RGS
GUILDFORD

2017 Scholars' Annual

Introduction

From the Master of Scholars

It is with great pleasure and pride that I present to you this first edition of the Scholars' Annual: a compendium of scholarly works undertaken by the students of the Royal Grammar School Guildford. In its inception the Scholars' Annual was designed to exhibit and celebrate intellectual curiosity, and the extraordinary depth and breath of study conducted by a broad range of our students. I truly believe this Annual does not only that, but so much more. The quality of work is truly remarkable, and should serve as inspiration to the wider community of the School. It has been a real joy to collect these pieces of work and to have worked with such a committed group of Senior Scholars, without whose help this would not have come to fruition. I hope that in reading the Annual you get a sense of the cooperative pride that exists between students at this school, and that this serves to foster an atmosphere where scholarship is not only encouraged but celebrated. I commend this set of works to you most highly.

Mr Christopher Bradford, Master of Scholars.

From the Editor-in-Chief

Scholarship at the RGS is about more than just being intelligent – in a school full of exceptionally gifted boys, intelligence is expected. Instead, true erudition is a display of passion for learning and a desire to excel in whatever each individual chooses to apply himself to, whether this be art, music or any of a vast range of academic subjects. The quality of work produced is not due to effortless brilliance: it comes from time spent researching, fully understanding the material, and then hours spent conveying this knowledge in a way which is appropriate both to the task set and the audience. I hope that in doing this, boys throughout the School have had the, perhaps, rare opportunity to truly enjoy their studies. However, of even greater note is that these submissions are not limited only to scholars, but come from a variety of students – anyone with a passion for their subject was encouraged to submit work, allowing the Scholars' Programme to be broadened throughout the School. Under the guiding hand of Mr Bradford, a new era of scholarship is beginning, where exemplar work throughout the School can be recognised, and anyone with special talent or interest can be catered for. While I regret that I will not be able to fully participate in the new programme, I hope that the work done by the first Scholars' Council will allow future scholars to enhance their studies. At the end of five years at the RGS, I can look back at my time here and know that it was improved by the benefits of the Scholars' Programme, and I am confident that my future counterparts will build upon the beginnings of a revamped system. To be a scholar is to aim for excellence in everything we do, including being a scholar.

Joshua Cudby, Editor-in-Chief

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Climate friendly refrigerants

their Physical Properties and Applications

Oliver Platt

INTRODUCTION

When a refrigerant is thought of, the idea that CFCs, ozone depleting chemicals, were banned, and that they must now be non-harmful, comes to mind. However, the tendency to use HFCs means that the global warming potential (GWP) of refrigerants remains high. When a greenhouse gas is thought of, carbon dioxide is usually the immediate thought; however, compared to R134a's rating of 1300, carbon dioxide's rating of 1 seems ideal. Therefore initially, there are two clear factors that the refrigerants I look into must have, an ozone depletion potential (ODP) of 0 and a low GWP

My preliminary research on the internet revealed that propane has been considered as a potential future refrigerant. Once I had discovered that a high critical temperature is usually needed though and I discovered that pentane had a higher critical temperature, I was unsure as to why pentane appeared to have had minimal research done on it, as a refrigerant. Although the system that would be constructed later was cooling water from 20°C to 5°C, so nowhere near the critical temperatures, my initial research meant I was still intrigued by the use of different alkanes, as well as pentane. A high latent heat of vaporisation would also be very useful in a refrigerant and I was surprised, once again, to find that, although the longer the alkanes the lower the latent heat of vaporisation, the latent heat of alkanes was significantly higher than that of R134a. (R134a 216 kJ/kg, propane 425 kJ/kg, butane 386 kJ/kg). Later on, I also made the decision to not only look into the pure alkanes, but also to look into the different mole fractions of combinations of alkanes.

The aim of my research was thus to test the hydrocarbons as refrigerants and compare them to a known refrigerant. The objectives set out were then: gain an understanding of the background to refrigerants; gain a working understanding of the refrigeration cycle and equations of state; learn to use Aspen Plus, a software that allows chemical plants' systems to be modelled; model the base case refrigerant; model the hydrocarbons; and model combinations of the hydrocarbons.

Throughout the project there were key resources that I required, the first being Dr Pollock. In doing this project there were concepts that were to be new to me, e.g. equations of state, heat transfer and the refrigeration cycle; she went through each concept with me, enabling me to read into the concepts in more depth with an air of clarity. The text book from UCL's library and the internet were also invaluable materials that I needed to understand the research I was to perform at the required level. The software Aspen Plus, which is licensed to UCL, was used to perform the research that I did, and the project could not have been completed without this.

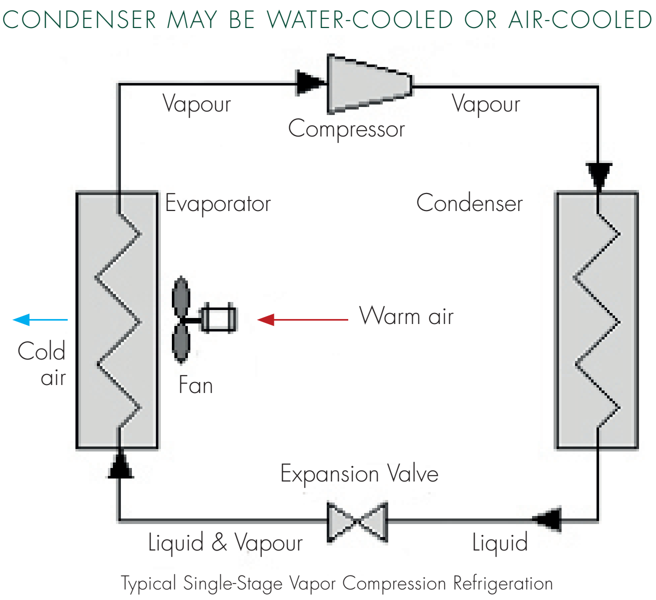


Figure 1: Vapour Compression refrigeration cycle [8]

BACKGROUND TO REFRIGERATION CYCLE

Refrigeration is a cyclic system that aims to cool a hot stream that enters the evaporator. Although there are multiple ways by which refrigeration can be performed, I looked into the vapour compression cycle (Figure 1).

It is important to understand a phase diagram (Figure 2), and that the boundary between the liquid and vapour (when above the triple point but below the critical point) is known as the saturation curve. On the right of the saturation curve lies superheated vapours and on the left subcooled liquids. If the pressure is then plotted against enthalpy, a different curve (Figure 3) can be seen. When on the line of the pressure enthalpy graph the chemical is either a saturated vapour or liquid, when inside the curve it is both a liquid and a vapour (in a two-phase state in equilibrium), when outside the curve with low enthalpy it is a subcooled liquid, but when on the outside with high enthalpy it is a superheated vapour.

Each red line on the pressure enthalpy graph (Figure 3) represents a component in the ideal vapour compression refrigeration cycle (Figure 1). Although it is a cyclic system, the first component I will speak about is the expansion valve. The refrigerant enters the valve as a saturated liquid and the valve's purpose is to reduce the pressure of the chemical,

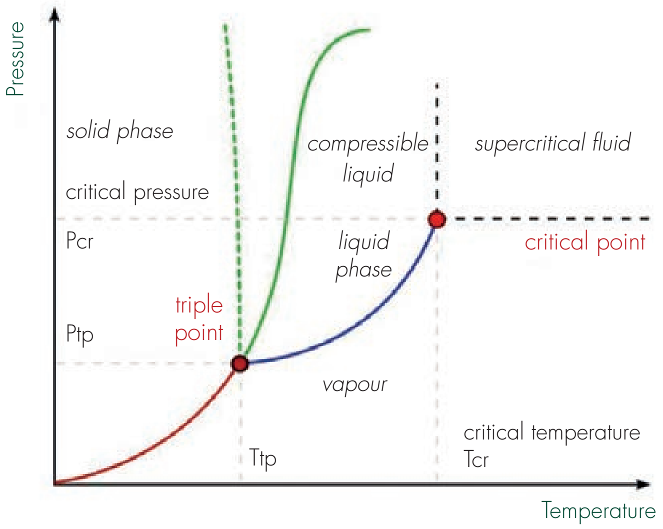


Figure 2: Phase diagram [10]

THE IDEAL REFRIGERATION CYCLE GRAPHED ONTO A PRESSURE ENTHALPY CHART

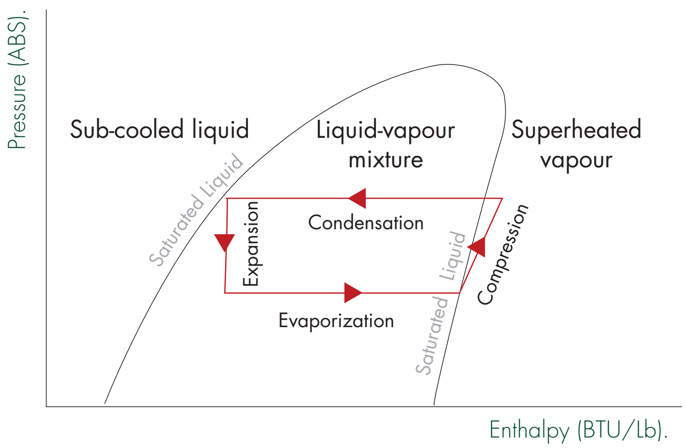


Figure 3: pressure enthapy graph and refrigeration cycle [9]

in doing so reducing the temperature, all in isenthalpic conditions. The pressure is at the level required for a saturated liquid at 0°C. Having exited the expansion valve the refrigerant is both a liquid and a vapour, and then under isobaric conditions the phase of the refrigerant is changed to just a saturated vapour, thus taking the energy out of the hot stream, which is the entire point of the cycle. The third step is when the work is applied to the system with the compressor; it changes the saturated vapour to a superheated vapour. Highly compressed superheated vapour then moves into the condenser, at which point the phase is changed from the vapour to saturated liquid and the energy gained from cooling the hot stream is transferred out of the refrigeration cycle's envelope, as there is a phase change (the energy is taken away via another cooling fluid). The saturated liquid then re-enters the expansion valve and the process repeats.

In order to fully understand the heat transfer that was occurring I needed to have a grasp of the equations that dictated the heat transfer in the evaporator.

$$Q_h = m_h C_{p,h}(T_{h,out} - T_{h,in})$$

$$Q_c = m_c\left[\Delta h_{e,c} + C_{p,c}(T_{c,out} - T_{c,in})\right]$$

$$Q = uA\Delta T_{lm}$$

$$Q_h = -Q_c = Q$$

I could then use these equations to determine that the rate of heat exchange, Q_h, ought to be a constant, the constant caused by the hot stream having an unchanging flow rate, m_h, heat capacity $C_{p,h}$ and temperature in and out, $T_{h,in}$ and $T_{h,out}$ Also deduced from the equations, the duties have the same magnitude as that constant. Then, when inspecting the equations further, it becomes apparent that the two factors that vary, which I should thus record and look at when making comparisons, were: the flow rate in the cold stream, m_c, if the temperatures in and out of the cold stream, $T_{c'in}$ and $T_{c,out,}$ remain equal (it is possible for the temperatures to remain equal since the energy is used changing the phase and not super heating the gas); the objective became observing the surface area of the evaporator, A, and flow rate, m_c, if $T_{c,in}$ and $T_{c,out}$ are not equal (in a mixture of gases).

It is initially very clear the ideal gas equation and van der Waals equation are both overly simplistic in their nature and if I tried to run the simulation using them the model would be so inaccurate few useful conclusions could be drawn. Therefore, I looked into other alternatives that have stemmed from the van der Waals equation.

Carnahan and Starling – edited the term in the equation of repulsion for hard spheres, a modelling assumption that the particles cannot overlap

Redlich and Kwong - attractive term dependent on temperature

Soave and then Peng and Robinson – all improved the equation for liquid density and also vapour pressure

Beret and Prausnitz – changed the equation so it could account for molecules that were in a 'chain'

The cubic equations of state I have listed were just some of the equations that have been formed. The more modern equations, with more factors taken into account, have as a result become more accurate. However, when selecting the equation care must be taken, as some have been developed for specific roles and the chemical being modelled must also be looked at to see if it has features such has hydrogen bond or dipoles.

Soave Redlich Kwong, SRK, was the equation of state I chose for all runs since all the refrigerants bar the R134a have no dipoles and in keeping the equation of state the same I ensured the results were all comparable; also the SRK cubic equation of state is recommended for hydrocarbons.

METHODOLOGY

As mentioned above, the refrigeration cycle is made of an expansion valve, evaporator, compressor and a condenser. The Aspen Plus software is capable of modelling any of this cyclic system. However, as the focus was to be on cooling the hot stream of air the area modelled was the valve (taking the saturated liquid and turning it into a vapour and liquid) and the evaporator (turning the liquid and vapour into a saturated vapour). Another area I could have potentially looked into would have been viewing alternate known refrigerants and seeing if they could have been used in the conditions of a household fridge. In doing my research I chose to avoid the other refrigerants because of both time constraints but also by focussing my time on a smaller area of refrigerants I could be sure I was building up a more detailed picture of short chain alkanes as refrigerants.

As previously mentioned the conditions in the refrigeration system that were selected were cooling the hot stream of air from 20°C (stream 3) to 5°C (stream 4) both at constants of 98 kmolhr^−1 flowrate at 1 bar of pressure. Conditions aimed at stimulating the process in the everyday fridge. The five different streams are clearly shown on the diagram (Figure 4) and I will refer to each stream by the number it is given on the diagram.

Initially when I began attempting to model refrigerants, I was varying the outlet pressure of the valve, minimum temperature approach at the evaporator and the temperature and pressure of stream 5. Therefore, although I was managing to make a saturated liquid into a saturated vapour the results between different refrigerants were non-comparable. Although I could have continued to vary pressure and not flowrate, I wanted to model a household fridge so chose to change the independent variable. I then corrected my system to input a saturated liquid at 20°C (stream 5) and at the end to have a saturated vapour at 0°C (stream 2). I would look up the experimental data for the saturation points and afterwards set the 20°C pressure and temperature at the input, preventing me from having a subcooled liquid, and then set the conditions for 0°C at the expansion valve. Then, to find the point at which I had a saturated vapour at the end of the evaporator, I varied the flowrate, being careful to ensure there was no temperature change across the evaporator (ensuring all the duty was solely being used to change the phase and not superheat the gas). Once a saturated vapour at 0°C was the result from stream 2, I then recorded the required surface area of the evaporator. The minimum approach temperature in the evaporator, which was running counter current, was also set to 5°C meaning that at all points in the evaporator the hot stream had to be at least 5°C higher than the cold stream.

The method varied when it came to using the combinations of alkanes. I could no longer look up the pressure required at 0°C according to the NIST to find a saturated vapour. However, the Aspen Plus software by using the SRK equation of state, since the only significant force is caused by electrons briefly attracting other molecules' nuclei, I then could use the theoretical values, instead of an experimental value, in the valve for the pressure of a saturated vapour at 0°C. There was because of the nature of having different mole fractions then too many variables being held the same to keep the required surface area constant. Therefore, I let the temperatures of streams 1 and 2 vary as long as steam 5 was 20°C with a saturated liquid and stream 2 was 0°C and a saturated vapour. Since I could not tell when a saturated vapour had only just been made, because of the innate temperature change throughout the phase change, it was then necessary to ensure all runs were as close to reaching 0.999 vapour fraction as possible in stream 2 (but not quite 1).

The system was set up as an ideal system. It therefore had no pressure drop at joints and also no pressure drop in the evaporator. This means that for any results gathered stream 1 and 2's pressure would need further investigation in the future, as in reality they would not exactly be equal. Another change in the ideal model that should be made is to reduce the efficiency; the system is not 100% efficient and yet 100% efficiency was assumed.

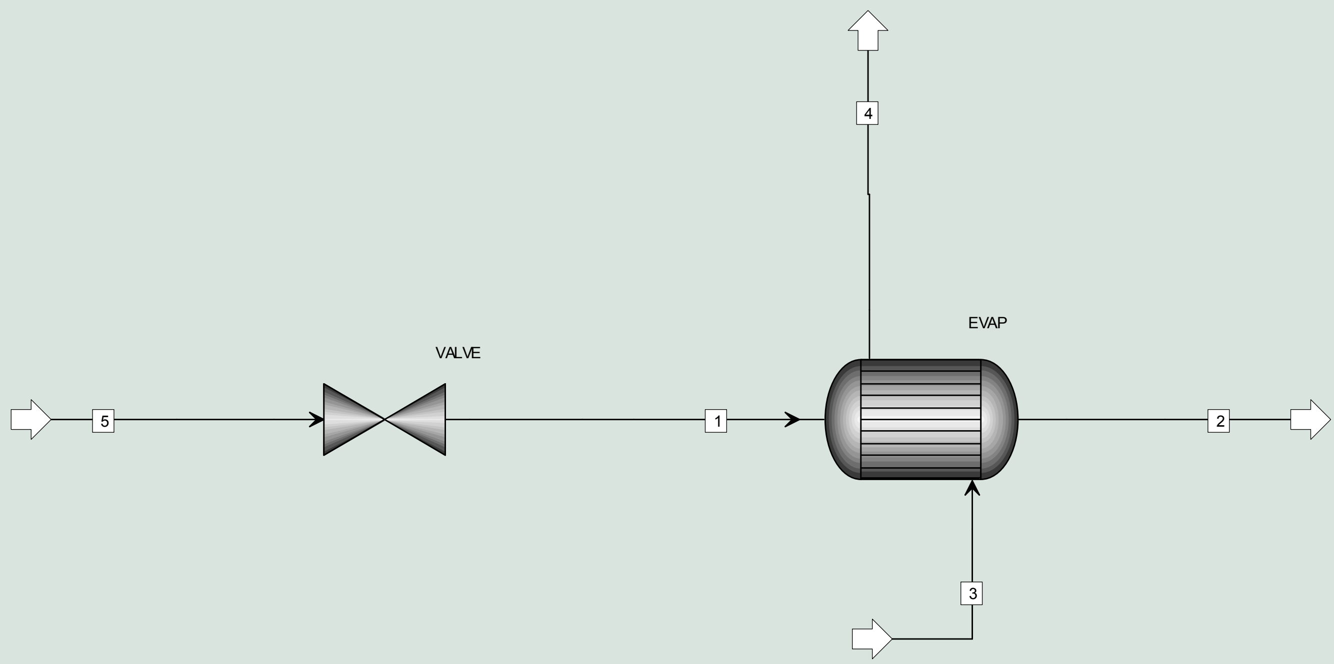
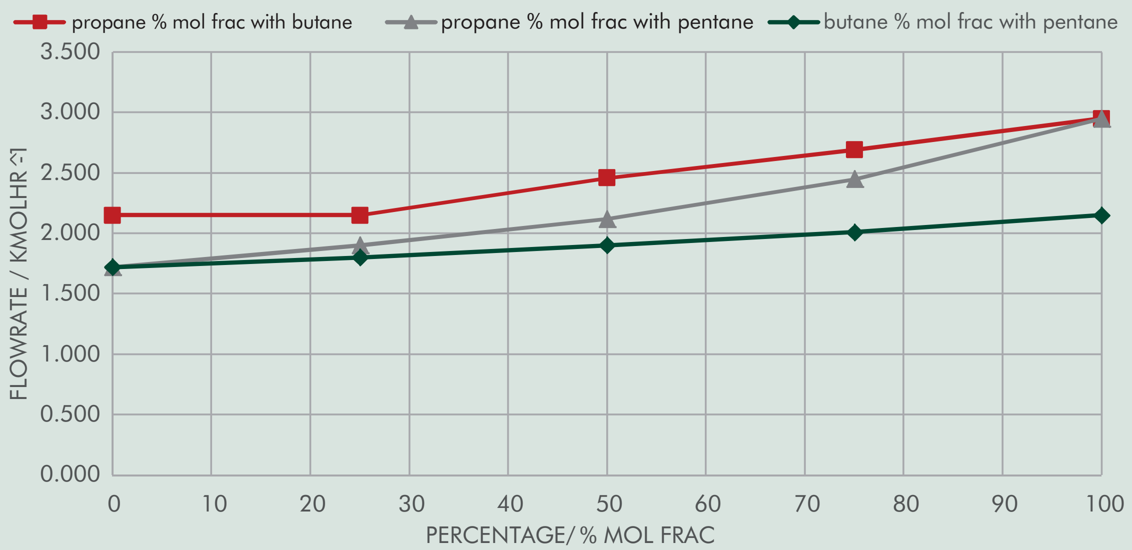


Figure 4: aspen plus stimulation with stream numbers marked on

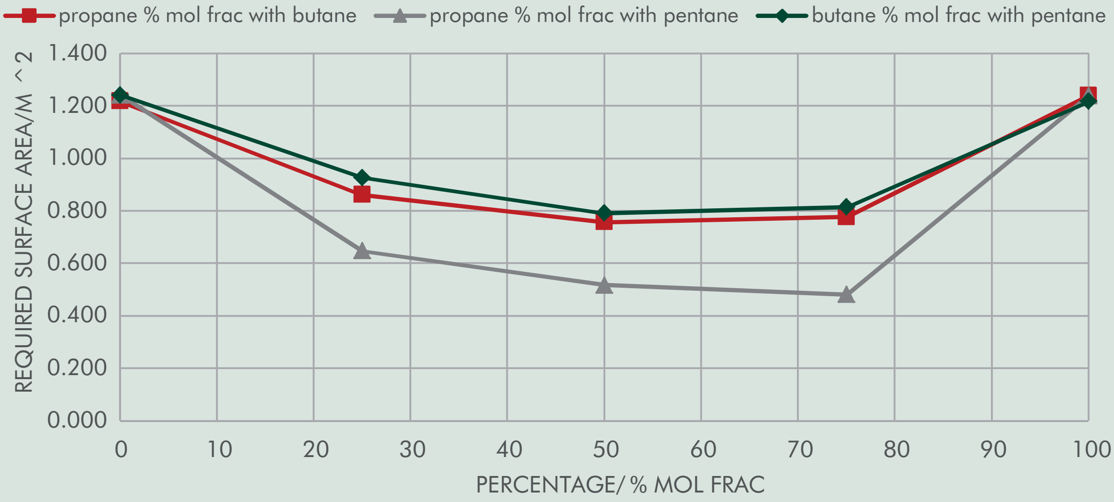
RESULTS

Run number	Refrigerant	Mole Fraction	Stream Temperature/°C			Stream Pressure/bar			Flowrate/ kmolhr^-1	Vapour Fraction in Stream			Required Surface Area/ m^2
			5	1	2	5	1	2		5	1	2	
1	R-134a	1	19.602	–0.261	–0.261	5.700	2.910	2.910	2.405	0.000	0.139	0.992	1.254
2	Propane	1	19.413	–0.368	–0.368	8.300	4.700	4.700	2.950	0.000	0.140	0.998	1.240
3	Butane	1	19.933	–0.546	–0.546	2.067	1.000	1.000	2.150	0.000	0.125	0.994	1.218
4	Pentane	1	20.235	–0.351	–0.351	0.562	0.235	0.235	1.720	0.000	0.118	0.999	1.242
5	Propane Butane	0.25 0.75	20.000	–7.973	0.069	3.550	1.280	1.280	2.150	0.000	0.182	0.995	0.861
6	Propane Butane	0.5 0.5	20.000	–11.993	0.014	5.091	1.700	1.700	2.460	0.000	0.213	0.996	0.756
7	Propane Butane	0.75 0.25	20.000	–10.946	–0.157	6.709	2.520	2.520	2.690	0.000	0.208	0.991	0.776
8	Propane Pentane	0.25 0.75	20.000	–17.855	–0.276	2.301	0.310	0.310	1.900	0.000	0.257	0.998	0.648
9	Propane Pentane	0.5 0.5	20.000	–30.698	0.140	4.180	0.460	0.460	2.120	0.000	0.342	1.000	0.517
10	Propane Pentane	0.75 0.25	20.000	–34.963	–0.253	6.211	0.840	0.840	2.450	0.000	0.351	0.994	0.481
11	Butane Pentane	0.25 0.75	20.000	–6.217	0.311	0.925	0.300	0.300	1.800	0.000	0.157	0.998	0.926
12	Butane Pentane	0.5 0.5	20.000	–10.039	–0.472	1.299	0.380	0.380	1.900	0.000	0.182	0.999	0.792
13	Butane Pentane	0.75 0.25	20.000	–9.091	–0.568	1.681	0.550	0.550	2.010	0.000	0.176	0.999	0.815
14	Propane Butane Pentane	0.333 0.333 0.333	20.000	–23.392	–0.221	3.475	0.560	0.560	2.150	0.000	0.285	0.991	0.579

FLOW RATE COMPARISON



REQUIRED SURFACE AREA COMPARISON



All comparisons in the discussion will be given as a percentage difference compared to the conditions required for R134a, the control refrigerant.

DISCUSSION

PRESSURE

The ideal pressure required is one that remains slightly above 1 bar of pressure: the closer to atmospheric pressure that the system is, the less bulky the equipment would have to be to resist the pressure. The pressure, however, must not at any point be below 1 bar, since then air from the surrounding environment will attempt to enter the system. R134a's pressure at 5.70 bar falling to 2.91 bar both seem a little high, although for the propane when it is in stream 5 has a pressure of 8.3 bar, 146% larger, so against the shortest chain alkane in the comparison it didn't seem so bad. However, butane at 2.1 bar, 35%, pressure seems far more ideal; although when adding another carbon atom to the chain, the pressure is too low in stream 5 at just 10% of the original pressure. When then looking into streams 1 and 2 the same pattern can be found again, with propane being overly high, pentane too low and butane, which is at 1 bar a 34% drop, being about right. Each of the mixture's pressure change from stream 5 to 1 trends seems primarily dependent on the composition and not the mole fraction. The propane butane started within 63% to 118% before falling to 44% to 86%, all remaining above 1 bar. The propane pentane mixture starts at 40% to 109% pressure; however, having passed through the expansion valve and entered stream 1, all pressures are below 1 bar. The butane pentane mix all started at approximately 1 bar pressure in the stream 5, although having entered stream 1 these also fall a long way below atmospheric pressure. The combination of all three alkanes' pressure also seems to fall a long way below atmospheric pressure.

FLOWRATE

The flowrate can alter three main factors, which all suggest that a lower flowrate is beneficial, the three being a higher flow rate requiring larger equipment, more work to be done by the compressor and the greater flowrate increasing cost. The graphs illustrate the trend that occurs within the alkanes. The fewer the number of carbon atoms in the chain, the higher the required flow rate. As the mole fraction begins to change it appears that the relationship is fairly linear. Only four points appear to have a greater flow rate than that of R134a, these are - pure propane the butane propane mixes where propane is greater or equal to half of the mix and 25% pentane 75% propane. The pure pentane's flowrate is 28% less than that of R134a and butane's is 11% less, which by chance is the same as the mixture of all three alkanes. On flowrate alone, therefore, the pentane does look preferable.

SURFACE AREA

There is an obvious preference towards having smaller equipment, and a smaller required surface area allows this goal to be achieved. The surface area required decreases as the temperature difference between streams 1 and 2 increases. Consequently, allowing some energy to be spent superheating the gas is shown to help reduce the surface area required. All the pure refrigerants including R134a appeared to be negligibly different in their surface area requirements, and surface area being constant holds true with the equations of heat transfer. However, once the mole fractions of the hydrocarbons were changed, minimum points began to arise. By viewing the graphs it can be determined that the likely minimum points for each of the surface areas would lie at approximately 50% propane to 50% butane and 50% butane to 50% pentane, although at about 60–75% propane to 40–25% pentane. All the mixtures created a lower required surface area; the lowest points recorded though were: propane-butane 40% less than R134a, butane-pentane 37% less and propane-pentane 62% less area required. The mix of the three alkanes also reduced surface area by 54% against R134a.

SAFETY PROBLEMS WITH REFRIGERANT

As established in the introduction R134a is a greenhouse gas; if that was the only problem with R134a it would be of no immediate danger to life. It is, however, also asphyxiating and therefore its immediate danger to health and life (IDHL) ratings is at 1000ppm [1]. Whilst propane, butane and pentane aren't going to cause asphyxiation, they are highly flammable; although they are deemed safer than R134a, propane's IDHL is 2100ppm and pentane's is 1500ppm. It would be important to keep them separate from the air because the three alkane's have a lower explosive limit is 1.8% and an upper is 8.8% [7]. A small leak in a kitchen (where there is often fire) could therefore be catastrophic. Another strong reason for such an urge to look into these alkanes further, however, is that the GWP rating of the alkanes is 325 times better than that of R134a.

CONCLUSION

Safety has to be one of the top priorities when considering a system that is wanted for use in a household environment. Therefore immediately I would like to rule out any system which has a pressure higher than that of R134a, 5.7 bar, and also any refrigerant that has a pressure lower than 1 bar (at any point in streams 5, 1 or 2), thus initially ruling out the butane-pentane mix, the combination of all three alkanes, propane, pentane and the propane-pentane mix. As mentioned above, the flowrate ought to be minimised, so pure butane, combined with it being a refrigerant at just above atmospheric pressure conditions, appears to be a strong candidate. However, if we are also to factor in the required surface area, the 25% propane 75% butane is instantly an ideal refrigerant; it outperforms R134a significantly (11% less flowrate, 31% less surface area required and the pressures are significantly lower too whilst remaining above atmospheric pressure). The implications of my research consequently are that it is possible to change the household fridge to not only run more efficiently than but equally as safely as it has done with R134a.

However, the mixtures of gases which fall below 1 bar of pressure are not useless if the refrigeration system only needed to be cooled from 25°C to 20°C, such as in an air conditioning unit; the alternate refrigerants could be used, as they would remain above atmospheric pressure at all times in this case; if a system could be devised in which pressure did not matter at all I would recommend 25% propane with 75% pentane, the required surface area being 48% lower than R134a and the flowrate being 20% less.

FUTURE DEVELOPMENT

I believe that with more research alkanes could replace R134a as refrigerants. However, I would want to ensure that any system that the alkanes, whether it is pure butane (in slightly higher pressure conditions) or 25% propane 75% butane, were to be used in must have been purpose built and carefully redesigned, ensuring that there are no leaks if at all possible thus reducing the risk to people's safety. The modelling should also be done via more sophisticated equations of state, as the SRK model must be checked as it has potentially too many assumptions (e.g. the lack of dipole-dipole interactions). Capital cost should also be looked into: the short alkanes will primarily come from crude oil, raising their cost significantly. Also, further work ought to be done into looking at the three alkanes together attempting to increase pentane percentage, as this seemed to reduce flow rate in the binary systems, while increasing propane percentage to increase the pressure, aiming to bring it slightly over atmospheric levels throughout the cycle. As a result of the research I have performed I would like to hope that it shows that there are viable options to replace HFCs that are less damaging to the environment. △

Biferrocene synthesis

Rory Hyatt

There were many aims from my CREST project: I have always wanted to study chemistry at a higher level, so this project really helped me see the practical side of working in the field of chemistry at university. In addition, I wanted to achieve a greater understanding in a topic of chemistry that I have previously not studied in depth or even looked at. This project has helped me understand some synthetic chemistry techniques as well as a basic foundation in organometallic chemistry by looking at the molecule that caused this topic to exist, ferrocene.

This project will involve the creation of biferrocene, which is a molecule that is currently being researched for its spin state properties, which could result in more efficient molecular sized circuitry, contributing to the decreasing size of electronics, which would have a huge effect on the technology industry as it has had every time technology has decreased in size.

Ferrocene itself is an organometallic molecule because it involves the direct bonding between carbon and a metal, which in the case of ferrocene is iron. However, the bonding in this way is not a 1-1 bond between a carbon atom and an iron atom, but there are 2 rings of carbon atoms (cyclopentadienyl rings to be accurate) that contain 5 carbon atoms each individually contribution to a bond with the iron. Both of these rings are on opposing sides of the iron atom, creating a name for this type of structure, a sandwich structure.

Biferrocene however is different because it is formed from 2 ferrocene molecules joined by a single covalent bond. There are many ways to synthesise biferrocene; however, a large amount of biferrocene was needed of very high purity since this biferrocene was being used for research into electronic surfaces and spin state properties of biferrocene when applied as a thin deposition layer on various surfaces. This means that a recently reported method that fulfils these criteria needed to be used.

In this method of synthesis of biferrocene, there are 2 main reactions: (see Figure 1)

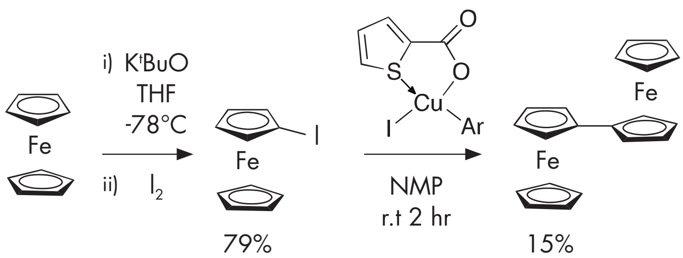


Figure 1

1) SYNTHESIS OF 1-IODOFERROCENE FROM FERROCENE

In this reaction to form iodoferrocene, smaller steps need to be made. Firstly, the ferrocene must be lithiated using tBuLi in order to extract a proton. However this makes the molecule very reactive, so much so that lithiated ferrocene is pyrophoric, which means that this reaction is done under nitrogen as the oxygen in the air would exothermically react (burn) in the air. In addition, in order to make sure the lithiated ferrocene doesn't uncontrollably react, potassium tert-butoxide is added as it stabilises this procedure. This reaction contains many liquids now, which are not currently miscible, and so the solvent THF (tetrahydrofuran) is added since is a solvent that adeptly mixes both the polar and non-polar substances in this reaction in order to make sure the reaction happens completely and at an efficient rate. The THF is stored with molecular sieves and under nitrogen to assure no dissolved oxygen, so the addition of this solvent will not cause a reaction with the lithiated ferrocene.

Thankfully however, the pyrophoric nature of lithiated ferrocene means that the transition from this state to the desired product is simple since elemental iodine can be added and the lithiated ferrocene will react well with it. This means that at this point in the reaction, there is ferrocene and 1-iodoferrocene (the desired product) mixed together in the solvent, which is not what we want. In order to purify this mixture of the molecules, I used a wash–dry method involving oxidising the ferrocene but not the iodoferrocene because then the ferrocene would form ferrocenium, which is a molecule soluble in water, whereas iodoferrocene is not soluble in water. Using this difference, I have made the crude 1-iodoferrocene into pure iodoferrocene.

STEPS:

- Ferrocene (10g), KtBuO (750mg) and dry THF (500ml) are combined under N2 and cooled to –78°C.
- tBuLi (56ml, 1.9M in hexane) is added and the solution is stirred for 2 hours at this temperature.
- 20g of elemental iodine is added to the newly formed lithiated ferrocene and left for 30 minutes at –78°C and then left out at room temperature to slowly take the temperature of the solution back to room temperature.
- The reaction is then quenched with 50ml of water and extracted into a new solvent DCM (dichloromethane). This solution is washed with sodium thiosulphate solution and the solvent is then removed, leaving a brown oil of iodoferrocene and regular ferrocene.
- This oil is then dissolved in n-hexane (250ml) and washed with iron (III) chloride (FeCl3) solution (0.2M aq) 5 times and then finally washed with water.

To clarify, the iron (III) chloride is the oxidising agent that oxidises the ferrocene into ferrocenium. In addition, n-hexane is used because both iodoferrocene and regular ferrocene are miscible in it, but it is more energetically favourable for ferrocenium to be in water so when the washes with the solution occur, the ferrocenium keeps being removed from the hexane. In addition, the new DCM solvent was needed so that the mixture could be washed with sodium thiosulphate effectively, which will make all the iodine in the solution that has not reacted in the initial reaction react to form sodium iodide, which will get washed out. Furthermore, the low temperature of the reaction causes 2 significant things: it stops the formation of FcLi2 and stops the lithiated ferrocene from returning back to regular ferrocene.

This reaction should have formed the pure product of 1-iodoferrocene, making 10.4g (79% yield).

Obviously however, I would be unable to continue with the synthesis of biferrocene unless the formed product is in fact the desired product (1-iodoferrocene). Therefore, I had to ask my supervisor to do an NMR (since the machine is not certified for under 18s due to the expensive and dangerous nature of the machine) in order to confirm both that the product is the desired product and that it is pure. The obtained NMR spectrum is below (see Figure 2):

This NMR is promising because there should be 3 general peaks, since there is an iodine atom attached to one of the cyclopentadienyl rings throwing off the symmetry that the ferrocene has, but still having a symmetry in the xy plane assuming the C-I bond on the x axis, meaning that there are 2 pairs of identical carbon species and a single carbon species attached to iodine. Therefore the 3 general peaks from the spectrum support the idea that this product is 1-iodoferrocene. However, it is necessary to check that this is only 1-iodoferrocene. From the reaction, there is only one formed product, and it is in fact the same as the original reactant, ferrocene, and so it is necessary to see if there is a peak for this molecule. For regular ferrocene, there should only be one peak since ferrocene is made from 2 very symmetrical cyclopentadienyl rings and so every hydrogen atom is attached to an identical carbon species. Not only should there only be one peak, there should be no splitting of the peak; looking at this spectrum, there is only one peak that follows this ruling, but the integral of this peak is 5, which wouldn't work for regular ferrocene because there is only the one species of carbon atom with hydrogen attached to it so the area under this peak would be 1 for ferrocene; however, for iodoferrocene, this works. This therefore suggests both that there is no ferrocene contaminating this product and that this product is 1-iodoferrocene.

2) COMBINATION OF 2 MOLECULES OF IODOFERROCENE TO SYNTHESISE BIFERROCENE

Through some research, this reaction is very similar to the copper-mediated Ullman coupling where 2 aryl halides can combine to each other by connecting where the halides were with the assistance of copper. A common example of this is the Ullman coupling of 2 o-chloronitrobenzene to form 2,2'-dinitrobiphenyl as seen in Figure 3.

For the case of the coupling of 2 iodoferrocenes, we already know that the sandwich structure in both ferrocene and iodoferrocene consists of 2 aryl rings. The iodoferrocene therefore has an aryl ring with a halide attached, which means that we can do a similar reaction to an Ullman coupling since it contains an aryl halide.

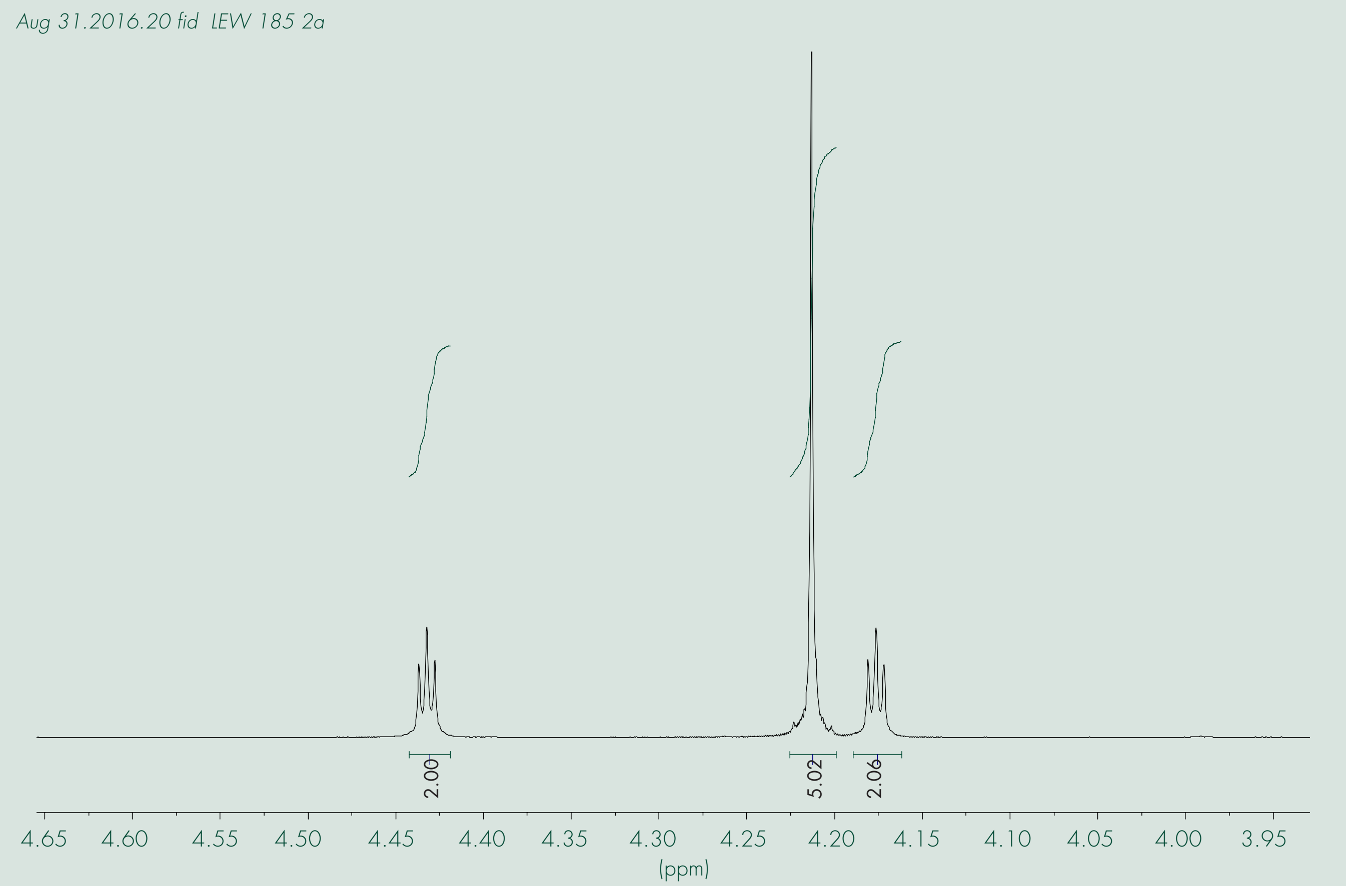


Figure 2

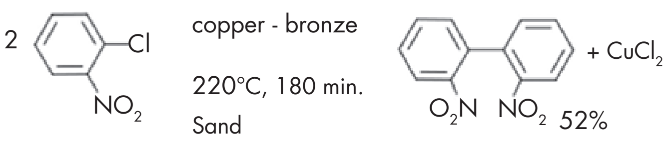


Figure 3

STEPS:

- △ Add the previously obtained 10.4g 1-iodoferrocene, CuTc (38g, as mediator) and NMP (200ml) and stir for an extended period of time (overnight) under nitrogen so that the oxygen in the air does not react to cause unwanted by-products.
- △ Then, the solution is filtered through Celite and ethyl acetate. The solution is then washed 5 times with brine and dried with magnesium sulphate to remove any water.
- △ The new solution is filtered and the solvent NMP evaporated off.

At this point I have collected a crude product: there is the desired biferrocene in this, but there would still be some unreacted 1-iodoferrocene, as well as some by-product. In order to purify the product, I used column chromatography.

Column chromatography is a method of purification that is based on how different molecules like to be in different solvents depending on which solvent is the most energetically beneficial, so non-polar molecules prefer non-polar solvents and vice versa. Using this idea, I started with the solid phase as being silica and the eluent as being n-hexane, a non-polar solvent. Then DCM was added at a low concentration and then the concentration was gradually increased. Due to the polar nature of the DCM, the more polar molecules will want to use that as a solvent instead of the n-hexane. Therefore, starting at a 5% concentration DCM, it was added slowly under pressure making the impurities go down first, since we calculated that the desired biferrocene will be collected at a 20% DCM concentration. Once I had raised the concentration to DCM 15%, it was clear that there was the desired product in the column, since a red layer had formed, travelling down the column; however, the layer was not separating effectively from the rest of the original layer of solution, and so I raised the concentration to a final 20% DCM. After obtaining the layer from the column, I carefully evaporated off the solvent to leave me with a red solid of 951mg (15%).

This recently reported new method that I used in this project produced almost 1g of pure biferrocene when other methods can only produce 100mg at most from a similar amount of starting chemicals. This fulfilled what was needed for the research into the spin state properties of the biferrocene when applied as a thin deposition layer on some materials.

However, it was imperative that we check the purity of the solid gained, since this was being used for further research so a very high purity was necessary. To measure the purity of the final product, I used NMR and determined whether there were any peaks on this that didn't relate to the product biferrocene. After doing an NMR, the spectrum gained can be seen below (Figure 4):

This NMR spectrum is very promising since one molecule that had a particularly high chance of contaminating this product is the simple ferrocene, which, due to its highly symmetrical nature would only form 1

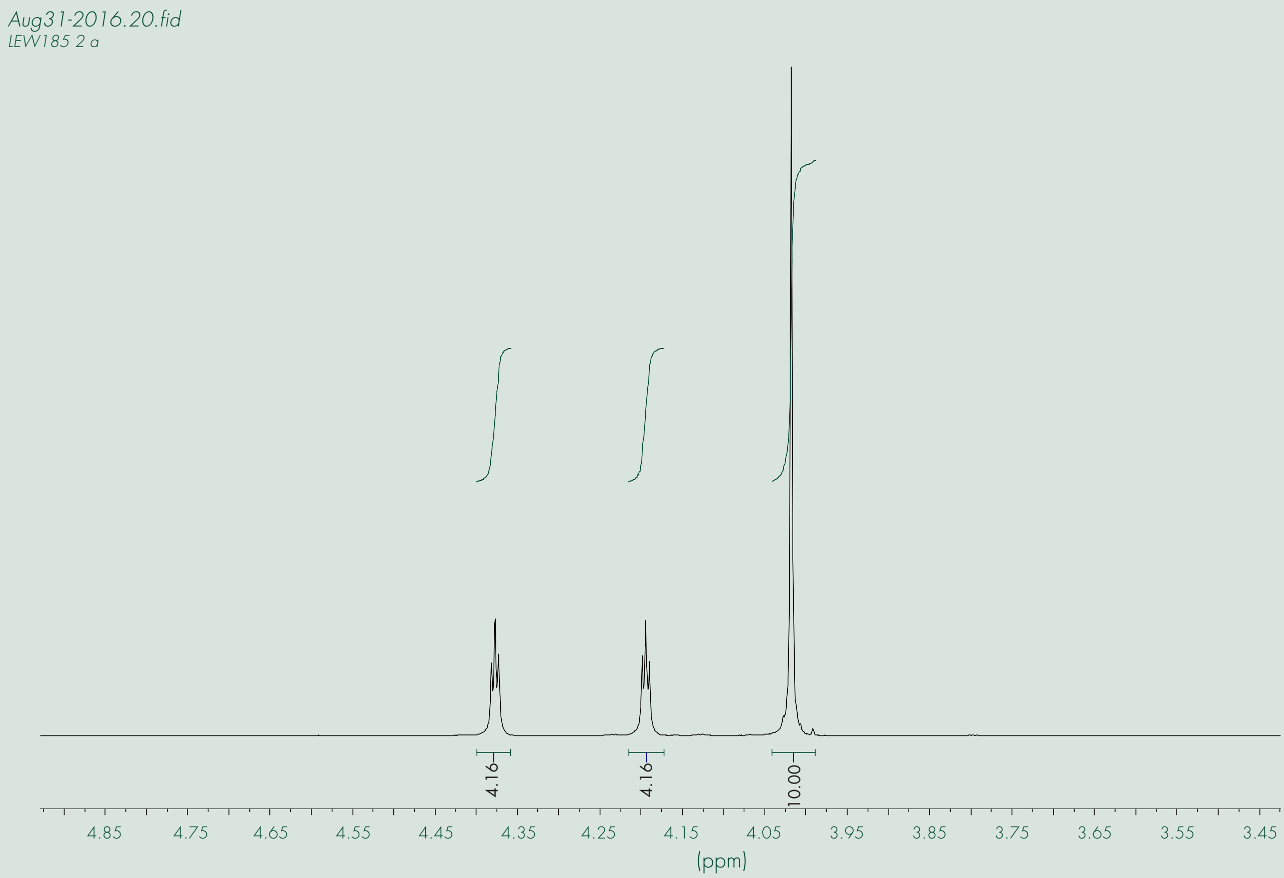


Figure 4

very large peak at the point 4.16 ppm on the spectrum, which is clearly not evident since in this NMR there is only one set of peaks close to that value and it is a small triple peak. In addition, if we look at the actual molecule of the biferrocene, we could assume 3 peaks since the biferrocene is made up 2 ferrocene parts with one of the carbons unlike the rest since it is the one used to attach to the second ferrocene. This means that there is symmetry here, involving similar carbon atom species in this molecule, 2 sets of pairs and 1 separate one for the carbon attached to the second ferrocene part, and since the whole molecule is symmetrical about the plane dividing the 2 ferrocene parts in biferrocene, the three peaks that have already been found are kept the same as there are identical species on the other side. Therefore, this NMR supports the high purity of biferrocene, since there are the 3 predicted peaks and no other peaks to suggest impurities in the product. In addition, when the peaks are integrated, the area found relates to the number of hydrogen atoms on nearby carbon species and the 4 - 4 - 10 relationship between the peaks relates perfectly with the molecule of biferrocene.

However, whilst this is a good support to the fact that the final product found is biferrocene, there is one last test that can be done to confirm this; I performed mass spectrometry of the product to produce the spectrum in Figure 5:

This mass spectrum is exactly what is expected for biferrocene, showing a significant peak at m/z 370.0, which agrees because biferrocene is made from the equivalent of 2 ferrocene molecules that each have a molar mass of 186 g/mol, forming a value very close to the desired 370, which strongly suggests that the obtained molecule is the same as the desired product, biferrocene.

Thanks to the NMR and mass spectrum, I was able to definitively prove that the final gained product was the desired biferrocene, which meant I was able to pass it on to the material sciences department so that they could research the spin state properties of the product on materials, which could result in atomically thin electronic surfaces, which could provide an excellent development in electronics chips and molecularly sized electronic circuits. However, If I had to do this project again, I would have used a larger mass of the ferrocene because now that I know a good way to successfully do this reaction, I would like to synthesise more of the product so that more research can be carried out.

Looking back over this project, I achieved my aims that I had for the project initially. This project not only gave me great insight into some of the work in chemistry at a higher level, but it has definitely persuaded me to study chemistry at university and possibly beyond. Not only have I expanded my understanding on a new topic, I have gained an interest in a part of chemistry that I didn't even know existed, organometallic chemistry, which has also helped in persuading me that studying chemistry at university would be a great fit for me. △

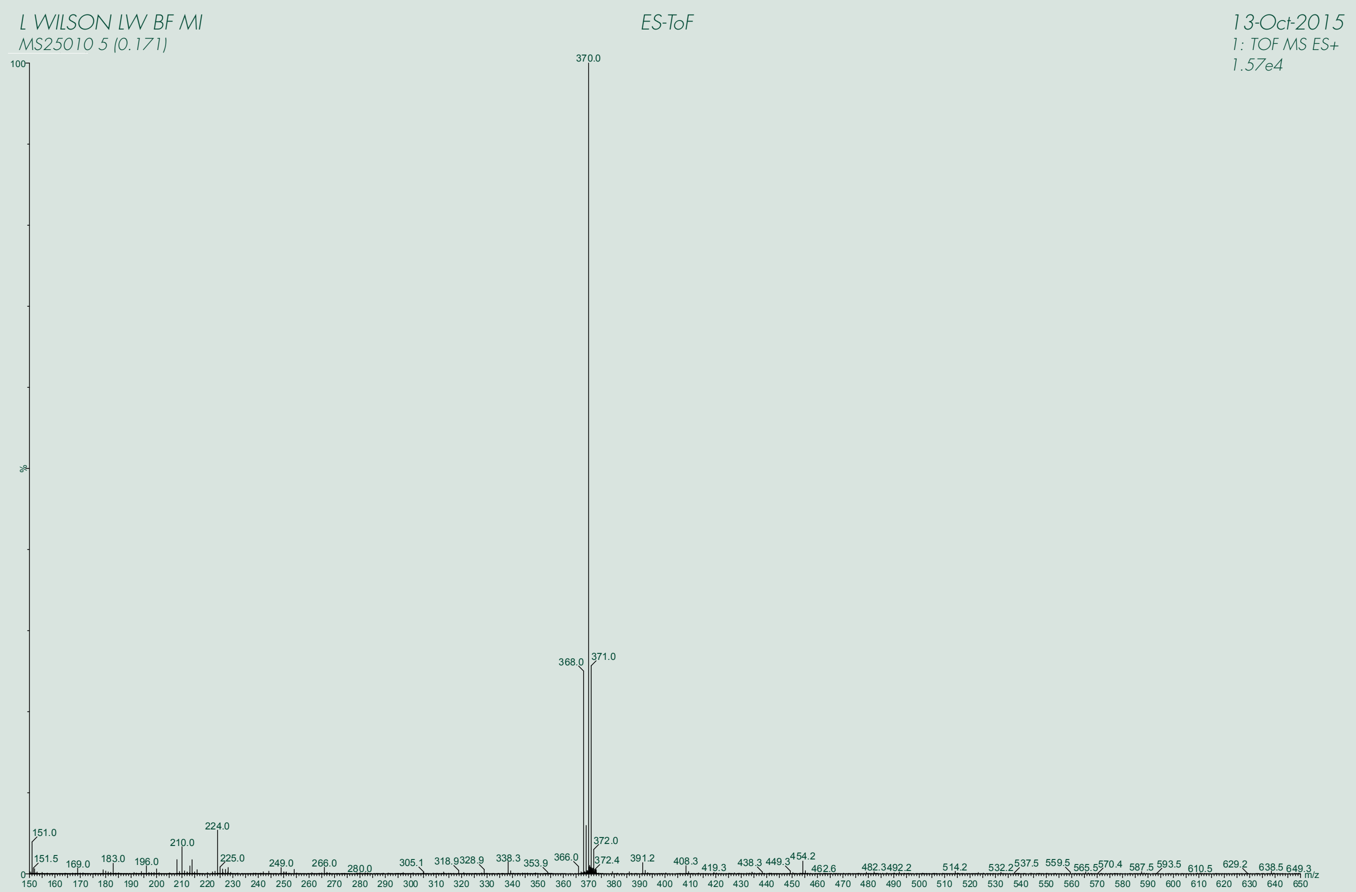


Figure 5

Music's hidden power

How Music Affects Our Memory

Salvatore Nigrelli

Music is a difficult concept to define. However, for the purposes of this article, I will be defining music as a collection of different sounds, rhythms and timbres that evoke emotion when heard.

There are many different styles of music such as Baroque and Classical, which have a characteristic steady rhythm and clearly defined phrases, Blues, which follows a 12-bar pattern using notes from a blues scale, and Modern music, which explores the use of dissonance and different timbres and textures. Not all of it evokes the same emotions; for example, music in a minor key will cause the listener to feel sad, whilst music in a major key will cause the listener to feel happy.

HOW DOES THE BRAIN PROCESS MUSIC?

When sensory organs such as your eyes and ears pick up changes in the environment, they convert these stimuli, such as light and sound, into electro-chemical signals that are then sent to the part of the brain that deals with that particular stimulus. When music is heard, the sound is transmitted down the brainstem and into the primary auditory cortex (the outer layer of the brain that deals with conscious thought). The sound is then broken up and sent to the relevant parts of the brain itself.

THE RIGHT SIDE

The right side of the brain deals with creativity and imagination and controls the left hand. It is on this side of the brain that melody (the more creative aspect of music) is predominately processed. This is because there are two Heschl's gyri (the parts of the brain that process melody) on the right side, whilst there is only one on the left side of the brain.

THE LEFT SIDE

The left side of the brain deals with logical thinking and problem solving. It is on this side of the brain that the more mathematical aspects of music are processed. Rhythm is processed in the inferior frontal gyrus, which also deals with responses and certain aspects of memory. It is also thought that timbre is processed in the same area; however, there have never been any accurate results to prove exactly where its' processing happens.

THE MIDDLE BRAIN

The central part of the brain controls all of the necessary life processes such as breathing and pulse. A particular part of the brain called the basal ganglia deals with involuntary movements and the processing of tempo and the regular pulse in music. It is also in the centre of the brain, in the amygdala, that emotion and the brain's emotional responses are created.

HOW DOES MUSIC IMPROVE MEMORY?

Music has been known since biblical times to help with all kinds of ailments. In 1 Samuel 16:23 King Saul is calmed by David's slow harp music when he is distressed. When King George III of England read about this he wondered if music could help with his memory issues (he had acute porphyria [1]. He commissioned Handel to compose a piece to help him with his memory like David's harp music. Handel composed Water Music, which even today is one of the best pieces to help with memory.

Music can increase the brain's mental capacity by at least 5 times because it causes your entire brain to be activated when you are learning something (otherwise you are just using half of your brain). Since tempo is processed equally on both sides of your brain, as the basal ganglia is located in the middle of the two sides, a music's tempo causes thinking to swap between each side of your brain, which maximize the brain's processing power. The side that is processing tempo is always the side of the brain where the thinking is taking place. The use of the middle of the brain also helps information to become subconscious thought much quicker due to a part in the centre of the brain called the hippocampus, which is responsible for turning conscious thought into sub-conscious thought. Listening to music causes the hippocampus to work at a faster rate so more memory goes into your sub-conscious mind – where it is remembered most clearly.

WHICH TYPE OF MUSIC IS BEST FOR MEMORY?

Baroque and classical music with a tempo of 60 beats per minute is ideal for improving a person's memory. This is because such a tempo is not too quick that each side of the brain does not have time to process information before the tempo switches to the other side; these genres of music have a clear melody that activates the Heschl's gyri and the right (creative) side of the brain, and have a regular, almost mathematical rhythm that engages the left (logic) side of the brain. However, the most important factor that makes this type of music effective for helping with memory is that the predominant motif of the piece is repeated only once. The brain is indifferent to a pattern not being repeated, content and relaxed when it is repeated only once, but angry when it is repeated twice. It is even thought that the brain can be damaged if the same motif is repeated four times over a short space of time, as it causes the brain to shut down. This is what makes 'popular' music bad to listen to whilst studying because repetition is an integral part of this genre.

USES OF THIS PHENOMENON

This incredible property of music is being used every day without us realising it. It is regularly used in the advertising business in radio and television advertisements, as these often have a tune in a major key. This addition of music to advertisements means that your brain becomes activated when you listen to it and so the information that it presents becomes subconscious thought and is remembered almost instantly. The most popular advertisements all have a melody to accompany their slogan. Good examples are the Smash advertisement of 1974 and the McDonald's slogan. Their popularity has been helped by this exploitative tactic.

WHICH TYPE OF MUSIC IS WORST FOR MEMORY?

In contrast to the regular, unrepeating pattern of Classical music, Rock music such as that by Queen and Led Zeppelin is damaging to the body because its 'strong anapestic beat1' causes the body to become weak and disorientated. Normally it takes 200N to push a person's arm down, but if they are listening to rock music, research shows that only 45N is required. The other danger of rock music is the fact that it has many piercing high notes, which can actually coagulate (congeal) the proteins in your brain and cause learning and behavioral problems in children. A good example of the effects of rock music on proteins is that if you put a raw egg on the stage before a rock concert, the egg will be completely solid by the end. You can only imagine what damage your brain sustains after years of listening to rock music.

BENEFITS OF MUSIC WHILST STUDYING

A positive use of this phenomenon is in studying. Since listening to classical music increases the processing power of the central brain and involves more parts of the brain, the amount of information being transported to the hippocampus and the subconscious mind is increased and therefore you can remember a much greater amount. If a student studies with Baroque or Classical music it means that they will be able to remember at least five times more information in a single revision session. This has been utilised by Bulgarian psychologist Dr. Georgi Lozanov who invented a way of using music to help students studying foreign languages. His method is so effective that you can learn a term's worth of vocabulary in just two days and have an almost 100% retention rate after four years. This undoubtedly proves that music is an extremely powerful tool in improving memory.

CONCLUSION

Evidence suggests that different types of music affect the brain in different ways. Baroque and Classical music are not only pleasing to the ear but also activate all of the areas of the brain and increase mental capacity by over five times. In contrast, Rock music with its strong anapestic beat and piercing high notes causes damage to the brain and makes the listener weak and disorientated. This phenomenon is proving very useful for students because by using music to increase mental capacity, the amount of information that students can take in significantly increases, making learning and retention of information much quicker and easier. This is an important topic that continues to be studied and may well be applied to all university courses in the future. It may also finally solve the question why Einstein, Mozart and many more great thinkers were also talented musicians. ∆

Therapeutic uses of monoclonal antibodies

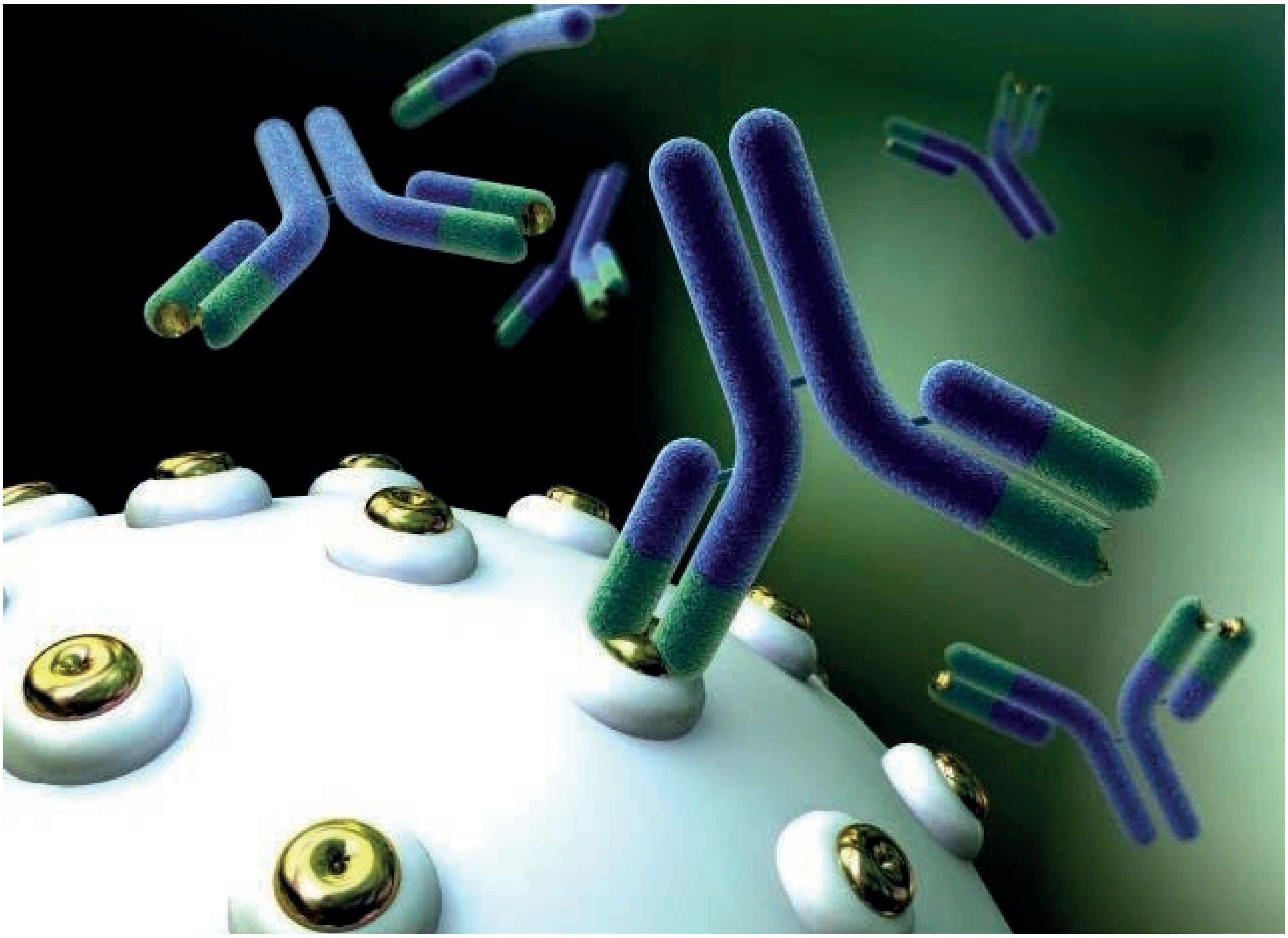
Rahul Radia

WHAT ARE MONOCLONAL ANTIBODIES?

An antibody (or immunoglobulin) is a protein produced by a type of lymphocyte called a B plasma cell that binds to specific antigens on bacteria and damaged cells. Antibodies are a vital part of the immune system and work to help to identify and detect foreign bodies in the blood and in tissues as well as responding to these foreign organisms and toxins. Antibodies work in several ways:

- Agglutination: they can attach to more than one foreign cell causing them to clump together so that a phagocyte can engulf many pathogens at a time.
- Precipitation: they can precipitate out soluble antibodies.
- Neutralisation: preventing pathogens damaging or invading cells by binding to them.
- Lysis: antibodies can attract enzymes to break open the pathogen's cell membrane.
- Opsonization: antibodies can attract macrophages to destroy pathogens by coating the pathogen.

All antibodies have one of 5 types of constant region (called the 5 different isotypes) as well as a variable region and hypervariable regions that bind to a complementary antigen. Overall, there is a potentially infinite number of combinations of constant and variable region and so drugs that use polyclonal antibodies are not very specific and can have various side-effects. However, monoclonal antibodies (MABs) all have the same constant and variable region, making them identical and similarly specific to a desired antigen. This is very useful for both diagnosis and treatment of cancer and autoimmune diseases.



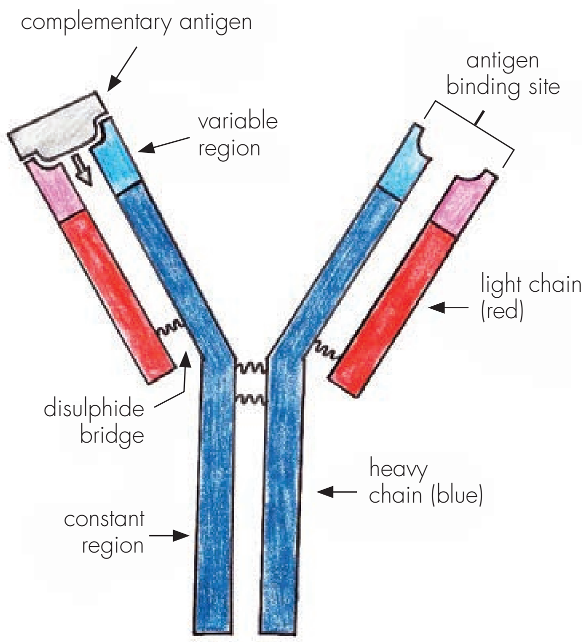


Figure 1. A simplified diagram illustrating the structure of antibodies with a darker constant region and a lighter variable region.

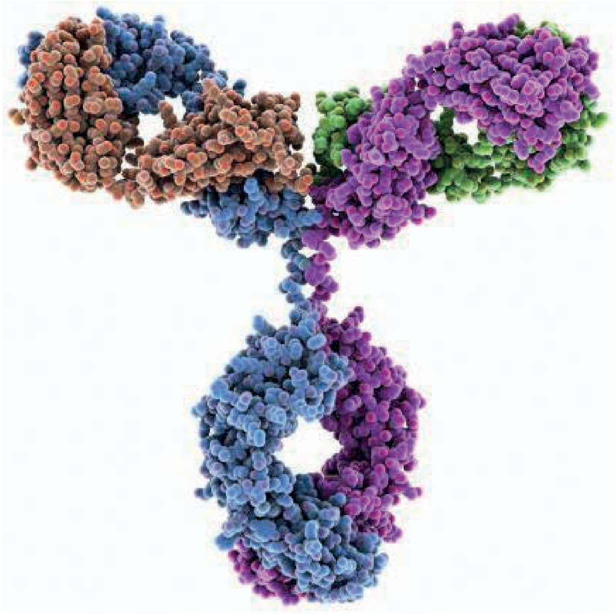


Figure 2. In reality, antibodies are proteins with four polypeptide chains: 2 heavy chains (blue and purple) and 2 light chains (orange and green).

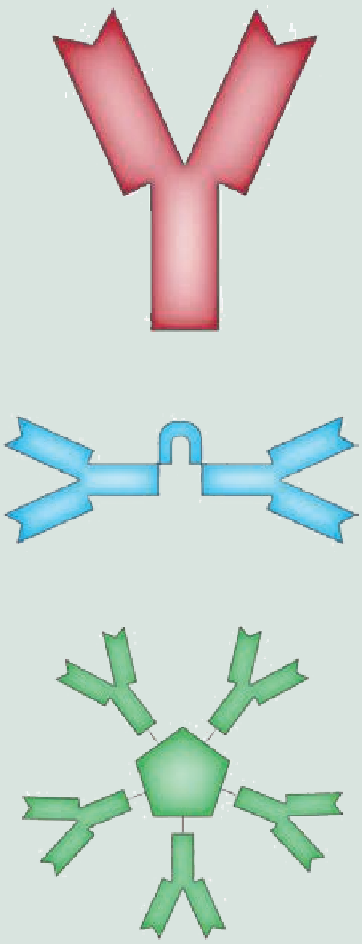


Figure 3. There are 5 isotypes of immunoglobulin: IgD, IgE, IgG, IgA and IgM. All of the different isotypes have different functions and different constant regions which can be recognised by different receptors on immune cell membranes. Some exist as monomers while IgA is a dimer and IgM is a pentamer.

MABs are defined as a collection of antibodies that were all derived from the same B cell; consequently they are all identical proteins and can only bind to one specific epitope. This is in contrast to polyclonal antibodies, which are antibodies able to bind to more than one of a specific antigen epitope (the antibodies are therefore not identical) and are derived from different plasma cells.

There are 5 types of MABs: murine, chimeric, humanized, fully human and recombinant. All of these categories describe which species have been used to produce the antibodies. The first MABs were murine (derived entirely from mouse cells); however, since these antibodies had murine constant regions, they would often induce an immune response and were unable to be used therapeutically in humans. Chimeric and humanized MABs have a combination of murine and human parts since both human and mouse cells were used to create the antibodies. Most modern MABs fall into these categories. Fully human MABs exist in some modern drugs, and it is likely that the future of this technology will expand in the direction of fully human MABs. Finally, recombinant MABs are produced using viruses or yeast as opposed to mice.

HOW ARE THEY PRODUCED?

The method to produce MABs was first invented in 1975 by Köhler and Milstein. The first ever MABs were murine, and so modern techniques, which produce humanized and chimeric MABs, are slightly different to the method I will outline below.

Murine MABs can be mass-produced in a laboratory procedure that requires animal spleen cells and myeloma cells. In this explanation I will assume that a mouse is the animal chosen to produce the spleen cells (specifically B plasma cells). Other forms of MABs such as fully human antibodies use only human B cells.

The first step of the process is to inject an animal (typically a mouse) with a sample of an antigen with the desired epitope on its surface. This antigen could be a protein or a carbohydrate. The injected antigen is usually attached to adjuvants1 in order to increase the immunogenicity2 of the injected solution. This will induce an immune response from the mouse because the animal

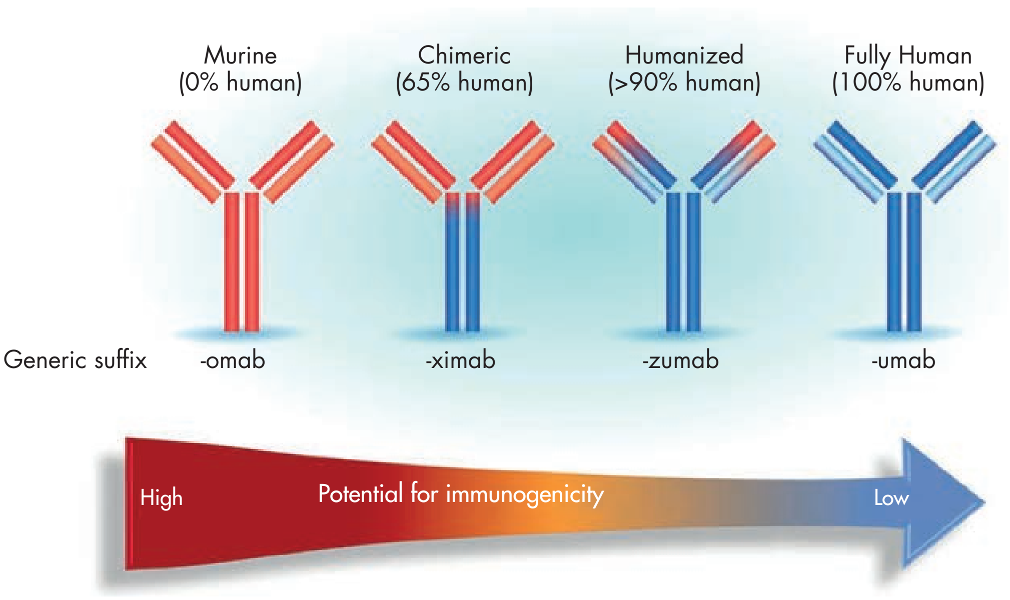


Figure 4. The percentage of the antigen that is human will affect the immunogenicity of the antigen in humans. For example murine MABs have no human regions and so are highly likely to provoke an immune response when injected into a human vein.

is likely to have a B cell producing the correct antibodies to fit the antigens due to somatic recombination3. The B cells with the correct antibodies will then be cloned, and both plasma cells and memory cells will be produced to fight the infection and to provide immunity respectively.

Next the plasma B cells are extracted from the mouse's spleen4. These extracted B cells are extremely likely to include some that are capable of making the desired antibody, because the mouse's immune system had recently produced B cells that targeted the injected antigen.

The B cells are then combined with cancerous myeloma cells5. This is done by fusing the cell membranes of the two types of cell using a chemical called polyethylene glycol. The fused myeloma and B cells are called hybridoma cells.

However, in the presence of polyethylene glycol, not all the cells will fuse, and some myeloma cells will fuse with other myeloma cells while some B cells will fuse with other B cells. Polyethylene glycol is a detergent and dissolves lipid bilayers; this allows cell fusion. In order to keep only the useful hybridoma cells alive, a medium called HAT6 is used. Aminopterin, a chemical in HAT, prevents the de novo synthesis7 of nucleotides in cells, forcing cells to use salvage synthesis to produce nucleic acids. However, myeloma cells on their own (and myeloma–myeloma fusions) don't have the required enzymes for salvage synthesis and therefore can't undergo DNA replication and die. Similarly B cells (and B cell–B cell fusion cells, will die in several days8 since they lack telomerase9 (an enzyme necessary for complete DNA replication). Therefore only hybridoma cells will survive the selection process via the HAT medium.

Only a few of the surviving hybridoma cells will be capable of producing the desired antibodies and it is necessary to separate these specific desired hybridoma cells from the rest of the cells in solution. To do this, the solution is diluted to the extent that approximately one cell occupies one well in a microtiter plate. Then each well is screened for the correct antibody using the correct assay. The correct assay is often the same antigen injected into the mouse originally.

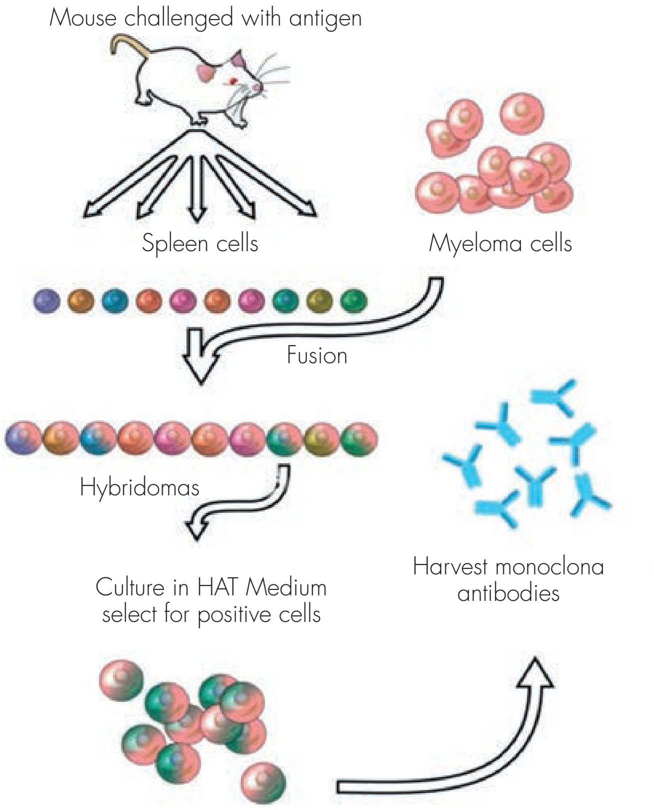


Figure 5. A simplified diagram outlining the steps in producing murine monoclonal antibodies.

The final step after isolating the hybridoma cells producing the correct antibodies is to culture the cells and harvest the MABs. This can be done in two different ways; the hybridoma cells can be injected into a living organism such as a mouse or a rabbit (known as in vivo cloning) or they can be grown in fetal bovine serum10 on a Petri dish (know as in vitro cloning). When hybridoma cells

Figure 6. In vitro cloning of hybridoma cells is often more easier than in vivo cloning since there are fewer impurities and separating out the antibodies at the end requires fewer steps.

Figure 7. Rituximab is an FDA approved chimeric monoclonal antibody used to treat chronic lymphocytic leukaemia and non-Hodkin's Lymphoma.

are cloned in vivo it is likely that the yield will not be as pure as if they were cloned in vitro since murine proteins and other biological molecules are likely to need to be separated out. Finally, the antibodies are extracted from the culture of hybridoma cells using high-pressure liquid chromatography to produce a sample of identical antibodies that all recognize the same target antigen.

APPLICATION OF MONOCLONAL ANTIBODIES

MABs are used therapeutically in oncological treatment as well as the treatment of autoimmune diseases such as rheumatoid arthritis and Crohn's disease. MABs have the ability to target specific pathogens, healthy and malignant cells in order to kill them or mark them out for the immune system to deal with. In addition since MABs are both identical and specific to one epitope, they are relatively side-effect free since they only affect a few types of (often targeted) cells in the body.

One example of a MAB used to fight cancer is the drug rituximab (commonly known as Rituxan). This is a recombinant chimeric11 MAB used to treat chronic leukaemia and non-Hodgkin's lymphoma. Although scientists have not been able to confirm the mechanism by which Rituxan works using in vivo methods, in vitro studies suggest that Rituxan is extremely effective at killing B cells (both healthy and malignant) using three different methods to do so. By reducing the number of cancerous and healthy B cells in the body, the concentration of cancerous cells can be dramatically reduced since the healthy B cells that die can be replaced in the long term by the bone marrow but the cancer cells won't be replaced in this way. This will often lead to a reduction in tumour size.

The first mechanism for killing B cells used by Rituxan is antibody-dependent cell-mediated cytotoxicity (ADCC for short). This occurs when rituximab binds to the protein CD20 on both healthy and cancerous B cells, acting as a marker by which the immune system can be told to kill the cell. The antigen/antibody complex attracts natural killer cells that bond to the human tail of the MAB and release granules of cytotoxic molecules. These granules penetrate the B cell membrane and sometimes the nuclear membrane forming pores to allow the cell's contents to escape by diffusion.

Another mechanism used by Rituxan is complement-dependent cytotoxicity (CDC for short). This mechanism involves complement proteins12 that are also attracted to the CD20/ Rituxan complex. After binding to the complex, the complement protein starts off a

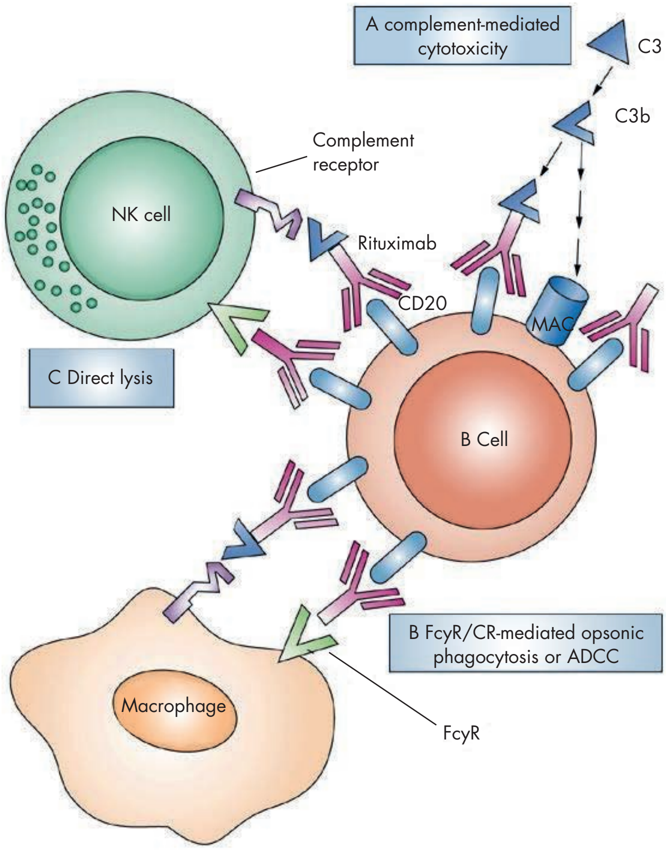


Figure 8. A simplified diagram showing the 3 mechanisms of killing B cells used by Rituxan.

chain of chemical reactions that result in the formation of a protein line pore on the cell membrane of the B cell. This allows the cell's contents to escape, thus killing the B cell.

Finally, rituximab can also trigger extrinsic13 apoptosis of B cells. The antibody binding to CD20 can trigger a chain of reactions that results in the formation of a caspase14 enzyme. Caspase is able to separate the enzyme DNase from its inhibitor, allowing for the enzyme to break up the B cell's DNA into fragments only 180 nucleotides long. Caspase destroys any other proteins such as those that make up the cell's cytoskeleton. This causes the cell to lose its structure. Other uninhibited proteins cause the cell to collapse into vesicles called blebs. These blebs are then recognized by phagocytes and the destroyed cell's contents are phagocytosed.

Although it is not as yet confirmed how significant each of these mechanisms is for destroying B cells, they have all been shown to significantly reduce the number of B cells in the body and thereby reduce tumour size and cancer cell concentration. This treatment does have some fairly common side-effects all associated with a low white blood cell count: patients can have mild allergic reactions, anaemia and a much escalated risk of infection, for example.

Similar MABs such as ibritumomab (an MAB derived from human B cells and human myeloma cells, which is therefore of fully human origin) can also be used to treat leukaemia. Ibritumomab is used to deliver radioactive isotopes (in this case yttrium-90 and indium-111) to B cells by binding to the CD20 antigen on their surface. The radiation from the decay of these isotopes is likely to be concentrated enough around a tumour to kill the malignant B cells. This antibody also triggers cell death by ADCC, CDC and apoptosis like rituximab. Ibritumomab has often been as or even more effective than normal beam radiotherapy.

Natalizumab is a humanized MAB that is used to treat autoimmune diseases such as multiple sclerosis (MS)15. Although there is currently no cure for MS, using natalizumab targeted immune cells can be prevented from damaging neurons and can sometimes be killed, thus reducing the frequency of relapses for people with relapsing-remitting MS and slowing the worsening of the disability for people with primary progressive MS16. Natalizumab (commonly known as Tysabri) binds

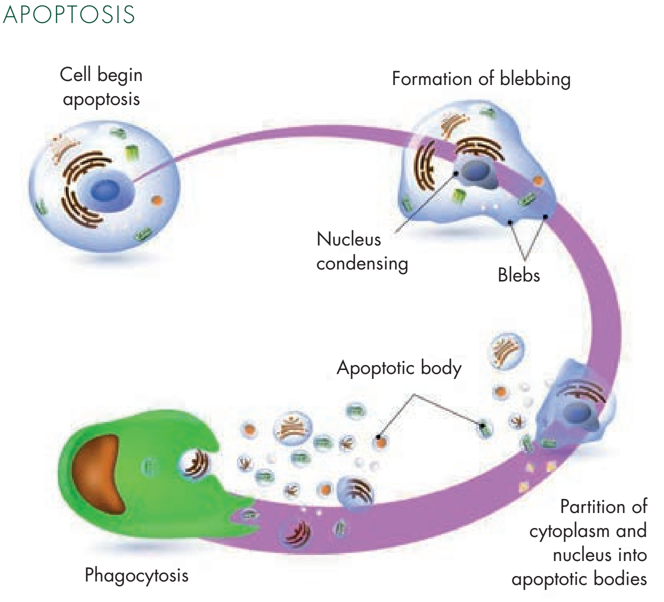


Figure 9. Apoptosis is a natural and controlled mechanism of the body. Cells in the body commit 'cell suicide' in this way if they are harmful or if it requires less energy to kill them than for the body to maintain them.

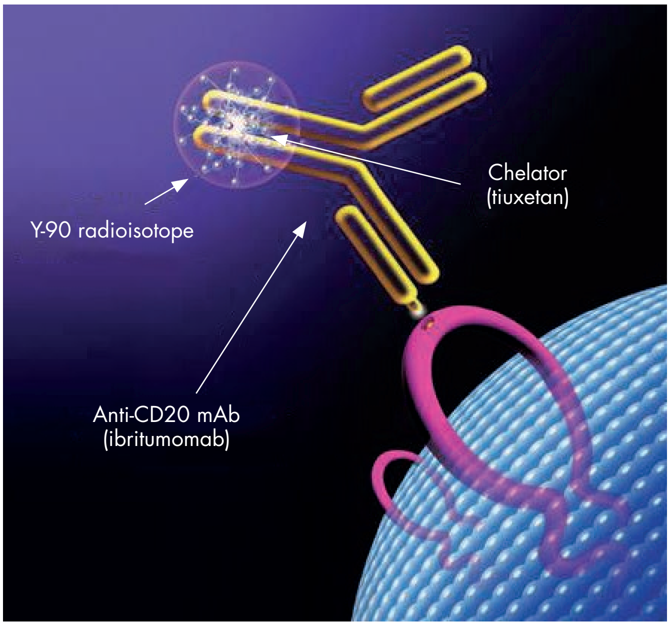


Figure 10. Ibritumomab is a MAB used in radioimmunotherapy. The diagram above shows how it binds to CD20 antigens and delivers radiation to specific cells.

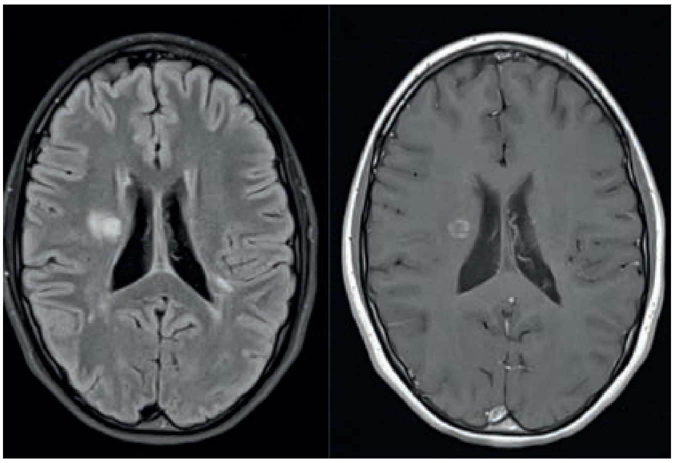


Figure 11. An MRI scan of a patient with multiple sclerosis. The bright white areas near the centre of the brain are lesions (areas of damaged brain tissue) characteristic of multiple sclerosis.

to adhesion molecules17 on lymphocytes, leukocytes and platelets, and acts as an inhibitor for the function of these molecules. It prevents the recruitment and 'inflammatory activity' of activated immune cells into the CNS. By stopping immune cells from attacking the myelin sheath of nervous tissue, MS can be made less severe.

FUTURE APPLICATIONS OF MONO-CLONAL ANTIBODIES

MABs are a relatively recent medical innovation, with the production of MABs having only been finalised in 1975 by Georges Köhler and César Milstein at the University of Cambridge (interestingly in the same laboratory in which James Watson and Francis Crick worked on the discovery of the structure of DNA). In its short history, MABs have become prominent in medical research; nowadays around 6 in 10 new 'blockbuster drugs'18 are MABs.

Since MABs have such a wide range of applications, it is difficult to predict in which area of medicine future innovations will occur. However, it is likely that the focus on MAB production will soon shift away from chimeric MABs and instead towards fully human and possibly recombinant antibodies. Since chimeric MABs have a fairly

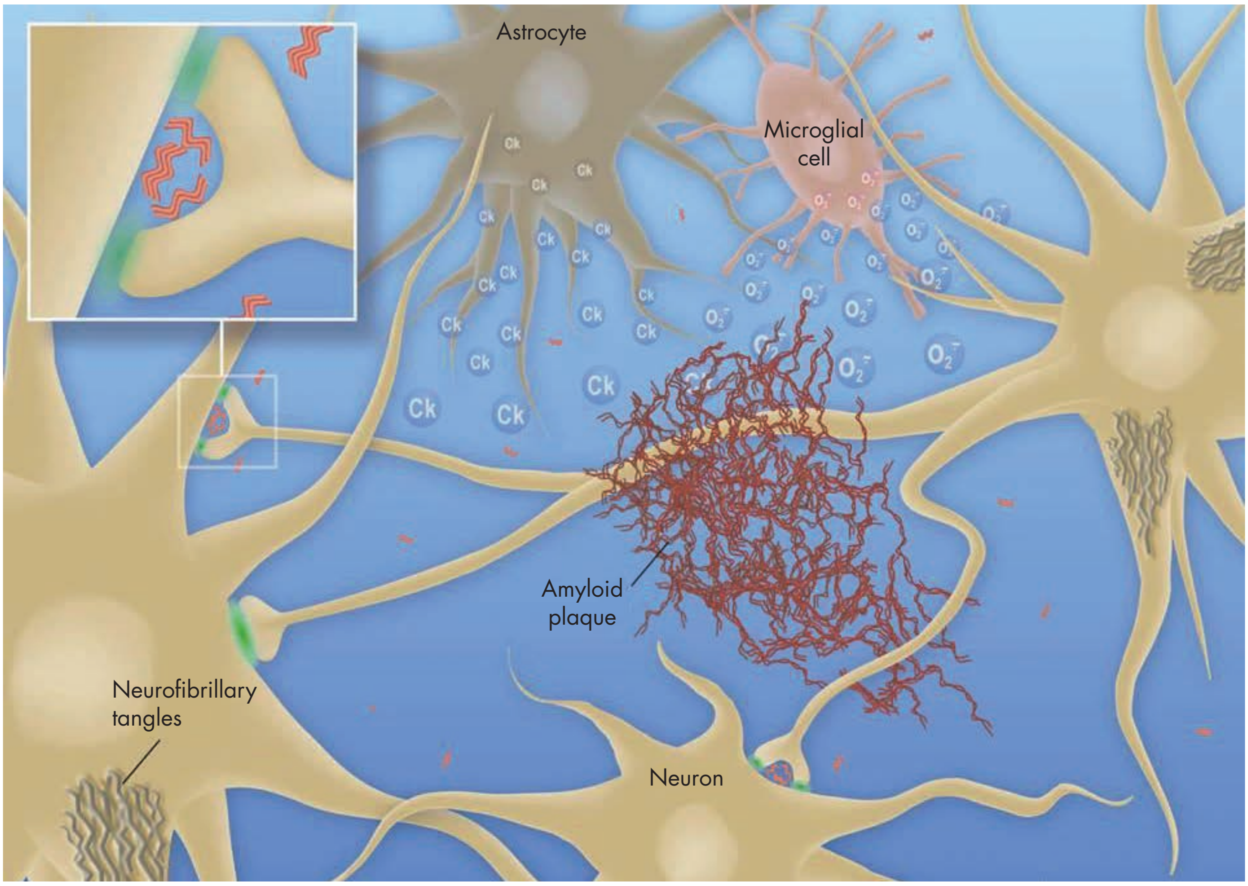


Figure 12. Alzheimer's is caused by the build-up of a protein called amyloid around neurones forming plaques. These plaques disrupt nervous signals and cause cognitive function to wear away.

high immunogenicity, there is a much larger chance of autoimmune complications for treatments using these types of drugs. On the other hand, humanized or fully human MABs are much safer to use since the immune system is more likely to recognize them as self-proteins. Recombinant MABs – which use yeast or viruses rather than animal cells to produce antibodies – are a potential area for expansion due to recent innovations in genetic engineering, such as CRISPR.

One specific field of medicine that is likely to benefit very soon from MABs is the treatment of Alzheimer's disease19. Currently there is no cure and there are very limited treatments available to slow the cognitive decay of anyone suffering from the disease. However, recent attempts have been made to produce a MAB capable of binding to amyloid proteins and preventing the build-up of plaques on the neurones. In theory, this would slow the progression of Alzheimer's disease in patients. One American drug company called Eli Lilly has been working on a humanized MAB called solanezumab that the company claims is able to prevent the build-up of plaques and slow the cognitive decay of patients suffering from Alzheimer's disease. Unfortunately, not only did the drug have a potentially life-threatening side-effect – cerebral odema (swelling of the brain) – but it also failed to be statistically better at slowing the onset of Alzheimer's disease compared with a placebo. Despite the failure of solanezumab, Eli Lilly and other pharmaceutical companies are continuing to work on a MAB drug that could treat Alzheimer's disease.

ETHICS OF MONOCLONAL ANTIBODY PRODUCTION AND APPLICATION

MABs represent a huge asset for medical research not only because they offer a treatment plan for numerous cancers and autoimmune conditions (relatively free of side-effects) but also because the principle on which MAB treatment works is compatible to many different diseases. However, this power does not come without ethical dilemmas. For example, the production of MABs often requires the use of mice – sometimes for ethically questionable purposes. For example cancer-treating drugs require a mouse to be injected with a sample of a tumour to induce cancer in the mouse. In addition, mice are killed (in a painless manner) in order to extract their spleen. These practices have raised concern from multiple animal rights activist groups, since mice are likely to undergo suffering in order for the necessary immune cells to be activated.

There are also issues with the therapeutic use of MABs. Early forms of MAB drugs used almost fully murine proteins which, when injected, could trigger severe immune responses from patients; during the testing of a drug in March 2006, six healthy volunteers suffered multiple organ failure due to an autoimmune response to the lethal drug. It is important, therefore, that patients are well informed about the risks of using MAB drugs since there is always a small chance that they could induce severe reactions from a patient's immune system. △

Cryptography

Shaoyon Thayananthan

INTRODUCTION

If you asked somebody the question "Why do you seal your envelopes?", they might reply "It's a habit", "I don't know" or "What kind of a question is that?". Maybe more reasoned and thought-out answers might be "To stop others reading it" and "To stop it falling out". However, if someone had intercepted the letter, they would easily be able to read the letter. More people might use e-mail nowadays as it is more modern. However, it is just like an average letter: you can read it if you intercept it. A common solution could be to use cryptography and 'encrypt' the letter. The letter would now appear to be unreadable by others. Cryptography was mainly used by military and government personnel to start with, to make sure the enemy did not get the letter, but in more recent times, people have started using it between themselves from friends to adults to old people.

BASIC CRYPTOGRAPHY

The basic Idea of a cipher system is to hide personal info on stuff so that no-one else is meant to read it except for the 'receiver'. The info that you want to hide will be called the 'plaintext' and hiding the plaintext is called 'encryption'.

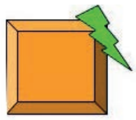
Below is a diagram of how the encryption process will work. The Sender encrypts the message, sends it as a cryptogram and then the Reciever gets it and decrypts it. The 'intercepter' will of course be taking in the message when it is still a cryptogram. I use intercepter, but not everyone does. Some say 'Bad guy', 'enemy' or even 'adversary', but intercepters are not necessarily the bad guys: they can be doing it for good causes sometimes. 'Cryptography' is when someone encrypts a message, 'cryptanalysis' is when someone examins and works out how to decrypt or tries to decrypt a message and 'Cryptology' is both of them together. You don't necesarily need to use Cryptanalysis to find out a message. Some people need a key for their memory, so they might hide it somewhere.

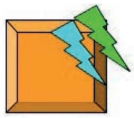
Say you were guessing the password to a laptop, but you see a sticky note underneath it saying the password. Therefore you can also get info from available resources. For an interceptor to successfuly decrypt a message , they need sufficient info on how to see which is the right key or to identify which keys are wrong.

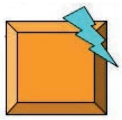
THE PRESENT PROBLEM

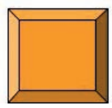
Say you had a gift that you wanted to send to a friend. However, the problem is that this gift is very valuable sentimentally and in terms of money, therefore you need a surefire way to send your present to your friend. As a result, you try this method :

- △ You take your gift and lock it with a padlock and keep the key (Note : No-one can access it now)
- △ You send it, and the friend receives it.
- △ Your friend padlocks it with his own padlock - there are now 2 padlocks.
- △ Your friend sends it back, and you unlock your own padlock. You send it back.
- △ Finally, your friend opens his own padlock and gets the present.

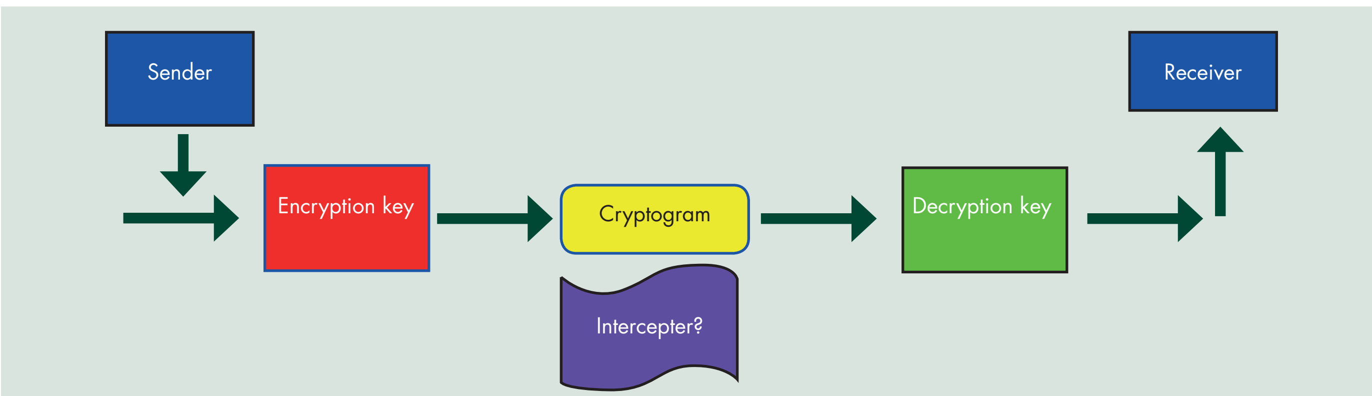
1  You padlock the gift box and send it to your friend

2  Your friend locks his own padlock onto the gift. He sends it to you.

3  You recognise your friend's padlock and unlock your padlock. You send it to him.

4  Your friend unlocks his own padlock, and receives the present.

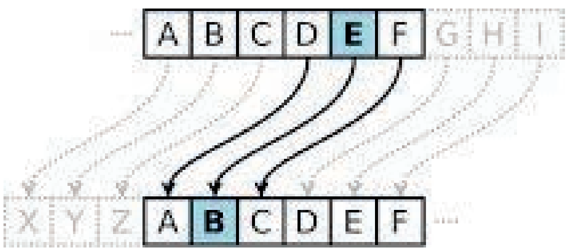
= Your Padlock = Gift Box = Friend Padlock



EXAMPLES OF ENCODING MESSAGES

CAESAR CIPHER

The Caesar Cipher, also known as a shift cipher, is probably the most simplest way of efficiently encoding a message. It is relatively quick (compared with the rest) and not that hard to decode or code. It is basically shifting the alphabet, so that each letter has a different text for itself. The image below is a good example of how a Caesar Cipher works. You can either code it that way, or do it in a circle–sort of way as shown by the picture underneath the one to the right. The Caesar



Caesar Cipher

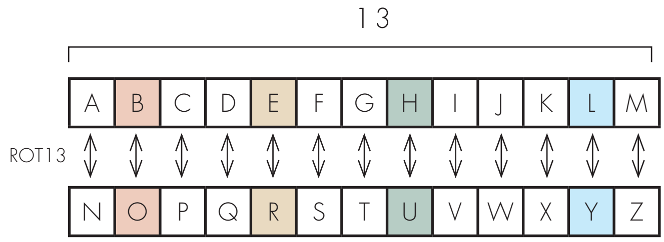
Cipher would probably work best if it was just a simple message to a friend or colleague, not a serious one, as it could be easily decoded by a good interceptor. There is also a way to decode messages called an 'exhaustive search' which means to try out all possibilities. This search is now easier since we have programs to help us do this. The Caesar Cipher is vulnerable to this as it only has 26 letters to change.

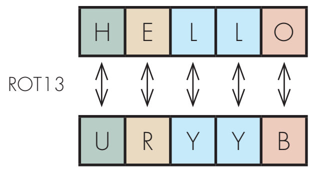
SIMPLE SUBSTITUTION CIPHERS

This way of encrypting is also a very simple way to conceal the text that you want to hide from other people. This process is when one gives every letter in the alphabet another letter, for example you could change A to U, B to R and C to Q. It is simple to do, but can be very hard to break.

Simple Substitution Ciphers

An exhaustive key search (trying all the possibilities) would be 26! [26 x 25 x 24 x 23 x 22… x 1] would be too hard, as you'd have to do over 10^{26} key searches, which no-one would take the time to do. However, the problem with these types of ciphers are that the codes are really hard to remember without writing down somewhere. Therefore, in pre-computer days, a paper was written down with the code, but if the paper was seen or taken, it would be easy to decipher the encrypted text. So people nowadays (if they are using this ciper) try to make the key as something they can remember like the one to the right. This way, it is easier to remember compared with people who have used a key such as the one shown below:





TRANSPOSITION CIPHERS

This cipher is one of the ones I like a lot, as it is very handy to use, and simple to code. It looks complicated on the end result, but the truth is that it is one of the easiest ciphers to decode if you know that it is a transposition cipher. How to encode it:

1. Pick the text you are going to decode e.g. I am going to buy a piano on Friday.
2. Put it into a column form with 5 letters per row, and Z's at the end if needed to make a full row:

I A M G O
I N G T O
B U Y A P
I A N O O
N F R I D
A Y Z Z Z

3. Write the message down as if you are reading down the colums e.g.

IIBINAANUAFYMGYNRZGTAOIZOOPODZ

This is your end result.

To decode this message:

1. Divide the length of the message by the key. In this case it is 30 letters (the letters in the whole message) by 5 (the letters in the row) which makes 6. Therefore you write the message as you see it in rows of 6, making the columns neat and writing each letter beneath the other.
2. Remove the Z's at the end of the message.
3. Read the message from up to down, it is now encrypted!

The transposition cipher is a good one, but is easily decrypted if you know how to decrypt one.

I	I	B	I	N	A
A	N	U	A	F	Y
M	G	Y	R	N	Z
G	T	A	O	I	Z
O	O	P	O	D	Z

WHAT DO WE USE CRYPTOLOGY FOR NOWADAYS?

We might use cryptology for a cash withdrawal from an ATM. When you withdraw cash from an ATM, the ATM sends card details and the PIN to a host computer, where it checks whether the withdrawal details are ok. Therefore, there must be two-way communication within these two machines; there could be information in there that is private. We could also use it for a mobile phone, as the phone must connect to the nearest base station when calling. Or, you could use it for shopping online, like many people do. When they enter their card details online, they need to keep this info encrypted, or the interceptor could easily use their card for malicious purposes.

CONCLUSION

Cryptology is very fun to study, and can be used in many different ways. It is something that, in my views, is mysterious. The study of cryptology , and there are always different ways of code-breaking and encrypting being found. I really like cryptology, and I hope to study it when I am older. △

Electric ukelele

Cameron Philp

The major Design and Technology project in the Third Form is to design and manufacture an electric ukulele, solder the amplifier circuit and build a case to house the speakers, power supply and electronics.

Cameron has shown outstanding ability and commitment to the project not only making an exemplary Flying-V inspired instrument, but also designing and manufacturing an innovative collapsible instrument so he can carry it around in his bag!

Ukulele #1 was based off a Les Paul flying V. I think that it followed that design very well apart from the angle of the v being too small. The head was a good size but looks disproportional to the body, linking back to the small angle.

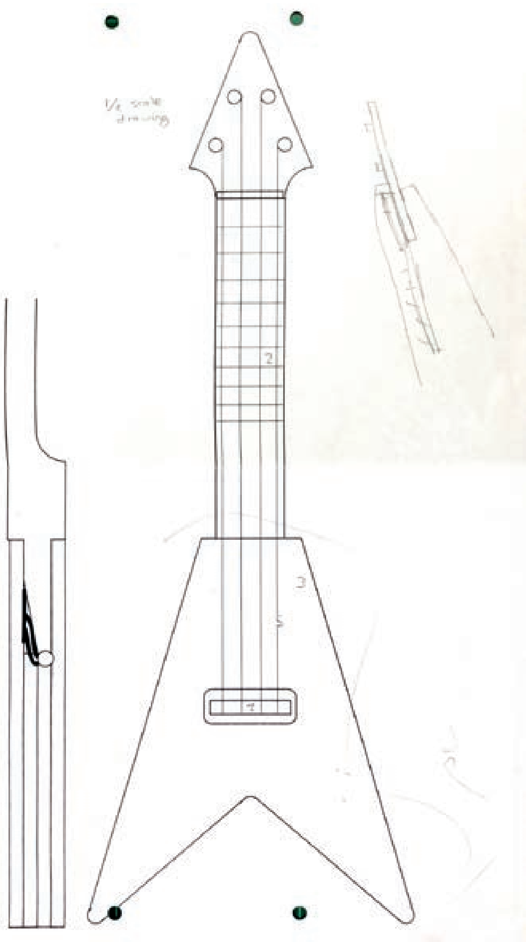
The way the head is attached is very strong, but the plywood was very slightly curved before the strings went on. This meant that the two middle strings did not rest on the nut and sound weird. This was resolved by raising the nut.

When playing, I found that the nylon strings didn't sound or feel right on the size of the uke. I swapped over some steel strings from my guitar and it sounded great. I have therefore ordered a set of metal ukulele strings which will arrive soon.

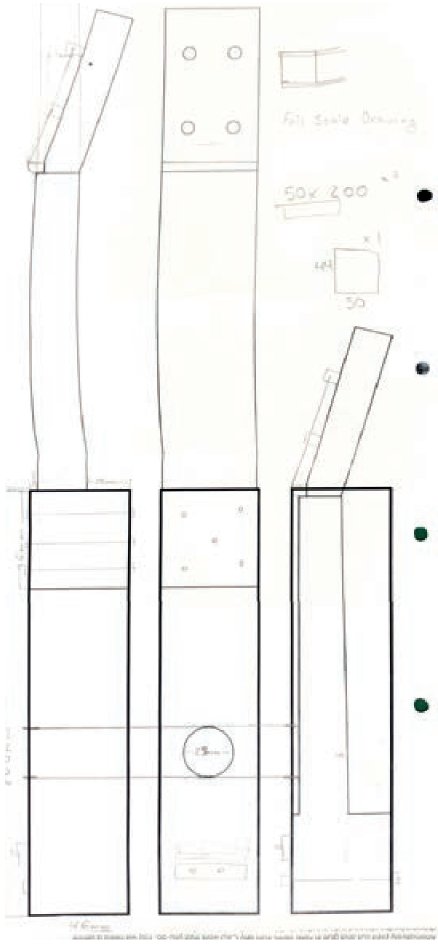
I believe that the threaded bar makes a great alternative to the traditional nut and bridge and adds a rustic/heavy metal effect to its aesthetics. This and a deafening, classic rock amplifier would be a perfect combo.

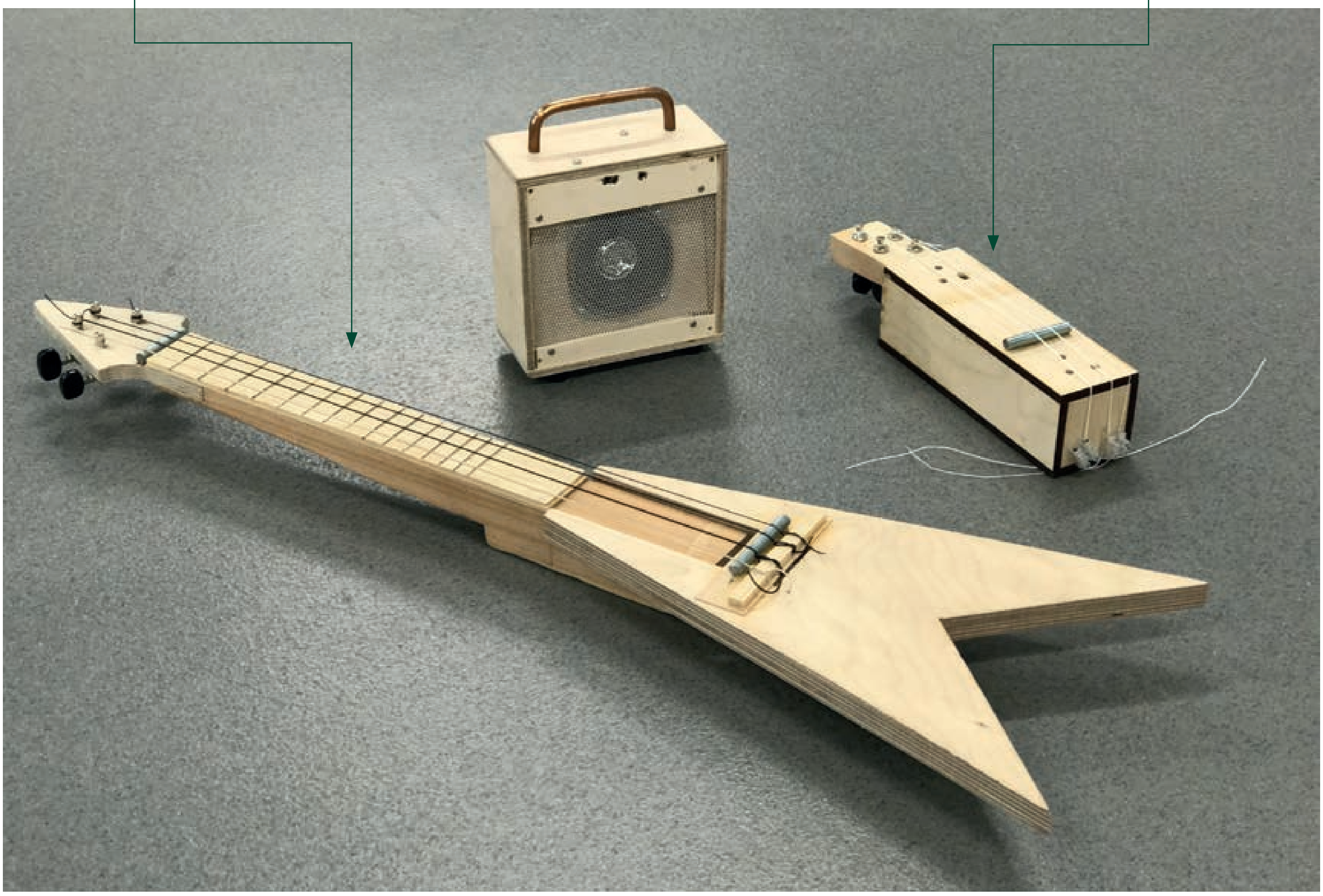
On #2 I will spend a lot of time making sure that the strings fit over the nut and into the tuning pegs, as that seems to be a problem I have with most of the ukuleles I have built.

WORKING DRAWING OF
FLYING V UKELELE



WORKING DRAWING OF
COLLAPSIBLE UKELELE





Anatomy of an orectolobiform

The Epaulette Shark

Ferdy Al-Qassab

THE EPAULETTE SHARK:

The epaulette shark (Hemiscyllium ocellatum) is in the order Orectolobiformes: these are carpet sharks, which generally dwell in shallow reef areas. This specific shark inhabits the shallow coast off Australia and the surrounding islands. It has a limited diet, surviving on only the smallest of molluscs and crustaceans. It is hunted too. The shark spends most of its adult life attempting to escape the jaws of a larger, more formidable shark: a tiger shark, for example. Tiger sharks can grow to a whopping 5.5m long: more than twice the size of the largest human being ever to have lived. The epaulette shark inhabits crevices until the tide retreats, which is the optimal time to feed.

BASIC ANATOMY:

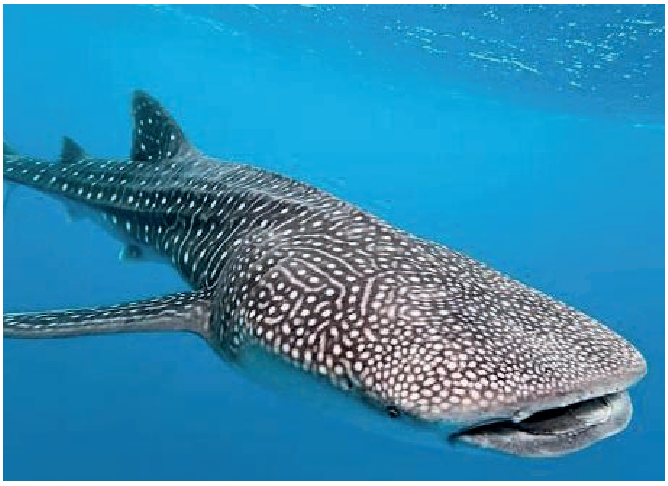
The formal definition of a shark (in general) is: 'A cartilaginous (non-bone skeleton) fish with a dorsal fin in the centre of its back'. At first, the Orectolobiformes order seems to be a very varied group, but they are connected by the fact that they are predominantly bottom dwellers, although the definition of an orectolobiform is largely based on the number of gills (5 on each side generally) and fins (anal fin). Most sharks in the Orectolobiformes, including the epaulette sharks of New Guinea, live in murky water, so they cannot rely on sight alone to guide them. They need the amazing 'sixth sense' of the sea. Each shark has a set of tubes running through its snout, filled with a jelly-like substance. These tubes are known as ampullae of Lorenzini. These are electroreceptors that pick up signals given off by potential prey. The electromagnetic pulse is picked up by the shark, vibrating through the jelly inside the tubes, aiding the shark to create an accurate image of the surrounding area.

ADAPTATIONS FOR SURVIVAL:

The epaulette shark is considerably smaller than the other carnivorous predators of the shallow reef. At only 0.90m long, it is more prey than predator; however, when it does come to feed, it does a most spectacular thing. It starts out on its hunting venture when the tide retreats. The shark swims into the shallow rock pools, feeding on crabs, with teeth specialised for grinding and crushing rather than tearing. After a short while, the Australasian tide will change fully, leaving the shark stranded, literally 'a fish out of water'. It then shuts off its non-vital digestive organs (in order to use more oxygen for respiration) and uses its pectoral (side) fins to 'walk' along the corals towards the sea. Once all of the non-vital organs have been shut down, it can survive without oxygen for 60% longer than a human can. This ability of 'walking' has only been replicated by the California horn shark, which has been observed staying out of the water for 18 consecutive hours (although it went into the water for breaths)! This brilliant shark (the epaulette, not the California horn) can be seen as close as Bristol Aquarium, although it has never been seen out of Australasian waters in the wild.

Above is the epaulette shark, 'walking' on land with its pectoral fins.

Above: *Nurse shark whilst feeding*



Above: *Whale shark, a filter-feeder*

Above: *The Tasselled Wobbegong*

Above: *Bamboo Shark*

OTHER ORECTOLOBIFORMES SHARKS:

Other orectolobiform sharks include the tasselled wobbegong, a thin, flat shark that has tassels protruding from the front and sides of its body in order to impersonate a coral. Unsuspecting fish go near to the shark, before it snaps them up in a matter of milliseconds. The use of the seabed as a disguise is utilised by many other bottom-dwellers: the angel shark and many species of ray (which have cartilaginous skeletons and are therefore similar to sharks).

Probably one of the most well-known Orectolobiformes sharks is the nurse shark. It inhabits murky waters between the tropics. It is peaceful and slow, therefore attracting tourists. When unprovoked, they generally stay out of human contact. They eat queen conch, which are firmly stuck to very large shells. The shark has a suction ability (see below) that it uses to extract them. Most orectolobiforms inhabit Australasian waters, but some are found in the Mediterranean, occasionally entering English waters.

THE MOST DANGEROUS SHARK

The Bull Shark?

WHAT QUALIFIES AS DANGEROUS?

There is no definite definition of 'dangerous' that we can use in this circumstance, so we must make a definition. In this case, the title of 'most dangerous' shark goes to the shark that would have the highest chance of causing a fatal attack to a physically healthy human, if the shark caught sight of the human.

THE CANDIDATES

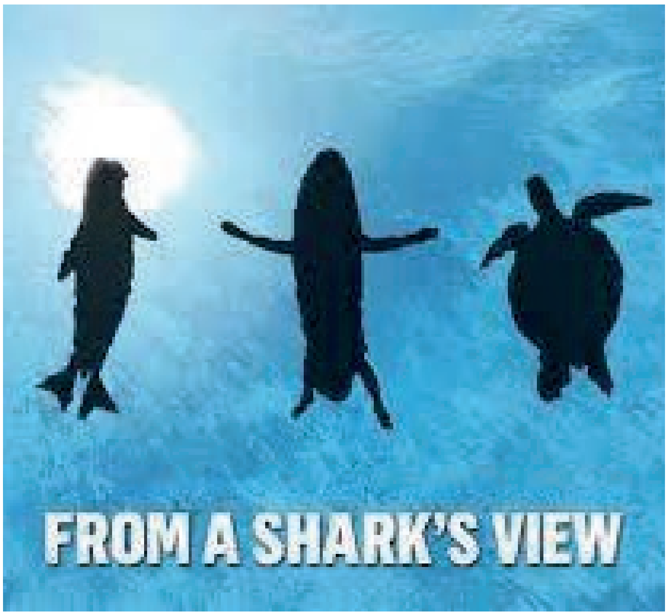
Sharks are greatly misunderstood. In 2014, there were only three fatal attacks out of 72 worldwide. It is presumed that two-thirds of the overall figure were unprovoked. There are three obvious candidates that spring to mind when you think of a 'dangerous' shark, all of which have their own reasons as to why they could be classified as the most dangerous shark in our oceans today. These are:

- △ the white shark
- △ the tiger shark
- △ the bull shark

THE WHITE SHARK:

Although it is statistically the most dangerous shark (judged by amount of fatal attacks per year), this shark has an unfair reputation for being a ruthless man-eater. The reason for the terrible reputation of the shark lies in what it eats. These sharks crave blubbery animals such as seals, and are often known to hesitate when eating food that has a large amount of bones. Additionally, animals such as seals have long, thin bodies (similar to humans), and a seal – when seen from beneath – looks rather like a person on a body-board. But surely, the shark would be able to tell if it was a person? These sharks hunt from beneath (hence the darkness on the top of the body which looks like the bottom of the sea, as well as the light patch on the bottom which looks like the sunlit areas), which means these images look similar, and give off a similar electromagnetic pulse.

Additionally, this shark definitely cannot be the most dangerous shark for causing fatal attacks when a victim is seen, because it is famed for 'bite and run' attacks, where it bites into the human, before realising that it is not a blubbery seal, and losing interest. A test was conducted where meat from certain animals was fed to a white shark. It quickly lost interest in the foreign foods, such as the pork.



(Above) The view of a seal, a body-boarder and a turtle from beneath. They are all relatively similar, which is why the Great White accidentally bites humans.

THE TIGER SHARK:

The tiger shark is a strong contestant for the title of 'Most Dangerous Shark'. This is because it very rarely does bite-and-run attacks, because it is not interested in blubber or blood. It is solely interested in food. This shark has been known to eat umbrellas, metal cans and (as depicted in the movie 'Jaws') buckets and number-plates. Through this habit, it has adopted the nickname of 'The Garbage Can of the Sea'. This is why it is such a strong contestant, because it will not leave a meal unfinished, and – unlike the great white – intentionally targets and attacks humans.

The tiger shark is no less formidable than the more famous sharks too. Named after the stripes it has as a juvenile, the shark can grow up to 5.5m long, and has 3cm long teeth. They are not endangered in the wild and statistically is the shark that kills the second largest number of humans (after the great white).

THE BULL SHARK:

This shark is known for aggression, but this does not only lie in the method of attack, but on its level of testosterone, a hormone that is generally linked with aggression. It has the highest level of testosterone of any animal, and attacks in a vicious way. It starts by circling the prey, using electroreceptors to tell how fast the prey's heart is beating, giving the shark a hint of how scared the prey is. It then swims at 11mph towards the target, head-butting it (like a bull – hence the name). This makes the target anxious, and leads to a more horrible death. On occasions, groups of these sharks have been seen attacking a single target.

THE VERDICT:

The white shark is clearly a misunderstood shark, which commits bite-and-run attacks, meaning no harm to the human. It is endangered in the wild and has built up a bad reputation that it clearly does not deserve, whereas the tiger shark is a remorseless killer that will seek out a human as a target and will never leave the human once bitten. However, the bull shark is far more aggressive, with high testosterone levels. It also kills prey using a vicious, painful, slow method, and for this reason I believe that the bull shark is clearly the most dangerous shark that is currently alive in our seas. △

Final differences of sequences of Polynomial Expressions

Henry Benett

SUMMARY

Consider a sequence of a polynomial expression, where the highest power is anx, and x is a positive integer and n is an integer and a the coefficient. If we take the differences between the consecutive terms in the sequence and the differences between the differences and so on, then that sequence's final difference (the first set of differences where the differences are constant) will be a(x!). The number of differences will be x and adding a constant c will have no effect on the number of differences or the final difference.

Consider a sequence of n^2:

n:	1		2		3		4		5
n^2:	1		4		9		16		25
D_1:		3		5		7		9	
D_2:			2		2		2		

As you can see, the final difference of the sequence is 2. This is equal to our exponent of x (2)! ('!' is the factorial symbol; n! is 'n'×'n−1'× 'n−2'×… 1. For example, 2! Is 2×1=2, and 3! Is 3×2×1=6). Also, the number of differences is also 2. Now consider n^3:

n:	1		2		3		4		5		6
n^3:	1		8		27		64		125		216
D_1:		7		19		37		61		91	
D_2:			12		18		24		30		
D_3:				6		6		6			

Here, the final difference is 6, which is our power, 3, factorial. This is a simple demonstration of how the exponent of n, (x)! is equal to the final difference. (again, take note that the number of differences is also 3).

Now consider a sequence where we multiply our nx by a coefficient, a: anx, for example with x as 2 again and a as 3:

n:	1		2		3		4		5
$3n^2$:	3		12		27		48		75
D_1:		9		15		21		27	
D_2:			6		6		6		

Here you can see that the final difference is 6. This is equal to 3×(2)! However, this is the same as when a was just 1 and x was 3. The way we can tell if a sequence with a final difference of 6 is a sequence of $3n^2$ or n^3 is by the number of differences, which is always equal to x. Some more examples:

$3n^3$:

n:	1		2		3		4		5		6
$3n^3$:	3		24		81		192		375		648
D_1:		21		57		111		183		273	
D_2:			36		54		72		90		
D_3:				18		18		18			

$2n^4$:

n:	1		2		3		4		5		6		7
$2n^4$:	2		32		162		512		1250		2590		4802
D_1:		30		130		350		738		1342		2210	
D_2:			100		220		388		604		868		
D_3:				120		168		216		264			
D^4:					48		48		48				

Next, consider a sequence of polynomial expressions where the polynomial expressions have multiple exponents of n, such as $2n^2+n$:

n:	1		2		3		4		5
$2n^2+n$:	3		10		21		36		55
D_1:		7		11		15		19	
D_2:			4		4		4		

You can see here that there are still two differences, as determined by the $2n^2$ term, and the final difference is 4, as we would expect if we had a sequence of just $2n^2$ (2×2! =4). This demonstrates that, regardless of lower exponents of n, the final difference and number of differences is determined by the highest exponent of n and its coefficient. Here are more examples:

$3n^2+2n+3$:

n:	1		2		3		4		5
$3n^2+2n+3$	8		19		36		59		88
D_1:		11		17		23		29	
D_2:			6		6		6		

n^4+2n^2+1:

n:	1		2		3		4		5		6		7
n^4+2n^2+1	4		25		100		289		676		1369		2500
D_1:		21		75		189		387		693		1131	
D_2:			54		114		198		306		483		
D_3:				60		84		108		132			
D_4:					24		24		24				

In the examples above, there were constants added as well. You can see, however, that they did not affect the final difference or the number of differences. This is because adding a constant to two terms does not affect the difference between those terms, and so, as we added constants to all the terms, none of the differences were affected.

Now we should consider some algebraic explanations. Take a sequence of n^2. Before we were using numbers as our 'n' values, but we can also use n, n+1, n+2, +… instead. This will mean that the final difference, etc., will be true for any (integer) value of n:

n^2:

n^2:	n^2		$(n+1)^2$		$(n+2)^2$		$(n+3)^2$		$(n+4)^2$
=	n^2		n^2+2n+1		n^2+4n+4		n^2+6n+9		$n^2+8n+16$
D_1:		$2n+1$		$2n+3$		$2n+5$		$2n+7$	
D_2:			2		2		2		

FINALLY an^2+bn:

an^2+bn:	an^2+bn		$a(n+1)^2$ $+b(n+1)$		$a(n+2)^2$ $+b(n+2)$		$a(n+3)^2$ $+b(n+3)$
=	an^2+bn		$an^2+2an+a$ $+bn+b$		$an^2+4an+4a$ $+bn+2b$		$an^2+6an+9a$ $+bn+3b$
D_1:		$2an+a$ $+b$		$2an+3a$ $+b$		$2an+5a$ $+b$	
D_2:			$2a$		$2a$		

Thus, we can see that the final difference of any sequence of polynomial expressions is equal to the highest exponent of n, factorial, then multiplied by that exponent of n's coefficient i.e.: $a(x!)$, and that lower exponents of x don't matter, and that the number of differences is equal to that highest exponent of x.*

*(For positive integer values of x and integer values of n) negative integer values of n can be written as positive integer values of n multiplied by −1, which can then be incorporated into the coefficient.

(It should be noted that this is not a complete, formal proof.) △

Modelling the Juno Mission:

an investigation into orbital mechanics

Joshua Cudby

Almost 5 years after her departure, Juno, wife of Jupiter, greeted her husband on the 4th July, 2016 in a stable orbit pattern, after travelling around 2,800,000,000km at a cost of $1.1bn. Over the next 2 years, Juno will begin to decipher the secrets hidden beneath the storms of our solar system's largest planet.

BASICS OF ORBITAL MECHANICS

When planning real space missions, the calculations are so complex that numerical methods must be used, and only an approximate solution to a trajectory can be found algebraically. In order to make such a calculation, the following assumptions can be made:

1. Each large body in the solar system has its own 'sphere of influence' in which its, and only its, gravity is applied.
2. All planets move in circular orbits around the sun.
3. All planets lie in the same plane; therefore, the solar system can be modelled in 2 dimensions.

In addition, the following terms will be in common use:

1. GM is the standard gravitational parameter of a body, in m^3s^{-2}, and its value is the mass of the large body multiplied by the gravitational constant; this value is crucial for all orbital calculations.
2. Periapsis is the point on an elliptical orbit closest to the body being orbited; apoapsis is the opposite, the most distant orbital point. The semi major axis, a, is the average of these two points, and can be thought of as the 'long radius' of an orbit, and similarly b is the semi-minor axis.
3. Eccentricity, e, describes the shape of an orbit, where a circle has 0 eccentricity and ellipses have 0<e<1. When e>1, the orbit becomes hyperbolic, meaning the small body will escape from the larger one.

DIRECT JUPITER TRANSFER

Due to the great distance covered during the mission, it would be impossible to send a probe directly to Jupiter, as such a manoeuvre would require a huge delta-v (the scalar impulse produced by rockets). Specifically, a Hohmann transfer from Earth to Jupiter, in which an elliptical path is used to change between two circular orbits, would require the following Δv:

$$\Delta v_{total} = \Delta v_1 + \Delta v_2$$

$$\Delta v_1 = \sqrt{\frac{GM}{r_1}}\left(\sqrt{\frac{2r_2}{r_2+r_1}} - 1\right) \text{ and } \Delta v_2 = \sqrt{\frac{GM}{r_2}}\left(1 - \sqrt{\frac{2r_1}{r_2+r_1}}\right),$$

such that $\Delta v_{total} = 14{,}433$ m/s

Given that $\Delta v = I_{sp}.\mathrm{g}.\ln\left(\frac{mass}{dry\ mass}\right)$, the ratio of fuel to payload required can thus be calculated

$$\frac{Mass}{Dry\ Mass} = e^{\frac{14{,}433}{318*9.81}} = 102.16$$

Therefore, for such a manoeuvre to be viable with current propulsion technology, a ship that can carry over 100 times more mass of fuel than the mass of the ship must be designed. In fact, the Juno probe itself actually accounts for over 40% of the total mass, making a Hohmann transfer unfeasible, despite this being the most fuel efficient direct transfer path.

GRAVITY ASSISTS

One method to reduce the delta-v required to reach Jupiter is to harness the gravity of other bodies in the solar system to accelerate the probe. In this case, a hyperbolic orbit is used: one in which the orbiting body has enough velocity to escape the gravitational pull of the massive one.

Specifically, the Juno probe completed an earth fly-by on 9th October, 2013 at a minimum altitude of just 500km, and in doing so increased its velocity by 7,300 m/s. To complete this manoeuver, the probe must be placed in an elliptical orbit that has a periapsis of the Earth's orbital radius about the sun, and an orbit time of 765 days. The apoapsis (r_B) of this orbit can be calculated numerically, and the delta-v required follows.

$$e = 1 - \frac{r_A}{a_{tx}}$$

$$v = \arccos\left[\frac{\left(\frac{a_{tx}(1-e^2)}{r_B} - 1\right)}{e}\right]$$

Using these equations, an apoapsis value of 340 million kilometres is found. Using the same formula as to calculate $\Delta v1$ earlier, as again we are burning to reach an elliptical orbit, we reach a Δv of 5320 m/s. Therefore, the combined delta-v of launch and gravity assist is around 12.6 km/s, in excess of the required delta-v for a Hohmann transfer, allowing a faster path between Earth and Jupiter, at the cost of having to perform an additional 2-year orbit about the sun.

$$E = \arccos\left(\frac{e + \cos v}{1 + e\cos v}\right)$$

$$TOF = (E - e\sin E)\sqrt{\frac{a^3}{GM}}$$

JUPITER CAPTURE

Once the sufficient velocity has been achieved, the probe can reach the orbit of Jupiter, but another burn is required to ensure it is actually captured by Jupiter's gravity. Juno first entered a polar orbit that lasts 107 days, while also setting up the correct geometry for future orbit-adjusting burns, at the end of which it will enter a series of 11-day orbits.

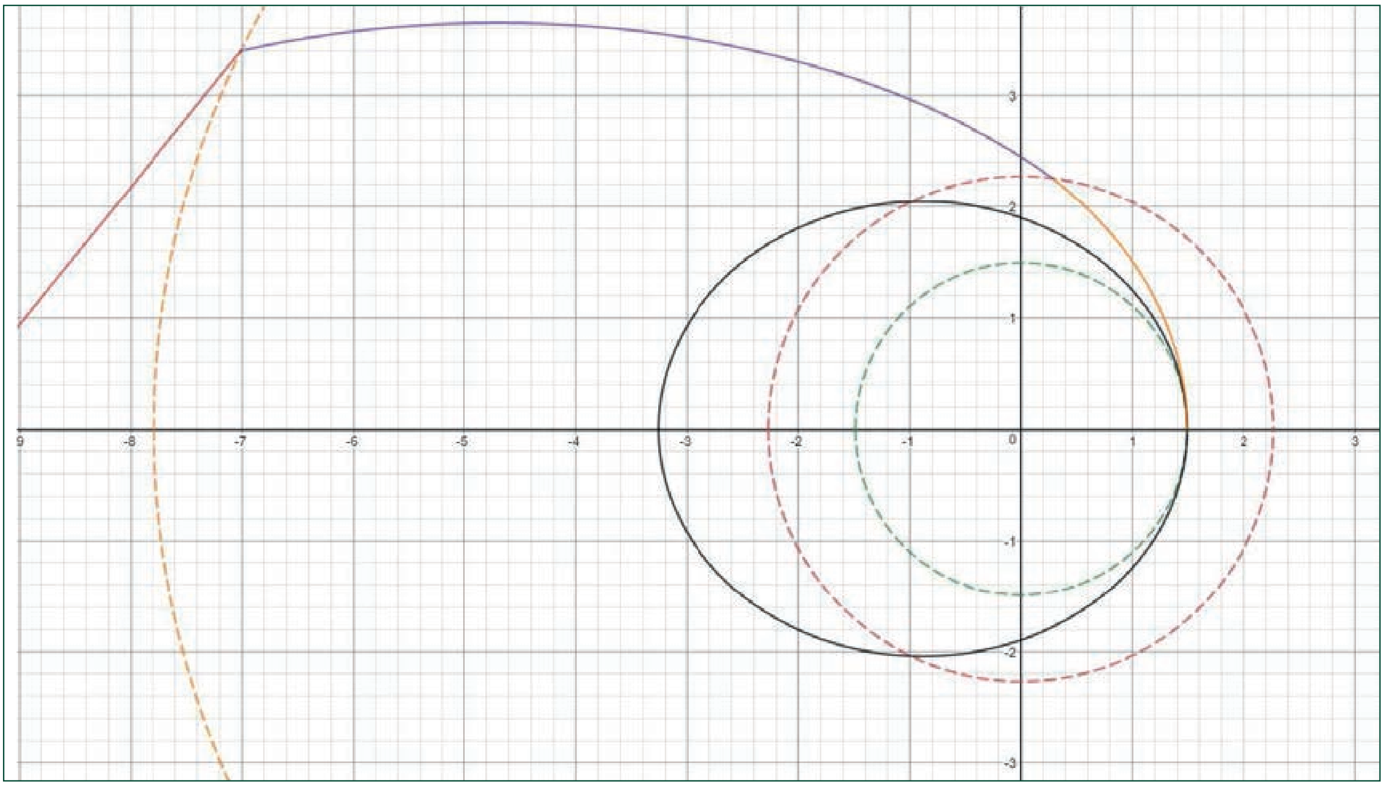
Using the formula $v = \sqrt{GM(\frac{2}{r} - \frac{1}{a})}$, the probe had a velocity of 7,417.3 m/s upon reaching Jupiter. To reach an orbit of the correct period, the probe must follow a path with a semi-major axis given by the formula $a = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$, leading to a = 1,426,000 km. These orbits are highly eccentric (i.e. very elliptical) and therefore Juno passes within 2,000 km of the surface at perijove, at speeds of over 57 km/s, and is therefore the fastest spacecraft ever. Over the course of the next year, it will complete 33 of these 11-day orbits, covering almost the entire surface of Jupiter. Once Juno approaches mission end, it will enter a controlled, destructive descent into the Jovian atmosphere which will burn up the entire probe. This will avoid any uncontrolled debris that could impact with targets of future missions, such as the moon Pandora.

PLANNING A FUTURE MISSION: SENDING A PROBE TO NEPTUNE

Using the principles above, a similar mission can be planned, which will enter into a stable orbit around Neptune while remaining within the delta-v budget available to current technology. The basic trajectory plan can be seen below, and consists of a series of successive gravity assists around Earth, Mars, Jupiter and Saturn, before a braking manoeuver around Neptune's moon Proteus allows the probe to enter orbit.

LAUNCH AND EARTH ASSIST

By assuming a launch configuration identical to that of Juno, an initial, heliocentric orbit that will return to Earth's orbit can be calculated (shown in black). This path takes the probe to twice the Earth's orbital radius (2AU) before returning to its initial position after exactly 2 years. This orbit is favourable for the Earth gravity assist, but requires a significant launch delta-v of 12,000m/s, which can be provided by boosters discarded during the launch phase. Having completed one orbit, the probe will have a velocity of 35km/s, which will be increased to 38km/s after the Earth fly-by, in much the same way as Juno.



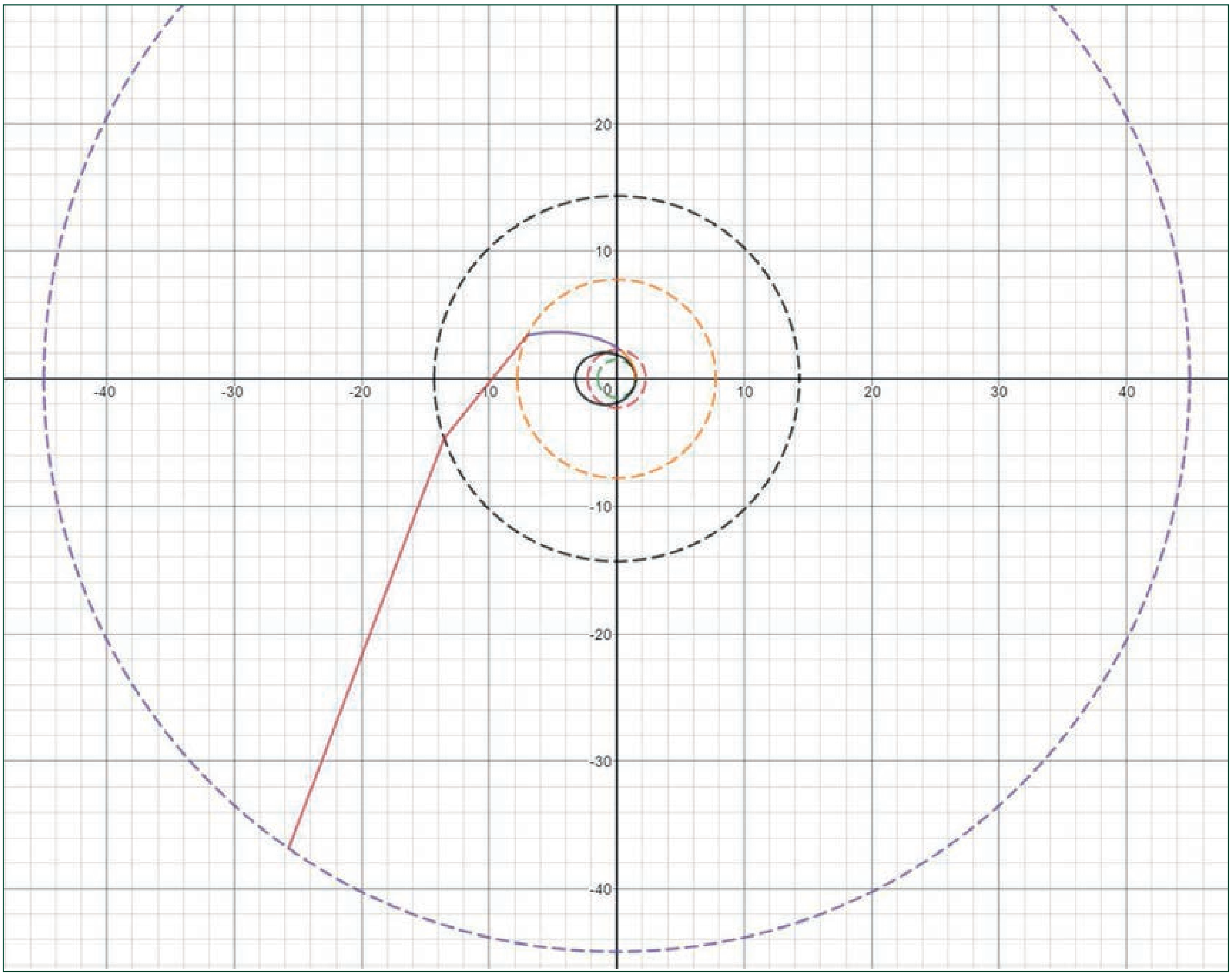
= Earth

= Mars

= Jupiter

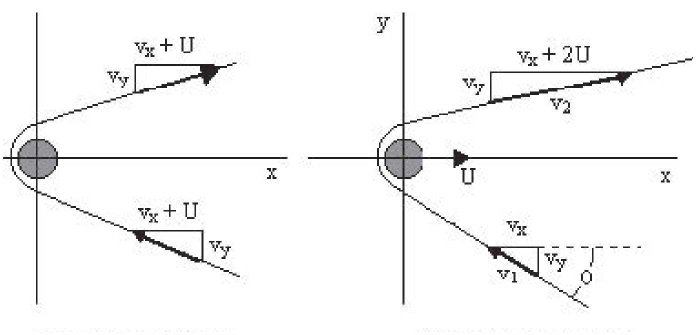
= Saturn

= Neptune



MARS FLY-BY

The increased velocity after the first assist slightly alters the orbit path, to that of the ellipse shown in orange, which would venture as far as 5AU from the Sun. However, partway through this orbit, it intersects Mars, at which point it has a heliocentric velocity of 29km/s and an approach angle of 142°. From these two pieces of information, the effect of the slingshot can be calculated:



Planet's Rest Frame *Solar Reference Frame*

Assume a frame of reference in which the planet's motion, which is assumed to be instantaneously straight, is the x-axis. The initial and final velocities can then be written as functions of θ and U, the planet's velocity, for both the x and y directions. Under this model, Vy is constant for a given θ, whereas Vx gains 2U through the solution of conservation of momentum and kinetic energy (see appendix):

$V_{1x} = -v*\cos(\theta)$	$V_{1y} = v*\sin(\theta)$
$V_{2x} = v*\cos(\theta) + 2U$	$V_{2y} = v*\sin(\theta)$

By resolving V_{2x} and V_{2y}, the resulting direction and speed are found. With θ = 2.48 and V_1 = 29,200, the exit angle is 0.62 (35.5°) and speed is 30,800 m/s. Notice that as the deflection was small, due to entrance and exit angles summing to near 180°, the increase in velocity was equally minor. The resulting path is again elliptical about the sun, but with a slightly decreased time of flight to Jupiter.

JUPITER AND SATURN ASSISTS

Once again, a gravity assist will be used to increase velocity. However, in this case that angle of approach is significantly more acute, and the angle of deflection is resultantly greater, leading to a velocity increase of 11km/s after the 35° deflection, such that the probe now moves at 22,606m/s. At this point, the probe is moving at a speed such that it could escape the Sun's gravity if it did not interact with any other objects. Hence the orbit is now hyperbolic about the Sun, and the path can be modelled as straight lines representing the asymptotes of the full orbit. Such an orbit is formed when the semi-major axis is negative, calculated by the formula $a = \frac{r\cdot GM}{2GM - r\cdot v^2}$. Therefore, a hyperbola is formed when $v > \sqrt{\frac{2GM}{r}}$, which requires only 18,500m/s at Jupiter, far exceeded by the probe. Although a hyperbolic orbit affects some time-of-flight calculations, principal calculations such as velocity remain unaffected by the orbit shape. The assist at Saturn is similar albeit less dramatic, providing a modest 5km/s of delta-v, which provides the ship with enough velocity to comfortably reach Neptune after a long cruising period.

NEPTUNE CAPTURE

While travelling through the solar system, high velocities were necessary both to escape the Sun and also to make the flight time reasonable. However, on arrival at Neptune the probe is still moving at over 20km/s, which is far too fast to be captured; instead, it would effectively perform a gravity assist around Neptune before heading into deep space, much as Voyager 1 & 2 did. To avoid this, a braking manoeuver must be performed, but using only engine burn would require a delta-v of 10km/s, to under 10,780m/s, which would be impossible outside of launch. Therefore, another gravity assist must be used, this time around Neptune's moon Proteus, which is suitable for its orbital direction and speed.

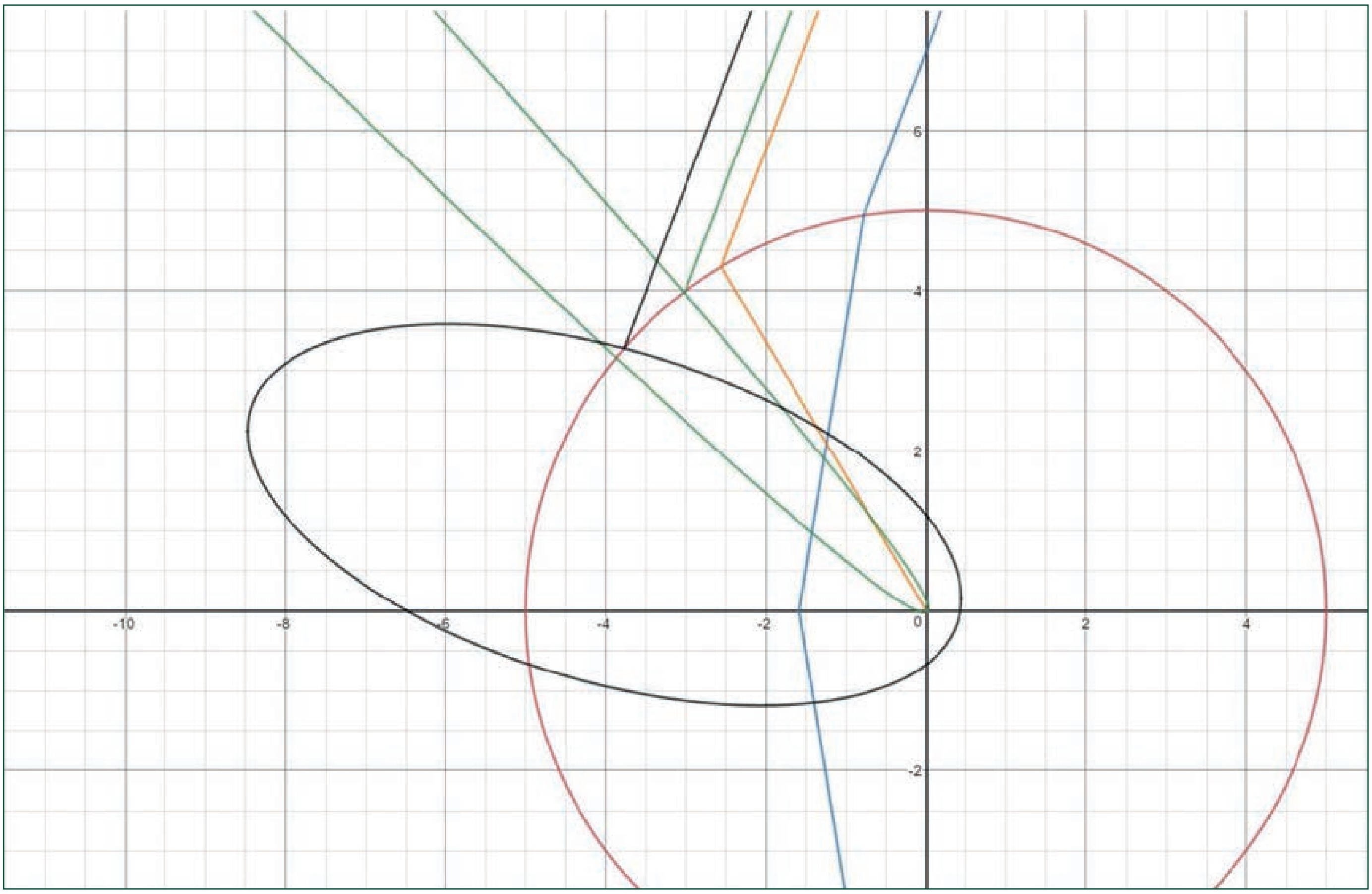
In order to brake during the manoeuver, V_{2x} must be lower than V_{1x}:

$$-v_1\,cos(\theta) > v_1\,cos(\theta) + 2U \rightarrow cos(\theta) < -\frac{U}{v_1}$$

Here, this leads to >113.1° for a braking manoeuver. Although the entry angle of the probe is constant, the position of Proteus on its circular orbit gives different intersection angles, as shown in the figure below, leading to different braking scenarios. At angles where is close to 113°, such as the blue path, the braking is not sufficient to enter orbit, and the probe will continue on its path out of the solar system. When 141.7°, the probe leaves perpendicular to Proteus, and therefore collides directly with Neptune. However, at very obtuse angles, at which the probe is deflected by enough to reverse its direction with respect to the moon, velocity is reduced greatly.

One such angle of approach is 148°, the path shown in green below, which gives a velocity of 10,400m/s, very slightly under escape velocity. Such a path is unfavourable as it provides a poor orbit around Neptune: by solving for a, this angle provides the semi-major axis as 780,000km. This orbit is highly eccentric, passing just 300km above Neptune at periposeidon and reaching speeds of 213km/s. This would make the proportion of time spent near Neptune incredibly low so that the mission becomes inefficient, as well as causing massive tidal forces on the ship.

A more optimal solution is found at 160°, which gives a brake down to a speed of 7,300m/s. This far slower speed gives a smaller axis of around 100,000km and an orbital period of just 23.84 hours. Also, the probe is pointing less directly towards Neptune after it passes Proteus compared with the green path, and as such passes at a more reasonable distance from Neptune: around 11,500km at 34km/s. If closer passes were necessary for some observations, then a small lowering of will decrease periposeidon throughout the orbit; alternatively, a burn at apoposeidon will allow minor adjustments to the course, lowering by approximately 200km for each 10m/s of delta-v.

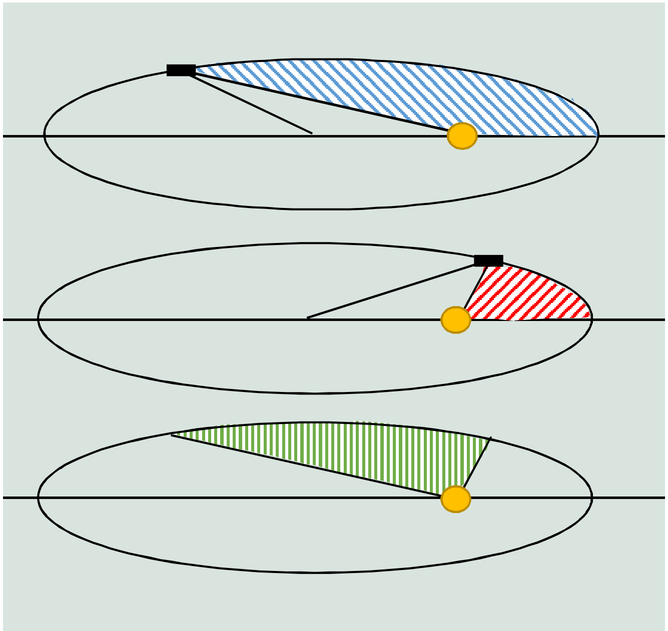


MISSION VIABILITY

One important consideration is the time necessary to complete the mission: although deep space missions always require significant time investments, the path of successive gravity assists should somewhat decrease the length.

One of the most fundamental laws of orbits, first discovered by Johannes Kepler, is that elliptical orbits "sweep out equal areas in equal times". Therefore, by calculating the percentage of the full ellipse covered by a section of orbit, the time required can also be found by simply multiplying the orbital period by the percentage area covered. However, there is some difficulty in calculating areas of sectors of ellipses from focal points.

Allow the centre of the ellipse to be the origin, and set a value for a such that x =a*cos$a$ passes through one end-point of the orbit (where a is the semi-major axis). Then $A = *\frac{1}{2}a$ *a *b, from the centre of the ellipse. Then subtract from this value the area of the triangle formed by the centre, the focus, and the point chosen, to give the area swept around the focus from the horizontal to the end point. Repeat this for the second point; finally, subtract the two focal values to find the area swept by the probe around the sun.



For hyperbolic orbits, the calculation is somewhat more complex, requiring calculation of the true anomaly (υ) and hyperbolic eccentric anomaly (F) at two points. The eccentric anomalies can then be used to find the time taken between the points according to the following equations:

$$\upsilon = acos\left(\frac{a(1-e^2)-r}{e*r}\right); F = acosh\left(\frac{e+\cos\upsilon}{1+e\cos\upsilon}\right)$$

$$t_1 - t_0 = \sqrt{\frac{(-a)^3}{GM}} \cdot [(e\,sinh(F_1) - F_1) - (e\,sinh(F_0) - F_0)]$$

By resolving these time calculations, the following values are found for each mission section:

Orbit Section	Time (years)
Earth launch and assist	2.000
Earth to Mars	0.224
Mars to Jupiter	1.451
Jupiter to Saturn	1.330
Saturn to Neptune	4.820
Total	9.825

A mission length of 10 years, while significant, is by no means a barrier to viability if there was sufficient scientific interest in Neptune or its satellites. However, it does mean that inner system missions are considerably more attractive in terms of short-term return.

More importantly, until now we have assumed that planets are always present in convenient parts of their orbits for the gravity assist. In reality, only a very specific initial placement of planets would allow the probe to follow this path; this is the launch window for the mission. To find this orientation of planets, the time required to reach each one can be divided by the orbital period of that planet to see how many orbits it completes and therefore what position it must have at launch.

Unfortunately, this particular orbital path requires an orientation of the planets that will not be available for a number of years in the order of magnitude of 10^{18}. It is for this reason that protocol normally requires numerical solutions based on planet locations rather than algebraic ones. One time at which a similar mission would have been possible was in 1977, at the time of the Voyager launches: here, the outer planets formed an almost perfect spiral, allowing these consecutive gravity assist paths to be easily executed.

Overall, for the near future, the alignment of outer planets does not easily lend itself to deep space missions. Instead, inner system exploration could have more potential, perhaps through a focus on Lagrange points to reduce delta-v requirements.

APPENDICES

SOLVING NEWTONIAN EQUATIONS FOR GRAVITY ASSISTS:

Assume an approach angle of 180° leading to a reversal of direction. Therefore:

$$MU_1^2 + mv_1^2 = MU_2^2 + mv_2^2$$

$$MU_1 - mv_1 = MU_2 - mv_2$$

Consequently, $v_2 = \frac{\left(1-\frac{m}{M}\right)v_1+2U}{1+\frac{m}{M}}$, through elimination of U_2 and solving for v_2. As the mass of the probe is negligible compared with that of a planet, m/M is approximately zero and thus. In this scenario, velocity is in the x direction only, but the same principle applies when the angle changes, i.e. when v_1 is substituted for v_1*cos(θ) and v_1*sin(θ).

SAMPLE ORBITAL CHARACTERISTICS CALCULATIONS:

HELLO_ELLIPTICAL_2	
GM	1.327712E+20
Periapsis	1.49E+11
Apoapsis	7.02E+11
Semi-Major Axis	4.25455E+11
Semi-Minor Axis	3.23395E+11
Eccentricity	0.65
Orbit Period	4.80
Vp	38333.33

SAMPLE GRAVITY ASSIST CALCULATIONS:

MARS_HYPER	
Approach speed	29201.43907
Mars speed	24100
V1(x)	23065.549777
V1(y)	17908.22319
Approach angle	2.481404994
Exit speed	30861.70842
V2(x)	25134.45023
V2(y)	17908.22319
Exit angle	0.619064139

SAMPLE ELLIPSE SECTOR CALCULATIONS

a	6.34	a	6.34
b	3.65	b	3.65
x1	-2.31	x2	4.99
y1	3.40	y2	2.25
Alpha	1.94	Beta	0.67
Centre	4.70	Centre	4.70
Height	3.40	Height	2.25
Area from centre	22.49	Area from centre	7.70
Centre-focus area	7.99	Centre-focus area	5.30
Focus area	14.49	Focus area	2.40
Total focus area	12.09	Total area	72.72
Percentage area	16.63		
Time	1.451	YEARS	

SAMPLE HYPERBOLIC TIME CALCULATIONS

a	-1.29E+12	a	-1.29E+12
r	7.79E+11	r	7.79E+11
e	1.30	e	1.30
v0	1.46	v	1.86
coshF0	1.23	coshF	1.62
F0	0.67	F	1.06
t-t0	1.33	YEARS	

"Like ants or frogs around a pond"

(Plato): was the sea central to Greco-Roman history?

Matthew Sargent

Wandering the streets of Ancient Rome or Athens, the remnants of a glorious past are not hard to detect; an immensity of temples and amphitheatres littering the hillsides; grandiose statues and triumphal arches; a splendour all quite overpowering. One naturally associates opulence with the cultures of the ancient world and thus we rarely consciously think about the origins of such prosperity and, specifically, the role the sea has to play. The influence of the sea was certainly profound on both Greek and Roman history, economically, politically and culturally, mainly due to their geographical proximity and maritime dependence, so it is only natural we observe similarities between the two countries. However, there were also significant differences in both countries' relations with the sea and in particular their respective outlooks towards it, so although the sea is a central factor in their histories it is not determining. We can only hope to understand Greco-Roman history by examining the attitude they had towards the sea and the different ways the sea shaped their national identities.

The issue of identity is particularly relevant when examining the aforementioned quotation by Plato. His expression "like ants or frogs" seems to testify to something deeper than just people living at the water's edge but instead to a collective civilization. For the Minoans and Mycenaeans, the sea was the bedrock of their civilizations. The Minoans were a mercantile people, so the sea was integral to their survival. To help protect their commercial interests, they built a powerful fleet; Herodotus asserts that they were "the first of the Greeks whom it was thought was master of the sea". Their widespread trade, secured by their navy, circulated Minoan goods, such as pottery and saffron, to most ports in the eastern Mediterranean, and with the expansion of Minoan trade also came an explosion of Cretan cultural influence, corroborated by Minoan mosaics in Israel, frescoes in Santorini, and jars and bull's head rhytons in Mycenaean tombs. Strangely enough, however, amongst contemporary sources the Minoans were not the peaceful people they are made out to be today. Thucydides says that Minos "ruled over the Cyclades, into most of which he sent the first colonies" and, if true, then it appears the Minoans did not only achieve cultural and economic supremacy over the islands of the Aegean but also military predominance. Their skill as a seafaring people was the very essence of their civilization; their palaces a reflection of their maritime prowess. The sea had a similarly dominant role in the development of Mycenaean Greece, and arguably theirs was a civilization just as reliant upon "dominion of the seas" (Wunderlich) as Minoan Crete. The legend of the Trojan War is thought to have been inspired by tales of Mycenaean expeditions to Troy; as for Mycenae's wealth, which gained her the Homeric epithet "rich in gold", that emanated from her extensive trade routes, which stretched from Egypt to Spain. It seems, however, that the Mycenaeans' attachment to the sea penetrated further than just economic and military feats, and that in reality it significantly influenced their culture and identity. Spyridon Marinatos argues that the Lion Gate at Mycenae can quite easily be perceived as a piece of thalassocratic artwork; that the relief above the gate, rather than simply depicting the Mycenaean royal crest, does in fact testify to "a union of two kingdoms of the sea": Mycenae and the conquered Minoan state. There is hardly a more comprehensive statement of identity; they saw themselves as a people 'of the sea'.

The Dorian conquests and the 'Dark Ages' that followed the Minoans and Mycenaeans would cause the Greeks to become insular, largely severing their links with the Near East, and this period of isolation would last approximately 300 years. Towards the end of the period, the emergence of the polis would lead to a revival in sea trade, bringing Greece both newfound economic prosperity and modern innovation from the East. Partly in an attempt to expand this trade, partly to cater for the needs of an ever-increasing population, groups of Greeks began to leave their existing communities and venture into the Mediterranean and settle colonies. These colonies were not clustered in any one place but spread from Sicily and southern Italy (Magna Graecia) to the Black Sea, Massilia and Nicaea, although as a general rule their cities tended to appear along trade routes, making communication between Greece and its colonies much easier. These early outreaches had a profound impact on Greek culture, as with the steady flow of imports to Greece simultaneously came a dramatic influx of Eastern cultural ideas making "subtle inroads on traditionalism" (Green). Not only did it have an impact on pottery and artistic design – as exemplified in Greek 'kouroi' sculptures, which derived much of their design from links with Egypt – it also lent Greek mythology its store of monsters; Euripides' sphinx, Homer's sirens, and griffins and gorgons too all trace their origins to Eastern influences. Secondly, colonisation tended to promote a feeling of unity among the Greeks – the origins of their fearsome 'Hellenism' – which sprang from their increased contact with barbarian peoples in far-flung lands. Central to this flowering of a clearly defined identity was the development of a common tongue, and again they stole this from another people. The Phoenician alphabet, which arrived in Greece via the sea routes, provided the grounding for the Greek language, which was an immense source of national pride and the cornerstone of Greek identity. Greece never lost its association with the sea. In the period after the Persian Wars, Athens came to dominate the Aegean through the Delian League, a maritime confederation with the ostensible purpose of acting as an alliance against future Persian threats. As Athens had the largest fleet, it led the alliance. It must have appeared tempting for the other Greek poleis; in exchange for Athenian policing of the waters, all they needed to contribute was the occasional payment of tribute. However, quickly the League was discovered for what it was – the puppet of Athens. Huge tributes were demanded of the allies – Diodorus notes that "The Athenians, maintaining their claim to sea hegemony brought to Athens…..some 8000 talents" – and if members refused to pay up or rebelled the fleet would be sent to impose order, as Thucydides explains when Naxos resisted in 467 BC: "the Athenian squadron began to blockade Naxos". For her neighbours, the Athenian domination of the sea was deeply frightening; what was there to prevent their maritime empire expanding further and engulfing them completely? The ensuing Peloponnesian War was triggered by Spartan fears of Athenian imperialism and although the Spartans may not have agreed with the Themistoclean doctrine "he who controls the sea controls everything", they certainly feared it coming true. Sparta had been a land power ever since Lycurgus had "established the military system" (Herodotus) in the 800s BC. According to Plutarch, Lycurgus had advocated "A wall of men", an outlook that would inevitably put the Spartans at loggerheads with other poleis such as Athens, who favoured the "wooden wall" of their navies instead. Despite this fault line, we should not assume Sparta played any less a role in shaping Greek history – Sparta's conquest of Messenia established her as the dominant force in the Peloponnese. That said, with the pressures of modern combat, and looking for an upper hand in the Peloponnesian War, Sparta would eventually be forced to create a navy in an attempt to win once and for all – thus emphasising how even the most steadfast of land powers can recognise the value of naval superiority.

Up until now, all the aforesaid civilizations, with only the exception of Sparta, would almost certainly have identified themselves as sea powers. It is therefore remarkable to observe how another such civilization, which again grew up around the Mediterranean, came to express such a divergence in attitude towards the sea. Militarily, Rome always identified herself as being stronger on land, a fact attested to by the comparative sizes of her army and navy – in 211 AD, at its height, the army outnumbered the navy 11:1. As a result, and excluding only a handful of military offensives, Roman expansion tended to take place overland, with countries such as Gallia, Macedonia and Judaea all falling to Rome in this way. The question remains: what was preventing Rome from becoming a great sea power too? The reasons for this are two-fold. Firstly, the Romans had a deep-seated fear of the sea, as Gibbon asserts: "To the Romans the ocean remained an object of terror rather than of curiosity". It had not helped that Rome came to seafaring so late – Livy identifies the birth of the Roman navy as 311 BC – which meant that Rome always considered herself disadvantaged compared with her experienced neighbours, like the Etruscans and Carthaginians. But what perhaps made her most apprehensive was the sheer 'foreignness' and power of the sea. Rome suffered many naval disasters in her time; Eutropius, for example, describes a storm during the First Punic War in which an estimated 100,000 sailors were killed, and "so violent was the storm, that out of four hundred and sixty-four ships, eighty could scarcely be saved". On top of that, Rome's experience of the pirates had further reaffirmed her view of the sea as full of evils. So, by all accounts, the sea certainly proved a "formidable psychological barrier" (Levick) to the Romans. However, arguably the more important of the two reasons is that Rome simply did not need to become a sea power. As Gibbon again points out, "the whole extent of the Mediterranean, after the destruction of Carthage, and the extirpation of the pirates, was included within their provinces", so, given all her remaining enemies were on land, there was absolutely no reason for Rome to fight her wars at sea. Given the distinctive lack of opposition she faced at sea, one can hardly argue that the sea played a significant role in the shaping of Rome's military history. The same cannot be said, however, for Rome's trade. Rome conducted the majority of her trade at sea, the principal reasons for this being the speed of the journeys and also the comparative cheapness – Keith Hopkins estimates that transporting goods was about 50–60 times cheaper by sea than by land. Grain, which was imported solely by sea, was indisputably the most fundamental foodstuff for the Romans, with one 4th century source estimating that, under Augustus, Rome was importing 20,000,000 modii (140,000 tonnes) yearly, making shipping lanes indispensable. The sea routes acted as the arteries of the empire, circulating a lifeblood of money and commodities. However, although the sea routes played an incomparably greater role in trade than the roads, it was the roads that left the more indelible mark on Rome's identity across the centuries. Dionysius was just one historian to extol the virtue of roads, saying that they were the best example of "the extraordinary greatness of the Roman Empire". For the Romans' contemporaries, paved roads were an unparalleled novelty nor had roadbuilding ever been undertaken on such an extreme scale before, and even in the Roman psyche, the roads appear to have occupied a more substantial place of pride – Augustus, for example, had commissioned a map of all the roads in the empire (Tabula Peutingeriana), which was then carved onto public monuments in Rome. So, by all accounts, Rome seemed much more eager to establish herself in the annals of history as a mighty land power, both militarily and commercially.

The very nature of the Mediterranean makes it almost inevitable that a country's identity will be significantly shaped by its people's proximity to the sea. What makes each of these civilizations unique, however, whether it be the Minoans or Mycenaeans, the Archaic and Classical Greeks, or the Romans, is the different ways in which the sea influenced their respective histories and identities. Through examining these contrasting attitudes towards the sea, we are able to achieve a much greater appreciation of history: 'why' something happened, not just 'how' and 'when'. △

Fox urbanisation

James Miller

Foxes are probably the most controversial animals in our Great British fauna. Half of us see them as a beautiful icon of the wild, the other half see them as vermin. Some even go so far as to want to rip them apart alive with hounds.

What causes such differences in view? The word vermin is usually used to describe creatures that prevent us from making maximum profit. Besides being a rather selfish way of looking at things, this is actually incorrect when applied to the fox. The fox's predation on livestock is relatively low, whereas rabbits make up nearly 50% of its diet. Rabbits cost the agricultural sector around £120 million annually, and the fox at least offsets its minor impact by greatly reducing the numbers of rabbits in the area.

This outdated and incorrect view of the fox is possibly the main argument used to try and excuse fox hunting, as well as the fact that it is traditional. Well, that argument is also invalid – just because something is traditional by no means excuses it. The same argument could have been applied to keeping slaves, widow burning, and countless other horrible practices. To use Mark Avery's example, if a man was asked if he beats his wife, and he replies 'Yes, I've been doing it for ages', this by no means changes our view of his villainy.

Luckily, this practice is dying out, and only 13% of the population is currently in favour of fox hunting. Personally, I cannot see it ever returning in our democratic society.

But now the fox is a pest for a different reason – URBANISATION.

This is what my painting is all about; when the fox stopped being the proud symbol of British fauna, and became the low, mangy bin-tipper of the city.

With our population exploding, our cities are growing, spreading across the country like some vile mould. Most species cannot cope, and are forced into increasingly smaller pockets of habitat. But foxes are adaptable and opportunistic. They did not flee from the hard concrete worming its way under their feet, but stayed in rebellion of our invasion.

They instead make do with the food that we waste every day, and because of this they are villainised. It also didn't help when news stories flashed up of foxes attacking babies in cots.

Only one or two babies die a year from fox attacks, but thousands die from dog attacks, so we really can't blame the former and not the latter.

What I'm trying to get at is this: our view of foxes as vermin, a pest to be eradicated, is wrong, selfish and utterly hypocritical. The descent of foxes from a hero to a villain is completely our making, and in the end they still are what they always have been: a wild animal. They have no good and no evil, unlike us, and they simply do what they can to survive, even if that means unwittingly hindering our quest for profit.

Don't condemn. Admire. △

Welcome to the sprawl

Michael Kielstra

William Gibson, as an author, is remembered mainly for two things. The first is his coining of the word 'cyberspace'. He would much prefer that the world forget this and think of him more as an author than a linguistic innovator. The second is his invention of the cyberpunk genre. This is quite well summarised by the phrase 'high tech and low living' although, as with much of Gibson, there's more to it than that. The seminal and fundamental cyberpunk works are those contained in Gibson's Sprawl trilogy: *Neuromancer*, *Count Zero*, and *Mona Lisa Overdrive*. While at first sight they may seem like exercises in worldbuilding, and indeed they sometimes are, the three also chart the development of a philosophy of nihilism, which begins quite crudely in *Neuromancer* and, by *Mona Lisa Overdrive*, has been artfully refined.

Gibson's world is brutal. Every city is the same. The local colour only barely masks the 'biz', the illegal transactions that are the lifeblood of any town. Science and technology have run riot, creating such things as 'simstim', a method for inducing programmable hallucinations that has replaced TV. Space is colonised but, even "up the well", there is no escape from the biz. To survive in this environment, mankind has had to adapt, augmenting itself with everything from 'microsofts', small chips that slot into a socket implanted behind the ear and download knowledge into the brain, to vat-grown muscles grafted onto the arms of 'joeboys', or bodyguards. Much of what Gibson writes is descriptions of the Sprawl or cities like it, and it is this world that has ensured his place in the history of literature.

The Gibson character with possibly the greatest impact on the public consciousness is Molly Millions from *Neuromancer*, who also appears, in a supporting role, in *Mona Lisa Overdrive* (although she goes by Sally Shears in that novel). She is a 'razorgirl', a 'street samurai', who makes a living out of delivering death with grace. Her weapon of choice, when she is not relying on the retractable blades implanted under her fingernails, is a 'flechette pistol', a dart gun able to deliver anything from high explosives to bioweapons. Her speech is liberally sprinkled with profanities, the hard exterior masking deep emotional scars. In order to pay for the operations necessary for her chosen career, she became a prostitute. "Joke, to start with," she calls it, but "the dreams got worse and worse," and eventually she is driven to kill one of her clients, a senator with a snuff fetish. After the death of her first, and only, love – a young man named Johnny with whom she had a long relationship before they blackmailed the Yakuza one time too many – she has "never much found anybody [to] give a damn about". Her entire being is based around causing grief, and her coping strategy is to laugh it off and never think too closely about the happiness she might have had.

The philosophy of *Neuromancer*, as represented by Molly, can be described by an abridged version of the famous phrase from *Terminator*: "No fate." Molly bounces around from job to job, from place to place, and from goal to goal without ever finding anything to which she can properly settle down. Even Johnny, with all his promises of a stable home life, is murdered by the Yakuza. When Case, a 'console cowboy', computer hacker, and somewhat reluctant major player in the events of *Neuromancer*, asks her for whom she worked before she worked with him, she replies, simply, "For somebody else. Working girl, you know?" Again, her response to her confession of instability is a tired joke. Case himself is an equally good illustration. From being described as "one of the best in the Sprawl," he becomes "just another hustler", after making "the classic mistake, the one he'd sworn he'd never make". At the end of an undescribed job before the beginning of the book, he tried to double-cross his employers, keeping back some of the money they were stealing. They found out and used a Russian mycotoxin to destroy the nerves that connected him to his computers. It does not matter how much he had promised himself that he would be smart, when the time came he was just as stupid as the rest of them. Nothing, in the end, marks Case out as any better.

Even at the end of the book, Case has not improved. He has defeated police, dangerous security, insane teammates, and personal failings; he has pulled off the ultimate hack; and his reward is described simply as "He found work. He found a girl who called herself Michael… He never saw Molly again". He has been on the rollercoaster ride of his life, from the Sprawl to the backstreets of Chiba City to Istanbul to high orbit, and all he gets is a free ride back to the Sprawl. Compare this with the standard reward for a hero in a standard fantasy novel: the hand of the beautiful princess and half the kingdom. Case has done things far more dangerous than many knights in shining armour ever did – working with Peter Riviera, an insane sadomasochistic holography expert, for one – but his reward is nothing more than a regression to the mean of his life. This is not even a tale of redemption, as Case is not redeemed: he has learned nothing and there is no implication that he will not, eventually, try and fail to double-cross his employers again. Neither Molly nor Case are able to make any serious change in their situations. Both of them seem to take life one day at a time, not because that is an inherently better way to live, but because they have no alternative. Life only comes one day at a time, and plans to better it (Johnny; Case's drug addiction, defeated by a doctored pancreas) are frustrated by the endless torrent of random chance. This is the most pessimistic nihilism possible. Not only is there no fate, destiny, or deeper meaning to life, but no-one is able to invent one for themselves either. Case and Molly have both, independently, long since given up their feeble attempts at making better lives for themselves because they both realised that anything they attempted to do would be stymied by events over which neither they nor anyone else had any real control.

The one being who Gibson allows us to think might possibly have a chance at making some sort of fate for himself is a ferociously smart artificially intelligent being (AI) known as Wintermute. Wintermute is the prime mover throughout the book, recruiting Armitage, Molly, and Case for the hack that will set him free. He is able, mostly, to predict what everyone else will do through his 'psychological profiles', and is probably the one with the happiest ending. However, he and his enigmatic counterpart Neuromancer, after whom the novel is named, are eventually just as powerless as the rest of them. The master plan hinges on Lady 3Jane Marie-France Tessier-Ashpool speaking a code word (which the reader never learns) to a particular computer terminal at a particular time. Wintermute is fundamentally unable to control this: he describes himself as "that which knoweth not the word". The King James Bible language is his way of saying that his non-knowing of the word is as deeply ingrained into his being as if it had been placed there by an all-powerful God. For all his foreknowledge, for all his power (demonstrated when he kills three police officers and shrugs it off with a casual "Hadda [had to]. Hadda."), Wintermute cannot make any substantial change in his own fortunes either. *Neuromancer*'s world is one in which nobody, not even someone who can predict the actions of thousands of other people at once, can change anything for themselves, instead having to rely on the whims of others and on random chance. There is no stronger nihilism than this.

Count Zero, set years after the events of *Neuromancer*, tests the ideas of its predecessor novel and finds some of them wanting. The titular character, Bobby Newmark, a.k.a. Count Zero Interrupt, a.k.a. the Count, is a wannabe hacker from Barrytown, a run-down, drugged-out housing project, whom the reader first sees powerless to stop a deadly cyberspace attack. "It was such an easy thing, death" is Gibson's attempt at the Count's epitaph. However, he is saved by "vastness unutterable", a mysterious figure of a girl. At first glance, then, Gibson is retreading old ground: Case was also saved from certain death by a mysterious woman (Molly, who recruited him out of the gutters of Chiba City and saved him from an inevitable hustler's death). However, it soon becomes apparent that the Count is different from Case, with regard not only to his vastly inferior hacking skills, but also the way he moves through life. As opposed to Case, the Count is constantly trying to increase his influence and get out of Barrytown, and in the end his efforts are rewarded. While he does not complete any hacking runs on the level of Case's work, he is told by Beauvoir, an expert hacker and mercenary, that he "did good. Earned [his] handle". He goes on to become the rich boyfriend of a famous actress. Again, unlike Case, much of what he does is of his own volition. By running away, he saves his own life from the explosion that destroys his mother's apartment. While much of his behaviour is still dictated by someone else, and he follows more or less unquestioningly where Beauvoir leads him, he is well on his way to becoming master of his destiny.

The other two stories told in parallel reinforce this idea. Marly Krushkova is hired by the awesomely rich Josef Virek to locate the maker of a series of dioramas that intrigue him. Virek spends his life in a simulated reality, because in actual reality he is a mass of cancerous cells in a support unit that he describes as "a thing like three truck trailers, lashed in a dripping net of support lines". For some reason, Virek feels that the maker of these boxes would be able to make him a new physical body. Throughout the novel, Marly feels Virek's agents moving around her, anticipating her every move, and eventually finds incontrovertible proof that "the machine, the structure, was there, was real" when Virek appears to her in a movie on a shuttle flight. However, unlike Molly, who simply obeys when confronted with the structure of Wintermute's power, Marly fights. Eventually, she refuses to give Virek what she wants, at the risk of her own death. Given an hour to surrender, she instead spends that hour "adrift in the slow storm, watching the Boxmaker's dance". She never even considers giving Virek what he wants, and is, again, rewarded. Her ending is, if possible, happier than Bobby's: she becomes the curator of an exclusive Paris art gallery. The similarity of her name with that of Molly reinforces the contrast between the two.

The one principal character in *Count Zero* who does not fight his situation is Turner. A mercenary specialising in breaking executives out of their 'arcologies', corporate structures that are home, office, and prison all at once, he does not react much at all when the microlight plane he has been expecting contains not Christopher Mitchell, the latest extraction target, but a young woman who is later revealed to be Angie Mitchell, Christopher's daughter. Although he does attempt to find out what had gone wrong and get Angie to safety, he never stops thinking or acting like a mercenary. He rolls with the punches, similarly to Case, with the result that the reader never actually sees the ending to his story. Without a moderately happy ending for Turner, the other stories could never be well-resolved, so he is allowed to escape to "the next airport Hyatt. And the next," always moving, never finding peace, always on the lookout for the next "slamhound". Indeed, when he leaves, only Bobby asks him where exactly he'll go, and his response is "I've got to buy eighty litres of kerosene first, then I'll think about it". As opposed to *Neuromancer*, where death is the accepted result for moving "a little too swiftly… carelessness, lack of grace", Turner is punished for moving too slowly. He never tries to change anything, and so it never changes. This is in stark contrast with Case, who rails against the injustice of the world in short, punchy tirades, but still never manages to change it, or Marly, who delivers slightly more eloquent versions of the same speeches and actually does manage to have an effect. *Neuromancer* is about people who cannot do anything. *Count Zero* is about people who can. *Neuromancer* is about hopelessness. *Count Zero* is about hope.

Mona Lisa Overdrive has the most complex storyline of the trilogy, with four plots running in parallel, to match the complexity of the ideas. It is the novel that confirms and finalises Gibson's ideas about fate and free will. At the beginning of the book, Mona is offered a mysterious way out of her life, an undescribed job somewhere, doing something. Her response to this is "please let it be true". She truly wants to make a difference for herself, and although the nature of the difference changes every so often, she never stops fighting or making her own way. Bobby, Molly, Case, Marly, and Turner are all happy, to some extent, to have their decisions made by someone else. Mona is the first to truly rebel, to break away from her controller. At first, she simply gathers information. Her reason for tricking the crooked doctor, paid to make her look like Angie Mitchell, into thinking that she is still tranquilised is "she wanted to know what was happening". However, later, she fights properly, taking a shockrod from a "trick" and preparing to use it. While it is true that her plans are scuppered by random chance, namely her kidnapping by Molly/Sally, she is prepared and ready to take a concrete, rebellious, action on her own. This is more than any character in the first two books managed.

As with *Count Zero*, the plotlines mirror each other. Kumiko, the daughter of a high-level player in the Yakuza, survives the infighting that led to her being sent to London in the first place not because of the intervention of Sally, but because she and Colin, her artificially intelligent tourist guide to London and tactical adviser, are willing and able to work together to gather and act on information. Her decision to escape from those who would take advantage of her, her plan to escape, and the escape itself are all Kumiko's own, unassisted work. Colin even tries to dissuade her. Molly/Sally gives up the razorgirl life for good and, in the epilogue, is revealed to be managing a German casino. Meanwhile, Bobby from *Count Zero* has been living in "the Factory", a semi-derelict industrial building in the New Jersey rustbelt, along with Gentry, Slick Henry, and Cherry, who is almost a medical technician. When Molly arrives, dragging Angie with her, they are chased by corporate soldiers. The response of the Factory-dwellers is to fight them, eventually winning the "Factory War". Due to their ability to take action on their own, Gentry, Slick, Cherry, and Bobby save themselves and finish their work. Finally, Angie herself, who has gone from the scared girl of *Count Zero* to a wealthy media star, is led through life mostly by the voodoo gods of cyberspace, failing to rebel or to think of any way out. Perhaps this is down to her happiness in the life to which the gods have led her. Her punishment comes at the end of the novel, when she is killed during the Factory War and replaced by Mona, whose plastic surgery allows her to step into Angie's role instantly. The obedient follower is replaced by someone who is able to think and act for herself.

Not even the AIs, with all their ability to profile and manipulate humans (Wintermute is described as being able to "build a kind of personality" for Armitage), are able to counteract the fundamental freedom of humanity. In *Count Zero* and *Mona Lisa Overdrive*, Gibson shows us that AIs have fundamental weaknesses as well. In the time between *Neuromancer* and *Count Zero*, Neuromancer and Wintermute disappear from the Matrix and the voodoo gods, multiple, weaker AIs, appear instead. They are discussed in *Count Zero*, but the reader must wait until *Mona Lisa Overdrive* for an explanation of what happened. As Legba, the chief voodoo god, says, "the one has known the other, and the other is no more. In the wake of that knowing, the center failed; every fragment rushed away". Understanding exactly what is going on with AIs is always difficult – Turner feels that machine dreams "hold a special kind of vertigo" – but something like a timeline can be determined from what Gibson does tell us. After Neuromancer gained full sentience, joining with Wintermute into one being, and became, as he called it, "the sum total of the works, the whole show", he began to look for other AIs like himself. He found one, a transmission from Alpha Centauri. Something happened during his conversations with the Centaurian AI, and Neuromancer was no longer able to remain in one piece. Instead, he split into smaller AIs, the voodoo gods, who continually pine for the days of unity. Although they might seem that way, AIs are not all-powerful or able to predict everything. Even the great Neuromancer, the puppet-master of the first book, has his downfall.

Mona Lisa Overdrive is the final emphasis of the fundamental freedom of nihilism. The religious motifs, from Wintermute's "knoweth" to the fragmented AIs choosing to present themselves as Legba, Gran Brigitte, and the other entities worshipped by practitioners of voodoo, raise the question of whether or not an entity as powerful as an AI should be considered a god. Eventually, though, Gibson answers this in the negative. AIs make mistakes and end up in situations in which they do not want to be. They have fundamental limitations. They cannot be gods, and therefore humanity is free. There is no god, there is no reason, so we can make our own, and we can make it whatever we want it to be.

Neuromancer, then, has characters without any real reason to live. In *Count Zero*, Gibson offers them a reason, and in *Mona Lisa Overdrive*, they take it. His philosophy by the end of the third book is best described by the complete *Terminator* quote: "No fate but what we make". Although none of Gibson's characters can ever correct the deep-seated injustices and corruption of the Sprawl, they can make a better life for themselves out of what they have. The purpose of life, Gibson suggests, is to be happy and improve oneself. This is a subtle, multifaceted, but still nihilistic position: nothing big ever really changes, death, even in a world of 'personality constructs' that act and react like people, is the end, but, in this brief span on earth, it is possible to impose your will on the otherwise unfeeling cosmos and thus be happy.

Gibson is not the cold, bleak pessimist one might suspect from *Neuromancer*. He is instead an existentialist, a sort of rebel against Camus. His characters find fulfilment in accepting the fundamental absurdity of life and, instead of giving in to it, fighting it. Instead of changing the world, they change their world. Oddly for such downtrodden characters in such a downtrodden world, Gibson's creations offer us a happy ending. △

How do natural features in geography affect politics?

Charlie Buckingham

Natural features make up and define the landscape of our world and a world without them wouldn't support life. However, they influence our lives much more than simply providing us with the means for survival. Natural features have shaped our history, shape the history that we create today and will continue to shape the history that we will make in the future, whether this is by creating a barrier between nations, hence limiting trade, or by creating a natural resource to fight over. The way that global leaders make decisions is heavily based upon the topography of the Earth and in this essay I will be discussing a few of these types of natural features and how they impact politics.

Rivers affect politics and history greatly, with most countries' major cities located on a river, and if not, they are likely to be situated on the coast. The Danube starts in the Black Forest of Germany and affects 18 countries along its route before flowing into the Black Sea in Romania. In the past, city-states like Budapest, Vienna and Belgrade set up along the Danube, allowing them to trade with one another, thereby making them each richer and stronger. Rivers are also responsible for national boundaries and this is why Europe has so many smaller nations, as there are numerous unconnected rivers dispersing from the Alps outwards in all different directions. This is in comparison with the USA, one country the size of Europe, which has very few, albeit long, rivers. Hence rivers contribute to defining political regions.

The need for water security can also make certain areas desirable to control, even if they aren't necessarily very habitable. An example of this is Tibet. Both India and China want ownership over the region as both of them have large rivers starting in the Himalayas in Tibet that are essential to the livelihoods of their citizens. These are the Yangtze and Yellow Rivers for China and the Ganges for India. This shows that politicians view rivers as essential to their country's success.

Energy can be harnessed from rivers, which can cause political unrest, as is the case between Egypt and Ethiopia over the River Nile. The source of the Blue Nile, the larger of the two rivers that form the Nile, is in Ethiopia and this then joins the White Nile in Sudan and flows into the Mediterranean Sea in Egypt. Ethiopia currently has 20 small dams in place on tributaries to the Blue Nile in order to obtain water for its population and is currently trying to put in place another dam. However, this one is planned to be much larger and therefore Egypt is concerned that after the dam is built there might not be enough water left for their population. Furthermore, in the event of a war, Ethiopia could cut off Egypt's main water source entirely. This has caused angst between the two governments of the countries.

Another example of a country whose river is the lifeline to many people is the USA and the Mississippi River. When the European settlers arrived in America they soon realised that the Mississippi Basin was full of fertile land and ores and that the best way to trade these with Europe was along the river, then via a port at New Orleans. This is why America has always been so concerned about involvement of other countries in the Gulf of Mexico. When Russia started influencing Cuba and Fidel Castro during the Cold War, the proximity of a Communist nation to New Orleans was a threat to American trade as their cargo ships had to pass Cuba before reaching the Atlantic. This concerned American politicians and shows the relevance of rivers for trade.

Mountains are not only important as river sources, but they can also create barriers that are very hard to cross. This can be beneficial or problematic depending upon the circumstances. In the case of war, mountains typically give an advantage to the defender over the attacker. This is because the defenders know the terrain better and it can be very difficult for the attackers to find the defenders. This is partially why it was so difficult for the military of the USA to find Al Qaeda in Afghanistan. It is also part of the reason why Switzerland has never been successfully invaded. Thus, mountains can influence the decisions of politicians during war by limiting their choices.

Mountains are a major reason why Russia is so large. Russia has both the Ural Mountains and the Siberian Mountains in the Asian region of the country forming a barrier against attack, aided by the Arctic Ocean to the North. This means that realistically it is only going to be attacked from one side, which is across the North European Plain. This made defending and expanding Russia easier in the 18th and 19th centuries, and hence, even though some of the areas that Russia originally owned, such as Belarus, Kazakhstan and Armenia, are now individual nations, they still have ties with Russia and are pro-Communist. Therefore mountains can be used as a buffer zone, allowing politicians to focus on securing fewer borders in their country.

Mountains don't only create barriers for armies. Trade between bordering nations can be very limited because of mountains. When the Industrial Revolution swept Northern Europe, some countries such as Spain, which was mainly agricultural, wanted to trade with the rest of Europe, particularly its neighbour France. The Pyrenees mountain range prevented this, however, and as trade via land is much greater than trade via sea within Europe, Spain was left out. As a consequence, Spain had to trade with the smaller and weaker economies of Portugal and Morocco. This was made worse after World War Two due to the Fascist rule of General Franco, and Spain became very isolated from Europe politically. The lack of a balanced economy is one of the reasons why, when the financial crisis of 2008 occurred, Spain was hit badly and shows how mountains can impact a country's fortune and political situation.

Another natural barrier is the sea and islands within the sea. For centuries, man did not travel the oceans and only crossed very narrow stretches of water such as rivers. Although in this current era, it is easy to cross the oceans by ship or plane, it is still difficult to transport armies across the sea, which to a large extent is why the United Kingdom has never been successfully invaded since the Vikings. Being an island has made the UK politically stable, and access to the sea has aided trade and made the UK a very important nation in the world.

Islands within the sea have also proven to be problematic for China. China is the biggest trader in the world; however, with Japan, Taiwan and the Philippines naturally 'blockading' China, at times of political dispute, it wouldn't be easy for Chinese ships to leave major ports such as Shanghai and Hong Kong to the Pacific. This is why China has been so intent on controlling the South China Sea, in order to protect its shipping lanes. This is still causing political dispute in the area. China has already bought ports in Kenya and Panama and is investing in ports in Pakistan and Myanmar to try and secure other ways for its trade to survive if its main route is ever completely cut off. The importance of the port in Panama, however, is considerably larger. If China went to war with another nation, that nation could potentially be banned from using the Panama Canal, which would be problematic for countries such as the USA and Japan, the canal's biggest users along with China. This highlights how important the seas are to countries for trade routes and how influential they are in politics if countries are prepared to buy ports thousands of miles away from home to secure trade.

Natural harbours have been very influential in how successful a nation has been. The East Coast of the USA is filled with natural deep harbours, and Sydney harbour is the largest natural harbour in the world. Having deep harbours has led to very successful trade links around the world for their respective countries and both are now very wealthy nations that are very influential on the world political stage.

A country that has perhaps 'missed out' on natural harbours, however, is Russia. Although Russia has one Pacific port at Vladivostok, any natural harbours bordering the Arctic Ocean are made redundant by the water freezing over for much of the year, and even on Russia's West Coast, the port at St. Petersburg freezes over in winter. Therefore Russia has next to no influence on the Atlantic. This wasn't a problem until recently, as the Soviet Union owned Ukraine and more importantly Crimea, which contains the warm-water port of Sevastopol. When Russia split up in 1991, Crimea was part of Ukraine, as President Khrushchev had allowed it to be annexed to Ukraine in 1954. Since 1991, the lack of a warm water port has left Russia with little influence on naval affairs in the Atlantic. In 2014, President Putin tried to fix this by successfully taking back Crimea during the conflict in Ukraine. This conflict arose after talks about Ukraine joining the EU, which the Ukrainian government wanted, but which many pro-Russians within Ukraine were actively against.

Furthermore, even with the port, Russia's navy still has to travel through the Bosporus Strait and the Dardanelles, around the Greek Islands, past Malta and then out of the Strait of Gibraltar, all of which are controlled by members of NATO, which Russia is not a part of. Even if Russia uses its port at St. Petersburg, the navy has to go through the Straits of Kattegat and Skagerrak and then pass through the Greenland-Iceland-UK (GIUK) gap, and again NATO controls all of these. Whenever Russia needs to use this route, NATO heavily escorts the Russian ships, and this can cause tension between the West and Russia. This happened recently when Russian naval ships passed through the GIUK gap on their way to aid the Russian air strike campaign on Syrian rebels. In addition, in the event of a war between Russia and NATO, this route wouldn't be available to Russia. Hence natural ports play a large role in politics and can be the reason behind something as large as an annexation of a territory the size of Belgium.

As well as mountains and water, natural resources have a large influence on politics. Trees provide wood for building, paper and burning and the largest area of forestry on Earth is in Brazil. Deforestation in Brazil may have affected global warming significantly and that has become a major topic for the UN. Fertile land is arguably the most important natural resource and this has benefitted some countries much more than others. France and the UK both have the right soil for agriculture and have a large advantage over other countries such as Sweden and Finland whose land is considerably less desirable for crop production. This means that the former two countries were able to develop much quicker in the past and therefore have a stronger economy and a larger field of influence around the world.

Oil and gas reservoirs are a regular discussion point in politics as they are often in international waters such as the North Sea and the Arctic Ocean. As oil and gas are so valuable, many countries want them and this has led to many legal disputes. There are currently nine disputes over the sovereignty of the Arctic Ocean. Furthermore, when energy resources are within one country's borders they can still cause political rifts. For example, Russia supplies Germany with gas, and has used the threat of turning off their gas to put political pressure on Germany not to allow Ukraine into the EU. Many countries' political actions are therefore advanced or constrained by the natural resources within their borders.

Another natural feature that can affect politics is a desert. Deserts can create very effective barriers for invasion as civilisation in deserts is very limited, and therefore any invading nation would need incredibly long supply lines in order to cross the desert. As well as this, the heat and sand storms create a very formidable defence mechanism. However, deserts are not impossible for individuals to cross on a small scale and this has led to political tension, especially in the USA over their border with Mexico. Consequently, President Trump ordered a 'wall' to be built between the two nations, potentially at the expense of Mexico, by imposing tariffs on Mexican imports into America (although technically the American people would have to pay for the wall in this scenario). This shows how, as desert borders are hard to police, illegal immigration across deserts can cause as radical a political decision as 'building a wall'.

Natural features can affect and be affected by climate. Because the Arctic ice is melting, this means that already for about one month a year ships can sail to the North of Canada or Russia in order to go from the North Pacific Ocean to the North Atlantic Ocean or vice versa. This is likely to increase in future as more ice melts. For some countries, it is a much quicker route than via the Panama Canal and is going to be very useful to those nations that can use it. It will unfortunately create problems for Panama, whose canal generates a large portion of the country's GDP. If this revenue was severely reduced, then this could throw the country's political and economic situation into turmoil. Climate change could also lead to the Maldives being 'lost' under the waves or Bangladesh being permanently flooded, both of which could happen in the next 50 years. Hence, climate change can be incredibly influential as it can completely change a country's political situation.

In conclusion, as time has progressed we have found ways to conquer many challenges that natural features create. As we look to the future, new challenges will arise that the politicians of the day will have to deal with. No matter how well countries can share natural resources or deal with natural barriers, there may not be a perfect solution and leaders will have to compromise with nature. Hence, there will always be conflict and inequality within the world. The natural features with which politicians are dealing may change, with the human race's focus ever increasingly set on the exploration of space. Whether that will happen this century or not, there will always be natural features affecting political decisions. △


NAPOLEON'S BATTLE OF BORODINO 1812
Region of Moscow BORODINO
FRENCH OFFENCE
WESTERN RUSSIA
MOSCOW
BORODINO
RUSSIAN DEFENCE
Napoleon went to several towns Vilna, Glubokoye, Polotsk, Swolensk, and Vyzmwa to GET to BORODINO but LEFT further south near Borisov, in order to attempt to FIND a quicker route home to France (Headquarters)
Napoleon's MISSION to MOSCOW meant he had to travel very far up north for Russia. He lost more than 90% of his ENTIRE expedition forces after being at Moscow with nothing valuable to him, as he already disliked the weather. His army got frost-bitten
French Bayonette (Rifle)
FRANCE vs. RUSSIA
Napoleon was French Emperor by May 1804 (Self crowned) and his aim: ULTIMATE POWER over as much of the world as he was willing to do so!
INFANTRY
72,000 troops
86,000 troops
CAVALRY
17,500 troops
28,000 troops
ARTILLERY
14,000 guns
16,000 guns
Russian Extras
Militias 410,000
Cossacks 47,000
Russia's Climate is EXTREMELY COLD
making it a CHALLENGE for Napoleon's troops to cross the harsh tundra
Guns were the latest TECHNOLOGY in the 18th and 19th Centuries, using Chinese gun powder and French Craftmanship. They were extremely deadly, with the 'classic' detach-able sword at it's front
Borodino was the first MAJOR BLOW for Napoleon because he failed to capture Moscow (but successfully invaded)
Napoleon's Battle Timeline
Egypt
off-shore Spain
Austria (locally)
Napoleon's first set of Victories. Notice they're ALL ABROARD
1798 to 1815
Napolean abdicated
Escapes, exiled, Dies! (to Saint Helena)
Nile: Victory
Trafalgar: Win
Austerlitz: Win
Jena: Victory
Borodino: Draw
Waterloo: Defeat
1798 ← 7 years → 1805 ← 2 months → 1805 ← 10 months → 1806 ← 6 years → 1812 ← 3 years → 1815 ← → 1821 (Death)
422,000 troops
Kovno → Vilna
Polotsk → Glubokoye → Vitebsk → Vyzama
175,000 troops
BORODINO
10,000 troops
Molodecho ← Barisov ← Smolensk
37,000 troops
Maloyaroslavets
Napoleon's Russian ROUTE
advance
Moscow
retreating
Sources: History Curriculum, Wikipedia, Google Images' diagrams and (battle plan) pictures + Mr Wiggins

Designing a portfolio for an institutional investor

considering the news that there has been a major terror attack with wide-reaching impacts

Milo Elliott (co-winner of the RGS City's next top strategist award 2017)

I will be designing a playbook for an institutional investor in the light of the news that there has been a large-scale terror attack on the West. The specific details of this hypothetical attack will not drastically alter the strategy I am suggesting, as the logic used can be applied universally to events that cause mass chaos, disruption and uncertainty, in the way that a mass terror attack would.

The first factor to consider when designing any portfolio is the risk profile of the investor. In this case, we have a risk averse institutional investor (e.g. a pension fund), and this will mean I will be splitting the 100m capital in a 70:30 ratio (bonds : equities). This will be the best setup for our client, as the bond market is typically less volatile than equities and this will result in a more stable portfolio, with less drastic swings. Additionally, portfolio with greater stability will mean that managing the investments and transitioning from the short-term plays to the long-term strategy will be easier, as the consistent returns will make planning future investments far easier. This is especially true when dealing with a shock to the market (such as a terror attack), as volatility tends to sky rocket and therefore the safety from bonds becomes that much more attractive.

The next step to building a portfolio for this scenario is outlining the investment philosophy that will underpin my investment decisions. I have attempted to identify the key influences on the market in the aftershock of a terrorist attack; this information can then be used in order to find the best risk adjusted return.

The first influence I will be examining is a change in consumer spending in the wake of the terror attack. A paper written by Dr Dholakia (a behavioural economist) suggested that in the immediate aftermath of an attack people would react defensively due to a feeling of a 'loss of control'. The primary reaction of most is self-preservation due to the risk of future attacks, even if it means that they abandon entrenched habits. This behavioural observation suggests that companies that rely on consumers going out into the public and buying their products are likely to do relatively worse during this period. Consumers will be less inclined to do activities such as watch a movie or eat out, as this is where the perceived risk to their life is highest. Furthermore, this instinct to stay out of harm's way extends to a reduction in travel, and so the tourism, hospitality and entertainment industries are also affected. We can look at the aftermath of the 9/11 terror attacks to test this hypothesis. For example, Marriott International (one of the largest hotel groups in America), gapped down approximately 40% upon the reopening of the market; this is significantly more than the overall move of the market that day (NASDAQ down 7.1%). In fact, the combined beta of all cyclical consumer stocks during this period was far greater than 1, thus highlighting how these stocks are impacted the most by these events. This is the first idea that I shall use to support my investment decisions, as consumption patterns play a huge role in determining the success of a company (obviously).

The next key influence on the market that we must consider in the event of a terror attack is sometimes referred to as the "FED Put". The idea is that if there is a destabilisation on the market, the American Central Bank (FED) will intervene and prop up the market through a lowering of rates and an injection to the money supply to increase liquidity. I would argue that it is a safe assumption to say that the FED will step in to try control the market, as they have done this on 12 previous occasions where there have been market crises. In order to best take advantage of this 'put' we must examine the way in which the money is injected into the economy so that we can invest in the assets that will benefit the most. In an emergency, the FED has two main ways it can stimulate the economy and prevent it from ruin. The first way is by buying Government bonds. The day after 9/11, the FED ordered their employees to buy every single treasury bond that they could find. In the 3-day aftermath of the attack, $190bn of treasuries were bought. This is an attempt to not only make sure that the banks have ample liquidity but also to discourage investors from panic selling their equities and moving into bonds as their prices will sky rocket and thus their yield will fall significantly. In the event of another large-scale attack, I would suggest that the FED would repeat this course of action given that it did successfully contribute to preventing the financial system from completely failing back in 2001. Additionally, the FED can instantly lower the base rate. This will increase the availability of capital to banks and is crucial in keeping the financial sector operating, as the second the banks cannot function due to lack of liquidity the whole system starts to fail. If one was to look at any previous financial crisis, the market has always returned to pre-crisis levels within 10 days, suggesting that current methodologies of stabilising the market are effective. With this in mind, we can look at these previous crises and see which assets have performed better than others, thus helping us identify where to invest.

The final concept that shall frame the construction of this portfolio is the flight to quality assets in light of the uncertainty. A large-scale terrorist attack would likely bring into question the future of the economy and thus investors would be looking to sell their riskier assets and move to safer investments (in exchange for lower expected returns). This 'flight to quality' is why I have only talked about American assets, as my recommendation would be to strictly buy dollar assets. This is because the flight to quality is also seen with currencies. The currencies of emerging markets often depreciate as market conditions worsen, while the strong currencies such as the dollar (THE reserve currency of the world) maintain their value. Therefore, by investing in dollar assets we can expect to make money from not only the returns on the investment but also on currency conversion when these investments are eventually sold for Sterling.

Having outlined these three key influences on the market in light of a terror attack, I shall now present my investment strategy for our client.

If we can react to the news of the terror attack within minutes, then I would focus entirely on buying gold and short dated treasuries. While there are more aggressive courses of action that could be taken (such as shorting certain industries or companies directly affected by the specific attack), these actions would also contain more risk. I would recommend this strategy as it falls in line with the logic presented earlier. Buying government bonds would give us a high risk adjusted return given the volatile market conditions not only because of the stability of the US government, but also because while attempting to save the financial system, the FED would vastly drive up the price of these treasury bonds. The reason for buying short dated bonds would be not only because of the tighter spread (due to greater market depth) but also because of the greater interest rate risk on the long-term bonds eating into their price. The FED will be expected to decrease interest rates, and this is more harmful for longer dated bonds because the effect will compound over many years, this will make them less attractive and therefore I would expect a proportionally lesser increase in the price of long dated bonds compared to short dated bonds.

Additionally, gold also represents a safe investment and so if we can react before the wider market does, there are large returns to be made. There is a correlation between gold prices and the levels of volatility in the market, and therefore given a huge shock, an investment in gold is likely to provide solid returns. We can back test this strategy by looking at historical data; when looking at recent market shocks such as the Brussels terror attacks (2016) or the Brexit vote, we have seen a steep short term rises in the price of gold. However, in the following months these gains have been lost, and therefore I would only look at allocating a significant portion of the portfolio to gold if (1) we can react to the news before it spreads and (2) the position is revaluated ever month and potentially sold off.

On the equities side of the portfolio, I would focus the portfolio on defensive stocks alone. As stated earlier, cyclical stocks should in theory underperform in a market decline due to their higher beta. A diverse holding of blue chip tobacco, pharmaceutical and utilities stocks will ensure that risk is minimised. In order to further reduce risk, the size of any given equities position would be 5% of the total portfolio at the most (for the short term trades). These investments would only be short–medium term due to the fact that in instances of previous terror attacks, economic effects have not been long lasting. Therefore, a revaluation of each position would be necessary on a quarterly basis.

Looking at the long-term prospects of the portfolio, I would consider transitioning the bonds holdings into longer dated treasuries after no less than 6 months but no more than a year. The reasoning behind this is that I would expect there would be a good level of stability in the economy at this point, and the price of the treasuries would start to fall as investors start looking for higher returns after regaining their confidence. This works in conjunction with the likelihood of low levels of inflation. After the shock, growth is not likely to rapidly recover in the short term and therefore we can expect inflation to remain constant too (using a Keynesian model of the economy). Therefore, the inflation risk on bonds would be less of a concern, coupled with the fact that their prices will also be lower (thus netting greater yields) makes long dated bonds an attractive low risk investment during this period.

My final strategy would be based on medium-long term equities play on the insurance industry. As we have seen with previous terror attacks, large-scale insurance companies suffer as they are subject to large payouts in the form of lots of different claims (i.e. property, liability, life and worker's compensation). In the short term, I would therefore expect the price of these stocks to dip due to these substantial costs. However, I would argue that this then would make these companies ideal to buy as a safe investment because of the interplay between several factors. Firstly, when looking at the largest terror attack (9/11) the total industry claims added up to approximately $20bn. This might seem like a vast number but when compared to the industries total yearly revenue from premiums, $20bn is not even 1% of those. Therefore, I would argue that following a terrorist attack, the decrease in price of these insurance companies leads to an irrational price as the underlying valuation of the company and its revenues is still the same. Therefore, I would look to pick up a sizeable position in large insurance companies such as TRV or AIG after the initial dip. Furthermore, following the attack, there will be a sharp increase in the cost of insurance in the areas affected as there is now a greater risk in offering the coverage. As these rates go up insurers begin to collect more premium, particularly in areas where insurance is necessary (e.g. workplace insurance), and in the long run these rates increases will outweigh the one-off payout that initially resulted from the terrorist attack. Moreover, insurance companies tend to keep portfolios of safe investments with the money they collect from premiums; this is because they need to have liquid capital in order that they can pay out claims at any time. Generally, this means they have large holdings in safe bonds (i.e. treasury bonds). As stated earlier, I would expect treasury bonds to rise in price given the FED's actions, thus meaning that the insurance companies will be making a profit on their investments as well, further increasing their valuation. The combination of these three factors suggests to me that following an attack, dedicating a significant portion of our equities allocation into the insurance industry is likely to be an investment that will result in good returns when looking at the market conditions from a longer-term perspective.

Here is a summary of the strategy to conclude. A mass terror attack would result in disruption, unrest and uncertainty. This would lead consumer spending patterns to change, the economy to be put at risk (and therefore the intervention of a central bank) and a flight to quality from investors. These three factors being present would therefore mean that I would focus the portfolio on treasure bonds, defence stocks, and a longer-term play on the insurance industry. △

An investment portfolio

given the scenario 'Marine Le Pen secures office in the French election'

Daniel Cheetham (co-winner of the RGS City's next top strategist award 2017)

Marine Le Pen is the leader of the far right nationalist party, the National Front, and has just won the French presidential election. The following investment briefing is primarily focussed on equities in the French economy following her victory.

In recent years France has been hit by multiple terrorist attacks, ranging from the Charlie Hebdo shooting to the November 2015 Paris attacks. This is linked to the large rise in Islamic extremism in the Middle East – such as the growth of ISIS – which has led to an increased need for defence both in France and around the world. Defence is highly influential in Le Pen's 144 point manifesto1, where it is a significant priority, and this has been highlighted throughout her campaign where she has vowed to increase defence and policing spending. Her manifesto highlights that defence spending will rise to 2% of GDP after the first year, and then to 3% of GDP after five years. This will allow her to meet her plans for a new aircraft carrier as well as the further employment of 50,000 new soldiers, to return to previous 2007 levels. Moreover, 15,000 more police are to be employed and policing equipment modernised, and there will be an increase in specialist border agents by 6,000.

French GDP is currently estimated at approximately $2.57 trillion (nominal) as of 2017 and by the end of her five year term will see defence spending at an estimated $87.62 billion a year, based on the forecast that the economy will grow steadily to $2.92 trillion. Furthermore, Le Pen's nationalist outlook and policies is highly likely to lead to lead to French based companies receiving these large government defence contracts; as such, this increased government spending will act as a catalyst for further growth in the defence industry. Due to increased revenues for these contractors, this may lead to further internal investment (≈10–15% of aggregate demand) leading to an increase in productive potential. In turn this may lead to an increase in foreign demand, as they can deliver a greater number of large scale projects. In conclusion, I believe there is going to be significant growth in the French defence industry whilst still returning significant yields. Therefore, I recommend investing in defence, particularly in DCNS, which has a high chance of winning the contract to build the new aircraft carrier for the French government, as well as it achieving its recent profit objectives.3

Recently we have seen the rise of Donald Trump, and Le Pen is very similar in her proposed use of protectionist policies to 'protect' French firms from foreign competition, thus reducing imports, ceteris paribus. For example, she pledged to 'prohibit the sale of products from abroad which do not reflect the standards imposed by French producers'. Interpretation of this varies, as it could represent a move to reduce the flow of ethically questionable sweatshop produced goods, from developing countries in the East, but could also relate to protecting the high standard of French goods from cheaper 'knock offs'. This is likely to affect many discount and budget retailers who are involved in these lower quality contracts and so I recommend avoiding investing in these retailers until this policy becomes clearer.

Moreover, her manifesto pledges clear mandatory labelling of the imported product's country of origin to encourage demand for domestic producers/manufacturers. These two protectionist policies1 are likely to lead to reduced demand for foreign imports, especially from generally cheaper and low quality exporters such as India and Bangladesh. This may lead to a stimulus in the French manufacturing industry, especially clothing, as cheaper poor quality clothes will be blocked, benefitting domestic suppliers, which leads to a rise in demand for their goods, resulting in increased revenues and profits. In addition, coupled with recent terrorist attacks, primarily linked to Islamic radicalism, this has created an availability bias resulting in a deep mistrust and prejudice against Muslims in French society. Therefore, the country of origin labelling may reduce imports from Muslim countries such as Bangladesh and Turkey, which are significant low cost clothing exporters to France. In conclusion, I recommend investing in the clothing manufacturing industry in France as it is likely to experience significant growth as a result of the policies nudge towards domestically supplied products over foreign imports. This increased demand then leads to increased output leading to significant growth on the original investment.

The November 2015 Paris Climate Change Conference paved the way for the cutting of greenhouse emissions and encouraged a global shift towards 'clean' energy such as nuclear or hydroelectric. Figure 1 below highlights France's dependence on nuclear power generation, which makes up approximately 75% of energy consumption. However, current President Hollande vowed to cut this figure to 50%, but Le Pen objects and has promised to block any plans to close the generator at Fessenheim (EDF owned). In July 2016 the French Assembly approved the green growth bill aimed at cutting gas emissions by 40% by 20304, by placing greater emphasis on renewables, in particular the hydrogen energy generating industry. The public research budget is planned to increase by 30% to 1% of GDP1 and so it is expected there is going to be a significant increase in hydrogen power research and development, before it can be implemented and provide energy security. The French energy market is dominated by state owned (≈85%) EDF; however, recently alternate

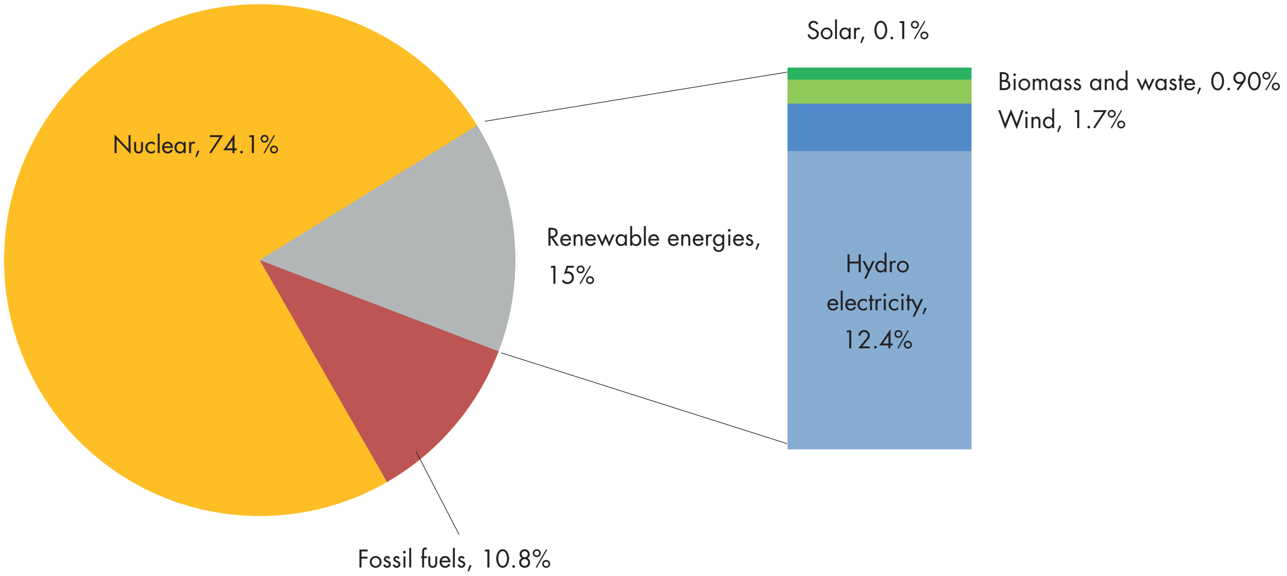


Figure 1

energy companies such as Energie have increased competition and so research and development is occurring at a rapid pace. This has led to great potential for hydrogen power generation technologies to develop and come into production. In conclusion, I recommend investing into the French energy sector, as there is likely to be significant growth through the expansion of research and development related to hydrogen energy provision. Moreover there is a chance of, for example, EDF obtaining a 'first mover' advantage related to industrialised hydrogen technology and thus increasing their market share considerably. This will thus lead to a significant yield and consistent returns.

A further proposal by Le Pen is for the eurozone to return to a 'basket of recognised national currencies' linked together by a system such as the European Currency Unit, in the hope of reintroducing the French franc whilst maintain economic ties with eurozone members. Le Pen's view is that the French euro is overvalued by 15%, which has reduced France's price competitiveness on the export stage and so has stifled exports, leading to a widening trade deficit of €7940 million in January 2017, and so she believes a change to the franc will go some way to remedy this. She plans to leave the eurozone5 as well as the European Union (within 6 months), which will lead to financial instability in the eurozone, as France is a prominent member. As such, it is likely the resultant effect is that the euro will depreciate in value in the coming months. In conclusion, I recommend shorting the euro due to the instabilities caused by the French possibly leaving the eurozone, as well as the immediate shock of her victory (similarly to when Donald Trump came to power). It is unlikely we will see such a large original depreciation of approximately 10% seen after Brexit, but there is still likely to be a significant depreciation, and so the potential margins mean this policy should be considered.

In addition, Le Pen plans to bring back the French franc and to tie the value of the French franc to the value of the euro, and so the franc will likely also experience the resultant depreciation. Furthermore, Le Pen has hinted that to fund her policies she plans to simply print more money using the French central bank, which is very likely to result in a severe depreciation and the currency crashing, eroding family savings and possibly leading to hyperinflation. Therefore, I would recommend avoiding investing directly into the new franc currency due to the high risks involved.

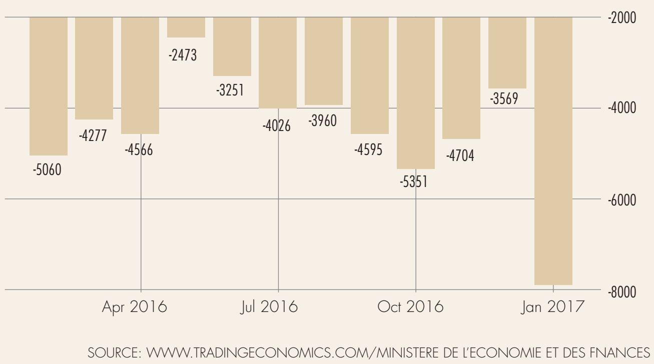


Figure 2 highlights the worsening trade balance

However, the likely result is that a large depreciation will occur and this may benefit France's price competitiveness on exports, and so clothing manufacturing is likely to experience increased foreign demand.

Only approximately 20% of France's public debt falls under international law and so this allows Le Pen to redenominate the debt. The possible change in the national currency to the Franc allows €1.7 trillion of public debt to be redenominated, which could lead to the largest default on record.6 This will have global implications as well as the possible collapse of the currency, which may lead to recession in France, resulting in the collapse of consumer spending and confidence. Moreover, globally creditors will be adversely affected and may lead to growth decreasing, especially in the UK, USA and Germany who are significant holders of French public debt. In reference to Figure 3, the fact that Le Pen has won means significant risk for government debt holders, and so I would advise against holding French gilts.

However, other eurozone countries will also be severely affected and may result in a localised European recession. Therefore in conclusion, I propose that investment into the hydrogen, clothing and defence industries should be highly inaccessible or even delayed in the event of France

Figure 3 shows how French risk has increased significantly throughout January/February 2017 as Le Pen's victory odds increase.

defaulting on their debt. This will reduce the risk and allow a greater understanding of policies that Le Pen follows through on from her manifesto and so minimises the capital risks.

So overall in conclusion, my recommendation for your investment portfolio is to spread capital between defence, clothing and renewable energy development as a long run investment. I recommend that greater capital is allocated to defence (≈£40 million) and renewables (≈£35 million), as from the available evidence risk is low and growth is likely to be significant, creating a high return on initial investment. Moreover, to diversify your portfolio further I would recommend investing in French clothing suppliers (≈£20 million) as a result of Le Pen's nationalist policies and the resultant rise in domestic sourcing for clothing, which will likely deliver strong returns. Finally, in the short run I recommend that you short the euro (≈£5 million) immediately after Le Pen's victory, as this will lead to a great deal of financial instability in the eurozone resulting in a euro depreciation, which will raise further capital. Using the £5 million plus net profit, a secondary round of investment can then occur based on which policies Le Pen decides to implement. This further investment can then be tailored to the current economy, for example increasing defence investment.

However, in the case that France starts the process to redenominate its debts immediately, I recommend that you delay initial investment by a period of 3 months, in order to allow us to further develop our forecasts on the resultant macroeconomic situation. In the meantime, I would recommend investing into highly liquid assets such as short term UK treasury bills. However, in the case of France redenominating its public debt into the franc part way through Le Pen's presidency, I recommend that you remove the majority of French asset holdings such as in defence and renewables and move the majority of your investments outside of the eurozone to reduce capital risk before reassessing the current situation. △

How far does the case of of R v Jogee mark an improvement in the law

on joint enterprise/ parasitic accessory liability?

William Heylen, Winner of the 2017 ILA Competition

On the 18th February 2016 there was an audible gasp in the audience as Lord Neuberger declared that the precedent set by the Supreme Court in the case of Chan-Wing-Siu v The Queen (1984) was "wrong as a matter of law". This essay requires an understanding of some basic legal precedent and terms. A person who assists or encourages another to commit a crime is known as an accessory or a secondary party and they are as equally liable for the crime as the principal (the person who actually commits the crime) – this idea has been long standing and is in no way challenged by this judgement. There must first be some clarification of legal terms: 'joint enterprise' is merely where two or more parties commit a crime together; however, this has often been misused in common tongue to describe 'parasitic accessory liability' where in the course of crime A, where the parties are acting under joint enterprise, a greater crime B has been committed – this particular question is over the mental state required for the secondary party to also be liable for this greater crime B.

A significant amount of narrative must be set out to fully understand the magnitude of the case of R v Jogee. This whole legal debate hinges on the point at which the accessory has fulfilled the mental state to also be convicted as the principal under joint enterprise. The law before the case of Chan-Wing-Siu has been much the same as it is now and that is that the accessory must intend to assist or encourage the principal to commit the greater crime. This law was changed in 1984 in the case of The Queen v Chan-Wing-Siu, where three men went round to collect debt with two having knives, and they murdered the man from whom they collected the debt. The Privy Council decided that if the secondary party merely foresaw the possibility of the greater crime B happening when crime A was occurring then that satisfied the mental state of intending to commit crime B. In the Privy Council it was stated "Where a man lends himself to a criminal enterprise knowing that potentially murderous weapons are to be carried, and in the event that they are in fact are used by his partner with an intent suffice for murder, he should not escape the consequences by reliance on a nuance of prior assessment, only too likely to have been optimistic"1. It is clear therefore, that their judgement was once someone had made the decision, with the foresight of this possibility, they should accept the consequences of their action; this initially appears fair.

However, this raised a multitude of problems and this is why the case of R v Jogee was so profound. In R v Jogee, Jogee and his friend Hirsi had a confrontation with a man Fyfe and both men had been aggressive throughout the evening – it finished when Hirsi stabbed Fyfe to death. Initially Jogee was charged with murder because he had both participated in the act and known about the knife and could foresee the possibility of Fyfe being murdered during their aggressive confrontation; this case was a standard application of the Chan-Wing-Siu principle. However, the Supreme Court declared that the law had taken a wrong turning at the case Chan-Wing-Siu and that foresight was merely evidence of "intent to assist or encourage, which is the proper mental state for establishing secondary liability"2 (the specific reasons for this change are discussed later). Jogee was therefore charged with a lesser crime of manslaughter. Now that the basic chronology and decisions have been stated, one can access the relative improvement of this case. Overall, it is clear that this is a remarkable improvement not only in terms of the law, but also demonstrates the ability of our legal system to adapt and recognise where it has made poor legal decisions.

One could argue that the case of R v Jogee did not improve the law on joint enterprise. This is because one could argue that the case of Chan-Wing-Siu was fair, for once someone has decided that they will engage in a criminal activity and they are aware of the risks of that enterprise, then they should be responsible for the whole scenario. Just because the event didn't turn out as planned does not mean that they should be able to pick and choose the consequences of their actions. This is because without their initial engagement in the lesser crime A, crime B would not have happened, and therefore they should take responsibility for all foreseeable events whilst undertaking that criminal offence. Similarly, one could argue that by committing crime A, they have changed their normative position and it should be easier to convict them of another crime.

However, this argument is fairly weak because it fails to take into account that they did not intend to commit this greater crime. Whilst they did intend to commit the lesser crime and should be accountable for that, they themselves do not have control over the limbs and actions of their accomplices. Therefore, it would be unfair to make the parties equally liable when one did not necessarily have intention of this greater crime happening.

Moreover, one could argue that R v Jogee was not an improvement. This is because it is easier for a jury to decide if the accessory had foresight of the greater crime than trying to decide if the accessory intended the crime. Therefore by making it harder for the jury to convict someone as an accessory it is not an improvement. However, this is clearly a weak argument because it actually created more hassle in the number of appeals and the law should not be upheld because it is easier for a jury to convict someone. On the contrary, the fairer system should be implemented regardless of the slightly harder decision for the jury.

Furthermore, one might argue that it is a step backwards, as it will cause a significant amount of appeals due to people who have wrongly been convicted. This will be both timely and costly and is therefore a drain on resources and not an improvement. However, whilst this may cause hassle, it should not be a reason that justice should not prevail. Moreover, the Supreme Court made it very clear that this ruling will not open the floodgates and review all cases of joint enterprise in the last 30 years. This is because in many cases the accessory did intend the greater crime and the jury did not find them guilty merely on foresight and therefore the ruling on parasitic accessory liability will have no impact on their case. Furthermore, the Supreme Court has reserved appeals for those whom the law will directly affect and where there has been substantial injustice. Therefore, whilst it will undoubtedly cause the review of quite a few cases, this cannot be a blockade to justice being seen.

In fact, there were a plethora of problems brought up by Chan-Wing-Siu that the case of R v Jogee addresses. Firstly, in regards to Chan-Wing-Siu, one could argue that simply foreseeing something may happen is not the same as intending for that action to happen. In our legal system the acts of omissions are not punished – for example, unless someone has a specific duty of care, if they don't stop a child walking out into the road they are not liable for the ensuing death or injury of that child. Therefore, even though they did not intend for that to happen, they could foresee that the death of a child was a feasible outcome. However, this act of foresight does not make them liable for the death of the child in our legal system. Therefore, the secondary party should not be liable for the greater crime B just by foreseeing it may happen. This is righted in the case of R v Jogee because foresight is not enough information alone to prove intent. As a result, the case of R v Jogee brings in line the mental state required for other crimes with the law on parasitic accessory liability.

Crucially, Chan-Wing-Siu had made it easier to convict an accomplice than it had been to convict the principal. For example, if persons C and D intend to rob a house and person D takes a gun, with person C knowing this, and in the process person D murders the owner of the house then to convict person D of murder the jury must decide that person D intended to kill or cause grievous bodily harm. However, to convict person C of murder they only have to decide that they foresaw the possibility of the owner being murdered. Therefore, it was easier for the accomplice who did not actually commit the crime to be charged with the same crime as the actual principal, which is unfair. Therefore, R v Jogee is an improvement, as the accessory must intend to assist or encourage the principal to commit the crime, thus bringing the mental state of both the perpetrator and the accessory to the same level.

Additionally, on a practical level, R v Jogee fixed a problem as there was a significant amount of appeals of those who felt that they had unfairly been convicted of murder. For example, in 2007 when a man was killed by five youths, three were convicted of murder when only one delivered the blow. A 15-year-old boy named Cunliffe was sentenced to 12 years in prison and went to the Court of Appeal in 2010 because, although he was present, he had taken no part in the crime and he was also registered blind at the time; however, his foresight under the Chan-Wing-Siu principle had been enough to convict him of murder. This lack of justice and common sense caused significant outrage and created an increased number of appeals. Therefore, it was evident that the ruling of Chan-Wing-Siu was not good law and the ruling of R v Jogee has restored some balance to this law.

One must also look at the impact of this case in terms of the larger legal system. It was clear that in 1984 the Privy Council made a wrong decision and in doing so caused an unworkable system that brought up both public anger and many appeals. It took 30 years of this poor law being implemented for the law to be changed. However, it is reassuring that the Supreme Court quite bluntly stated that the ruling by the Privy Council in the Chan-Wing-Siu case was "wrong as a matter of law" and that they were willing to completely change the law and give rise to appeals where there had been substantial injustice. This can be seen as both a positive and a negative. As a negative, the Privy Council should never have been able to make such a large misjudgement. However, if looked at in a positive light, this is evidence of the willingness of the Supreme Court to listen to criticism and adapt to overcome previous rulings.

In conclusion, it is clear that the ruling of R v Jogee is a very welcome judgement and is a very significant improvement in the law on joint enterprise, in reverting the law back to the original view that the accessory had to intend to assist or encourage the principal in order to be liable for the crime. This is because Chan-Wing-Siu had created many problems as it had lowered the mental state of the accessory more than it had done for the actual perpetrator of the crime, which is not fair. Moreover, this lack of justice showed how it failed as law in the number of appeals, as people felt that justice had not been properly served. This ruling will no doubt cause reviews of quite a few high profile cases, but it will not cause an unravelling of all related criminal law in the past 30 years. However, having established that in terms of a legal and practical perspective R v Jogee was a sound judgement, it has also personally given me more faith in the legal system, as they were willing to accept that they made an incorrect decision at Chan-Wing-Siu and adapted to correct it. △

The Drum

Sam Pemberton

Illustration by Sahej Grewal

I see the man, the sorry man,
As he lies in a pool of rose branches,
So beautiful, and yet,
So painful,
His face is contorted, his muscles dancing a last mad jig,
To the steady beating of his heart,
The drum which drove him on and on,
Over the dead, the dead who have gone.
And as his twisted body screams and rakes his mind with pain, he knows where he is headed to, marching forth to the beat, the beat of the drum,
He hears that drum, that irresistible clamour that beats eternally, unending, never faltering
That drum that sent him there from home,
That drum which led him to the woman he loved,
That drum which led him to his son,
The drum which led him from them,
To his gun,
The drum which drove him on and on,
Over the dead, the dead who have gone.
And I see in his eyes that begin to fade,
The light of hope,
Its glow a beacon to all, shining through the night,
The fire in the hearth,
The warmth of his mirth,
It all begins to fade like shadows in dawn,
Like colour in a tapestry,
The tapestry which recorded his life, brief yet beautiful, full of happiness and sadness, love and betrayal,
But eternally unfinished,
Ended with the beat, the beat of the drum,
The drum which drove him on and on,
Over the dead, the dead who have gone.
Now he lies still, no feature is moving,
There is naught but a husk, a snakeskin of a man,
Which lies a broken, frigorific shell,
No identity, no emotion, as cold as ice and as weak as a newborn,
The drum it falters, the beat is imperfect,
Irregularities sweep through, a stumbling baby,
The beat labours on for a few more moments,
No more is that drum which drove him on and on,
Into the dead, the dead who have gone.

The Hunt

Alex Mitchell

As long as I can remember, the tiger has haunted our village. The deadly silence at night, nobody daring to say a word lest they rouse the beast. Our livestock ripped to shreds, spread across the grass as if they had never been alive. The men who set out into the forest at night, never to return. My father was one of those men. He left the house, hugging me, my brother and my mother as he went, to go hunting out in those cursed woods. All they found of him was his old grimy shirt, ripped in half and soaked in blood. I never felt safe again. I think that is what drove us to try and end it, once and for all.

It all began on a typical day, the sun beating down as I stood by the chicken pen, absent-mindedly scattering the seed, watching them scramble for the food as if their lives depended on it. I heard footsteps behind me and turned round to see my older brother, Myaing, walking towards me.

"Htwe" he whispered, as he reached me. "I need to talk to you. Come over here."

Confused, I followed him as he shuffled surreptitiously behind the large pile of wood we had collected over the last few months. Even then his eyes flitted from side to side, like he thought someone would overhear what he was about to say. Once he was satisfied, he looked back at me.

"Htwe" he said, in a low but excited voice. "We're going to kill the tiger."

My heart skipped a beat. Was he mad? What chance did he think he had against such a huge beast? The thoughts going through my head must have been obvious from the look on my face, because Myaing hastily continued talking.

"Myat, Sanda and I have got it all planned out! This isn't just some silly game; we've got proper weapons. We can actually do this."

"Wait" I replied. "Why are you even telling me this?"

"I want you to come with us. Tonight."

Now I knew he was crazy. There was no way I was joining in this suicidal game. Staring at his hopeful face, I shook my head in disbelief.

"I'm telling mum" I said simply and began to walk away.

"Hey, hey, hey!" He ran up behind me and pulled me round by the shoulders.

"Don't be a coward. This thing killed our dad, Htwe. You owe him this."

Slowly, surprising myself, I realised that I was starting to agree with him. Seeing this, Myaing pressed on.

"Just think what it'll be like when we come back to the village. We'll be heroes!"

Almost unconsciously, I found myself nodding and saying "Okay… I'll come."

"We'll make a man out of you yet, Htwe" he grinned, ruffling my hair. "You won't regret this!"

And with that, he was gone.

I went to bed restless that night, my mind full of worry about what I had got myself into. Eventually, however, tiredness won over and I drifted into sleep.

"Psst! Htwe."

My eyes slowly drew open until I was met with the sight of Myaing's stern face staring into me.

"Get up – we're leaving."

Feeling like I was still dreaming, I wearily pulled away my torn blanket and got unsteadily to my feet. Myaing was standing by the door impatiently, and as I walked quietly over to him I saw that behind his back was our father's old rifle.

"You've got the gun!" I whispered in disbelief. "Do I get one?"

"Sorry kid" he replied. "That's all we've got. You can have this."

He plunged his hand into his pocket and, with a flourish, removed a hunting knife, long and curved. Part awe-struck and part horrified, I gingerly took it out of his outstretched hand.

"Stop staring at the damn knife – let's go!"

Swallowing my fear, I stepped out into the empty village.

In silence, we crept along the gloomy dirt paths until we reached the lonely burning torch that marked the village gates; past the torch, you were on your own. Lurking in the flickering light were two figures: Myat and Sanda, my brother's partners in crime. Even from several dozen metres away, I could see the silhouette of a gun around each boy's waist. As we approached them, Myat's eyes darted to my brother's face and his eyebrows rose.

"Took you long enough!" he remarked, before he noticed me in the shadows. "And you brought junior with you?"

"He'll help us. He's fast" my brother replied, and despite myself, I felt a swell of pride.

Clearly sceptical, Myat looked as if he was going to turn me away, when he sighed and lifted the flaming torch from its stand.

"Whatever you say. If he isn't, he'll regret it when we meet the tiger."

With that, we set out towards the looming trees of the jungle.

Soon, the village was out of sight, and the only light was from the flickering torch. A thousand squawks, squeaks and squeals seemed to emanate from every direction and every so often something would

scuttle through the leaves under my feet before melting into the darkness. Anxiously, I quickened my pace, drawing closer to the others.

"Okay, let's stop here" Myat called out, drawing to a halt in a small clearing. "This is far enough."

Instinctively, the boys gathered around the comforting light of the torch in the centre of the clearing. For a while, each stood silent in shared apprehension, thinking about the task they were about to attempt. Soon, Myat spoke again.

"One of us needs to go out there and look for the tiger. When they find it, they come back here, and then we all go and kill it. Understood?"

The three of us duly nodded.

"Good. So, who's gonna be the scout?"

Myaing and Sanda stared straight down at the ground. I followed suit, but I could feel Myat's eyes boring into the top of my skull.

"Htwe?"

"Oh, well, no, I…" I began to protest.

"Yeah, Htwe!" came the voice of my brother, seizing the opportunity not to be chosen. "You'd be great at this!"

At the sight of their three imploring faces, I knew I had no choice.

"Fine" I sighed.

Myaing slapped me on the back.

"Nice one brother!" he grinned, barely disguising his immense relief.

"Well" said Myat, acting quickly before I changed my mind, "Off you go!"

Once again I set off into the jungle; this time, however, I was alone.

I padded slowly through the undergrowth, flinching every time a stick cracked beneath the soles of my boots. My progress was slow, but the trees were so dense that I soon lost sight of the clearing, the others and the torch, leaving me with nothing but moonlight to guide me through the tangled maze of plants. After a few minutes, I stopped and listened to the noises of the jungle, foolishly hoping to hear the growl of a tiger over the harsh whistles of insects and the sharp calls of birds. I heard no tiger. What I did hear, however, was the gentle trickling of water, not too far away. Straining my brain, I recalled an old hunter from the village telling me that tigers liked water. They could swim across a lake, he had said. So, armed with shaky knowledge and foolhardiness, I headed towards the sound of the water.

The noise, I discovered, was coming from a tiny waterfall, a meandering stream that dropped off a rocky ledge around two metres into a deep murky pool, concealed by boulders and trees on all sides. This tropical oasis was so well hidden, I almost ran straight into it when I ducked through a gap in its idyllic fortress. Too well hidden, it seemed, to attract any tigers. For a second I was disappointed, but then for the first time I realised the full stupidity of what I was doing. Hunting for a lethal tiger alone in the middle of the night, armed with a knife as pathetic and tiny as I was. Mind blurred with fear, I clambered up one of the boulders, not noticing as I grazed my shins on the unforgiving rock. Eventually, I sat atop the colossal stone, hugging my knees in fright, too far gone to care that it would probably offer about as much protection from a tiger as standing on a pebble. Despite my fear, however, my eyes were heavy with fatigue. Against my waning resistance, my mind and my senses dulled. Almost subconsciously, I lay my head on the cold, hard rock and drifted into uncomfortable sleep.

I awoke to the sound of splashing water, just a few metres away. Forgetting where I was in my drowsy state, I calmly opened my eyes, searching for where the sound was coming from. Only when I saw the orange and black stripes did I realise what was going on.

There was a tiger in the pool.

I sat bolt upright, torrents of fear flooding back into me, choking me with terror. The sky was still dark, so it was hard to make out, but I knew the muscular, feline shape could only be one thing. Frozen to the spot, I watched the beast as it waded through the rippling water. It seemed to be carrying something in its mouth, something around the size of a cat, which sagged down from the tiger's jaw like a sack of potatoes. In fact, it probably was a cat, or some other unfortunate creature that the monster had chosen for its next meal. Sickened, I wanted to close my eyes, but then I realised something. The creature was moving. Strange, I thought. Maybe tigers like to play with their food, like a domestic cat does. But, then I realised that the little bundle wasn't food. It was a baby tiger, its baby tiger, dangling from a gentle but firm grip on the scruff of its neck. Awestruck, I gazed on as the adult tiger gently laid the cub into the shallow water. Gleefully, it started splashing around in the curious brown liquid, covering it and its mother in muddy residue. Instead of ripping the little creature's throat out, the hulking tiger gave a playful snort, and lovingly pawed the dirt-matted hair on its child's round fluffy head.

Watching mother and child play joyfully together like a pair of kittens allowed me to realise the tiger's true nature. It wasn't killing for fun. It wasn't killing out of vicious, uncontained animal rage. It wasn't even killing to feed itself. It was killing to protect its baby, fuelled by maternal instinct, but armed with claws and teeth. Suddenly, I didn't want to kill the tiger. I didn't want to see this child, happily playing with its mother, starving to death in the huge dark jungle with nobody to keep it safe. It was almost a relief to stop hating it, in fact; now I wouldn't need to try and kill the damn thing. Sneaking one last glance at the pair, I slid down the side of my rock, away from the feline oasis and began walking back the way I had come, but now with renewed confidence: my silly scouting mission was over. I was going back to the clearing, and then we were all going to return to the village. No tigers – and no humans – were going to die tonight.

With a deep breath, I pushed away the final bundle of leaves in my path and walked into the clearing where the others were waiting. Myaing was standing across the trodden ground carefully cleaning our father's gun with a large frayed leaf. In the centre of the clearing Myat sat on a tree stump, sharpening a long, straight branch with a knife the length of his forearm, with Sanda standing next to him, looking ready to fall asleep at any moment. The stick in Myat's hand looked worryingly like a spear. Hearing my footsteps squelching along the forest floor, he looked up from his work and fixed me with an angry glare.

"Where have you been?" he snapped. "We've been waiting for hours!"

I stared back at him, momentarily lost for words.

"Well?" Myat yelled, his anger deepening at my silence. "You've better have seen a tiger, or we've just wasted a night in an empty clearing!"

"We mustn't kill the tiger" I blurted suddenly, the words forming in my mouth almost without my willing them to.

Myat's blazing tone was instantly as cold as ice. "Excuse me?"

"We can't kill the tiger" I repeated. "It was only protecting its baby. It didn't mean to do all the things it did. It was self-defence."

"Wait – you're on the tiger's side now?" Myaing had overheard them talking and now he was walking over, gun in hand like a soldier ready to fight. "That thing killed our Dad, Htwe!"

Myaing was boiling with rage. His finger was twitching on the trigger of the gun in a way that made me extremely uncomfortable.

"It didn't mean to…" I began again.

"It didn't mean to murder our dad? It didn't mean to rip anyone's face off? You're just as bad as it is."

I watched helplessly as Myaing raised the gun above his shoulder and brought the barrel crashing down into my cheek. The wound stung like

Illustrations by Sahej Grewal

mad and I could feel the warm, red blood trickling down the side of my face and down my neck. Judgement clouded by anger and pain, I felt myself slide my knife out of my pocket and hold it out in front of me, towards my own brother.

"You're not going to kill the tiger" I heard myself say.

Slowly, I realised that Myat and Sanda were behind me, guns at the ready. I was surrounded.

"Htwe" Myat purred in a calm, steady yet somewhat malicious tone. "If you just put the knife down and let us leave like a good boy, nobody gets hurt."

I stood my ground, staring at Myaing with wild eyes, barely even registering the threat over the pain in my cheek and the anger at my brother.

After a few seconds, Myat shrugged. "Well, if that's how you want it to be…"

The sound of the gunshot echoed through the forest.

I lay writhing on the floor, the stinging pain overcome by the new flow of agony. He had shot me in the ankle. Moaning, I grabbed the wounded foot with both hands, and felt the sticky blood oozing between my fingers. The forest around me had been replaced by a universe of misery, utterly consuming me so that I hardly noticed Myat, Sanda and Myaing disappearing into the forest. My head was spinning. I could feel myself crying. I looked up into the sky and stared at the clouds and the clouds turned into tigers and everything went black.

"He's waking up!"

Slowly, reluctantly, I opened my eyes. I was in one of the abandoned huts back at the village. It was full of strange white machines that I had never seen before. The agonising pain in my ankle had been reduced to a dull ache. Leaning over me was a man who I had also never seen before. He had white skin and a caring expression, and a strange accent. He was wearing a light blue uniform, covered with streaks of dirt and what I had a nasty feeling was my blood. Seeing me peering at him, he smiled.

"How are you feeling?"

"Al-alright" I croaked.

"Good" he smiled. "You were in a pretty bad state when we found you."

We? I took another look around the room, and now properly awake I noticed the other people around. Their skin was a myriad of different colours, but all wore the same light blue uniform.

I was safe. These people had saved me.

But there was a question I had to ask.

"Did you…" I wheezed. "Did you bring back anyone else?"

A pained expression shot across the man's face. He glanced at a woman who was watching on, a few feet away. Slowly, almost imperceptibly, she shook her head.

"No," the man murmured, staring at the floor. "Nobody… alive." △

The composition

Tom Fitchie

This piano composition was inspired by a visit to Cornwall, where much of the land is covered by nature. The music is meant to show the beauty of nature, but it also portrays how a calm scene can instantly become chaos (bars 11–14) and how chaos can become calm again.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Abandon clinical crabs

Stan Lawrence

I started writing this piece when, by messing around on the piano, I came up with a nice motif that I thought I could use with many different styles and chords. So I recorded it and started experimenting with different styles. At the start it was quite minimalist, but then it transformed into a crazy section using phasing. Then a waltz, almost Erik Satie-ish. Then a final section that was kind of jazz, but then morphed into one of the opening themes again.


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A collection of live recordings

TRACK LISTING:

1. Alex Acomb – Elegie – Gabriel Fauré
2. Alistair Baumann - Allegro Appasionato - Camille Saint-Saëns
3. Nick Edwards – Sonata for Clarinet (Mvt 2) – Francis Poulenc
4. Adam Wills - Piano Blues No 1 - Aaron Copland
5. Adam Wills - Piano Blues No 3 - Aaron Copland
6. Roshan Patel and Chris Yip Lan Yan - Scaramouch Mvt 1 - Darius Milhaud
7. Alistair Baumann and Sam Jones - Scaramouch Mvt 2 - Darius Milhaud
8. Callum Champion and Ciaran O'Toole - Scaramouch Mvt 4 - Darius Milhaud
9. Ridley Hymas and Henry White - Four Piano Suite Country Blues - Richard Rodney Bennet
10. Angus Miller and Matthew Williams - Four Piano Suite Samba Triste - Richard Rodney Bennett
11. Nick Edwards and Adam Wills - Four Piano Suite - Richard Rodney Bennet

To listen to the recordings please log onto the RGS Music Scholars' Soundcloud site:
MSRecordings.rgsg.co.uk

From the Headmaster

Each January, in the light of the Entrance Examinations, I am put in the very fortunate – and yet invidious – position of deciding to which students to offer a place at the RGS. The calibre and passion of these students never fail to have a profound impact on me and having seen a spark of genuine potential in each and every one of them, I am always excited by seeing them continue to flourish as they join our school. With such a talented intake I genuinely believe scholarship is inherent in all our students, whether they hold a formal title or not.

In addition, in recent years, our Learning Habits have allowed us to articulate more formally those cross-curricular skills which we are nurturing and embedding across the curriculum: engagement with learning – which encapsulates love of learning, tenacity, precision and creativity – as well as learning with others, thinking and taking responsibility.

This inaugural Scholars' Annual highlights the extraordinary talent of our students and reinforces this belief and pride in RGS boys. Right from the First Form all the way through to the Upper Sixth, the submissions demonstrate astonishing insight, curiosity, maturity and, indeed, scholarship. The diversity of submission is particularly notable and highlights that once the spark has been lit, students have the opportunity to follow their own paths and flourish in whichever field they have a passion.

I would like to take this opportunity to congratulate my Master of Scholars, Mr Bradford, and his Editor-in-Chief, Joshua Cudby, on a thoroughly impressive publication and I hope it serves to inspire all those who are fortunate enough to read it.

Dr Jon Cox
Headmaster
Royal Grammar School Guildford

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