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Introduction

From the Head of Scholarship

Welcome indeed to this, the second edition of *The Annual*. The keen-eyed amongst you may have noticed the subtle re-naming of this publication from *The Scholars' Annual* to simply *The Annual*. This purposeful, albeit subtle, change is intended to reflect the implicit nature of scholarship here at the RGS. We are now in the second year of a move away from a Scholars' Programme towards a true Programme *for* Scholarship, a programme designed with one singular ambition: to gift every student the opportunity to see themselves as scholars of the truest sort, and to celebrate their intellectual individuality. This annual, and a newly accompanying Upper Sixth Form Journal, are but two avenues for our students to do just that. I hope you agree that once again both the breadth and depth of these published works are truly extraordinary and that they serve to give you but a flavour of the intellectual, inquisitive and creative environment that is this school. I must, of course, give thanks to the Senior Scholars' Council, whose help was invaluable not only in the production of these fine publications, but also in the organisation of our inaugural scholarship conference. They have consistently been exceptional ambassadors of scholarship and, for that, both myself and the wider school community are indebted to them. Thank you sincerely for all you have done. It then leaves me simply to commend these works of scholarship to you and trust that you will find them as enjoyable and illuminating a read as I have.

Mr Christopher Bradford, Head of Scholarship.

From the Editors-in-Chief

Sitting on the Scholars' Annual board, reading these pieces is a terrifying experience. What right do we have to judge pieces of unique excellence and varied focus? There is no mark scheme or principal examiner to whom we can appeal, and to negatively critique any single submission to this Annual risks undermining the purpose of Scholarship.

Our modern education system places incredible weight on standardised examinations definitively outlining what is right and wrong; by its very nature, Scholarship cannot be considered in this way. True Scholarship must be created beyond the curriculum and deserves to be viewed on its own merits and studied within its own context. Of course, this makes ranking Scholarship in order of merit extremely difficult, and for this we apologise to anyone whose work has not been published. We firmly believe that every Scholar has the right to be listened to and taken seriously, an ever less popular view in this age of instant judgement. As such, it seems right to emphasise the inclusivity of Scholarship, that most ivory tower of activities. After all, anyone who can back up an opinion with facts can be considered a Scholar with the same fundamental merit as any one of their peers. That being said, it is certainly possible to write rubbish, but this year we were lucky enough to get none.

It has been a pleasure editing this Annual and immersing ourselves in work of such high calibre, and we hope that you will enjoy reading it.

James Dickinson and Michael Kielstra, Editors-in-Chief

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Making Collatz cry

An examination of necessarily-failing Collatz-like conjectures

Michael Kielstra and Adam Wills

INTRODUCTION

The traditional Collatz conjecture states that, for any number, if you divide by 2 if it is even, multiply by 3 and add 1 if it is odd, and repeat, you will eventually reach 1. For example, starting with 5, we have 3 x 5 + 1 = 16, 16 ÷ 2 = 8, 8 ÷ 2 = 4, 4 ÷ 2 = 2, and finally 2 ÷ 2 = 1. This conjecture has proven un-provable to mathematicians for 80 years now, with many believing that new areas of mathematics must first be invented to solve the problem. In this paper, we explore Collatz-like rulesets and we examine which must necessarily succeed and which must necessarily fail. We first define some important words:

Ruleset A set of mathematical operations that is applied iteratively to successive integers based on their remainder modulo a certain constant. The traditional Collatz ruleset states that any even integers should be divided by 2 and odd integers should be multiplied by 3 and 1 added.

Succeed A ruleset is said to succeed if all integers, when inputted into the ruleset, reduce to 1. We will not explore what happens after the number 1 is achieved (in the traditional Collatz conjecture it cycles 1,4,2,1 infinitely).

Cases The 'cases' of a ruleset are the number of rules that the ruleset contains. The traditional Collatz conjecture ruleset can be said to be in 2 cases.

For the purposes of this paper we will explore what happens when a Collatz-like ruleset is created in a cases, where a is an integer. Motivated by a desire to ensure that our rulesets are as close as possible to the classical Collatz conjecture, we require them to have two features. All rulesets must have a 'primary rule': all integers expressible as an are divided by a. As an example, for a Collatz-like conjecture in 5 cases, all numbers expressible as $5n$ become n. Also, all other rules must be of the form 'multiply by x and add y', where x and y are non-zero integers. There are always a rules for a ruleset in a cases. $a - 1$ of these rules result in numbers increasing and 1 (the primary rule) results in a decrease. As an example of a Collatz-like ruleset in 3 cases that must necessarily succeed, $3n$ is divided by 3; $3n + 1$ is multiplied by 2 and 1 is added; and $3n + 2$ is multiplied by 2 and 2 is added. This ruleset can easily be shown to be strictly decreasing for all n and therefore it must succeed. We write this in shortened notation as $3n \Rightarrow n$; $3n + 1 \Rightarrow 2(3n + 1) + 1$; $3n + 2 \Rightarrow 2(3n + 2) + 2$ or in even shorter form as $3n \Rightarrow n$; $3n + 1 \Rightarrow 6n + 3$; $3n + 2 \Rightarrow 6n + 6$.

COLLATZ CYCLES – COLLATZ-LIKE CONJECTURES THAT MUST FAIL

The first thing to note is that if the ruleset is such that an integer of any form is run through a rule that causes it to return to the same form, the ruleset must fail. For example, for a ruleset in 6 cases, numbers expressible as $6n + 1$ may be multiplied by 3 and 4 is added. $6n + 1 \Rightarrow 18n + 7$ which is equivalent to $6n + 1$ so this rule is applied repeatedly and numbers expressible as $6n + 1$ must tend to infinity. This is an example of the most basic form of Collatz cycle, or a set of rules that continually feed into each other in such a way that any number run through them will never reach the primary rule. More complex cycles can be set up, where numbers of form $an + b \Rightarrow an + d \Rightarrow an + b$ and so numbers of both forms $an + b$ and $an + d$ must tend to infinity. For a ruleset in a cases, the largest cycle that can be made is of size $a - 1$. If the primary rule is incorporated into the cycle at any stage, the cycle does not necessarily cause a strict increase in integers in that cycle and the primary rule may even cause the ruleset to succeed. Whether the decreasing eect of the primary rule outweighs the increasing eect of the non-primary rules is something to be shown on a case-by-case basis. Being able to show this generally would result in a proof of the Collatz conjecture.

Theorem 1. *There are an infinite number of Collatz-like rulesets in a cases that fail for all integers other than powers of a.*

Proof. Because of the nature of the primary rule, any number that is a power of n must decrease to 1 by repeatedly applying the primary rule. However, an infinite number of Collatz cycles can be constructed such that all other numbers must tend to infinity. Let us set up a ruleset such that $an \Rightarrow n$; $an + 1 \Rightarrow c_1(an + 1) + d_1$; $an + 2 \Rightarrow c_2(an + 2) + d_2$; $an + 3 \Rightarrow c_3(an + 3) + d_3$; and so on. We wish to build a cycle such that numbers expressible as $an + 1 \Rightarrow an + 2$; $an + 2 \Rightarrow an + 3$; $an + 3 \Rightarrow an + 4$; and so on until $an+(a \ 1) \Rightarrow an+1$ in order to omit the primary rule. In general, $an+m \Rightarrow an+(m+1)$ or $an+(a \ 1) \Rightarrow an+1$. Therefore, we require $c_m(an+m)+d_m = c_m(an)+(m+1)$. This can be done if $d_m = m+1 \ c_m(m)$ for $1 < m < a \ 1$. For $m = a \ 1$; $d_m = m+2 \ c_m(m)$ to ensure a cycle is created omitting the primary rule and ensuring numbers of every form are included. There are therefore an infinite number of possible rulesets that result in cycles, which can be created by varying c_m and calculating the relevant d_m for each m. An example of such a cycle is $4n \Rightarrow n$; $4n+1 \Rightarrow 5(4n+1)+5$; $4n+2 \Rightarrow 6(4n+2)+3$; $4n+3 \Rightarrow 17(4n + 3) + 2$.

RANDOM COLLATZ-LIKE CONJECTURES

If we consider Collatz-like conjectures as a series of rules that link to each other, we can derive a very interesting result from the idea of randomly generating these conjectures. Let us introduce the notion of a 'random Collatz-like ruleset': a ruleset in which for every rule of the form $an + b \rightarrow cn + d$, c and d have been randomly chosen. We can now prove the following theorem.

Theorem 2. *The fraction of random Collatz-like rulesets that succeed is at most $\frac{(x)!}{x^x}$, where x is the number of distinct rules in the ruleset.*

Proof. For a Collatz-like ruleset to succeed, it must not contain cycles. We must thus find the probability that a random Collatz-like ruleset with x rules will contain no cycles. To do this, we consider each ruleset as a set of interlinked nodes. Each rule links to exactly one other, and in a random Collatz-like ruleset this is determined at random. Now, for there to be no cycles, every rule must link, eventually, to the primary rule in a tree formation. We will start with an unlinked set of nodes and attempt to add links one after the other in a random way until this condition is fulfilled. The first link we add must go to the primary rule, which it will with probability $\frac{1}{x}$. (There are x rules to link to, of which only 1 will work.) The second link may go to either the primary rule, or the rule which we just linked to the primary rule. The probability that it will go to one of these is $\frac{2}{x}$. The third link may go to either of the three newly linked rules, which it will do with probability $\frac{3}{x}$, and so

on. One possible hiccough will be if a rule links to an unlinked rule that then is later linked to the primary rule, but since the order in that the links are added does not affect the final outcome, we may resolve this by simply adding the same links in a different order. Now, to find the probability $P(x)$ of all links being part of this tree formation with no cycles, we multiply the probabilities for individual links to get $P(x) = \frac{1}{x} \times \frac{2}{x} \times \frac{3}{x} \ldots \times \frac{x-2}{x} \times \frac{x-1}{x} \times x = \frac{(x-1)!}{x^{x-1}}$. Multiply above and below by x to get the more elegant $P(x) = \frac{x!}{x^x}$.

This falls to zero extremely quickly as x becomes larger. $P(2)$ is $\frac{1}{2}$, while $P(3)$ is $\frac{2}{9}$ and $P(4)$ is $\frac{3}{32}$ and so on. Should the classical Collatz conjecture be true, it will be part of a very rare species.

ABOUT THE AUTHORS

Michael Kielstra goes by many names. As 13Clocks, he is the creator of a number of apps and websites, fluent in a large number of programming languages; as the Wandering Mathematician, he runs a mathematics blog at https://wanderingmathematician. wordpress. com. As himself, he is a student and an avid mathematician, specialising in number theory.

Like Michael, **Adam Wills** focuses on pure mathematics, but he is also an excellent chemist and physicist. This paper is his first collaboration with Michael, or with anyone for that matter.

Badger Cull

James Miller

The badger cull is one of the most controversial policies that the government has ever adopted, and without doubt one of the most emotive. On one side of the debate are the livelihoods of thousands of farmers, and on the other, the lives of thousands of one of the nation's most loved animals.

Why is it happening? Despite its prevalence in the media, many people still misinterpret the issue. Essentially, the government believes that badgers are spreading the disease bovine tuberculosis (TB) to cattle, and thus causing those infected cattle to become unfit for consumption and trade. In this brief article I'll try to give you a (relatively) unbiased introduction to the debate, and talk through some of the key issues.

SCIENCE

Do badgers carry and spread TB? Yes, they do – I'm not denying that. In fact, all mammals have the capacity to carry and transmit bovine TB – everything from dogs to humans. Somewhat unsurprisingly, cattle themselves are the worst culprits. The crux of the matter is how many badgers have it and how many of them transmit it to cattle. This is very hard to test – so far studies have proved inconclusive, and by no means justifying thousands of deaths.

The prevalence of the disease in the badger population varies dramatically, as does the disease in cattle. Historically, in some areas, the levels of TB have been recorded as 17%, in others 40%. However, we don't know what they are today. Since the cull in 2014, the government has stopped taking regular post-mortems of the badgers to see whether they have the disease. In 2015, only 28 were examined, and in 2016 and 2017, only 1 out of over 60,000 – and that was under special request. What possible reason could the government have for stopping examining TB prevalence in badgers, when this is

realistically the only way that we can know that the cull is effective? Perhaps the same reason that they have repeatedly refused to release the data that they collected on post-mortems before 2015. Perhaps a high proportion of the thousands of killed badgers were completely clear of the disease.

As mentioned earlier, we need to consider how much badgers transmit to cattle. The most rigorous scientific studies undertaken have shown that at least 94% of TB transmissions are cattle to cattle. So why is the government putting so much money, so many resources, and so many lives into reducing that <6%? We should clearly be focusing on the bigger problem, the one that caused this epidemic in the first place – the industrialisation of farming. Huge numbers of cattle are being bred closer together, and the biocontrol and hygiene is not up to scratch. This is where efforts need to be focussed.

So how effective are the culls, if so few transmissions are from badgers? The Randomised Badger Culling Trials (RBCTs), performed from 1998 to 2007, showed that if over 70% of badgers are killed over a 4-year period across 150 km2, then there can be a reduction in infected herds of an absolute maximum of 16%.

This 16% reduction might conceivably be worth it for some people. But the government have a record of not reaching the 70% kill target needed to see this slight decrease. Badgers are quite difficult to shoot, being nocturnal and very shy, and historically contractors haven't been able to kill enough of them. In recent years, the Independent Expert Committee claimed that the government was deliberately lowering cull targets to meet more achievable goals, but ones that would not meet the required level to have a positive impact on the disease. Strangely enough, this independent watchdog has since been disbanded by the government.

As the RBCTs showed, a failure to meet the 70% target not only reduces the chances of having a positive impact – it actually makes a negative impact quite likely. By failing to kill all of these badgers that are vectors of the disease, it disturbs the established territories of the badger clans and causes the remaining badgers to travel more, spreading the disease further to other setts. So while it was seen that the culls caused a decline in TB outbreaks within the cull zones, areas within a 2-km radius saw a slight but definite increase in TB incidences. This is called the perturbation effect.

This prompted the independent scientific group to write in their report: 'While badgers are clearly a source of cattle TB, careful evaluation of our own and others' data indicates that badger culling can make no meaningful contribution to cattle TB control in Britain. Indeed, some policies under consideration are likely to make matters worse rather than better'.

This is the conclusion of leading scientists on the best scientific trials conducted on the issue; contradicting them is synonymous to contradicting science itself. This policy is not scientific.

Furthermore, it's actually been proven that the disease can be reduced without culling. Wales has instigated a very different method of tackling the problem, combining annual cattle testing, movement restrictions on cattle, more intensive testing in high risk areas, and providing free gamma-interferon tests for farmers (a more accurate type of test). TB incidences have been reduced by 48% since 2009, and more than 95% of herds are now TB free in Wales.

MORALITY

As humans, priding ourselves on humanity (as in benevolence), we should be seriously concerned by the morality of the cull.

The government has experimented with several methods of killing badgers over the years.

Initially, from 1975 to 1981, they were gassed with hydrogen cyanide. This was initially believed to simply 'put them to sleep', however when scientists actually watched the badgers being killed they reported seeing the badgers 'retching and vomiting while uttering distress calls'. This method was soon halted after protest from the public.

Then, in later culls, the government tried both cage-trapping badgers before shooting them and 'free shooting', which involves cull contractors shooting free-moving badgers at night. Perhaps at first the latter seems the best way, involving minimal stress and a quick death. But studies say otherwise. Between 7.4 and 22.8% of badgers took longer than 5 minutes to die in 2013, and this figure didn't improve in 2014–2015. When you consider the thousands killed in each year, that's a lot of pain. The British Veterinary Association condemned free shooting for this reason, but DEFRA decided to reject this advice and claimed that the method was fine, continuing to pursue it as they knew that this method was the only economically viable one.

As well as the welfare of individuals, we need to look at the bigger picture. Ultimately, what the government is doing is wiping out vast numbers of a (protected!) species native to the UK, to act as a scapegoat for a form of industrial pollution that we have inflicted on ourselves and the countryside.

Besides, even if badgers were found to be largely responsible, would it really be right to wipe out a species from large areas of Britain to fuel the meat industry? Unquestionably, the answer is no, but as is the case with many issues today, it is a matter of weighing our greed and selfishness as a race against our conscience.

COST

So far, the government has spent somewhere in the region of £50 million culling. That's £1,100 per dead badger, or, in other words, ridiculous. That's more than 5 times as much as it costs to vaccinate a badger (although figures vary). Vaccination is not only more ethical, but provides more long-term group protection from the disease by actually increasing the proportion of immune animals rather than removing random badgers regularly, which is unsustainable.

CONCLUSION

Finally, a thought to finish on: is bovine TB actually a problem? Yes, it can affect humans, through transmissions in food mainly – historically, this has been a big problem. But since milk pasteurisation was introduced in the 1960s, human cases have declined massively, and still continue to decline despite increasing in the cattle population. It is predicted that if we were to totally stop controlling TB, there would be less than 20 incidences annually in the human population. To put this in perspective, the NHS spends £30 million annually on HIV prevention, with thousands of human cases per year, while DEFRA has so far spent £50 million for a risk of 20 cases per year, for a fully treatable disease.

Is it therefore done for animal welfare? I think we know DEFRA better than that.

No, TB is a long-term chronic disease. Physical symptoms take so long to develop and cows are killed at such young ages for meat that there is little chance of them ever developing this disease to the extent where it would become painful. On the other hand thousands of badgers are killed painfully every year. So I think we can assume that it is not for animal welfare standards.

Is it for money through trade? Cows are exported all over the place to other herds in other countries for profit, and TB-positive cows cannot be traded. In response to this, I'll simply say that the government are spending more money controlling TB than they are making through these live exports, not even taking into account the £37 million that farmers lose through cattle they aren't allowed to sell.

So, in conclusion, we are spending millions ineffectively combating an insignificant disease, and in doing so killing thousands of sentient creatures. This is despite countless petitions, 89% of the public against the cull in a recent poll and a wealth of scientific evidence. This is wrong.

The Next Generation of Nuclear Energy

How using thorium 232 in molten salt reactors will revolutionise the nuclear industry

Salvatore Nigrelli

Currently, 80% of the world's energy comes from fossil fuels. At this rate of consumption, all fossil fuel reserves will run out within the next 100 years. Renewable energy resources such as photovoltaic (solar) or wind are seen by many as the future, but these methods of energy generation are geographically limited and rely heavily on unpredictable processes such as the weather. The only feasible alternative to fossil fuels is nuclear energy. There is a stigma associated with nuclear power plants as they will always be associated with wide-scale disasters such as Chernobyl and Fukushima, but they are so much more effective than other sources of energy – a typical Pressurised Water Reactor plant (the most common type) is 70 km2 in area and produces the same amount of energy as a 1200 km2 solar power plant. So what if there was a safer and more efficient way of generating nuclear energy?
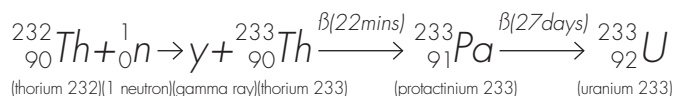
USE OF THORIUM IN NUCLEAR REACTORS

Since its discovery in 1829 by Swedish chemist Jakob Berzelius, thorium has proven to be an intriguing element. Like other actinides, it is a reactive silver metal, except that it is normally seen covered with a coating of black thorium dioxide. It has the longest half-life (the average time it takes for half of its atoms to have decayed) of any significantly radioactive element at 14.05 billion years. Thorium was originally used in gas lamps and lanterns as its oxide glows brightly when heated, but in the last 50 years, one of its isotopes, thorium 232, which is four times as abundant as uranium in the Earth's crust, has shown to have some unique applications in the nuclear industry.

There are two different types of radioactive elements that are used in nuclear reactors:

1. Fissile – the atoms that start the nuclear chain reaction to create energy.

2. Fertile – the atoms that breed (create) fissile material.

Thorium 232 is a fertile substance and it breeds uranium 233 when it absorbs a neutron in the reactor by the following sequence:

$$^{232}_{90}Th + ^{1}_{0}n \rightarrow y + ^{233}_{90}Th \xrightarrow{\beta(22mins)} ^{233}_{91}Pa \xrightarrow{\beta(27days)} ^{233}_{92}U$$

(thorium 232)(1 neutron)(gamma ray)(thorium 233)   (protactinium 233)   (uranium 233)

Or in simple English: Thorium thorium 232 converts to thorium 233 by absorbing a neutron in the reactor, and releasing a gamma ray, which in 22 minutes converts to protactinium 233 by beta decay in sealed containers, which then converts to uranium 233 by further beta decay over a period of 27 days.

An exciting potential use of this process is in a type of nuclear reactor called a molten salt reactor. What differentiates this nuclear reactor from the others is that the fertile and fissile material are dissolved in a molten salt. An early prototype of such a reactor, first tested in 1964 at the Oak Ridge Laboratory in the USA, showed that molten FLiBe salt (see Image 1) was the best salt to use. A thorium reactor that uses FLiBe is called a Liquid Fluoride Thorium Reactor (or LFTR for short).

WHY IS FLIBE USED?

FLiBe is a 2:1 mixture of lithium fluoride (LiF) and beryllium fluoride (BeF2). As all of its constituent atoms are very small, the bonds in the mixture are very strong and so unlike most other salts, FLiBe remains stable at 900°C, the average temperature of a nuclear reactor. In fact, the compound does not even begin to react until it is very close to its boiling point (1430°C). This stability also means that if its molecules are bombarded by radiation from the reactor, as happens very frequently, they remain unchanged. Stability is important for chemicals that are used in nuclear reactors because if they react or decay into other compounds, they can no longer perform their primary function, and this can lead to cataclysmic consequences.

As well as the above properties, FLiBe can dissolve all of the fissile and fertile material that the reactor needs to function as well as the nuclear waste that is produced, which makes the removal of nuclear waste a much simpler and safer process. Moreover, FLiBe has one of the highest volumetric heat capacities of any chemical, 4540kJ/m3K. To put this
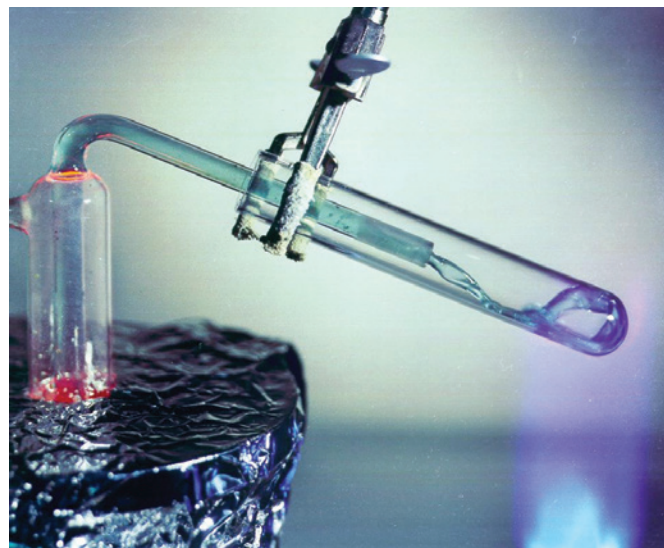

Image 1 Molten FLiBe (Oak Ridge National Laboratory)

into context, water is considered to have an exceptionally high volumetric heat capacity, and it is 4180kJ/m3K. This means that as well as being the transfer fluid for the nuclear material, FLiBe can also act as the coolant for the reactor as it takes away a lot of thermal energy from the reactor while only increasing in temperature by a few degrees. Due to its incredible thermodynamic effects it can also act as a heat-transfer fluid, which transports heat from the core into the heat exchangers that drive the turbines to generate electricity. Another advantage is, as the coolant is not water, unlike all other reactors, this reactor does not have to be near a water supply so can be built almost anywhere.

However, a couple of extra safety precautions have to be carried out before FLiBe can be used in a nuclear reactor. First, although FLiBe has a low fluoro-acidity (it does not have many separated fluoride ions), the materials that the reactor is made from need to be corrosion resistant metals such as nickel and its alloys, otherwise the molten salt would corrode parts of the reactor. Secondly, as the molten salt contains fluoride ions, no water can be present, as if the fluoride ions lose one of their outer electrons, they form fluorine atoms, which react extremely violently with water and thereby trigger an explosion. Fortunately, this problem can easily be overcome by using argon flux (covering something with argon gas) to cover the FLiBe when it is being synthesised because the argon acts as a barrier preventing water from entering the salt.

IMPROVED EFFICIENCY OF LFTRS

The most efficient type of LFTR (shown in Image 2), is called a Two Fluid LFTR because the fluids containing the thorium 232 and the uranium 233 are separate. The dissolved, fertile thorium 232 is in a 'blanket' around the reactor whilst the uranium 233 atoms are in the reactor core. This improves the neutron economy of the reactor because any neutrons that escape the reactor are absorbed by the thorium atoms to start the decay sequence to make the fissile fuel (uranium 233). Having the two fluids separate means that any unused uranium 233 can be removed easily from the reactor by pumping fluorine gas through the reactor core to make uranium hexafluoride; once separated from the fluorine atoms this can then be re-used as fuel. These adaptations mean that this thorium reactor is 40% more energy efficient than the most commonly used reactors: Pressurised Water Reactors.
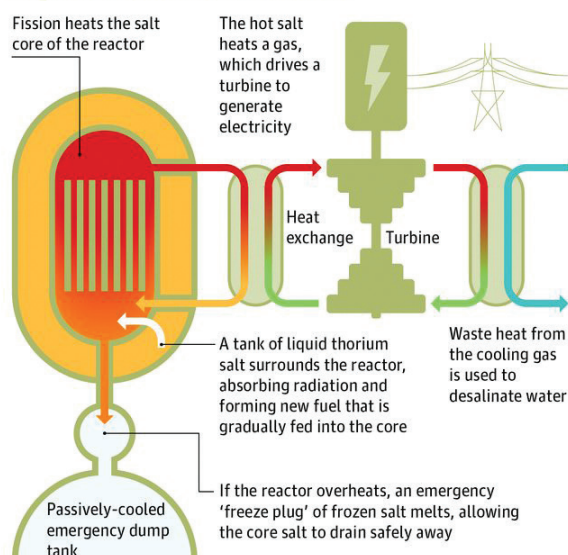

Liquid-fluoride thorium reactor

Fission heats the salt core of the reactor

The hot salt heats a gas, which drives a turbine to generate electricity

Heat exchange   Turbine

A tank of liquid thorium salt surrounds the reactor, absorbing radiation and forming new fuel that is gradually fed into the core

Waste heat from the cooling gas is used to desalinate water

If the reactor overheats, an emergency 'freeze plug' of frozen salt melts, allowing the core salt to drain safely away

Passively-cooled emergency dump tank

Image 2 A diagram outlining an LFTR (New energy portal)

SAFER REMOVAL OF NUCLEAR WASTE

The removal and processing of nuclear waste is a hot topic at the moment because the products of uranium 235 fission in traditional nuclear reactors take thousands of years to become stable. In LFTRs, the two main fission products are xenon 137, which decays to stable barium 137 within 30 years, and strontium 94, which decays to stable zirconium 94 in a few minutes. LFTRs have chemical processing plants on site to remove nuclear waste, particularly isotopes with a high neutron cross section such as xenon 137 and the lanthanides as these absorb a lot of neutrons; so many in fact, that they are referred to as 'neutron poisons' and heavily reduce the neutron economy of the reactor. Xenon 137 escapes from the molten salt as a gas and is contained and stored underground until it is stable; strontium 94 quickly decays and the zirconium 94 forms fluoride compounds in the FLiBe, which can easily be removed, and fluorides of lanthanides and actinides can be removed by bubbling fluorine gas through the solution to form fluorides of the elements that can then be removed. Molybdenum 99 is also produced by the reactor and is highly sought after for cancer detecting dyes, so can be sold in order to make the plant more profitable.

SAFETY AND COST

The question often associated with nuclear reactors is "How are they protected against a nuclear disaster?". LFTRs are protected against such events in two ways: first, the fact that the coolant (FLiBe) is not pressurised, unlike most other reactors, means that if the reactor overheats, the coolant can expand and reduce pressure on the reactor core, preventing the breaking of parts in the rector and thereby stopping a meltdown. Secondly, many LFTR designs contain a 'freeze plug' mechanism. This is a wall of material that melts if the reactor overheats and when it melts it opens a channel that drains all of the nuclear material out of the reactor, thereby again preventing a potential meltdown.

Another huge advantage of LFTR reactors is that they cost 30% less than uranium reactors to build at $780 million and due to the lack of harmful nuclear waste, they cost much less to decommission. Although no commercial LFTRs have been produced yet, it has been calculated by the writers of the Thorium Energy Bill of 2015 that the energy will cost just 1.4 US¢ per kWh to produce compared with 4.2¢ for fossil fuel burning and 6.0¢ for offshore wind power. This staggering comparison makes you wonder why we are not already using thorium as a nuclear fuel.

WHY IS THORIUM NOT USED MORE?

After seeing the many advantages of thorium over uranium as a fertile nuclear fuel – greater neutron economy, more efficient heat transfer, the ability to reuse unreacted uranium, safer nuclear waste disposal, and cheaper cost of producing electricity – the question is, why is it not used more? Particularly as thorium is four times more abundant in the Earth's crust than uranium. The answer seems to lie in the Cold War when the first nuclear reactors were developed. USA and Russia preferred to use uranium 238 as it can absorb a neutron and decay to form plutonium 239, which was used in nuclear bombs; whilst possible, it is very difficult to make plutonium 239 from thorium. Therefore, at that time, most nuclear reactors used uranium 238 and countries have had no need to change them. Having now realised that thorium is a more effective fuel and the need for nuclear weapons greatly reduced, we may, one day, see a thorium powered energy revolution.

Bioluminescence

Ferdy Al-Qassab

WHAT IS BIOLUMINESCENCE?

According to the Oxford English Dictionary, Bioluminescence is: 'the biochemical emission of light by living organisms such as glow-worms and deep-sea fish'. This biochemical emission of light can be created using several different combinations of chemicals.

HOW DOES IT WORK?

Photons are created when a photoprotein combines with a luciferin (a light producing substance) and oxygen. This can more effectively happen when a luciferase (an enzyme that speeds up the reaction, or a 'catalyst') is present.

The actual chemicals that cause bioluminescence differ between animals. Some animals' luciferin (such as the splitfin flashlight fish, Anomalops katoptron) is riboflavin phosphate, which can be found in bacteria, which the fish keeps in a light organ below its eyes. Such fish live in a symbiotic relationship in which they feed the bacteria, and the bacteria provide them with a luciferin.

Fireflies use a different type of luciferin, aptly named 'firefly luciferin'. 'In the firefly, oxidation of luciferins, which is catalysed by luciferases, yields a peroxy compound 1,2-dioxetane. The dioxetane is unstable and decays spontaneously to carbon dioxide and excited ketones, which release excess energy by emitting light (bioluminescence).'[1]

A firefly lights up, searching for a mate. This is performed with the aid of a unique firefly luciferin. Other animals tend to use bacteria and other luciferins to produce light.

HOW IS IT USED IN THE NATURAL WORLD?

Bioluminescence has five main uses in the natural world. These are: using it as a deterrent, a distraction, a predatory lure, to send signals and to find a mate.

It is little known that over half of all jellyfish species use bioluminescence, most notably as a deterrent. This is because a fast flash of light in the inky blackness of the deep sea shocks predators. However, some shallow-dwelling octopuses* such as the blue ring octopus, use blue or red lighting to indicate that they are poisonous or dangerous (as the blue ring octopus certainly is). Some animals that are harmless use this to fool predators as well, such as the brittle star. This is known as aposematic bioluminescence (when an animal pretends to be dangerous by having conspicuous warning patterns). In a scientific study[2], it was concluded that, in the case of brittle stars, aposematic bioluminescent animals are rejected by predators three times quicker than non-bioluminescent animals.

Some squid and jellyfish in the deep sea eject bioluminescent 'ink' or mucus to confuse predators, giving themselves a chance of escape. The bright discharge distracts, working just as a 'feint' move does in many sports: the predator follows the 'ink' rather than the squid or jellyfish itself. Marine annelids – a type of worm – use bioluminescent 'bombs' to confuse predators.

Arguably, the best-known use for bioluminescence is as a lure. The deep-sea anglerfish has a dangling bulb of bioluminescence that catches the eyes of other fish furtling for food. It lures them towards the bacteria-produced light on the end of its barbel, to be abruptly swallowed by the ugly behemoth behind it.

Bioluminescence can be used to send signals to a mate as well. Light can travel very far, hence why we use long-distance light-based Morse code. Several crustaceans and worms (as well as fireflies) flash or glow to make themselves visible to mates. For example, syllid fireworms are usually found on the sea floor, but become planktonic when looking for a mate, at which point the females use bioluminescent signals.

The pyrosome, a colony of phytoplankton formed into a tube, seems to glow at random intervals, possibly when it hits something or to communicate. The exact purpose is yet to be understood by scientists.

HOW HAVE HUMANS HARNESSED THE POWER OF BIOLUMINESCENCE?

Believe it or not, bioluminescence is not something that only animals can use to their advantage. Many concepts have been developed for human applications, including bioluminescence in medical research, bioluminescent trees and even bioluminescent sweets.

1.   Aldo Roda Chemiluminescence and Bioluminescence: Past, Present and Future, p. 57.
*   Octopuses is the correct plural of octopus – the word comes from Ancient Greek in which the plural is 'octopodes'
2.   Brittle-star bioluminescence functions as an aposematic signal to deter crustacean predators. Author links open overlay panel: Matthew S. Grober

Bioluminescent trees would provide a non energy-sapping way of lighting our streets, without any harm to the atmosphere. But how exactly would this work? Scientists at Cambridge University say that, by splicing the genes of trees with photosynthesizing bioluminescent plankton, it would theoretically be possible to make a tree that absorbs the light of the sun during day, and emits light at night, hence emitting light when needed. To add to this, Dr Sanderson at the Sanger Institute, Cambridge created a bioluminescent tobacco plant, as well as making *Escherichia coli* bioluminescent, about which he stated: "We were able to read by the light of our bacteria, but only just." But why has this not entered our homes yet? There are ethical problems with using animals to light a room, and it is expensive to feed the plankton. Furthermore, they function primarily as a novelty item because they do not provide enough light for a room.


A light has already been developed that harnesses bioluminescent plankton – providing a method of lighting a room with no electricity involved.

Moreover, there are further applications for bioluminescence. It is possible to make certain cells, such as cancer cells, bioluminescent to better track the 'behaviour' of tumours and cancers, a method that has already been tested on mice. This has prompted the US government to fund research into bioluminescence.

WHERE NEXT?

Such methods of using bioluminescence have already been partially developed, yet there are further exciting prospects for the future. Bioluminescent plants could tell a farmer when they need water.

The military is already asking how they could use bioluminescence to their advantage, via tracking or labelling. Bioluminescence has infinite ways in which it could influence our lives, and we have hardly scratched the surface of its potential.
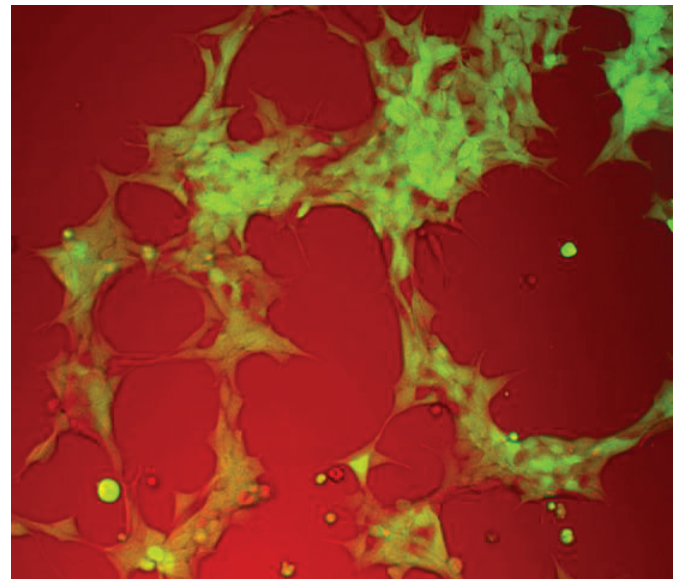
Cells (including cancer) can be made bioluminescent

In the future, bioluminescent trees could light our streets at night

Enceladus

Winner of a Middle School Essay Competition

Marcus Hinton

In the year 1789 the seventh of Saturn's 60 moons, Enceladus, was discovered by the German composer and astronomer William Herschel. For two centuries, little was known about the moon until the two Voyager spacecraft passed by in the early 1980s. Many astronomers and scientists found Enceladus' glow intriguing, resulting in the moon becoming one of the prime focal points of the Cassini–Huygens Saturn expedition. In July 2004 the unmanned spacecraft Cassini entered into orbit around Saturn. Huygens, the moon lander, separated from Cassini on Christmas Day 2004 and landed on Saturn's largest moon, Titan, on 15 January 2005. This was the first successful outer solar system landing. During 2005 Cassini remained in orbit around Saturn and started to perform multiple flybys of Enceladus, revealing large plumes coming from the southern polar region. The plumes, also called 'cryovolcanoes', were discovered to be rich with water.

NASA has described Enceladus as a "promising lead in our search for worlds where life could exist". This is not only because the plumes have been found to come from an underground ocean beneath Enceladus' thick icy crust, but also because organic compounds such as methane – as well as other gases such as ammonia, carbon dioxide, carbon monoxide and nitrogen – have been detected in the plumes. By 2015, having collected and examined years of data from Cassini, scientists suggested that the magnitude of the 'wobble' in Enceladus' orbit was likely to be caused by its icy crust not being firmly affixed to the surface of the moon. Calculations led to the theory that there was a 10 kilometre deep sea beneath a 30–40 kilometre thick ice crust at the southern pole.

Enceladus, although it is Saturn's sixth largest moon, is not an especially big celestial body. It has a mean radius of 252 kilometres (approximately one quarter of that of Earth's moon), and is about as wide as the US state of Arizona. However, Enceladus manages to exhibit a wide range of terrain in this small area. Parts of Enceladus are believed to have craters with a diameter of up to 35 kilometres; other regions show large areas completely without craters, therefore suggesting that there have been significant 'resurfacing' events (such as parts of the surface being stripped away by extremely strong storms) in the relatively recent past. Further examples of different terrain found on the moon are fissures, plains, corrugated terrain and geysers.

The southern pole of Enceladus is almost entirely free from craters, instead being littered with large ice boulders (most of which are about the size of a house). Warm cracks in the ice crust supply water vapour to the already large cloud above the region, sourced from the sea believed to be below the crust as described above. These cracks resemble crevasses, as found on glaciers on Earth, with the large plumes of water spewing out of the hottest parts of the crevasses.

The plumes themselves consist mainly of water vapour and tiny ice particles approximately one ten-thousandth of an inch in diameter, making them about the width of a human hair. These plumes come rushing out of the planet at speeds of up to 400 metres per second, or 800 miles per hour. The plumes travel about 750 kilometres (three times the radius of Enceladus) into space. From there the water vapour and miniscule ice particles either return to Enceladus – and refresh the surface – or add to Saturn's E ring (an icy ring that forms part of the ring system around Saturn). The plumes from Enceladus' surface are constantly refreshing: another reason for scientists to believe that there is an ocean below Enceladus' surface.

Many scientists and researchers believe that if there ever has been an ocean below Enceladus' crust, then it would have frozen a long time ago. However, scientists discovered evidence from gravity measurements based on the Doppler effect that supported the idea of a planet-wide ocean below the crust. This reinforced the aforementioned hypothesis of an ocean below the southern pole. It is believed that the ocean has not frozen because of Enceladus' resonance with Dione, another of Saturn's moons. This resonance with Dione results in Enceladus' orbit becoming more eccentric, which in turn increases tidal forces inside Enceladus leading to the moon's interior being tidally heated. This is believed to be the reason why the ocean below its crust has not frozen and how it can therefore still supply the large plumes with water.

Due to the plumes being rich in water, carbon dioxide and carbon monoxide, methane and other hydrocarbons, many scientists agree that Enceladus seems to have possibilities as a suitable place for life to develop. Dr Hunter Waite, a scientist in the Cassini project, said "We're pretty darn sure that the internal ocean of Enceladus is habitable… [But] it is almost as equally interesting if there is no life there, given the conditions." What Dr Waite means here is that he believes the sub-surface ocean on Enceladus to have such good conditions for supporting life that he would be surprised and curious if life is not present on the moon. This, along with all the other scientific research provided by the Cassini probe (such as the detection of salt in the water plumes), shows us that life on Enceladus is possible – if not likely – due to the moon's ocean containing everything required that scientists believe to be necessary for life to start.

Energy is needed for life to exist. The solar system's main source of energy is the sun and almost all life on earth depends on the sun to exist. Therefore, this could cast doubt into whether life could exist on Enceladus, so far from the sun, underneath a kilometres-thick covering of ice. However, we already have evidence of life living in analogous situations here on Earth. At the very bottom of the ocean, in areas of volcanic activity, hydrothermal vents spew super-heated water – full of nutrients and minerals – through the Earth's crust into the very cold and aphotic sea. Hundreds of organisms have evolved in the local region near the vent. The significance of this is that it demonstrates that sunlight is not necessary for life; instead of photosynthesis, organisms living from these hydrothermal vents (such as tube worms) use chemosynthesis to produce energy. Chemosynthesis is where the nutrients and minerals inside the hydrothermal vents are converted into energy, instead of sunlight, glucose and carbon dioxide as in

photosynthesis. It could be argued that these hydrothermal vents are similar to the plumes on Enceladus, providing support for the belief that the moon could support life.

The research therefore tells us that life possibly could exist on Enceladus. This does not, however, mean that there will actually be life. Life could have evolved and died out already, or it could appear in the next 1000 years. All we know at the moment is that Enceladus has very good conditions for supporting life. A discovery of alien life on Enceladus would be groundbreaking and could lead to new areas of research relevant to our understanding of the cosmos and of life-creation processes in general. However, we have to wonder how 'alien' it will actually be. On Enceladus, we are not in the world of Star Wars; any life we find on Enceladus is likely to look similar to micro-organisms found on Earth. It is possible that any life on Enceladus would consist of very basic organisms that might, for example, resemble Archaea, which are prokaryotic microbes first found on earth in extreme environments, such as volcanic springs. Although we would therefore probably just find 'alien amoebae', this would still be fascinating and very significant, but due to the length of time taken and the remarkable circumstances needed for life to develop and evolve, I find it unlikely that anything found will be larger than a few cells. It is also important that – although the discovery of basic alien life in our solar system might be possible in the near future – the discovery of intelligent alien life is altogether different and dramatically more unlikely.

With this taken into account, we can see that although any discovery of life on Enceladus would be one of the biggest scientific discoveries ever made, once people realise that we are talking about tiny micro-organisms and not intelligent life there should be a measured response to the findings. The fact that the life would not be intelligent also means that people accept the facts more easily, instead of some people possibly being shocked or frightened by the news.

Hopefully we could expect a discovery of alien life, no matter how basic, to increase interest in space exploration and astronomy, not to mention evolution and microbiological processes. Finding out that Earth is not the only life-supporting body would revive a general interest in space and space exploration. We could probably expect NASA's budget to increase, if anything just so that we can learn as much as possible about Saturn's moons and the variety of life they might harbour. A discovery of life on Enceladus would mean a globally refreshed interest in space exploration, and hopefully result in more nations trying to work together to find out as much about what's out there as possible. A discovery like this would hopefully cause nations to put more resources towards exploring our solar system and learning about the universe, which would in turn increase our rate of discoveries and would mean we learn a lot more a lot faster.

Learning that Earth is not alone in its ability to support life would not be accepted overwhelmingly positively by everyone. Some religious groups may find it hard to accept, and of course conspiracy-theorists would claim that NASA is lying. Personally I think the response to the discovery of alien life would be overwhelmingly positive, but we should be aware that some groups might not like the news as much as others.

It might seem far-fetched and naively optimistic, but the discovery of alien life could help to give the population of our planet a wake-up call. Realising that the Earth is not the only place harbouring life in the universe could make people – and nations – realise that our fights and arguments on Earth and our incapability to work together are insignificant when compared with the size of the universe and the endless possibilities that it represents. In a way, realising that there is other life in the universe could bring nations – and us as a global population – together and perhaps realise that our introspective infighting is self-destructive. A discovery like this would give everyone a sense of perspective, which I believe would only be a good thing. Nations working together to look beyond their insular borders into the cosmos might, I hope, lead to better cooperation, understanding and harmony, something that our planet is arguably desperately in need of.

Finally: the inevitable. A discovery of alien life, no matter of what kind, would cause many people to start asking about intelligent alien life. A discovery like this could lead many people to believe that there is intelligent life outside our solar system, and that we are not the only intelligent beings in the universe. To be honest, I would probably agree. We are just one planet amongst more than 100 billion stars in our galaxy alone. The Milky Way is then just one galaxy of 54 in the Local Group galaxy cluster, which measures 10 million light years across. In turn, the Local Group is a dot inside the Virgo galaxy supercluster, which contains more than 100 other galaxy clusters. The huge Virgo supercluster measures 110 million light years across. In turn, the Virgo supercluster is a speck of dust inside the Laniakea supercluster, within which our galaxy is just one of more than 100,000 others. The distance from one side of the Laniakea to the other is approximately 520 million light years. If we then zoom out even further, we can see that even the colossal Laniakea supercluster is a tiny, seemingly insignificant, part of the observable universe. The width of the observable universe is 93,000,000,000 (93 billion) light years. However, the truly mind-numbing fact is that in the observable universe there are at least 2,000,000,000,000 galaxies. After considering all of this, imagine us discovering alien life on Enceladus, in our own solar system. When the actual, almost completely unbelievable, size of the universe is spelled out like this, we realise that if we found life in our own solar system, then we could be almost sure that there would be more out there.

However discovering it, contacting it and visiting it, given the scales involved, is assuredly something that is monumentally more of a challenge and, I conject, impossible in the foreseeable future.

PRINCIPAL SOURCES

△ "Solar System", by Marcus Chown

△ "How it Works" magazine issue 74, article "Cryovolcanoes on Saturn's Moons" and issue 97, article "Cassini-Huygen's Grande Finale"

△ "Life's Other Secret", by Ian Stewart

△ Encyclopaedia Britannica

△ Official NASA website, Wikipedia pages and other smaller websites

△ "A Brief History of Time" and "The Universe in a Nutshell", by Professor Stephen Hawking

Keratoconus

Solomon Poole

Keratoconus is a fairly common disease in which the normally round cornea thins and begins to bulge into a cone-like shape. As one of the main jobs of the cornea is to focus on what you are seeing, it is a problem as it distorts your vision. There are not any obvious causes; however, there is a link in family genetics and also rubbing your eyes from allergies.

Normal cornea   Keratoconus
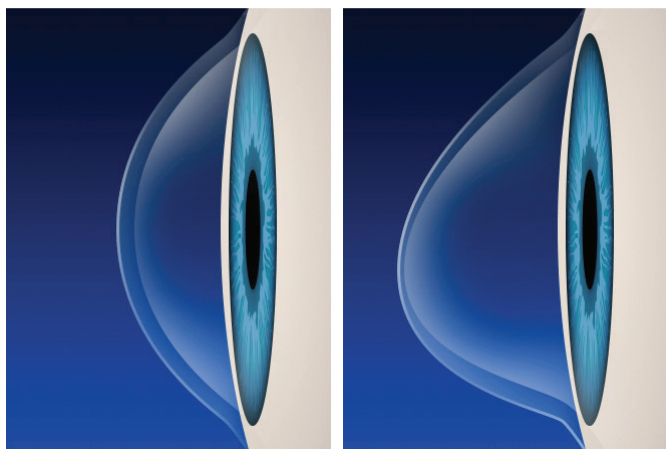
EARLY TREATMENT

This treatment is very recently invented – based on the same technology that dentists use for putting on brace brackets…

Under anaesthetic the epithelium (the eye's protective layer of cells) is taken off. Then for 20 minutes riboflavin (vitamin B2) eye drops are soaked; this makes the eye look slightly yellow. Then for a further 10 minutes a UV light is shined onto the cornea. This (similar to dentists' blue curing light) makes the drops harden slightly into place. This then prevents it from bulging outwards.

ONE DOWNSIDE TO THIS TREATMENT IS IT IS VERY PAINFUL FOR 2 DAYS – IT NEEDS MORPHINE!
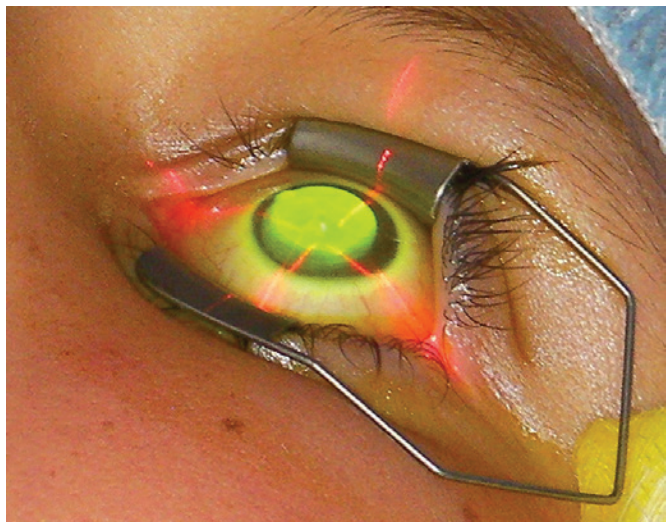
ALTERNATIVE TREATMENT
### EITHER CONTACT LENSES OR PLASTIC CORNEAL INSERTS

Using contact lenses, you can solve the problem short term. This simply forces the cornea back into its original shape. However, if this is not possible – for example, if the patient is elderly and cannot put them in themselves, or they do not like them, then you have to resort to using plastic corneal inserts. The process to putting these in is relatively quick. All is needed is a quick 20 minute operation. In this operation, a small incision is made on the surface of the cornea. (Lasers are very efficient at doing this.) Then a centre guide is placed on the eye. Finally, the small plastic Intacs inserts are placed. The incision is sewn back up. This procedure is quite effective.
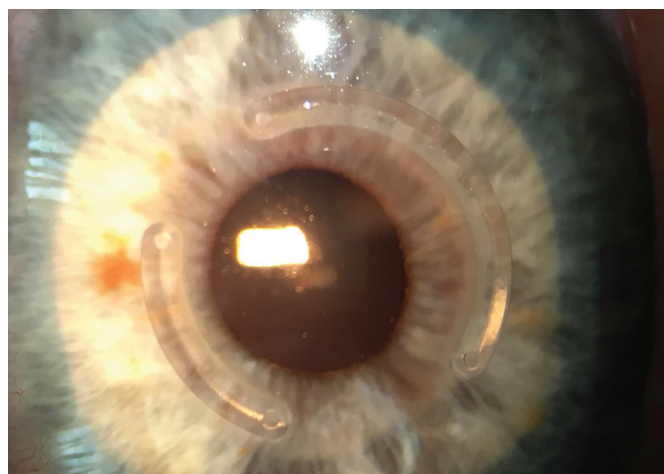
IF REALLY BAD
CORNEAL GRAFT TO SEW INTO PLACE

When it gets to this point the only way to treat it is to perform a corneal graft. This operation relies on a donor. The original cornea is taken out and the donor's is sewn into place… However, such is the high demand for this sort of procedure, the waiting list on the NHS is 5 months.
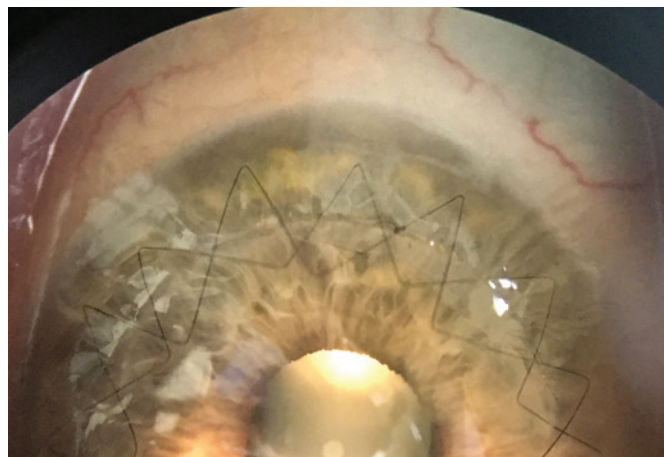
Formula for the distance between two objects orbiting the same point

A derivation from first principles

Sam Cherry

Let r_1 and r_2 be the orbital radii of orbiting objects O_1 and O_2 respectively.

The path of the orbits of objects O_1 and O_2 can be modelled respectively as:

$$x_1^2 + y_1^2 = r_1^2 \text{ and } x_2^2 + y_2^2 = r_2^2$$

when both objects are modelled as orbiting around the origin.

Subsequently the respective co-ordinates of points on the lines
$x_1^2 + y_1^2 = r_1^2$ and $x_2^2 + y_2^2 = r_2^2$ can be expressed as:

$$(r_1 \cos\theta_1, \ r_1 \sin\theta_1) \text{ and } (r_2 \cos\theta_2, \ r_2 \sin\theta_2)^1$$

Where θ_1 and θ_2 are the angles between the line $y=0$ and the points $(r_1 \cos\theta_1, \ r_1 \sin\theta_1)$ and $(r_2 \cos\theta_2, \ r_2 \sin\theta_2)$ respectively.

θ_1 and θ_2 can be derived from the formulae for angular velocity, given the radii (r_1 and r_2), the linear velocity (v_1 and v_2) and the time (t) from which the co-ordinates of both orbiting objects were $(r_1, \ 0)$ and $(r_2, \ 0)$ respectively:

$$\text{Angular Velocity} = \frac{\text{Angle Displaced}}{\text{Time}} \ ; \ \text{Angular Veollocity} = \frac{\text{Linear Velocity}}{\text{Radius}}$$

$$\frac{\text{Angle Displaced}}{\text{Time}} = \frac{\text{Linear Velocity}}{\text{Radius}}$$

$$\text{Angle Displaced} = \text{Time} \times \frac{\text{Linear Velocity}}{\text{Radius}}$$

$$\theta_1 = \frac{t v_1}{r_1} \ ; \ \theta_2 = \frac{t v_2}{r_2}$$

Subsequently the co-ordinates of the points are:

$$\left[r_1 \cos\left(\tfrac{t v_1}{r_1}\right), \ r_1 \sin\left(\tfrac{t v_1}{r_1}\right) \right] \text{ and } \left[r_2 \cos\left(\tfrac{t v_2}{r_2}\right), \ r_2 \sin\left(\tfrac{t v_2}{r_2}\right) \right]$$

According to Pythagoras' Theorem, the distance (d) between these two points is:

$$d = \sqrt{\left[r_2 \cos\left(\tfrac{t v_2}{r_2}\right) - r_1 \cos\left(\tfrac{t v_1}{r_1}\right) \right]^2 + \left[r_2 \sin\left(\tfrac{t v_2}{r_2}\right) - r_1 \sin\left(\tfrac{t v_1}{r_1}\right) \right]^2}$$

NB All angles in Radians

Is it a good idea to have public policy determined by voting in national referendums?

Winner of the Corpus Christi Cambridge Bacon Essay Prize for Politics and International Relations 2018

Kit Edgecliff-Johnson

J ust off the M25, Junction 16, directly opposite London Heathrow, sits a giant yellow billboard with a single word: 'Swindled'. Accompanying it are two images of burger: one appetising, one not. The tagline reads 'It's not too late to stop Brexit'. This billboard is a timely example that the lack of a sufficiently politically educated electorate, sub-optimal turnout, the impact of propaganda and fake news all make using referendums to determine public policy highly risky. Past tyrannical regimes such as the fascist dictatorships of the 20th century in Italy and Germany making use of national referendums to legitimise their actions must remind us of the many dangers of using national referendums to determine public policy.

However, this does not mean that there is no place for referendums in modern politics; merely that it should only be used when determining changes to the rules within which public policy is enacted. Namely, referendums should be used for *constitutional issues*, for those concerning devolution and transfers of power, as well as citizens rights.

Langdon C. Stewardson summarised the moral arguments for having public policy determined by national referendums in his essay 'The Moral Aspects of the Referendum'[1]. His argument was simple: referendums are a good way of determining public policy as they adhere most closely to the democratic values within which we claim to live. A referendum employs direct democracy to ensure that members of the sovereign public have the ability to make decisions about their future – putting power in the hands of those our system claims to represent.

However, this only applies in a perfect world. The global average for voter turnout is currently c. 65%[2], 68.7% in the UK, whilst Switzerland, the preeminent case study for regular, binding referendums, sees only 49.2% turnout. These data suggest that were referendums to be implemented on a large scale within the UK, for example, repeated use of referendums would slowly erode turnout to the point where the minority of the country was determining policy that would affect every single member of that country. This is hardly democratic, and demonstrates perhaps the most frequently raised argument against using voting in national referendums to determine public policy, summarised by the political blogger Chris Prosser as 'Referendums look a lot like democracy'[3] (but actually are nothing of the sort). So whilst at first glance a national referendum might look like an incredibly democratic system, voter turnout trending downwards coupled with voter apathy would surely result in public policy being determined by a minority of society.

Stewardson's second argument is that public policy should be determined by referendums because they avoid the issues that representative democratic systems face, namely corruption and a lack of representation. In theory a referendum bypasses the issue of corruption and bribery, as the large numbers of voters involved in a referendum (the USA has a population of 325 million, and a legislature of only 535) means that any attempt to 'pay off' individual voters would be not only hugely expensive, but also quickly found out. Furthermore, issues of 'safe seats', where a vote for a certain party is doomed to have no value, would be avoided, and the issue of unequal constituency sizes (in Malaysia some constituencies have over 100,000 voters, whilst others have fewer than 18,000) would be removed – a straightforward vote on an issue where everybody's vote has the same worth seems the best way to decide an issue. Even better, Switzerland's 'legislative referendums' allow for a referendum to be called repealing legislation if 50,000 supporters can be found within three months, limiting the extent to which special interests can force through legislation unchallenged.

Yet, this argument fails to recognise that the very same issues that plague elected legislatures play just as big a role in national referendums, if not bigger. Take, for example, the infamous promise of £350,000,000 a week for the NHS by the 'Vote Leave' campaign, propaganda trying to bribe the citizens of the UK with extra funding for its health service in exchange for an 'out' vote in the Brexit referendum. It may not *look* like bribery, due in parts to its audaciously public nature, but the principle remains the same. Whilst the commercial world maintains advertising standards agencies to prevent misleading claims from being published, there are no such political controls. In fact with the rise of divisive right and left wing extremism throughout Europe and America, the more radical (and often incorrect) an advert or piece of propaganda is, the better it is received.

Ultimately, claims that referendums should be used due to supposed unfairness in current (representative) political systems fail to realise that political reform and use of a representative democracy are not exclusive – referendums should not be used just because the current political system has flaws, as these flaws can be assessed, discussed, and ultimately fixed. Instead, any argument for using referendums

would exist purely of its own merit; mere complaints about current systems have no place in discussing whether public policy should be determined by voting in national referendums.

Referendums also suffer from the influence of special interest groups, which attempt to espouse their vision for society, no matter whether or not the referendum is directly related to that issue. As a result, the decision making abilities of a referendum in reference to public policy soon becomes impotent in the face of external issues hijacking the referendum to further an agenda.

Third parties can have a huge effect on referendums, attempting to influence the result of the vote in order to further the goals of whatever pressure group, party or lobbying firm is involved. One case study examining the effect of political parties on referendum results used regression analysis to conclude that 'one of the two major parties in Greece - New Democracy - lowered significantly the percentage of voters opposing (the question at hand)'.[4] This offers a strong case for referendums being less democratic than would be supposed – it would appear that calling referendums the 'will of the people' is an overstatement; in the case of the Brexit referendum a 'handful of multimillionaire businessmen' … 'rarely straying from the shadows' played a huge role in the financial result, says Nick Clegg, citing their own 'reasons of self-interest'[5]. These individuals made use of their significant wealth, media influence and political capital to drive the national debate and propagate misinformation. The UK Statistics Authority called a number of campaigns used in the lead up to the Brexit referendum 'a clear misuse of official statistics', making any claim that referendums are a pure, untainted expression of the people's opinion dubious at best. If the electorate are so often bombarded with information aimed to mislead then they have no chance of making an informed, morally conscientious decision (as was shown in the recent case of the Cambridge Analytica scandal).

Furthermore, referendums over a particular question often have a number of other, unrelated issues dragged in. One good example of this is the 2016 Colombian peace agreement referendum, a vote on a peace treaty four years in the making. Whilst it would be assumed that the debate would be over whether or not the peace deal would be worthwhile, the opposition groups instead painted the vote as a decision on whether or not the rebel group FARC (Revolutionary Armed Forces of Colombia) deserved leniency in trials to be held after the election. This attempt to redefine the narrative of the referendum proved successful for the opposition, who won the referendum 50.2% to 49.8%, showing just how powerful control of the narrative can be in a referendum, further frustrating the ability of the electorate to express their opinion. A similar situation occurred in Thailand, where a military-led government held a referendum on a new constitution, essentially giving it the powers of a dictatorship, whilst promising that unless it was given these powers it would not hold democratic elections, wrapping up a vote for dictatorship as a vote for democracy. Rather unsurprisingly, the vote passed.

This concept of referendums being used as a tool of dictatorship and tyranny is far from an outlier. In fact, historical evidence has shown that demagogues and dictators often use referendums to legitimise and extend their power. This is largely due to the fact that 'Referendums look a lot like democracy'[6], in that correctly manipulated they can be used to justify a wide range of actions, even when those actions run counter to the democratic spirit of referendums themselves. The Nazi state under Adolf Hitler held four referendums between 1933 and 1938, each of which allowed him to consolidate his power: merging the positions of Chancellor and President – making Hitler the 'Fuhrer', approving the military occupation of the Rhineland, creating a single Nazi-approved party list, and supporting the annexation of Austria. These referendums were used by the Nazis to legitimise their actions, claiming to be representing the will of the people when invoking the mandate these referendums gave them. These referendums proved so damaging to German democracy that they are now banned under the German constitution, evidence from a country that knows all too well the dangers of dictatorship just how far 'referendums are a device of dictators and demagogues'.[7] Similar examples have followed in other countries: Turkey held a referendum in 2017 over whether to amend the constitution to introduce an executive presidency with expanded powers, described as an 'illiberal form of democracy', where the president is free to 'indulge in authoritarian tendencies'[7], suggesting that increased use of referendums, as proposed by Stewardson[1], does not lead to a more democratic state, but instead can often result in authoritarian pseudo-dictatorships.

In addition, certain parties have a large deal of influence over the result of a referendum before the public debate even starts: in Robin Farquharson's 'Theory of Voting' he describes the power of the question setter over the outcome of a vote, expanded upon by Richard McKelvey, who mathematically proved that given control over a voting agenda it was possible to bring out almost any outcome the agenda setter desired.[6] So referendums are actually less 'fair' than would be supposed; incumbent political parties have power over a referendum for no other fact than they control the setting of the referendum question.

Yet, whilst the above arguments are concerned with the morality and risks of setting public policy by referendum, there exists a far stronger argument than any before stated: public policy should not be determined by voting in national referendums because those who vote in national referendums are not best placed to make decisions about public policy. Despite claims that people in Britain 'have had enough of experts'[8], the fact remains that public policy is an enormously complicated issue. A large proportion of any country lacks the political education or skills needed to make major decisions about how that country is run. In the week after the 2016 Brexit referendum, the most searched term in reference to Brexit was "What is the EU?"[9], demonstrating just how lacking in knowledge the millions of people in Britain were about an issue that would have huge political and economic implications for generations. Some would argue that the electorate have a right to a say in how a country is run, and they would be perfectly correct – elections voting in representatives allow those with the experience and skills needed to make complex policy decisions to act in a way that benefits their constituents, without putting the onus of day to day policy decisions on the electorate. The greatest advantage of an elected democracy is that it frees the electorate from having to worry about running the country; overuse of referendums in the more mundane areas of public policy would only result in stress and discord as those with little idea of the complexities of different political systems are lied to and manipulated into making decisions beneficial for pressure groups with large marketing budgets and media influences.

In conclusion, there is a moral case to be made for the use of national referendums; democratic values fundamentally grant the public the right to determine how they are governed. However, this right to political self-determination can equally be extended to the use of a representative system, in which the public uses this same right to appoint those who can be considered experts, or at least knowledgeable, on the subject of public policy. National referendums should *not* be used to determine public policy because they suffer all too often from cases of misinformation, 'fake news', and quickly become affiliated with outside issues. As a result, using national referendums to determine public policy would be a poor idea; voters find it difficult to consider a single policy in isolation and so would find it difficult to make a reasoned judgement without being affected by outside factors. Yet, beyond any other argument against the use of national referendums to determine public policy, the strongest argument lies in their potential for misuse. National referendums have been used to enable and legitimise oppression and tyranny, hardly the ideal tool for creating public policy and safeguarding citizens' rights in a democratic system. Ultimately, whilst it is not a good idea to determine public policy by national referendums, infrequent use of referendums on issues of governance such as constitutional matters and transfers of power may be required. Providing constitutional referendums are not overused to the extent that voter apathy sets in, they can be the most democratic way of citizens determining the way in which they are governed, whilst ensuring that public policy is created and implemented effectively.

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Intelligence... is it enough?

Rishabh Das

I am going to talk about whether intelligence is enough to be successful and happy in life.

What is intelligence anyway? As a general understanding, intelligence is possession of knowledge and skills. Your parents, your siblings, your friends and even you believe that you need to be more intelligent to get a good job, to become rich or to become successful.

I agree that if somebody hadn't discovered gravity, we wouldn't know why apples fell from trees. And if there were no teachers, how would we receive an education? Life will constantly throw you problems and struggles. But, is being intelligent the only way you can solve those problems, or are there multiple other life skills necessary?

Well, this question can be answered using real life examples. Online IQ tests could be completely useless. Having a low IQ doesn't make you a brainless donkey, because these IQ tests usually test you on Maths, Science or English. If you're not great at these three subjects, that doesn't make you unintelligent. Exams only happen on one day, and if you have been revising for a year to succeed but just couldn't perform as well as you would have liked to on the day, the time you put in shows how intelligent you are. Effort is absolutely vital if you want to do well, because intelligence is something that needs to be exercised to stay perfect, and you exercise it by putting in effort.

Besides effort, being cooperative means you are approachable, can work well with others and give genuine thought and contribute often. One needs to be considerate about other people's thought process, way of working and things that motivate them to deliver good results. If you are not working well with others, it is unlikely that you, as a team, would achieve the desired outcome of any activity.

Another very important skill to have is communication. If your dream job is to become a lawyer or politician, you have to be able to speak confidently to millions of people or fight a case. If you have a really high IQ but don't have a good connection with whoever you are speaking to, it's a bit like having a very high tech car with flat tyres. Most importantly of all, communication can share and spread knowledge. Human beings are not mind readers, but the power of words is huge. Expressing your ideas and thoughts is like patting your head and rubbing your tummy. It seems difficult at first but eventually you learn to do it.

Combining effort, cooperation and communication, one obviously needs to have a sufficient amount of common sense. We as human beings consider people who do very well in tests or exams in schools to be more intelligent than the rest, when the truth is actually that they have memorised many things and are just taking information directly from the brain onto the page. Common sense is not an extraordinary quality to have, but it is an essential skill. You wouldn't put your hand in a fire or eat strange plants, would you? This means common sense is the ability to make sound practical judgements, which proves it to be the basis of intelligence. You have to judge situations before thinking of an efficient solution.

If you were accepted into the highest ranked secondary school in the country, it would be based on your intelligence during the exam. But if you came to school by train and it got delayed, common sense tells you to find a different route or possibly catch a bus with friends. Whatever your IQ or life experiences are, common sense can definitely be learned and applied in everyday situations. Obviously, you wouldn't take shorts and t-shirts on a skiing trip, and you wouldn't use the lift of a building if there was a fire.

If you remember anything from this speech, let it be this. No human can make you intelligent. You become intelligent through many tough life experiences, and from these experiences you get knowledge and skills. And these skills – effort, cooperation, communication and common sense – are skills you must have. Intelligence is like a seed. Worthless on its own, but when given 'nutrients' and 'energy', can go very far in life.

What lies behind the rebirth of political populism as a genuine force in recent years?

Winner of a Middle School Essay Competition

James Pyper

Political populism exists as a challenge to the constitutional status quo of the time while representing neither a right or left wing political persuasion. In recent times, it has manifested itself in different forms across the globe, most famously Donald Trump, the republican president of the USA, and the French presidential candidate representing the Front National, Marine Le Pen. Populism proclaims itself as representing the people against the constitution or in Donald Trump's words borrowed from Nixon "The silent majority against the establishment".

The popularity of movements such as Trumpism or Brexit is caused by a discontent and disconnection of certain societal groups from the ruling establishment. Globalisation and creative destruction (the destroying of one industry as it is taken over by another as necessary consequence of economic progress) leaves many in society behind. A prominent factor in Trump's popularity comes from blue-collar workers who have been left behind as the number of skilled manual labour jobs has seriously declined. For example, America has moved towards a service-based economy with a greater focus on an intellectual skill set. These Rust Belt areas saw the greatest support for Trump in the 2017 presidential election, unable to keep up as technology and society moves forward. In many cases populism seeks to oppress technological change that would harm current job bases, despite the fact that it would create new jobs in other areas and hugely increase productivity. An example of this is in Silicon Valley, California, where they are trying to advocate the usage of self-driving trucks. Now while this would be a more efficient method than humans and it would eliminate many avoidable accidents through human error, it would also put America's 3 million truckers out of business. This is the rational step that increases productivity and therefore consumerism. However, it is met with fierce disapproval from many areas due to the damage it would cause to the existing trucking community. In some of the world's richest areas such as California you find increasing inequality, and populism puts this down to technology that opens the divide between rich and poor.

Populism also attacks globalism as it prefers to advocate protectionism. For the majority of the later 20th century the most prominent political movement has been neoliberalism, which seeks to accelerate globalism and international trade not only of production but also labour. By pursuing globalism, it opens markets up to the cheap labour of other countries such as China. While this can squeeze out producers in America as they can't keep up with the lower production costs, there is an overall economic net gain. Lower prices not only

benefit the American consumer, they also help accelerate the growth of the emerging economies, thus producing a demand for higher standard goods that American industry has the skills to satisfy. This is backed up by the direct correlation between international growth and trade, showing that globalism leads to international prosperity. In America, Trump's ripping up of international trade deals in order to try and create a more autocratic state proved popular among his supporters. In his eyes, he is preserving American industry from cheap imports from countries such as China, and although he is ignorant to any economic laws on trade, growth and consumerism, this message certainly strikes a chord with his audience. Trumps nationalist rhetoric, blaming people's lack of status and usefulness in current society on bad trade deals allowing countries to take advantage of America, is just what his supporters want to hear. What populism is very good at is pointing out the problems that the establishment have caused, attacking them and invigorating people who feel like their government is against them. However, it fails to provide any good alternatives and this was certainly a major part of campaigns such as Marine Le Pen's election attempt or the 2016 Italian referendum on constitutional reform.

Along with these problems in society, it is the establishment itself and political elite that much of the anger is directed towards. In recent times, the integrity of the political elite is often challenged and they are faced with many scandals. The corruption of the political elite leads to a lack of trust between them and the people, leading people to want change in order to take back power for themselves. In Italy where many major officials have faced corruption scandals, the Five-Star Movement, which was founded by a former stand-up comedian, has recently gained a lot of support. The tactics of the party are more based on attacking the establishment rather than actual political policies, which has the support of many in a country that has unprecedented levels of inequality. A significant part of Donald Trump's victory over Hillary Clinton was because Clinton personified the classic political elite who many felt did not represent the everyday person and Donald Trump is just the candidate who fights directly against that.

Many people were not interested in Trump's policies at all but it was a protest against the establishment, which people felt didn't have their interests at heart as society moved forwards while leaving them behind. Similarly, to the Five-Star Movement, Donald Trump's campaign also used a lot of rhetoric against the political elite and he tried to portray a divide between the people and the

inefficient political elite that in his and also his supporters' eyes was characterised by Hillary Clinton. A disconnection with the political elite also stood as a major factor to the 'yes' campaign of the British EU referendum. I don't want to draw too many parallels between the EU referendum and the 2017 US presidential election; however, the outcomes did stem from similar reasons. As in America, many blue-collar workers have lost status with the death of traditional skilled labour industries such as steel workers and ship yards. The British steel industry has suffered hugely from subsidised Chinese steel and Britain does not have the same cheap labour available as China. Some Britons also see the influx of EU immigrants as a threat to their jobs (even though EU migrants account for a £20 billion net benefit to the country) and the anti-trade/anti-immigration sentiment of euro-sceptics certainly parallels that of Trump supporters.

Immigration has become a very prominent concern in Britain recently despite no significant changes in figures. This is because what people fear most, far greater than the power of their economic reasoning, is a loss of government control. The recent conflict in Syria has created an influx of refugees into western Europe and the piling up on borders such as the Calais immigrant jungle strikes fear into the hearts of many. This fear leads people to movements such as Brexit that challenge the establishment and the traditional way things are run, even if their alternatives are irrational. For example, by voting to leave the EU it removes the incentive for France to protect our borders, which is currently done at a great expense to them. What perhaps is a more important factor behind the Brexit decision was the political protest about being controlled by some distant centralised parliament. People don't like being told what to do and even more so by a foreign parliament that doesn't seem to represent them or have any relevance to their lives.

One factor in the recent rise of populism is the increased ability to connect via technology. The current prominence of social media allows emotions to be brewed and the unreliable sources have more power than ever, meaning that unregulated news can quickly be spread around the Internet without sufficient regulation to stop it. This was present in the 2017 US election when the Kremlin sponsored $100k of Facebook advertisement designed to subtly target 10 million Americans. These groups were those that could be vulnerable to fake news that would demonize immigrants and promote nationalist values. Even if not every one of those 10 million were converted, it certainly made a huge difference, which commentators argue may have influenced the outcome of the election.

To conclude, political populism has risen as a genuine force in recent time as growing inequality has left sections of society feeling the establishment is not working for them. Globalisation, while it brings inherent benefits, leaves those who cannot adapt behind with a loss of status in society and feeling distanced from the political establishment. The facts and viable alternatives are not what is important to them but personalities able to capture these emotions achieve vast support. Trump's stark protectionism appeals to those who have been left behind in the neo-liberal era of globalisation while Hillary Clinton characterises the established political elite who are unlikely to bring change and connect to them. Growing economic inequality creates anger and traditional sentiments such as anti-immigration and anti-trade reappear as people look for something to blame. They favour inward-looking policies that in their minds will preserve their livelihood without forcing them to make the necessary adaptations to a truly international world. All these emotions are catalysed by the rise of social media, which exposes the vulnerable to targeted influence.

Euclid's *if:*
The essential unknowability of mathematics

Michael Kielstra

Opening the first book of my copy of Euclid's *Elements*, skipping through page upon page of introduction and footnotes, and skimming the definitions, I am finally confronted with the first preposition: "On a given straight line to construct an equilateral triangle." Thus begins a strange hodge-podge of mathematical thinking. Euclid appears extremely self-assured, delivering proposition after proposition and proving theorem after theorem, and yet he always begins with an 'if' or a 'given': 'if a triangle has certain properties, it also has certain other properties,' perhaps, or 'if a line is cut in a certain way, the squares on the line and on its pieces will be related to each other through some formula.' Never once does Euclid attack the question of where, exactly, his lines and triangles are coming from. This does not make his theorems any less valid, but it does imply that he was more interested in the properties of geometric objects than their origins.

It's easy to say that we are much wiser nowadays: we define a straight line as the locus of all points equidistant from all other points, or as the graph of $y = mx + c$ for constant m, c, or as a million other things. We define a point as a vector, a vector as an ordered finite set of numbers, a number as a complex offshoot of set theory, a set as a grouping of objects, and so on and so forth. No mathematician has ever been able to rigorously define mathematics in terms of objects in the 'real world'.

Such a definition has often been a dream of mathematicians. Russell proposed defining the number 3 as the set of all sets with 3 elements. Notwithstanding the difficulties of adding and subtracting within this system, let alone multiplying, dividing, and taking square roots, it would be impossible to gather this set together physically. The idea of a box containing everything of which there were three copies and nothing else is absurd. For one thing, such a box would have to contain everything in the universe, as the set 'three random objects' contains three objects. Since it contains everything, it would be exactly the same box as the box containing everything of which there were four copies and nothing else. If we try to define mathematics in terms of real-world objects using Russell's system, we are led to the inescapable conclusion that 3 = 4.

This may be true. I have seen no evidence against it that does not come from mathematics. However, we would obviously prefer it if there were to be more than one number. We must therefore resort to more abstract definitions of numbers, which eventually appeal to intuition to describe what an object is. Since intuition cannot be rigorously defined, the idea of mathematics as an inviolable structure of pure logic breaks down.

This does not appear to leave Euclid with much, although instinctively we would hope that all his hard, and often ingenious, work would count for something. What Euclid wrote was a grand series of if-then statements. "If," he says, "there exists such a thing as a triangle, and if it has certain properties, we may deduce the following." This is no different to what any other mathematician does. When I say that two and two make four, I am actually saying that if there were to be such a thing as two, and such a thing as four, then we could apply this contrived operation known as 'addition' and get the latter from the former. Mathematics is a grand structure of deductions from the most desperate of hypotheses.

Physics is even worse. The mathematician begins every proof with 'Suppose the following numbers, functions, and other abstract objects exist', and nothing more. The physicist begins every paper with 'Suppose the following numbers, functions, and other abstract objects exist, and suppose that they map directly on to the real world in a certain manner.' The mathematician's work would go on just as easily if combining two gallons of water suddenly gave us an amount that would fit in nothing smaller than a three-gallon jug. Combining gallons of water is not addition, so any mathematician studying the effects of addition would be unfazed. A physicist confronted with this new phenomenon would have no choice than to rebuild his field, predicated on the assumption that the mathematician's own predicates can be fulfilled by the real world, from the ground up.

It would now seem that mathematics is an inherently worthless undertaking. On the contrary, it is useful for three reasons. First, human experience has shown that the physicist's assumptions are generally correct. The nature of the universe might change at any moment, but, given that in our experience it tends not to, it would seem to be worth continuing to suppose that today's models will be just as valid tomorrow. More importantly, mathematics gives us tools to model any situation. If the sum of the forces acting on an object suddenly became equal to one-half the mass times the velocity of the object, rather than the mass times the acceleration, the basic tools of calculus would still be there, waiting for us to formulate our new assumptions about how abstract numbers map onto the real world. Finally, mathematics cannot be a slave to the demands of modelling the messy, dirty thing that is our universe. Almost through pure luck, mathematicians have stumbled into a series of if-then statements of great order and beauty. The study of these statements is an art in itself, and should be encouraged as much as any other art would be encouraged.

Mathematics is often advertised as the sole absolute truth. Certainly, the deductions that it makes follow accurate rules of logic, as defined by what we intuitively feel are accurate rules. Beyond that, though, mathematics is no more accurate a portrayal of anything at all than postmodernist literature. Both can say deep things about us and about our universe, and both express surprising and occasionally utterly idiotic thoughts. Mathematics may be pursued as an art and as a science with as much validity as, and often more validity than, any other, but to say that it is a wellspring of absolute knowledge is to fall victim to the hype perpetuated by armchair enthusiasts and non-philosophical mathematicians.

Flight

Winner of a Middle School Essay Competition
Mohammed Hussain

The eagle dominates the sky, as is her birthright, spreading her wings as broad as they are black. The sky was almost too dark to see the spread wings, darker even than the encroaching night, but the snowy white hood of the eagle was still visible. Yet in her talons she carried a twisted piece of junk, rusted enough to give it any earthy hue from far below. She cannot nest with such a thing, but to her it must look as good as any twig, bent and brownish-red.

When Caleb looked up to the cloud-splotched sky he barely saw it. It had alighted on a nearby tree and Caleb held his breath trying not to catch the perched bird's attention. How overwhelming it would be to see the hills and forests spread out like the most beautiful blanket. He held out his arms wide, wondering whether those inky wings were longer than his arms. His head caught the moonlight every occasionally, as he scanned the woodland taking in the new setting, until its glare fell upon me. Her eyes were a bottomless pool of darkness, he knew, but he could not help trying to find the bottom. There was a bundle of sorrow swimming in them and he wanted, needed to do something to help her. But Caleb saw fierceness and proudness in her eyes, and knew she would not accept any help. Caleb made a mental note of where this eagle had set her nest and again looked up. The lingering light was obliterated by the rapidly falling night. The once salmon, purple sky transformed into a vast expanse of jet black that engulfed the town. A canopy of luminous stars materialized amongst the ocean of blackness. Some were dull, merely flickering into existence every now and then, but there was an adequate amount of shimmering stars to illuminate the dark, moonless night. The lake glistened, mirroring the dazzling assemblage of glittering stars and the luminescence from the restaurants and designer boutiques that lined the marina. The faint wind brushed against the water's surface, the ripples ruffled the stillness of the surface and shattered the reflection of the harbour.
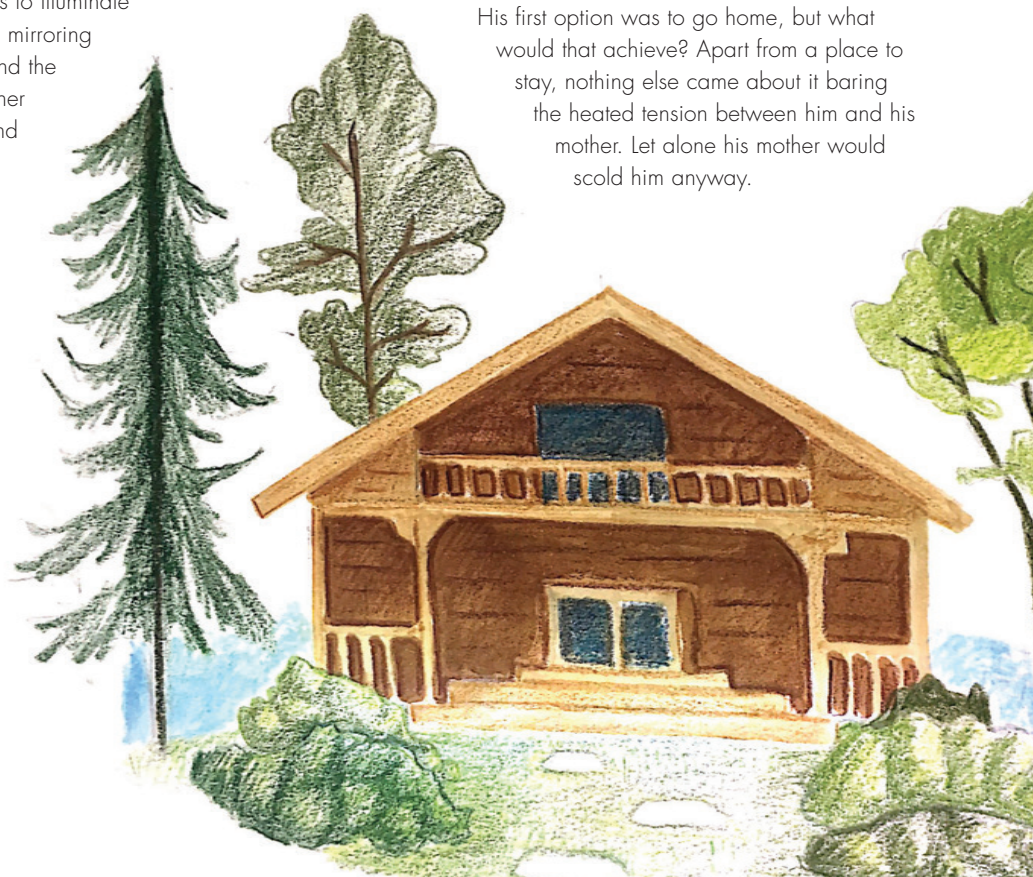
All the beauty did not help. It only made him think more about his mum. Lost hope covered his eyes. All he saw now was how hopeless he was, having no impact on the world around him. What was his purpose? In the space that should be filled with love – at his foundations, keeping his soul aloft – there was a void so deep and so black no light could penetrate. There was a wound that could never heal no matter how much salve is poured on.

"The best I can hope for," Caleb thought to himself, whilst subconsciously plucking grass from the ground, "is to shore my mind with new loves and pray they never leave. Because if they do, my house will fall like the tower of cards it is. Though I like to pretend the walls are brick held together with mortar, they are just card that gets damp in the rain and wobbles in the wind. I have you to thank for that, but I don't harbour bitterness. You are what you are, you see like a person who can never look past their own reflection. Of course, you are the star of your world, you're the only one truly in there. Perhaps if my eyes were like that then I'd be just like you. But my eyes have always taken in the light from every angle, seen the detail you can't. So, though I love you, I decline to be part of your life, you haunting me is plenty enough, Mom."

Other than the darkness and himself, all that seemed to exist was the chilly wind whose harsh bite could be felt through his cloak. He could feel the hairs on his arm raised and the wind had left its mark in the form of small bumps that were tingling on his arms, but its bite was more than flesh deep. His blood ran cold through his veins and his bones were chilled. Caleb thought the eagle had felt the same, as it took off from its branch, gliding with its outspread wings after a small black silhouette scurrying back into the woodland. Feeling more alone than before, Caleb brushed the dew of the grass and wiped it on his trousers. Wanting to stay alone to consider his actions forward, he took the long route home, one covered by the overlooking trees and their roots that occasionally threaded themselves in and out of the ground, proving difficult to walk through. This was a path only he knew about, and those footsteps that painted the blanket of leaves were all known to him.

His first option was to go home, but what would that achieve? Apart from a place to stay, nothing else came about it baring the heated tension between him and his mother. Let alone his mother would scold him anyway.
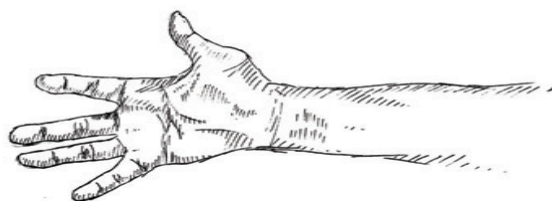
Packing only the necessities and what meant a lot to Caleb, he was soon ready. Finally, by the door he quickly snatched a post-it note and wrote a note to his mum.

"My mum would not care anyways," Caleb thought to himself. He stuck it on his mother's forehead and opened the front door. Hesitating only for a minute, he picked up his bag that he had dumped by the front door and dared not to look back, closing the door on his mother and the light. He did not know where he was going to go. Perhaps a hostel, maybe a hotel, there were so many things to think about that his mind was blank.

He walked aimlessly towards the nest on which the eagle had perched. Caleb took one hand and leant against the ancient oak, his fingertips gripping into the crevices that ran through the bark. His eyes came to rest on the pattern, chaotic like the cracks in the dry, parched earth. Under his boots the golden leaves were as noisy as the static in his head. Nothing was making sense anymore, not even trees. His life had no direction and no meaning. There was no reason for the world to exist anymore. Why was it all still here? Why was he still here? He willed the world to dissolve around him, just to melt away, yet he could still feel the unweeping rough bark and the chill breeze that refused to reflect the howling pain that tore through his body. Without warning, he felt his insides become wooden as he looked up at the nest. Only to see another eagle.

It was much younger, evident from its smaller size, beak, wings and feathers. It was its mother's kid. The mother was trying to cover its young with her wing, but the youngster was edging further and further away until it perched and took off into the darkness. Caleb looked with intent and interest at the mother; her heart broken, scanning the dark woodland she took off in the direction he left from, chasing her son. Caleb watched the mother fly between the trees scanning the floor below her, and then carried on walking, smiling whilst realising, "I have long since closed my eyes… My only goal is in the darkness, the world ahead of me. Through tonight's darkness I shall take my flight."

"Why did she care about me anyway?" "I am 22 for Christ's sake, just let me be like any other boy, be a normal mum for once."

His second option was to live away from her. Get his own house rather than the cramped cottage he was living in now. It made him feel as if he did not belong there, a ragdoll in a deckchair. His place of residence was situated at the far end of a long gravelled driveway, surrounded by well-manicured lawns; the chalet-style cottage nestled in a pocket of light, semi-woodland. It was isolated, the only thing that Caleb liked about it. Its proximity to the forest was the only reason Caleb was staying there. Everything else about the house Caleb disliked. Caleb could never run up the stairs in the old house. Every one of them was a different height from the last, making it impossible to properly judge how high to lift his foot. Either it was too high and he stumbled forward with his foot beneath where he was expecting it to stop, or he kicked the step lip with his socked foot. Had they been carpeted like the ones in his friends' suburban homes it might not have been so bad, but in this old cottage they were unforgiving grey stone, cold as a castle but without the precision or attention to detail that Caleb had always had an eye for. He and his mother were oil and water, these differences visible in the contrast of Caleb's room to the rest of the house.

As Caleb walked in the smell of alcohol hung in the air, as if it lived in the house with his mother. He knew his mom was sleeping on the couch, after drinking the four empty bottles on the counter. The fact that she was holding a half-full bottle supported the idea that she had fallen asleep whilst drinking. "She won't be up for a while," Caleb thought to himself as he walked up the uneven stairs; he couldn't care less to soften his footsteps – his mum was knocked out by her habitual drinking. Caleb's bedroom was small and cluttered, tucked away towards the back of the house. It used to be a bathroom, before they, being his mum and her fiancé, had renovated, replacing the tiles with dark blue carpet and floral wallpaper. He hated the toilet stench that was the only similarity one could make between the former and latter. But at least Caleb had his own space. His mum was always complaining that his room was messy, but it was in Caleb's interest to keep it that way. For he loathed empty bare rooms – there was nothing to speculate about or look at. There was no detail. His mother's room, however, was exactly like that. It was a room with a bed, a wardrobe and nothing more. Her walls were occasionally whitewashed and the door polished, every few months, but otherwise no effort was made to add spirit into her room.

Freedom, your Freedom

Samuel Heatley

It's so dark down here,
I haven't seen the morning sun for as long as I can remember,
Nor the warmth of a sunray touching my face;
Just the cold, damp ground.

I can remember my time above the earth,
Running among the lush green fields,
The sun rising above the horizon,
Its glorious light flooding the lands,
Freedom.

Until the day I turned twenty;
And those days among the trenches,
Muddy water, barbed wire, gunfire;
And the day in November,
When the General told us to stand upon No Man's Land…

We were mown down:
First comes the chatter of gunfire,
Next you find yourself sprawled on the ground,
Lying in a pool of your own blood,
As you kick and flail and scream.
And no one comes to save you.

Your wounds burn,
Your head throbs,
You can't breathe,
You exhale foam instead of air,
And you die;
Right then, right there.

As your body lies on No Man's Land,
And coils of barbed wire and corpses surround you,
The battle rages on;
Yet only one side wins.
And then the battle stops.

And, on the previously bloody and bruised land,
Lie lush green fields,
With the sun rising above the horizon,
Its glorious light flooding the lands,
Freedom.
Your freedom.

And I'm just another grave of many,
Who fought for their country,
And were killed;
But you are free,
Your country is free,
Because we sacrificed ourselves for your freedom:
For Britain's Freedom.

In your choice of target language, choose a role model from that country whom you particularly admire, past or present, and explain why.

Winner of a Middle School Essay Competition
Tom Koide and George Osborne

坂本九

私の一ばん好きな日本人は坂本九と言う歌手です。坂本九は千九百四十一年十二月十日に生まれて、千九百八十五年にひこうきのじこでしぼうしました。

彼は「上を向いて歩こう」と言ううたでゆうめいです。坂本さんは米国で人気が一番な曲をもつさいしょのアジア人でした。でも坂本さんの曲が英語にほんやくされると意味が失われました。古い歌であるにかかわらず日本でまだふきゅうしています。

「上を向いて歩こう」はぼくの大好きなうたです。なぜなら、曲にしあわせなかんじがあるが、かしはとてもかなしくてうつくしいです。将来、私は坂本さんのように社会の大きいなえいきょうをあたえたいと思います。何かの作成できることをのぞみます。

By Tom Koide

Translation: By George Osborne

SAKAMOTO KYU

My favourite Japanese person is a singer called Sakamoto Kyu. Sakamoto Kyu was born on the tenth of December, 1941 and died in a plane accident in 1985.

He is famous for a song called "Ue o muite arukou". Sakamoto was the first Asian to have a Number 1 song in America. However Sakamoto's song lost its true meaning when it was translated into English. Despite being an old song it is still popular in Japan.

"Ue o muite arukou" is my favourite song. Because, the song has a happy feeling, however the lyrics are very sad and beautiful. In the future, I want to have a big impact on society like Sakamoto. I hope that I can create something as impactful as he did in the future.

HAYAO MIYAZAKI

1940年に生まれた日本の世界中に有名である宮崎駿はすばらしい映画を作るから私の大好きなディレクターです。私の大好きな映画は「となりのトトロ」と言います。日本に小さい女の子がいます。この子はくらい森に大きい木を見つきました。この木の中にトトロというふしぎな動物にあって友達になります。トトロは優しくて親切な動物です。たくさん面白い動物がいるからこの映画は本当にすごいと思います。例えば「青い中トトロ」と「白いチビトトロ」もいます。そして女の子は病気のお母さんを見るためにいもうとを連れて「ネコバス」というバスにのって行きました。ディレクターのゆたかな想像力があるし、絵も美しいし、とてもきれいな映画だと思います。

By George Osborne

Translation: By Tom Koide

HAYAO MIYAZAKI

In 1940 a man named Hayao Miyazaki, who is my favourite director, created a splendid Japanese film that is famous around the world. My favourite film is called, "My neighbour Totoro". In the film there is a small Japanese girl. The girl finds a large tree in a dark forest. Inside the large tree she meets a mysterious creature named Totoro and they become friends. Totoro is a gentle and kind creature. I think this movie is truly amazing as it has so many strange animals. For example, there is a blue Totoro and a small white Totoro. The little girl's sister goes on a cat bus with her little sister to visit her mother who is ill. I think the film is beautiful because of the director's use of his rich imagination and beautiful art.

Reading review of The Arrival by Shaun Tan

Joshua McGillivray

I first encountered and read *The Arrival* by Shaun Tan around two years ago, in the summer holiday of 2015, after reading a newspaper poll for the fifty greatest children's books of modern years. As I came to re-read it recently, I found that a significant amount had changed – I recalled the surreal edge to the story, the fantastical creatures and the underlying theme of immigration, fitting to the Trinity Schools Book Award topic of New World, certainly, but I had forgotten, or possibly missed, the intricateness of the story's world, and the author's remarkable ability to communicate with more power with pictures in around one hundred pages than many authors do in a lifetime.

The Arrival tells the story of millions, of every person who has either chosen, or been forced, to leave their home country to live, perhaps for the rest of their lives, in another. It begins by showing a father, the story's protagonist, spending time with his wife and child, as he walks up to a harbour with them to travel to a far and distant country. As he enters, we become like him – strangers who know nothing of the place that we visit, as he moves through the town, with nothing but hope to push him forward. Tan uses images to effectively move the reader through the immigrant experience, along with its uncertainty and alienation from the normal world.

The setting of the novel is perhaps its most interesting point, especially in the moment the protagonist arrives at the destination that he has travelled to, shown first by one of the story's best pictures, one encompassing a double page, viewing an Egyptianesque landscape, with a large sculpture of a bird carrying an egg towering over much of it, smoke filling the skies and countless dwellings on many floor levels, as well as a bizarre language – the only use of text in any form in the novel – covering many walls. We can also see large flying boats, some of the most visually stunning pieces in all the book, later on, and even message carriers to be created by paper origami. There are many similarities to the world we know, however, as we can see from paper-boys, busking musicians, advertisements for beverages, barbers shaving their employers and groups of people, crowding around benches, talking happily to one another. As a whole, however, these pictures seem to be reminiscent more of an image of the past than of the present.

The people present in the novel are often more difficult to characterise owing to the lack of narration. The unnamed main personality is, for example, a relatively ordinary person – sharply dressed, likeable and humble – and it seems easy to explain this as him having a lack of

notable temperament, but this is incorrect. Tan leaves him without a distinguishable nature in order to make this less a story of one, but of all. The Arrival is the tale of every immigrant, and to fit this, he creates a person with whom all can empathise – including the wide variety of characters shown on the inside cover, all used to show how many people, of all kinds, have made the journey that we read of here.

The techniques of storytelling used in this tale are unlike any that I have ever previously encountered. One of the most frequent is his use of moving out of a scene gradually, rather like a film. For example, upon the character's entry of the ship, and its departure, we are shown a picture that he chooses to bring with him on his travel of him with his wife and daughter, all smiling at a camera, a drawing that, in its own right, produces a melancholy, hypnotic effect. Then we see his food bowl with it, and a little more of the section, then the protagonist's whole body as he eats, then a view from outside his cabin window, then further, then showing three windows, then thirteen, and then countless, showing much of the ship, so we no longer know which compartment he is in, and finally, the whole ferry, moving towards an uncertain future.

Some pages show thirty images of different clouds, done using a variety of sepia, black and white and an almost golden print. Others show multiple images relating to the man's home life, such as drawings of house clocks, hat stands, child's cartoons and cups of tea, which are revisited later in the story, from which we can see how life has changed in the fresh world. Perhaps the most successful of these methods is the character's wakening, in which we see his gradual return to consciousness, starting with mere puffs of colour, and then gradually focusing into a creature.

To conclude, I will comment that I found reading *The Arrival* to be, upon both occasions, a truly memorable and rewarding experience. Early in our lives, we, as people, become accustomed to using images to create understanding, and we sometimes lose an element of our visual deduction as we grow older. With its varying styles, colours, storytelling techniques, characters and settings, this book is not only mentally enriching, and inventive, but also engaging and intelligently produced. I have never read a book, and suspect there are, in the entire world, very, very few, quite like *The Arrival*.

C. Julius Caesar

Winner of a Middle School Essay Competition

Written in Latin & then translated by Henry Benett

C. Julius Caesar in historiā Romae unus insignissimium potentissimiumque hominum erat. cuius caedes clara idibus Martiis, finem res publicae et principium imperii signavit sed dum vivebat multa propria admirabilia habebat. imperator prosperissimus erat sed propria notabilia alia possedit.

ubi Caesar iuvenis erat, ad Graciam navigit et captus est a piratis. piratae Caesarem bene tractaverunt sed Caesar saepe minatus est se piratas inventurum esse et occisurum esse, dignitate a piratis laesā male. tandem Caesar praevaluit et piratas interfecit. eō per vitam totam praevalentē, hanc constantiam Caesaris, admiror.

reverentiam militum a Caesare acquisitam quoque miror. ars militaris Caesaris fidem e militibus ei meruit amorque, qui eis ostendit, fidem ei quoque meruit. Caesar itinera tutiora causa militum saepe faciebat.

Caesar tamen dux audax crudelisque erat. Caesare Romam revenire iusso, urbem oppugnavit; denuntiatio erat. effugere poterat sed hostes elegit pugnare. tam audax erat ut eum admirer. crudelissimus quoque erat; Alesiā circumsessā, incolas Alesiae aut interfecit aut eos sevos vendit. audacia, quamquam dura est, duci vitalis est.

propria Caesaris imperatorem optimum eum fecerunt. tribas Hispaniae Galliaeque vicit et Pharsali maiorem exercitum Pompeii vicit. hoc ostendit Caesarem ducem optimum fuisse.

Caesar tamen vir rerum publicarum quoque erat. dum dictator erat, Caesar multas res bonas fecit, quibus debitum allevavit. kalendarium quoque mutavit, simillimō kalendariō nostrō attonite.

in meā sententiā, Caesare tot proprias admirabilissimas habente, nobis possibilis non est dicere quod proprium gravissimum sit. dux optimus et vir rerum publicarum optimus erat, et caedes cuius terminum aetatis monstravit sed ei imortalitatem dedit. Caesarem miror quod facta eius etiam nunc valent.

TRANSLATION

C. Julius Caesar was one of the most significant and powerful men in Roman history. His famous assassination on the Ides of March was essential to the end of the republic and the beginning of the empire, but whilst he was alive he had many admirable characteristics. He was a very successful general but possessed many remarkable characteristics outside of the battlefield.

When Caesar was a young man, he sailed to Greece and was captured by pirates. The pirates treated Caesar well but Caesar often threatened to find and kill the pirates, because the pirates had badly damaged his dignity. Caesar finally prevailed and killed the pirates. Because he succeeded throughout his life, I admire this determination of Caesar's.

I also admire the respect gained by Caesar from his soldiers. Caesar's military skill earned him loyalty from his soldiers and the love he showed them also earned him their loyalty. Caesar often took safer routes for the sake of his soldiers.

However, Caesar was a daring and ruthless leader. After being ordered to return to Rome, Caesar attacked the city; this was a declaration of war. He could have escaped but chose to fight his enemies. This was daring enough to make me admire him. He was also very ruthless; after besieging Alesia, he either killed the inhabitants of Alesia or sold them as slaves. Ruthlessness, although harsh, is of importance for a leader.

The characteristics of Caesar made him an excellent general. He conquered the tribes of Spain and Gaul and, at Pharsalus, defeated Pompey's much larger army. This shows that Caesar was an excellent leader.

However, Caesar was also a politician. While he was dictator, Caesar did many good things, such as relieving debt. He also changed the calendar, with it being fundamental to our calendar.

In my opinion, because Caesar had so many notable characteristics, it is not possible to say which is of the greatest importance. He was both an excellent leader and a very good politician, and his assassination marked the end of an era but immortalized him. I admire Caesar because his deeds, even now, stand out.

Crucified on the Banyan Tree – A Ghazal

Poem short listed for the Tower Prize
Sahej Grewal

Look into that dirt – that is all you can be, boy.
Dry dust and red earth – is that all there's to see, boy?

Hidden pith, expose the god and songs of my skin.
Veins, made for spice, run with milk – blood of a free boy.

Grandmother, you see the cusp of decay on my tongue –
Tacked, curdled eyes watch the loss of a latchkey boy.

Drawn by the cast chains of fetid and bloody shores
Lie rent coconut husks and your ancestry, boy.

Gold-girt hips ravish arms steeped wholly in honey.
Still, each mother thinks she bore a heavenly boy.

Don't let expire the coagulate airs of your throat,
For night's dark pall won't hide you from blasphemy, boy.

Piercing fibroid tales of knot-knuckled voices
Leaves you to cleave and scrabble for legacy, boy.

Through bottle-glass tops whine laments for palaces.
Through dank tea leaves wade yourself to history, boy.

Shun the venom that stirs in grass-root gatherings
Or we'll find you crucified on the banyan tree, boy.

All illustrations by Sahej Grewal

A collection of live recordings

TRACK LISTING:

1. *Clarinet Sonata - 2nd Mvt - Brahms* (Christopher Yip Lan Yan)

2. *Kol Nidrei - Bruch* (Alex Acomb)

3. *Clair de Lune - Debussy* (Nicholas Edwards)

4. *Prelude in D Major - Rachmaninov* (Sam Jones)

5. *Dichterliebe - Mvt 1 - Schumann* (Yousuf Mirza)

6. *Dichterliebe Mvt 3 - Schumann* (Yousuf Mirza)

7. *Oboe Concerto in A Minor - 1st Mvt - Vivaldi* (Josh Powell)

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

From the Headmaster

For those of a certain vintage, brought up on a diet of novels set in Victorian public schools, scholarship is a rather quaint, old-fashioned concept. Scholarship is synonymous with row upon row of dusty, leather-bound first editions in a rather grandiose, panelled library. Scholarship is synonymous with ageing schoolmasters replete with elbow patches and half-moon spectacles. Scholarship is elitist and rooted in weighty tomes.

This impression could not be further from the truth at the RGS and this, the second edition of *The Annual*, reinforces how vibrant, inclusive and creative scholarship is at the RGS. Just by looking at the *Contents* page alone, the sheer diversity and originality of the research tasks are plain to see, equally spread between the Maths and the Sciences, the Humanities and associated subjects, and the Creative Arts.

Rather than being the realm of an elite few, scholarship is a concept which, we feel, is an achievable ambition for all our students who by their very nature have the potential for true scholarship. You do not need to be an ageing academic to have insight as evidenced by some extraordinarily astute and mature work from our First Form students.

I would like to take this opportunity to congratulate my Head of Scholarship, Mr Bradford, and all the members of the Senior Scholars' Council on a thoroughly impressive publication. I have no doubt that it will serve to inspire all those who are fortunate enough to read it, even in the fullness of time as the dust starts to settle!

Dr Jon Cox
Headmaster
Royal Grammar School Guildford