaction. Finally, I will look at power as a whole, the varying dimensions of power and the imbalance of power between myself and the young person and how this can present implications when working with the young person.

The young person in question is subject to a Youth Rehabilitation Order following committing "robbery of personal property" (Theft Act 1968, HM Government) and "assault occasioning actual bodily harm" (section 47, Offences Against the Person Act 1861). As the social worker, I will be meeting with the young person every week for 15 months and working towards rehabilitating the young person back into society.

When working with any young person, it is important to collate facts about their life situation and their background in order to further understand their actions. This young person, 16, witnessed domestic abuse from an early age, which, arguably, had a significant effect on his development into adolescence. According to McIntosh (2003) "parental conflict is a more potent predictor of child adjustment than divorce," which suggests that the conflict the young person saw between his parents had more of an impact on the young person's behaviour than their eventual separation.

Bandura's Social Learning Theory (1977) could suggest an explanation for the young person's violent tendencies based on the conflict he saw between his parents at a young age. The theory suggests that an individual observes a role model and imitates their behaviour if they see the potential for reward. In context, the young person looked up to his father and they had a very close relationship, which has now broken down. The young person would have seen his father being violent towards his mother and gaining control through his actions. Through seeing this, the young person may have developed his tendency to be volatile and violent, perceiving dominance in situations as his reward. This is called vicarious reinforcement, where the young person has seen his father receive a reward (in this case, having control of the situation) and wants to gain the reward too. As the social worker, I will need to help the young person find alternative ways of managing situations where he feels he needs to be violent.

This could be teaching him verbal reasoning techniques or encouraging him to just walk away. In the local area, I could also encourage the young person and his mother to get involved in charity functions such as 'Hands Are Not for Hurting', working with both of them to manage their emotions. Working with his mother alongside the young person can encourage progress as he will be able to see that his mother cares about his future too.

In addition to this, the young person was excluded from school at the age of 13. A study lead by Professor Tamsin Ford at the University of Exeter (2017) concluded that there is a "bi-directional association between psychological distress and exclusion". This means that while children who show signs of psychological problems are more likely to be excluded initially, being excluded predicts an onset of psychological problems within three years. While witnessing abuse will no doubt have caused some psychological distress for the young person, being excluded will have heightened this and as a response the young person uses violence to manage situations.

Furthermore, the young person's exclusion from school at 13 means he missed key opportunities to develop social skills and interact with others. As a result, he may struggle to interact with me as a social worker because he has not had the opportunity to interact positively with professionals. Because of this, he may struggle with face to face engagement and find working with people of authority uncomfortable. To overcome this, I will need to take note of the young person's behaviour cues and posture and work with this to ensure he is at ease throughout our meetings.

I will need to work towards maintaining an instrumental relationship with the young person, which is a relationship that works towards an immediate end goal (Lincoln and Miller, 1979). In building a relationship with the young offender, I will need to respect certain boundaries to ensure that the relationship remains wholly professional. The relationship is likely to have a 'one sided start' (Collins and Behan, 1981), which means that I will have to work for and instigate the relationship alone. It is likely that the young person will be reluctant to engage and it will be up to me to prove to the young person that it is worth investing emotional energy into interacting. I will need to overcome some barriers when working with the young person to completely develop a working relationship.



My interpersonal skills, defined as 'meaningful engagement with the service user' (Trevithick, 2005) are key in ensuring that the relationship develops and initial barriers can be overcome. I need to demonstrate empathy, warmth and a genuine engagement with the situation as it will be myself that sets the initial tone of interaction. I will also need to establish my own identity within the relationship (Collins and Behan, 1981). The young person needs to be aware that the relationship is strictly a professional one and there are certain boundaries in place because of this.

Every point of contact with the young person will have an effect on their engagement, including my initial impression on them. Because of this, I will have to consider what I am wearing when interacting with the young person. For example, a suit is not suitable attire for weekly meetings with the young person, however neither is a short skirt and revealing top. I will need to ensure my clothing is suitable and will not embarrass the young person while also remaining professional and not too casual. I will also wear any formal identification (such as a name badge) only when I deem completely necessary – this will make my authority less obvious, thus less embarrassing for the young person.

I need to focus my work with the young person on changing his perception of himself and of his situation. His personal and social identity has a huge impact on his own aspirations. I can use the Definition of Situation axiom (Powers, 2010) to explain the young person's behaviour. This is where the young person reacts to situations based on their own perception of it, rather than the actual truth. It is likely that the young person has a very pessimistic view of his life situation and possibly blames himself for how things have turned out for him. This loss of aspiration may mean that the young person believes there is no point in trying to engage with me as a social worker. To raise the young person's aspirations, I could encourage him to take opportunities within the local area. The young person has an interest in motorbikes, regularly buying and mending old pit bikes. This is a hobby that I could work with the young person to engage in. There may be local courses that the young person could enrol on, which also could lead to qualifications and help to shape his future. However, as the young person struggles to interact with others, specifically adults with authority, this cannot be put into place until some work has been done on his attitude and social skills.

I can further change the young person's perception by working with the self-fulfilling prophecy (Merton, 1948), in which a person believes something of themselves because the idea has been engrained in them by previously false conceptions. One way of working with the young person could be to reverse the beliefs engrained in him by this system. I can use praise and positive regard to help boost the young person's self-esteem. At the end of each meeting I have with the young person, I can point out some positive outcomes of the session and make effort to acknowledge any progress he makes. While this may help reverse the negative conception the young person has of himself, I will also have to ensure that I do not patronise the young person and remain honest with him.

Power is when one person or authority can influence another to do something or behave in a particular way. Power usually comes from above and has a hand in the development of many social hierarchies. Dahl (1957) defines power as 'A [having] power over B to the extent that he can get B to do something B would not otherwise do.' While working with the young person, it is likely that there will be an initial power imbalance, which I will need to try to counterbalance as effectively as possible. Both parties will try to exercise power, and this can be impacted by the several "dimensions of power" (Smith, 2010). As a social worker, I have had power invested in me by the state to improve the life of the young person and challenge any decisions made around his wellbeing to ensure the best possible outcome.

Smith (2010) suggests that power is not a fixed entity, and can be used in several ways to influence outcomes. By allowing changes and balance of power in my meetings with the young person, I may encourage future



compliance. For example, the young person uses his power to get someone to listen to his wants and needs, but may also hinder any progress through non-compliance to protect his emotions. To overcome this, I need to prove to the young person that I care about what he says and that I am genuinely there to benefit him. I can do this through active listening, which is where I will seek to 'show responsivity and empathy towards the [young person] as he is encouraged to talk about issues and concerns in [his] family life' (Hutchby, 2005) among other things. I can also work to try and put in place any reasonable requests he has and be understanding of his situation.

Furthermore, Smith (2010) also suggests that power can be exercised in several different ways. This means that the relationship between myself and the young person is a two way process and the relationship will be based on the dynamic between us both. It is important that I am assertive and clear with my aims with the young person, so as not to overcomplicate matters or confuse him. It is likely that due to his lack of education, the young person will struggle with verbal and written communication. Because of this, I will need to ensure that I am explaining everything to the young person in simple terms and clarifying any use of jargon.

The young person will try to use his power to influence the outcomes of each meeting in ways that will satisfy him the most. He may be aggressive, as this appears to be his 'go to' way of managing with his emotions. To manage this, I could end any engagement at the first sign of aggression. This shows the young person that I am not willing to work with him while he is being aggressive, so may also encourage him to find different ways to manage with his emotions and get what he wants. This also protects me from any physical harm that may be inflicted by his aggression. However, the young person may also be reserved and reluctant to engage. This could be because he doesn't want to open up and share his emotions because he is so resigned to the idea that he is going to be let down. To overcome this, I need to be honest with the young person and ensure that I am doing my utmost to achieve the best for him, while not creating false expectations.

As a social worker, I am a representation of social dominance. I have the power to influence outcomes and to change the life of the young person for the better. However, this would be hard without the input and work from the young person too. The process, however hard it may be to initiate, eventually has to be a two-way process, because while I have the power to put things in place and initiate change it has to be the young person who acts on it. I can only encourage and support the young person, so realistically, it is the young person who has the most power.

Finally, it is important for me to bear in mind that the effect of power is situational (Powers, 2010) and various settings can have a different impact on how effective my work with the young person is. For example, a formal setting, such as a courtroom or a social work office can be intimidating and scary for a young person and in this situation they are likely to be reserved and quiet. It is unlikely that in a formal setting a young person will open up enough to make the work worthwhile. In contrast, if the setting is too informal then the young person may feel like they have more power and use this to their advantage to gain dominance and control in a situation. An example of a highly informal setting is the young person's bedroom or living room. Also, by meeting with a young person in their home setting, there is a risk of hostility from family members; this would be less than ideal because to ensure the best possible outcome for the young person there needs to be a certain degree of interaction from family members too.

The ideal setting for a meeting with a young person would be a local café or community setting. This setting puts nobody at an advantage. Being in a closed public setting also decreases the risk of a violent outburst from the young person and can encourage him to be more reasonable. Without the distractions of home life and the intimidating nature of a courtroom or social work office, the young person is most likely to open up and work towards sensible solutions. However, I do need to keep in mind that in accordance to the subculture theory (Cloward and Ohlin, 1966) the young person may feel embarrassment at being seen with an authority figure such as social worker. The theory suggests effectively that 'being bad is good' and, for the young person, who will have spent a lot of time avoiding interaction and working against those in control of society (such as the police), having to work with the authorities to better his life goes against what he believes and also what his peers believe. This would prompt the establishment of automatic barriers between myself and the young person, as if he was seen to be interacting with me it may impact his perceived social status. To avoid this, I will allow the young person within reason to negotiate on the setting of the meeting to ensure he is most comfortable.

In conclusion, when working with the young person I need to ensure that I am mindful of his past and the experiences that have led to him behaving in the way he does. It is important that I keep in mind that it is not the young person's fault entirely; his history, past experiences and the beliefs of society have shaped his perception of his current situation. In respect to this, I need to understand that establishing relationships with young offenders can be a difficult task when taking into account their past life experiences. It is important to consider even the minor details to ensure that the young person feels comfortable in interactions, and this can help to instigate positive action in their life. All communication with the young person needs to be clear, and meaningful, and through this I can begin to break down barriers and work towards rehabilitation.

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PhD Tutor Comment:

B. is a Year 12 student studying at Quarrydale Academy. Throughout this Brilliant Club module on working relationships, she demonstrated an engagement with both theory and the case study of a young offender. Doing this enabled a sensitive and constructive plan to deal with offending behaviour. The composition, maturity and articulation of this approach was way beyond the level expected of an A-level student: a big well done B.



