FINALISTS
MAGAZINE 2022

#700STEMChallenge

INTRODUCTION

Congratulations to the finalists of the fifth Sydenham #700STEMChallenge.

There were so many amazing entries, all of an extremely high standard. After much deliberation, the following articles were selected as the top three entries for each category.

Annabelle Simmonds, creator of the Challenge in 2018 whilst in year 12 at Sydenham High.Currently completing an apprenticeship with Ernst & Young.

UNDER 14 RESULTS

Science:

1st - The Healthy Fantasy of Veganism
Alexandra Allan, South Hampstead High School

2nd - The Placebo Effect
Arwa Kinana, Croydon High School

3rd - Astronomy and Psychiatry: their enigmatic parallels
Tvisha Lakshmeesh, Oxford High School

Technology/ Engineering:

1st - Bioprinting a healthier life
Yumna Zameel, Oxford High School

2nd - Will Artificial Intelligence Conquer The World?
Abby Gherendi, Notting Hill & Ealing High School

3rd - Has Lockdown increased the impact of social media on young people?
Gisele Oakley-White, Streatham & Clapham High

Mathematics:

1st - Why the connections between mathematics and art needs to be recognised. *Jessica Story, Oxford High School*

2nd - Fractions, division, and reciprocals – oh my!
Sophie Hudson, Royal High School, Bath

UNDER 16 RESULTS

Science:

1st - Dark matter and dark energy:
How much do we know, know we don't know and don't know at all?
Nathan Firla, Dulwich College

2nd - Why is the Use of Bioluminescence so Important in Medicine?
Eve Hampshire, Sydenham High School

3rd - The Melody of Science
Anwita Vedula, Blackheath High School

Technology/ Engineering:

1st - A Technological Advancement in Combating Climate Change
Robby Marshall, The American School in London

2nd - A study in Levitation with electro-magnetism and My Invention
Julia Pfeiffer, Blackheath High School

3rd - One Programming Language: Is It Enough?
Boris Hall, Wilson's School

Mathematics:

1st - The History of Nothing
Mili Thakrar, Northwood College for Girls

2nd - Will Goats and Birthdays Forever Challenge Mathematicians?
Lauren Marshall, The American School in London

3rd - Modular Arithmetic and RSA Cryptography
Talia Mitchell, South Hampstead High School

UNDER 18 RESULTS

Science:

1st - Metallic nanoparticles -
could they be the solution in the battle against antibiotic-resistant bacteria?
Clarice Nassif, Norwich High School for Girls

2nd - Nanocellulose; is it the solution to the plastic problem?
Ruby Gratrick, Sydenham High School

3rd - Is there a cosmic speed limit?
Kirsty Martin, Croydon High School

Technology/ Engineering:

1st - Quantum Dots. Minuscule in nature, but boundless in potential
Shanjai Mathialagan, Wilson's School

2nd - Aluminium Air Battery Technology application for electric vehicles
Jon Hiew, Dulwich College

3rd - Structural colour: the future of materials?
Sia Patel, Notting Hill & Ealing High School

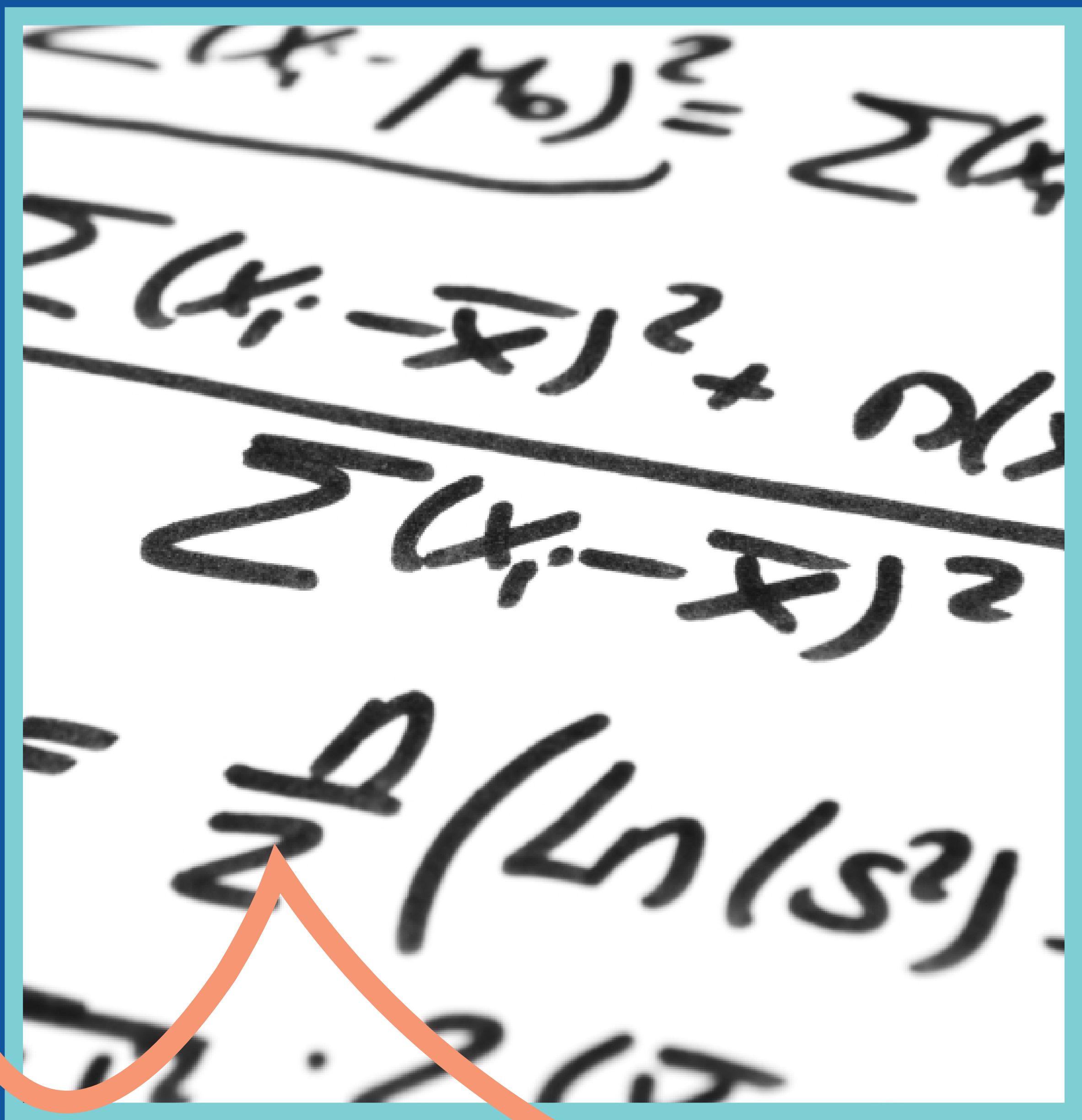
Mathematics:

1st - What would a world without mathematics be like?
Nooriya Mohamed Rafi, Wimbledon High School

2nd - Is Maths invented or discovered?
Vanessa Ajero, Sydenham High School

3rd - The Painter's Paradox: Gabriel's Horn
Cat Doan, South Hampstead High School

MATHS ESSAYS UNDER 14



Why the connections between mathematics and art needs to be recognised.

Jessica Story, Oxford High School

Of the whole education system, at the heart it is maths and science. I recognise it is quite a bold statement to say that art and mathematics are so highly linked that they need to be educated on, but my perspective is that this can be used in a very beneficial way. There are so many examples where fields of maths and arts overlap. Go to any modern or old art gallery and all pieces of art will have incorporated maths in one way or another. Basic concepts of geometry and colour theory have both aspects involved. Look in the right places and maths will be found in any type of art.

If I were to list all pieces of art that had mathematics involved, I would simply name them all. To describe my point the best I can, I will focus on some of the most common and heavily maths influenced examples. Ode to Da Vinci here, my first example is the Golden Ratio. Probably the most common example of maths in art. Approximately equal to 1.618, this number has been used in so many of his paintings. Looking at the face, torso and general proportions of the Mona Lisa as one example, it is easy to recognise the areas that this geometrical figure could be seen in. How she is positioned, and the distances of nose to eyes all have a framework of numbers and a mathematical system involved. Another artist named M.C. Escher used mathematics almost exclusively in his work with his portraiture, optical illusions or drawings. A specific example where geometry is featured primarily is 'Study for Stars' a piece of art derived from ordinary shapes stuck into each other to form new sometimes 4 dimensional figures. This work seems to be his interpretation of stars and how they are formed, so a combination of science and mathematics to create a stunning image.

Considering the whole spectrum of art contains something to do with maths it must go both ways. When sitting in a maths lesson, your first thought isn't to get out watercolours and start painting but you have to think that just because you are writing numbers and formulas on your page it's not all black and white. Infinite numbers or patterns within shapes and simple geometric ideas all have artistic connotations. Both can be used in cooperation with the other. Know where to look and art will be found.

We can see both thrive on each other to survive and flourish with ideas and new perspectives, therefore this can be used to explain both art and maths concepts. Surely if they have so much in common then why couldn't they be taught using each other. Maths is taught as a very singular subject, nothing really connects with it in a physical sense and this is why people may get confused. Introducing the artistic side of maths could benefit those who find maths hard to visualise or learn. Teaching through creative manners and more stimulating exercises could help massively. Pupils who have natural skills for the arts and love the complete nature of colours and visualisation, could learn mathematics using the resources they already have. Just because of the polar opposite ideas around the subjects, the thought of combining the two might seem poor. However, if you approach this proposal with an open mind then why couldn't it be incredibly effective.

After explaining the link between these seemingly opposing subjects, it is clear to see that the two have so much in common and it would benefit both so much to be more intertwined. Just because norms have shown that the two should be separate, doesn't mean we can't change that. The applications of the connections are too strong to ignore and should be used to the best of their abilities. In conclusion, the links between the arts and mathematics needs to be more recognised purely for the benefit of students. Concepts, ideas and theories would all be so much easier to perceive if presented in a form that a student was capable of understanding. Two areas that have been seen as so far apart could not be closer and this could be revolutionary.

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Example Harvard referencing
In-text citations are used when directly quoting or paraphrasing a source. They are located in the body of the work and contain a fragment of the full citation, e.g. "After that I lived like a young rajah in all the capitals of Europe..." (Fitzgerald, 2004).
Reference Lists are located at the end of the work and display full citations for sources used in the assignment, e.g. Fitzgerald, F. (2004). The Great Gatsby. New York: Scribner.
For more information see https://libweb.anglia.ac.uk/referencing/files/QuickHarvardGuide2018.pdf

Fractions, division, and reciprocals – oh my!

Sophie Hudson, Royal High School, Bath

I have been in Year 7 for maybe five months now, and in my maths classes I have been learning about a variety of topics. Above all, the topic that most interested me most was fractions, where we learned about adding, subtracting, multiplying, and dividing them, but I soon hit a problem: I was taught that the way to divide fractions was to flip the second fraction then multiply rather than divide, but I wasn't taught why this approach worked.

I wanted to know why fraction division was handled this way, because I've always found that understanding the "why" of an approach is just as important as understanding the "how." So, I went on a quest to find out why we used this method for division, and I wanted to share both my journey and my findings.

When we write a fraction such as 1/2, we are saying we want to split 1 into 2 parts, making a half. We can make equivalent fractions by multiplying the numerator and denominator by the same number, for example 2/4 and 4/8 are both equivalent fractions to 1/2:

$$\frac{1}{2} = \frac{2}{4} = \frac{4}{8} = \frac{100}{200}\ etc$$

If the denominator of a fraction is 1, it means we are not dividing it at all because you are just separating it into one part, which is the whole number:

$$\frac{12}{12} = \frac{1}{1} = 1$$

This will be important a little later on, but first I needed to learn about reciprocals. A reciprocal is one of a pair of numbers that produce 1 when multiplied together, which means if you multiply a number by its reciprocal you will always get 1. You can find the reciprocal of any fraction by "swapping its numerator and denominator" (El-Bahrawy, 2018, p.35), so for example the reciprocal of 3/4 is 4/3.

This works because "the multiplication of natural numbers satisfies the commutative property" (Darling, 2019), meaning that no matter which order you multiply numbers the outcome will always be the same. We can see that the reciprocal of 3/4 must be 4/3, because it would result in us multiplying the same numbers twice: the numerators 3 x 4 to produce 12, and the denominators 4 x 3 to produce 12. This results in the fraction 12/12, which as we've seen is equivalent to 1/1, or just 1. For whole numbers such as 15, we find the reciprocal using 1 divided by the number (Norman, 2015, p.99). This is often represented on calculator as "1/x", which means the reciprocal for 15 is 1/15. The only number that doesn't have a reciprocal is 0, because it is not possible to divide by 0.

Putting all this together we can return to the topic of dividing fractions. If we were given the question "what is 3/4 divided by 5/6" we would start by writing this as a complex fraction, which is a fraction that has a fraction inside its numerator or denominator. In the case of 3/4 divided by 5/6 we would write this:

$$\frac{\frac{3}{4}}{\frac{5}{6}}$$

We can then multiply the denominator by its reciprocal, like this:

$$\frac{\frac{3}{4}}{\frac{5}{6} \times \frac{6}{5}}$$

In order to ensure that this is an equivalent fraction, whatever we do to the denominator of a fraction we must also do to the numerator. In this case, that means also multiplying 3/4 by 6/5:

$$\frac{\frac{3}{4} \times \frac{6}{5}}{\frac{5}{6} \times \frac{6}{5}}$$

As already shown above, any number multiplied by its reciprocal results in 1, which means our denominator can be simplified down to this:

$$\frac{\frac{3}{4} \times \frac{6}{5}}{1}$$

Any number divided by 1 is equal to itself, which means our final fraction becomes this:

$$\frac{3}{4} \times \frac{6}{5}$$

So, by working through the process step by step we have shown that 3/4 ÷ 5/6 is actually the same operation as 3/4 × 6/5.

To sum up, we have taken a journey through a variety of mathematics topics and learned about reciprocals, equivalent fractions, and most importantly, division of fractions. At the beginning I said that understanding the "why" of an approach is just as important as understanding the "how." I hope my essay has shown both of these along with my thought process along the way, because as Ralph Waldo Emerson said, "it's not the destination, it's the journey."

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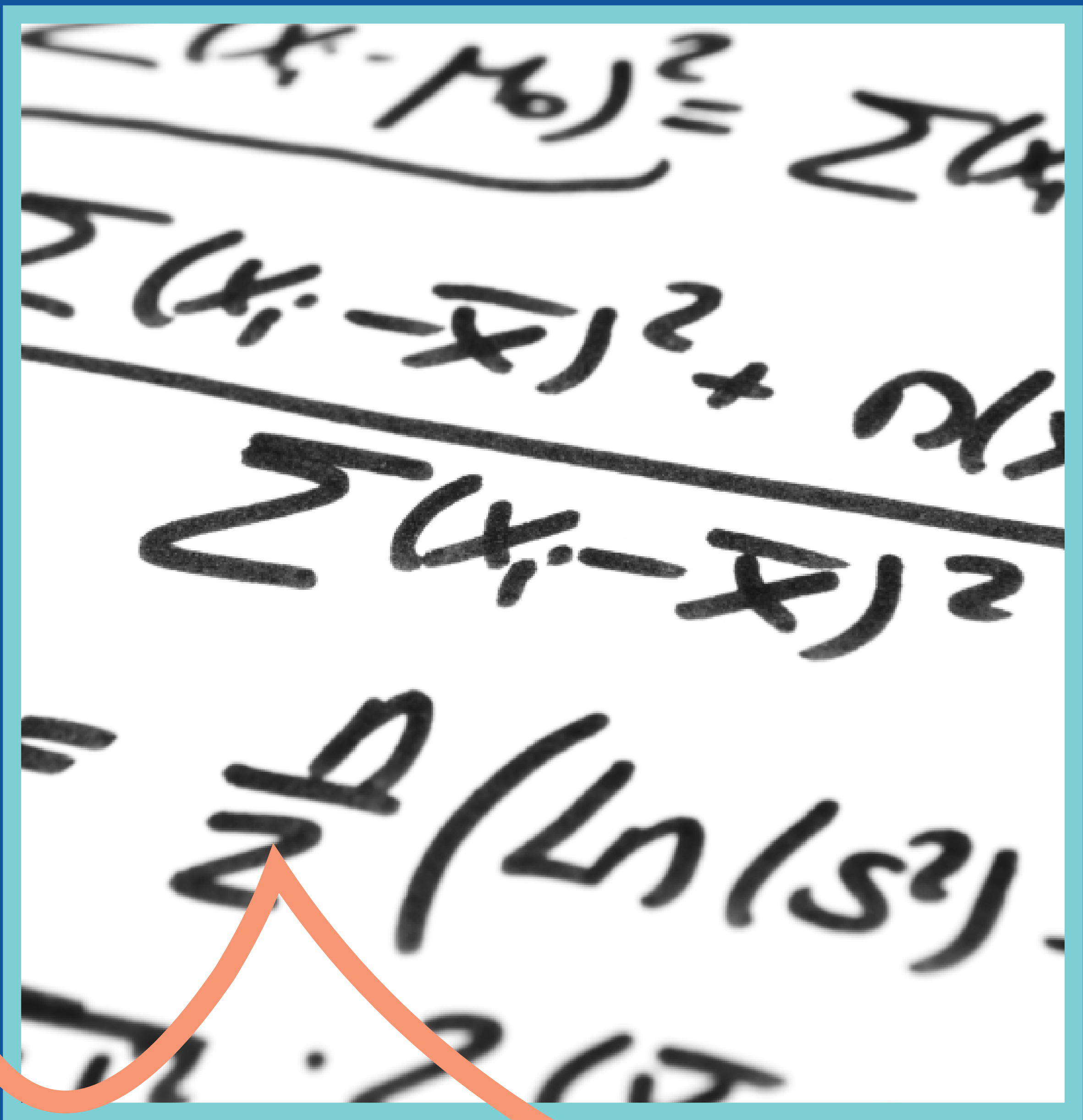
MATHS ESSAYS UNDER 16



The History of Nothing

Mili Thakrar, Northwood College for Girls

Many years ago a Roman citizen was walking down the street when he came across a friend. “Good day, Boethius! Say, everyone is talking about the game last night; what was the final score?
“It was a low scoring affair: Patricians IV, Plebian... I don’t know. We don’t have a number for nothing”

The creation of a symbol representing nothingness is a relatively recent development, having overcome its controversial path to being defined as a value itself, despite the number zero being a crucial organisational component of our numeric systems. Regardless of the chaotic origins of zero, the effects of its integration into out numeral systems justify this delay. The function of zero in the modern world is critical to both the simple and complex mathematical processes to an extent that it seems impracticable for zero not to have always been an intrinsic part of our mathematical systems.

Since mathematics is so broad, we cannot credit a specific person with the invention -- or perhaps discovery, but that’s a different matter entirely -- of mathematics itself. The first counting systems are similar to the procedures of our current system but were only compatible with requisite menial activities such as telling the time or recording quantities. Although these methods served their basic purposes, civilisations and societies grew larger and were therefore more demanding. This led to numbers being used for more than documentation, being needed in the distribution of materials, creation of accurate calendars, and calculations for architecture.

The first recording of zero dates back to the Ancient Mesopotamians, yet it was the Babylonians that first to used a variation of zero that remains active today -- the placeholder. They would only use the placeholder in medial positions, however -- think the 0 in 101 -- different from modern numbers that include zeros on the end of numbers that can be infinitely set and indicate its size. The Babylonians, however, had unique symbols for each number that could have been used as a placeholder.

The Babylonians are but one example of the numerous other civilisations, such as the Greeks or the Mayans, that had their own variant of zero, yet its function remained as a placeholder until 7th Century India where mathematician Brahmagupta applied the concept of nothingness into the symbol, through a mathematical lens. He produced rules into calculations with zero, such as in division, by treating the symbol as a number itself.

As zero made its way around the globe, the concept soon became an essential component in the Arabic number systems, having strongly influenced mathematicians in the Middle East. Despite this popularity, before its breakthrough in calculus -- which highlights zero’s greatest achievement -- it still had numerous obstacles to overcome. In 1299, zero, as well as other Arabic numbers, was banned in Florence as it was believed to encourage fraud. Furthermore, the placeholder use of zero was turned down because the addition of zeros at the end of the number was interpreted as allowing the inflation of prices. Zero received additional criticism for offering the possibility of negative numbers and therefore the legitimisation of debt.

During the renaissance era, the passion for knowledge rescued zero as thinkers became more dedicated to understanding the idea of representing nothingness as a number and its consequent uses. Later, the digit was integrated into the cartesian plane with (0,0) origin. Scholars were enthralled by zero’s ability to increase and decrease numbers infinitely, and was the kind of precision needed for 17th century thinkers Newton and Leibniz to develop calculus.

In this new technological era, zeros are vital for our existence. Computers are made of circuits that are ‘on’, represented by ‘1’ or ‘off’, represented by ‘0’. The programming code, binary, written to control computers, is composed of 1s and 0s. It is inconceivable that computers could have been created without the concept of zero. Nothing matters. Zero fostered some of the most influential advancements in society today. The once resented number shaped the different operations in algebra and sparked the creation of calculus. From the day nothing was discovered, it created an inclusion in mathematics that has shaped the modern world. So let’s hear it for zero, the strange beast, for its importance can hardly be overstated.

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Will Goats and Birthdays Forever Challenge Mathematicians?

Lauren Marshall, The American School in London

In school, students solve maths problems by following a system of formulas. Even the most complicated problems can usually be explained in a manner in which the mathematical reasoning and intuition of the strongest mathematicians align. However, mathematical paradoxes have answers that do not intuitively make sense even once logically explained. Some are highly controversial among mathematicians.

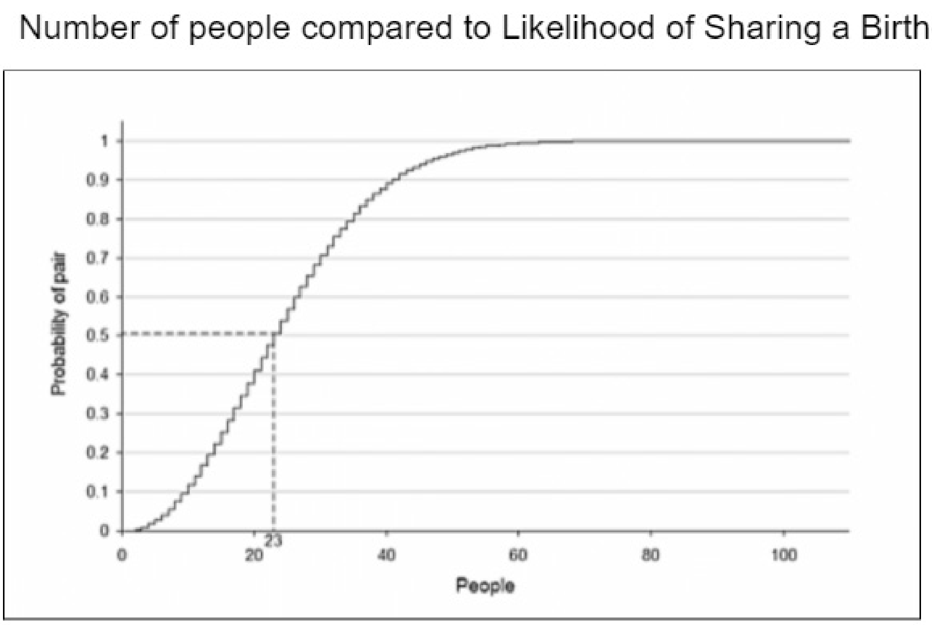
One well-known paradox is the Birthday Paradox. Within a room of 30 people, there is over a 50% chance two or more people share a birthday (Scientific American, 2012). The likelihood that two or more people in a group share a birthday is much larger than assumed. At first, it does not appear likely that the statistic is accurate with these few birthdays.

Initially, many people, even mathematicians, assume just one birthday is being compared. However, the birthdays of all 30 people is being compared to every other birthday. The probability (p) that two or more people in a group of n people can be found with the equation (Khan, 2016):

$$P = 1 - \frac{365 \cdot 364 \cdot \ldots \cdot (365 - n + 1)}{365^{n}}$$

The 1 in this equation is utilized as it is easier to find the chance that no one shares a birthday with someone else than finding the chance two or more people share a birthday (Khan, 2016). The numerator represents all possible separate birthdays. The first person has 365 options, and the second has 364 options (as not to have the same birthday as the first person). This pattern continues until the last person has the same number of birthday options as the days of the year (365) minus the number of people plus one [so that one person will still have 365 possible birthdays]. The denominator shows the possible number of birthday combinations with 365n.

As the number of birthdays compared increases, the chances two or more birthdays are shared increases, as shown in this graph (Math. Cornell):



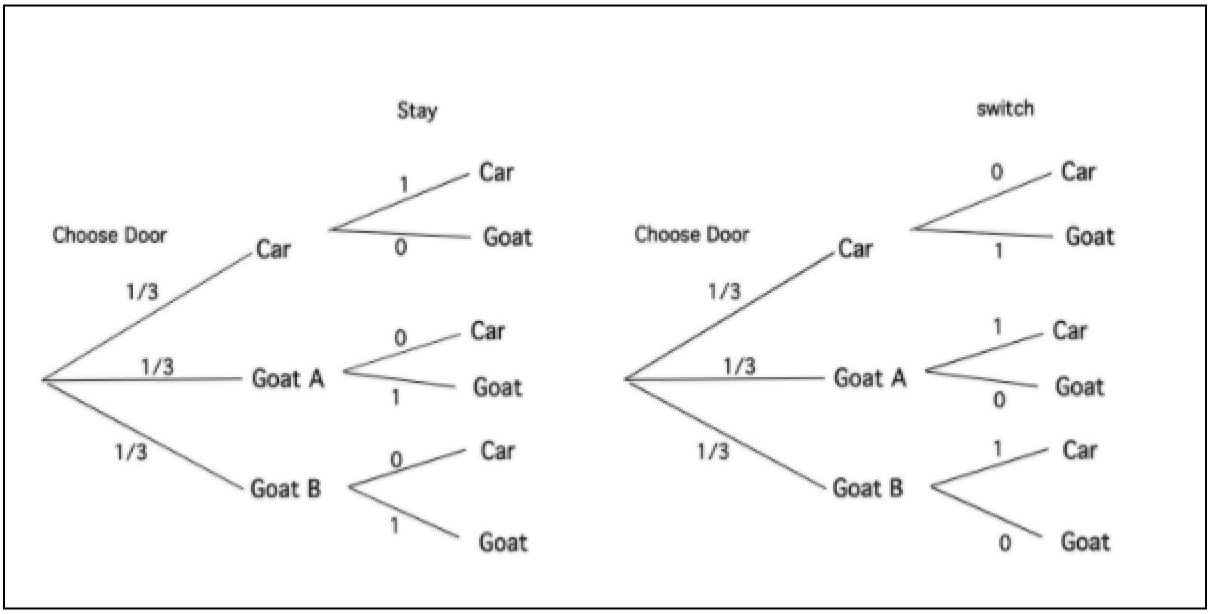
If rather than 30 people, the number of people in the situation was increased to 57 people, about 1/3 the capacity of a tube train, the equation would be $1 - \frac{365 \cdot 364 \ldots 316}{365^{50}}$ or a 99% chance two people will share the same birthday!

An even more puzzling paradox is the Monty Hall Problem. The Monty Hall problem was first popularised in a 1990 newspaper column by Marilyn Vos Savant, who proposed the correct solution. This paradox was so confusing that she received over ten thousand letters, claiming her answer was incorrect (BehavorialScientist, 2021). The Monty Hall Problem asks one to imagine a three-door game show. Behind each of the two doors is a goat, but behind one door is a prize. At the beginning of the game, the contestant selects one of the doors. The host then reveals a goat behind one of the doors not chosen. After this, the paradox becomes fascinating.

Should the contestant switch doors or stay with the original door? At first, the answer appears not to make a difference; it seems there is a 1 in 2 chance of winning the prize as one door hides the goat, and one hides the prize. However, the contestant has a better chance of winning by switching doors (Khan, 2012).

At the start of the game, there is a 1 in 3 chance of selecting the prize. If the contestant keeps his original selection, the chance of winning remains the same: 1 in 3. However, if the contestant switches, one of two things can happen. The contestant can either have initially selected the prize and switched to a goat, or the contestant initially picked one of the two goats. The other was eliminated, so the contestant changes to the prize.

As a result, when keeping the original selection, the game is won when the contestant initially chooses correctly [1 in 3 chance] and loses when a goat is chosen [2 in 3 chance]. Conversely, when the contestant changes their original selection, the game is won if a goat was initially chosen [2 in 3 chance] and only lost when the car is chosen initially [1 in 3 chance]. Therefore the chances of winning are doubled when using the switching technique (Khan, 2012).
This diagram shows the chances of getting the goat or the prize (in this case, a car) if the contestant stays with the original door or switch (nd.edu):



Mathematical paradoxes challenge our intuitive nature towards real-life maths problems. This causes us to examine our logic and work through problems creatively and carefully to reach the answer. The only question remaining is what will puzzle mathematicians next?

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Modular Arithmetic and RSA Cryptography

Talia Mitchell, South Hampstead High School

In short, Modular Arithmetic is a system. It's a form of arithmetic that deals with remainders. Arguably its one of the purest topics in pure mathematics, but it turns out to have an unexpected application to cryptography (communication theory).

A key term regarding this topic is modulus; this refers to an absolute value of a real or complex number. For example, if we were to take a positive integer c(the modulus) and any pair of integers that differ by a multiple of c you could construct the following:

$$a \equiv b (mod\ c)$$

This reads: a is equal to b modulo c. Other examples include "2 = 6(mod4)" or "3=12(mod9)". The meaning of this generalized statement is "a and b differ by a multiple of c" .

Another definition of modular arithmetic is that if m≥2 and m R then integers a and b are congruent modulus m if they have the same reminder when divided m.

More examples of where we use modulus regards the 24-hour (If we consider n=12, e.g. 17.30 = 5.30 = half 5) clock and the day of the week, However, as economy continues to grow, the demand for secure and effective design will continue to increase, especially in sectors such as banking and governmental agencies.

In 1977, Ron Rivest, Adi Shamir and Leonard Aldman presented RSA to the world, an asymmetric cryptography algorithm. This means that it uses both a public and private key in its form of encryption. The encryption scheme works through encrypting and decrypting messages using keys (encryption and decryption keys). The encryption key is pubic and can be given to everyone and the decryption key is private and only known by the recipient of the of the encrypted message.

Let's assume that you want to use the RSA Algorithm to encrypt a message with the public encryption key (5,14) : "B". Firstly, this number is converted into a denary equivalent using a key. Perhaps it becomes the value 2. 2 is then raised to the power of the first digit of the encryption key, modulus of the second. In this example:

$$B \rightarrow 2^5 (mod 14) = 32(mod 14) = 4(mod 14)$$

The cipher text would then be equal to 4 and the original message is lost. In this specific case the decryption key is (11,14). To decrypt the ciphertext you would take the first number of the decryption key and raise the cipher text to this power, modulus of the second decryption number of the decryption key.

$$4 \rightarrow 4^{11} (mod 14) = 4194304(mod 14) = 2(mod 14)$$

You can see how we ultimately result with the original text "2".

RSA Algorithm works because it is extremely difficult to determine the decryption key from the public encryption key. RSA derives its security from the difficulty in factoring large integers that are the product of two large prime numbers and determining the original prime numbers from the total is considered infeasible. Generally, Encryption strength is directly tied to key size. RSA keys are typically 1024-2048 bits long.

It has been proven that the RSA algorithm can have a low process speed when large amounts data are requested to be encrypted by the same computer because it requires a third party to verify the reliability of the public keys. Despite this some argue that the prowess of new technologies compensate to make this issue somewhat irrelevant as the real value is that the complex mathematics of the RSA algorithm makes it safe and secure for its users; the factorization of prime number makes the algorithm hard to crack.

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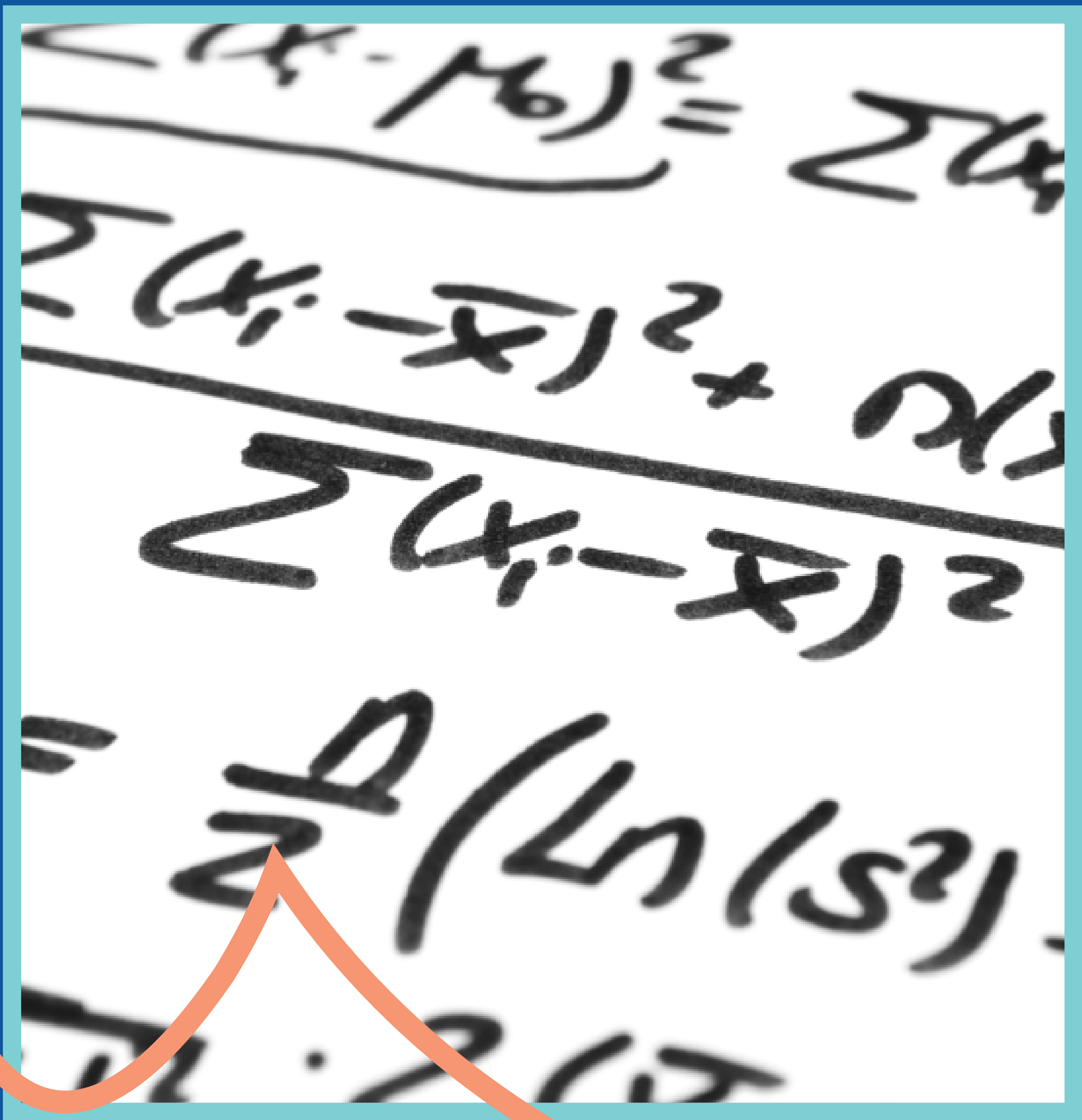
MATHS ESSAYS UNDER 18



What would a world without mathematics be like?

Nooriya Mohamed Rafi, Wimbledon High School

For the past 6,000 years, mathematics has underpinned every aspect of our lives- (Betz, 2020) This can be traced back to ancient Sumer where civilisation flourished through the development of irrigation and architecture. (Kiger, 2019) Many of these innovations led to mathematical developments like the sexagesimal system as mathematics was used as a tool to explore these fields. (Numberphile, 2012) Thus, in a world without mathematics, without the prerequisite foundation of knowledge to explore, it can be imagined that our world would become Primitivist. (Hayes, 2020) This would be characterized by a lack of technology, subsistence farming, and localized economies. In this article, the likelihood of a shift towards Primitivism will be investigated by imagining what computing, architecture, government decision-making, and monetary systems would look like without mathematics.

How we work without mathematics would differ drastically as the absence of electronic devices would lead many industries into decline. In the secondary sector, handheld computers are essential to ensure manufacturing worksites operate smoothly. (Keyence, 2022) Likewise, in the tertiary sector, communication devices and financial programs are relied on for day-to-day company operations. (Mahrra, 2021) This technology is enabled by Boolean algebra, which deals with logic functions, and two states "true" and "false" conveyed by 1 and 0. (CrashCourse, 2017) Examples of logic gates are AND, NOT, and OR which have different conditions as characterized by the number of inputs required to be "true" or "false" to work. Emergent properties arise from the interaction of these logic gates which form digital logic circuits to perform increasingly complex tasks. These tasks occur in a manner like flowcharts to fulfill an electronic device's overall function. (Electropaedia, 2005) Thus, without modern technologies, a shift towards Primitivism follows as types of professions resultantly become less intertwined with technology.

How we live would also change in the absence of mathematics as without engineering, only simple structures can be built. Through the use of trusses, trigonometry has helped construct structures like the Eiffel Tower, the Golden Gate Bridge, and the Louvre Pyramid. (SkyCiv Engineering, 2019; Golden Gate Bridge Highway and Transportation District, 2022; LF-BJMB, 2022) Trusses, which are structures of connected triangular units, are often utilized to ensure robustness. (Lin and Yoda, 2017, pp.1–30) The interlinking nature of trusses allows forces to be evenly distributed as they are applied axially. (Ochshorn, 2010, pp.1–37) Without trusses, building supports like beams may be employed which are far less efficient as they face unevenly applied stresses. (Liang, 2019) Furthermore, calculations of angled forces also rely on trigonometry. (Harrison et al., 2009) Thus, the lack of architectural possibilities signals a shift towards Primitivism as only simple structures can be built through trial and error.

How we make choices would also change in the absence of mathematics as statistical analysis is essential for decision-making in all sectors. In the UK, the NHS must make difficult choices between treatments because of a limited budget. When deciding, a Quality Adjusted Life Year, (QALY) which is a year of life in perfect health, is used as a benchmark of comparison between medications. (Gardner, 2021) The number and costs of extra QALYs each treatment provides is taken into account in what is known as cost-utility analysis. However, whilst measuring cost is easy, quality of life proves far harder. Thus, scientists devised the EQ-5D questionnaire. This survey was used to classify patients of the NHS into 245 health states and determined the utility of each state through normalizing the data values of each condition for easier comparison. This provided the NHS with a structural framework to make difficult choices in quantifying the quality of life in relation to monetary value of each treatment. (Gardner, 2010) Thus, without mathematics, governments would not make economically optimal decisions which may result in welfare loss that could affect the quality of life of current or future generations.

How we allocate resources in a world without mathematics would also change drastically because complex monetary transactions could not occur. Throughout every school of economic thought, economics is underpinned by the applications of mathematics. In basic economic theory, this would create challenges in economics as to how to allocate limited resources, among infinite wants. (The Editors of Encyclopaedia Britannica, 2020) This is as, without using graphs to model the supply and demand curves and their intersections, market equilibrium cannot be found. Price changes affect these diagrams by signaling consumers and producers to change their consuming and supplying habits to allocate resources without waste in what is known as the price mechanism. (The Editors of Encyclopaedia Britannica, 2018) Thus, without financial transactions, society would enter a bartering system which would result in waste and less trading because of mismatched needs. (Hall, 2019) Thereby, weakening international relations, limiting economic growth, and making economies localized. Fundamentally, modern monetary systems would change for the worse as without financial transactions, and monetary interest, neither stock markets nor banks would have incentive to exist.

Thus, in a world without mathematics, society may revert to a Primitivist system as resources cannot be allocated without waste, and the innovation needed to engineer would be limited. In essence, this suggests our society would become stagnant.

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Is Maths invented or discovered?

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For years, this question has been a recurring debate amongst mathematicians. Many believe that mathematics is invented and the way our brains interpret all elements of this world, as well as the patterns in it; that mathematics is a human construct, like a language. However, others believe that maths is discovered: meaning, the universe we encompass was created using mathematics.

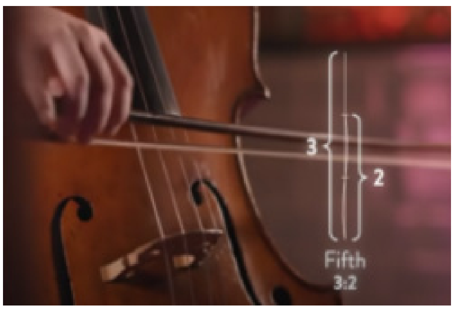
Firstly, it's important to ask ourselves what mathematics is. By dictionary definition, mathematics is the abstract science of number, quantity and space, either as pure mathematics or applied. This 'abstract science' feels as tangible as ever when exploring the mathematics behind nautilus shells.

Measuring the width of an inner chamber gives 14.5mm, then the second measurement to the outer rim at the same angle gives 46.7mm. Another pairing has widths of 23.9mm and 77.6mm, and another, 30.7mm and 99.5mm. When dividing one number by the other, we get approximately a value of 3.2. This means that every time it does a complete turn while growing, it ends up sitting in a chamber 3.2 times the width of the turn before, creating this beautifully intricate shell.

Another interesting showcase of mathematics in nature is that of the petals on a flower. When counting the petals of flowers, some have 3 petals 5, 8, or 13, but rarely numbers in between. They may seem random, but they're all part of what's called the Fibonacci sequence. Furthermore, if you look at the head of a sunflower, the seeds are arranged in a spiralling pattern and when counting the number of spirals in one direction, you get a fibonacci number, as well as in the opposite direction.

3 petals + 5 petals =8 petals

Another brilliant example is the connection between mathematics and music. Pythagoreans and the Greeks discovered that perfect harmonies are made with simple ratios between notes. For example, playing an octave between 2 notes, as well as playing what's called a perfect fifth, at a ratio of 3:2. When playing a note that isn't one of these neat fractions, you would hear a very detestable sound.

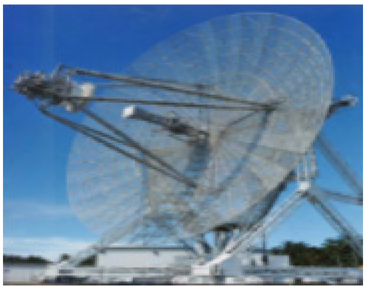


These arguments may give the impression that mathematics is discovered. However, there is also a probability that it is all just in our heads. Dr Sam Wass is an experimental psychologist at the University of East London, who had 2 babies help him with some experiments concerning maths being an invention. To begin, each child was placed in a room to be presented images. The first experiment used eye tracking technology to see how the babies react to the movement of a puppet. The screen presented the puppet jump up twice in a row, then disappear multiple times, for the babies to learn the sequence. Then instead of twice, the puppet appeared 3 times in a row. These tests revealed that the babies were surprised when the puppet appeared more often- therefore, before attending primary school, they had a sense of 'twoness' and 'threeness', and the difference between them, suggesting that maths is hardwired by DNA in our genetic code, proving it to be an invention.

Another proof of mathematics being invented is what is known as the most beautiful equation in the world, called Euler's Identity.

$$e^{i\pi}+1=0$$

The beginning of its construction concerns cos(x) and sin(x) being added together to form an equation similar to e^x, but not quite there. But in order to do this, mathematicians needed a number that can square to equal -1, even though it's recognised that squaring numbers always give positive values. Therefore, they resorted to creating an imaginary number 'i', showing how as humans we are brain wired to manipulate, interpret and create quantity. The imaginary number i is useful for solving problems concerning electricity or wireless technology that would otherwise be impossible to solve- so people working with waves, work with i.



In fact, if you've ever flown an aircraft, you've already trusted your life with this strange number. Imaginary numbers are efficient for manipulating radio waves, and therefore allow us to track planes in real time and use radar. The number i didn't come from a world of ethereal mathematical ideas, or God-given - it was definitely invented.

Now back to our main question, is Mathematics discovered or invented? To me, mathematics is invented. Mathematics is the abstract representation of patterns in nature which encompasses quantities and their relationships. It started with simple observations like two rocks are more than one. Humans developed language and symbols to express these relationships and this evolved over time. I don't believe mathematics explains something to us, but the other way round; it's just a way that we have devised to describe and communicate the reality we see around us.

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The Painter's Paradox: Gabriel's Horn

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Picture a graph with the function y=1x (Figure 1). Now rotate the graph around the x-axis with the domain $x \geq 1$ (Figure 2). We now have a solid of revolution or Gabriel's horn.

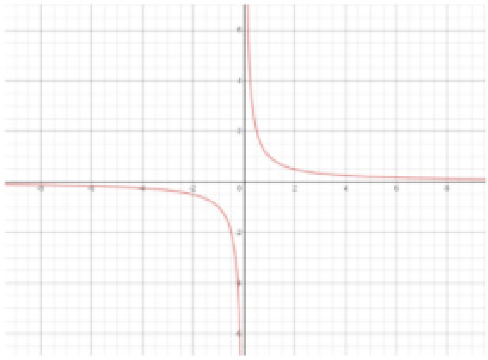

Figure 1 Graph of y = 1/x (Runevic, 2021)

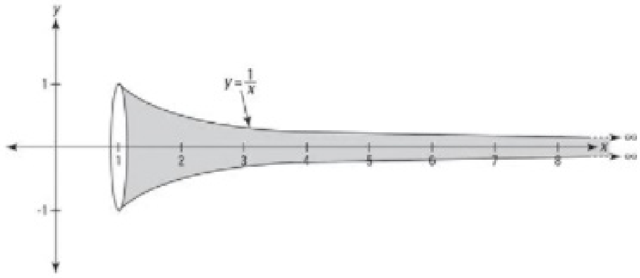

Figure 2 Solid of revolution (Dummies, 2016)

We'll begin with the volume. But wait! Surely since the horn is infinitely long, the volume would also be infinite? Well, let's see if we can get a definitive answer using Maths.
The definite integral of a function from two points (a and b) gives you the area of the region underneath the curve [a,b] by adding up the areas of multiple subintervals of equal width of the region as it goes to zero. If we cut the horn into many vertical slices, we will get 3D discs similar to cylinders, but with a curved edge. If we make them very thin, they will get closer to cylinders. Let the width of one cylinder be dx and we get the volume of a cylinder: r2dx. The radius is the distance between the x-axis and the curve, which we know is the value of y, which is given by 1x . So we substitute that into the volume of a cylinder to get 1x2dx. Now we integrate to get the volume of the horn:

$$V = \int_1^\infty \pi \frac{1}{x^2} dx$$

$$= \pi \int_1^\infty x^{-2}\, dx$$

$$= \pi \left[-x^{-1}\right]_1^\infty$$

$$= \pi \left[-\frac{1}{x}\right]_1^\infty$$

$$= \pi \left[\left(-\frac{1}{\infty}\right) - \left(-\frac{1}{1}\right)\right]$$

$$= \pi\,[(0) - (-1)]$$

$$V = \pi$$

So, the volume of Gabriel's horn is . Unexpected?

Moving on to the surface area. Let's go back to the idea of slicing the horn into lots of (n number of) discs of equal width (Δx) (Figure 3) – notice how they are similar to conical frustums? This time, the curved edge is important so we will derive a formula for the surface area of a solid of revolution.

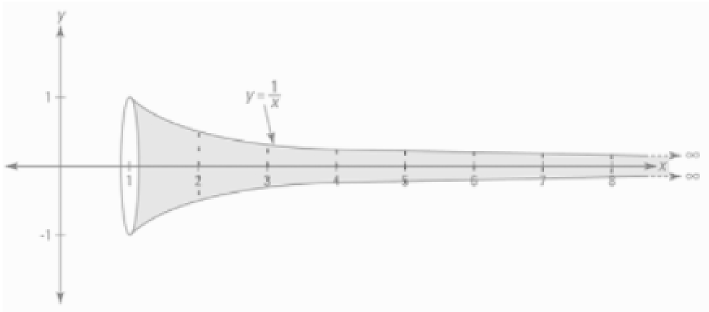

Figure 3 Solid of revolution sliced into multiple subintervals, modified from (Dummies, 2016)

The surface area of a frustum is given by:

$$S.A. = 2\pi r L$$

where,

r = radius = $\frac{1}{x}$

L = slant length

We can find L by finding the arc length of a function. Figure 4 shows another function, f(x), unrelated to our horn but we will use this for our derivation. Divide the interval [a, b] into n equal subintervals, each with a width of Δx, denote each point with Pi, and connect each point with a straight line. We will denote the length of each line segment by Pi-1P1. Since below n = 4, we can only approximate the length of the curve by finding the summation of the lengths of all the line segments, but if we make n tend to infinity, we can get the exact length.

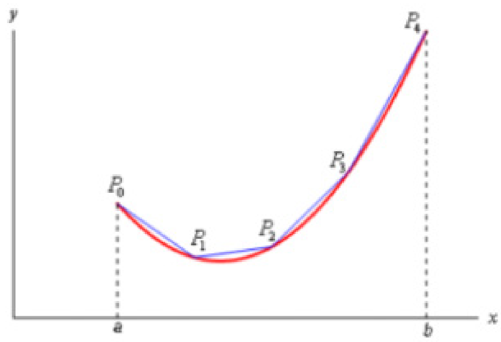

Figure 4 Graph of new function, f(x) (Runevic, 2021)

So far we have:

$$L = \sum_{i=1}^{n} \left| P_{i-1} P_1 \right|$$

To find the length of one line segment, we can use good old Pythagoras' Theorem:

$$\left| P_{i-1} P_1 \right| = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$

Now having Δy isn't beneficial to us if we want to end up with an integral with respect to dx, so let's take a quick look at the Mean Value Theorem:

If a function, f(x), is:

- continuous on the closed interval [a,b]
- differentiable on the open interval a,b

Then, on the interval [a,b], there exists a point, c, such that

$$f'(c) = \frac{f(b)-f(a)}{b-a}$$

Back to defining Δy. On the interval [xi-1, xi], there exists a point, xi*, such that

$$f'(x_i^*) = \frac{f(x_i) - f(x_{i-1})}{x_i - x_{i-1}}$$

$$f(x_i) - f(x_{i-1}) = f'(x_i^*)(x_i - x_{i-1})$$

$$\Delta y = f'(x_i^*)\,\Delta x$$

Therefore,

$$|P_{i-1}P_1| = \sqrt{(\Delta x)^2 + [f'(x_i^*)\,\Delta x]^2}$$

$$= \sqrt{(\Delta x)^2 + [f'(x_i^*)]^2\,(\Delta x)^2}$$

$$= \sqrt{1 + [f'(x_i^*)]^2}\,\Delta x$$

Plug this back into equation for the exact length of the curve:

$$L = \lim_{n\to\infty} \sum_{i=1}^{n} |P_{i-1}P_1|$$

$$= \lim_{n\to\infty} \sum_{i=1}^{n} \sqrt{1 + [f'(x_i^*)]^2}\,\Delta x$$

$$= \int_1^\infty \sqrt{1 + [f'(x)]^2}\,dx$$

$$= \int_1^\infty \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\,dx$$

Since $y = \frac{1}{x}$, $\frac{dy}{dx} = -\frac{1}{x^2}$.

So to find the surface area of a frustum:

$$S.A. = 2\pi r L$$

$$= 2\pi \int_1^\infty \frac{1}{x} \sqrt{1 + \left(-\frac{1}{x^2}\right)^2}\,dx$$

$$= 2\pi \int_1^\infty \frac{1}{x} \sqrt{1 + \frac{1}{x^4}}\,dx$$

Oh great, now we have to solve this nasty integral? Well, no. Since $x \in [1, \infty]$,

$$\sqrt{1 + \frac{1}{x^4}} \geq 1$$

So we can replace that by 1 to leave ourselves with:

$$S.A. = 2\pi \int_1^\infty \frac{1}{x}\,dx$$

$$= 2\pi[\ln x]_1^\infty$$

$$= 2\pi[\ln \infty - \ln 1]$$

$$S.A. = \infty$$

So we can fill Gabriel's horn with π-units of paint (a π-nt of paint!) but not paint the surface.
Suppose the thickness of the horn is so thin that the surface area of the inner side is equal to that of the outer side. Surely then, as you fill up the horn, you are painting the inner side and, therefore, painting the horn's surface?
Well, as I approach my (word) limit, I will leave you with this question. The Painter's Paradox is a fascinating paradox which encapsulates both a converging series $\left(\sum_{n=1}^{\infty} \frac{1}{n}\right)$ and a diverging series $\left(\sum_{n=1}^{\infty} \frac{1}{n^2}\right)$, resulting in a finite volume (but with an infinite number of decimal places!) and an infinite surface area.

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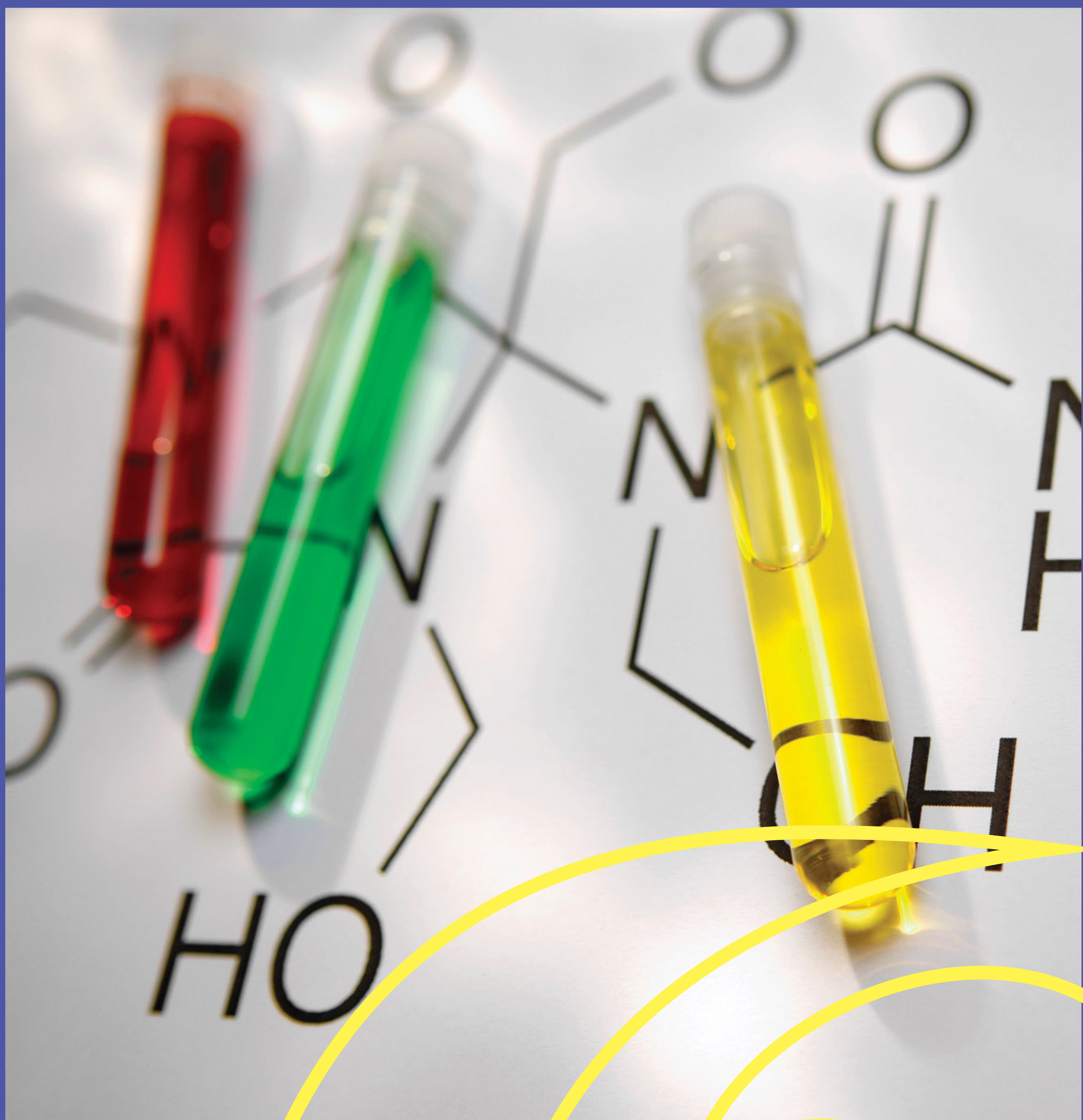

The Healthy Fantasy of Veganism

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I guarantee that you know at least one vegan. As of 2021, 2.7% of London's population follow a vegan-based diet. Furthermore, stated by a recent UK wide survey, 42% of adults eat meat substitutes once a month or more. This past decade has witnessed the miraculous growth of vegan visibility. The Economist labelled 2019 the "year of the Vegan". The start of veganism was established by Nataputta Mahavira who lived in the Indus Valley, he was a philosopher and the founder of Jainism. The basis of Jainism is non-violence to all living creatures, which has developed into veganism as we know today. Fast forward throughout the ages, past prominent figures in history who promoted veganism and vegetarianism, including Pythagoras, St. Anthony of Egypt and Mary Shelley, and we come to point where veganism is advancing into a common trend in society today. A trend which is presented as healthy, eco-friendly and moral. However, as popularity rises, and veganism has evolved so much, consequences begin to reveal themselves. The main consequence is ultra-processing- a topic which is dangerously overlooked, and which poses as a malignant problem for ourselves and healthcare systems.

Ultra-processed food should be distinguished from processed food. Processing can be done by adding ingredients like oils, sugar or salt, which people do every day whilst cooking and preparing food. Ultra-processed foods, in contrast, have to be industrially manufactured. Most ultra-processed vegan foods are made from substances that have been extracted from other foods, including starches and hydrogenated fats. Ultra-processing is carried out on vegan foods for a multitude of reasons, but they all bear the same outcome- an unbalanced, dangerous diet.

There are three main aspects, that producers try to follow to make plant-based meat taste as delicious as normal meat. Firstly, colouring plays a major role in contributing to the processing of the product. Beetroot juice and pomegranate powder are often used to copy the juicy, appealing look of meat. Secondly, to imitate the chewy texture, pea or soy protein is used in many vegan meat products. Although, a common misconception about pea protein, is that because it indeed contains all nine essential amino acids, it automatically makes the food "healthy". In reality, protein does not make up for the missing nutrients- a frequent problem in vegan foods. Finally, flavouring is an important factor to make a food tasty. Salt and fat are the two primary ingredients added to make food taste good. However, what most people are unaware of is the significant amount of fats and salts added to plant-based meat. Last year, an article written by the New Scientist compared the nutritional value of vegan meat substitutes and real meat. Vegan "salmon" contained 0.7g of salt, whilst Atlantic salmon contained 0.1g of salt. Similarly, a vegan "chicken" burger contained 17.8g of fat; however, a grilled chicken burger contained 8.9g. It is evident how mimicking meat in vegan replicas leads to an ultra-processed, yet seemingly innocent meal.

Due to the fact that ultra-processing involves the addition of many ingredients such as fat, salt, colouring and more, there are serious health risks linked. Research from the Nutritional Epidemiology Research Team (EREN, University of Paris) examined the daily food intake of 9,821 meat eaters, 646 vegetarians, 500 vegetarians and 254 vegans. The study found that, between the four groups, there was a correlation between the avoidance of animal-based foods and increased consumption of ultra-processed foods. This high consumption of ultra-processed foods notably increases the likelihood of obesity, type 2 diabetes, cancer and cardiovascular disease. Some extremely overlooked, ultra-processed products are milk alternatives, including oat milk and soya milk. Plant-based milk sales have doubled globally between 2009 and 2015. Meanwhile, natural cow's milk sales have decreased by roughly 15% from 2013 to 2018. The key issue related to plant-based milk, is the lack of vitamin B12, calcium and iodine. 50 to 60% of our calcium comes from milk, and other milk products. The deficiency of calcium can lead to a dramatic loss of bone mass, and, especially because most plant-based milk consumers are young teenagers, it can lead to osteoporosis and other bone disorders.

In conclusion, whilst generally plant-based food products with a vegan stamp are thought to carry a "health halo", they are often victims of ultra-processing. It is important to highlight, that this does not mean that all plant-based alternatives are equally harmful to your health. Some vegan products contain a lot more nutritional value than others. If you do follow a vegan-based diet, it is worth checking whether the product is fortified with the right vitamins and minerals, and whether it has a long list of ingredients, as that is often a red flag in ultra-processed foods. The key point to take away, is that vegan does not always equal healthy.

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The Placebo Effect

Arwa Kinana, Croydon High School

When we are sick, we turn to and rely on (generally) our doctors. We sit for perhaps hours on end, flicking through magazines and feasting on sweets, just to see a doctor. We then answer a stream of endless questions, endure being closely examined and prodded. And in return for this, we expect something. And that something happens to be a piece of paper with scribbles on it - a prescription for medicine. You aren't that concerned about what you are taking, you place your complete trust in a doctor. What if, however, your doctor suddenly said that your medication wasn't scientifically proven to provide any form of relief at all? But you had become better - you trusted that the medicine would make you feel better, and so you did.

The placebo effect - strange name, but whether you have heard of it or not, it is incredible and intertwined with the way our brains work. The word placebo comes from the Latin for "I will please." A placebo is a "medicine" which, in reality, contains no pharmacological substances and actually is only made of inert substances; in other instances, the placebo may contain chemicals proven to treat other conditions. Examples of placebos include pills made of sugar, injections that actually only contain saline (salt and water) and "sham" surgeries (made more realistic by use of fake blood, for example). What all placebos have in common is the fact that they cannot treat what they are meant to treat i.e. they are fake.

Some factors which affect the efficacy of the placebo and the strength of the placebo effect are the characteristics of the pill - that is, colour, size and other things related to appearance.
If the pill looks real, the person taking it is more likely to believe that it contains a medicine. Research shows that larger sized pills suggest a stronger dose than smaller pills, and taking 2 pills appears to be more potent than swallowing just one. Also, injections have a more powerful placebo effect than pills, and surgeries have a more powerful effect than injections. Another factor which affects the strength of the placebo effect is the environment in which the placebo is taken. This includes the level of trust between a doctor and the person taking the placebo, as well as the level of empathy and kindness shown by the doctor. If a person trusts their doctor, they are more likely to believe that the placebo will work for them. The appearance of the packaging and labelling is also important. This was shown by an experiment by Ted Kaptchuk at Harvard Medical School. He gave some migraine sufferers either the drug Maxalt or a placebo. But both were divided into three further groups. The groups were given their drugs in envelopes with one of the three labels: "Maxalt", "Placebo" or "Maxalt or placebo". The placebo labelled "Maxalt" and Maxalt labelled "placebo" both had a similar effect.

There are two main theories regarding the placebo effect. One reason may be classical conditioning, or association. We associate different things with different experiences - an example is if you ate fish, didn't enjoy it, and became sick soon after, you may avoid eating fish in the future due to this negative experience. Similarly, if you take a pill for headaches, receiving a pill the same size, shape and colour as your previous medicine, you will associate this pill with healing headaches and believing that the pill can cure you may improve your symptoms, even if it is just a sugar pill. Another reason is the release of hormones. Scans and research show that taking a placebo triggers a release of endorphins. Endorphins have a structure very similar to painkillers and act as the brain's own natural painkillers.

Astronomy and Psychiatry: their enigmatic parallels

Tvisha Lakshmeesh, Oxford High School

A tale of two branches

Astronomy and psychiatry, two branches of science that are commonly juxtaposed with each other. Psychiatry delves into the enigmatic abyss of the human mind- looking inward- while astronomy opens its eyes to the secrets of the vast universe- looking outward. We almost never think of the two simultaneously. However, the two have a multitude of enigmatic parallels.

The 'darkness' of the Universe

Dark matter is a substance present at the dawn of the Universe, and it is something that we know extremely little about (L Kaplan, 2016). It has never been witnessed directly, but it is believed to account for roughly 27% of the Universe. In the 1970s, an astronomer called Vera Rubin confirmed dark matter's presence (American Museum of Natural History, 2020).

This substance is opposed by dark energy, discovered by astronomers Adam Riess, Saul Perlmutter and Brian Schmidt. It is extremely prevalent in the universe, estimated to account for 68% of our universe. This substance dominates the dark matter due to its abundance and while dark matter endeavors to slow the expansion of the universe, dark energy accelerates it (NASA, 2012).

The 'darkness' of the brain

Recent neuroscientific studies have shown that during the development of the human brain, there are some segments of the brain- known as silent synapses, essentially the 'dark matter' of the brain- which do not react to impulses and stimuli like other synapses, leaving us inquisitive and curious about the function of silent synapses, how they collaborate with other synapses and their impact on brain function (Horgan, 2021) (Zimmer, 2019).

The foundations of the sciences

All sciences- not just astronomy and psychiatry- are, essentially, humanity's way of trying to understand the world around us. Humanity's fundamental nature is to label everything we see, categorize, and accumulate knowledge. All sciences endeavor to fully understand each segment of our life- whether our interior or exterior world- so that we can develop and improve our world- specifically our lifestyle.

Science is, essentially, a tree of knowledge: the roots of humanity's thirst for knowledge, the tree of science dividing into overarching, unique branches of science and leaves of specialized fields.

Role of Astronomy in Psychiatry

Studies have shown that astronomy is very beneficial to our wellbeing. Astronomy, at its core, is not a branch of science reserved for professional or budding astronomers, it is an observation of the beauteous, natural world around us.

Star gazing has been extremely beneficial to the betterment of people's welfare- especially in our world in which our skies have been clouded with pollution and artificial lights blinds us. One of the many byproducts of industrialization and development is that the skies are no longer able to reveal their magnificence and 1/3 of the population have never truly been able to see the milky way (NOAA, 2016).

Additionally, star gazing- the crude form of astronomy- has helped people with various types of depression- for example SAD (seasonal affective disorder)- and other mental health difficulties and issues. Furthermore, the environment star gazing creates is tranquil and serene, giving solace to those overstimulated by today's overwhelming world. Star gazing allows us to relax, unwind and appreciate the little things in our world, allowing us to take a breather from our tiring lives.

The fruits the branches bear

Astronomy and Psychiatry are two fields which share a great disparity but there is more that connects them than we might imagine. Upon examination, Astronomy and Psychiatry complement each other quite well, each providing insight into different aspects of our world. Their parallels and connections cause them to exemplify the duality of the sciences, residing on opposite ends of the spectrum of scale. Perhaps, in the future, the links between them could strengthen and multiply, and future fields of science could combine them, providing us with a new perspective on our world.

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Example Harvard referencing

In-text citations are used when directly quoting or paraphrasing a source. They are located in the body of the work and contain a fragment of the full citation, e.g. "After that I lived like a young rajah in all the capitals of Europe..." (Fitzgerald, 2004).

Reference Lists are located at the end of the work and display full citations for sources used in the assignment, e.g. Fitzgerald, F. (2004). The Great Gatsby. New York: Scribner.

For more information see https://libweb.anglia.ac.uk/referencing/files/QuickHarvardGuide2018.pdf

In conclusion, the placebo effect is a powerful phenomenon which affects every aspect of our lives. Even if it isn't yet known how this works, scientists are aware of its power and use it to their advantage in clinical drug trials. As a child, did you ever feel better after your mother kissed your bumped knee? Just remember that it was the placebo effect in action!

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SCIENCE ESSAYS UNDER 16

Dark matter and dark energy:
How much do we know, know we don't know and don't know at all?

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One of the most curious aspects of space – one that fiddles with our quite finite comprehension of the universe – also happens to be one of the hardest aspects of our universe to observe. The discovery of dark matter and dark energy are some of the most pivotal discoveries in the field of cosmology, initially theorised in 1933 by astronomer Fritz Zwicky, which have helped scientists to explain the rapid expansion of the universe, from the big bang to the ends of time. However the question still remains: how much do we know about dark matter and dark energy and what don't we know?

First, let's start with what we do know, and its effects on the human understanding of the universe. Zwicky's indirect discovery of dark matter happened while he was observing the Coma cluster – a group of galaxies close enough to each other that are bound together through their gravitational attractions to one another. However, what surprised him was the shocking realisation that the gravity from the visible matter was only accountable for around 1% of the mass which held together the galaxies. There was another source of gravity which was holding the cluster together. Later coined with the name dark matter, this undetectable matter was also seen to have an effect on a smaller scale, within individual galaxies. Again, the visible mass in a typical galaxy only accounted for ~10% of the gravitational pull required to hold the galaxy together. Without dark matter, galaxies would just disintegrate and form smaller clumps of stars which were close enough to each other that their own gravity would keep them bound together.

So we definitively know that dark matter has a gravitational pull, helping to hold together galaxies and galaxy clusters, however, if they are invisible to the naked eye and have a strong gravitational pull, couldn't they be lots of blackholes? This is not the case for two main reasons. Most blackholes come in two main categories, stellar and supermassive. Stellar blackholes are far more common and have a similar mass to a large star. Saying this, if we were to replace the sun with a blackhole of similar mass, nothing much would change to the planets' orbits (except we would all freeze to death). Applying the same logic to a galactic scale, filling in empty space with lots of stars would not have the same 'glue' like effect as dark matter.

On the other hand, supermassive blackholes are far more massive than stellar blackholes. While they both start at similar masses supermassive blackholes feed on stars and other blackholes to grow, and over billions of years, become thousands of times more massive than their original mass. However supermassive blackholes are not as common as their stellar cousins. They are always found at the centre of galaxies, such as the one at the centre of the milky way, Sagittarius A*, which is over 4 million times more massive than our sun. However, dark matter permeates vast regions of empty space, therefore there is no way a supermassive blackhole could be formed in these regions as there isn't enough matter for a blackhole to grow to a supermassive size anyway. While both dark matter and dark energy are mostly unknown, we know even less about dark energy. Roughly 68% of the universe's energy is dark energy and that number is increasing. We also know that there is a relationship between the accelerating rate of the expansion of the universe and the amount of dark energy, however this relationship is largely a mystery. Some researchers believe that because dark energy permeates all space, as the total 'amount' of space increases there is more dark energy created for that space, but once again, this is just a theory.

In conclusion, we have very finite knowledge on the topic of dark matter and dark energy, which becomes very evident when we ask ourselves what we don't know about them: why can't we see either of them, why don't they interact with light or why dark energy has no transfer of its energy or if it does? Even further, there are questions we don't even know to ask yet largely because our knowledge is limited to the principles which we know and understand, like asking a toddler who can count to five about the safety precautions of a nuclear power plant. So while researchers are still trying to find answers to our questions, there are still so many things we don't know, and the challenge to find the answer is the true drive of science.

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Why is the Use of Bioluminescence so Important in Medicine?

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In Genesis, when God says “Let there be light” you probably envision the hot, glowing ball of hydrogen and helium at the centre of our solar system, the sun. In reality, there are many other forms of natural light, such as fire, or a meteor: a beautiful shooting star, or a bioluminescent organism.

Bioluminescence is the production and emission of light by living organisms, it is found in the sea and on land, ranging from a miniature firefly to the 6-foot long giant squid found off the coast of New Zealand. The chemical reaction that causes these organisms to glow consists of a light-emitting molecule, luciferin; an enzyme to catalyse the reaction, luciferase; and oxygen, however, luciferase is not always needed. Sometimes photoproteins are used instead, these combine with luciferin and oxygen, and often a calcium ion is needed. The words luciferin and luciferase are derived from the Latin “Lucifer”, meaning “Lightbringer”. There are many factors that determine the colour of light emitted, for example, the structure of the enzyme and substrate, and the environment in which the organism lives.

In 1962, Japanese organic chemist and marine biologist Osamu Shimomura discovered that green fluorescent proteins (GFPs) could produce their own light without a separate light-emitting compound, they are proteins made up of 238 amino acids and numbers 65-67 form a structure that emits green fluorescent light. He did this by isolating the GFPs from a species of jellyfish called Aequorea Victoria, more commonly known as the crystal jellyfish. An important feature of GFPs is that the chromophore forms spontaneously in the presence of oxygen, meaning that it can be extracted from the jellyfish and injected into any other organism while remaining fluorescent. In this species, he found that the luminescent substance was a protein he called aequorin and it was activated by $Ca2+$. American biochemist Roger Tsien engineered different colours of GFPs, and neurobiologist Martin Chalfie showed that the gene that tells a cell to make GFPs could be put into the nucleic acid of other organisms so that they would make their own GFPs. In 2008, Shimomura, Tsien and Chalfie won a Nobel Prize in chemistry for their amazing discovery.

GFPs play such an important role in medicine because they can be used as a marker protein, meaning that they can attach to and mark another protein in order for it to be observed. They can be used in research about diseases, neuroscience and other medical fields. Some advantages of GFPs are that they are highly visible, can be targeted at specific things, and are non-toxic. They have been used in research about heart disease by tracking proteins such as calmodulin and troponin C that regulate levels of calcium in the human body. Neurobiologist Andres Villu Maricq found a regulatory protein similar to these in the roundworm, he tagged it with GFPs to find out what would happen without the function of this protein, and because calcium is responsible for muscle contraction, he found that the heart would stop beating without it. GFPs have also played a role in research about malaria. Plasmodium, the protoctista that causes malaria, can be tagged with GFPs so the targeting of haemoglobin in the blood, leading to the collapse of erythrocytes, can be observed first-hand, giving scientists further understanding of the disease. Another disease that can be investigated using GFPs is cancer. The metastases of cancer cells can be seen by putting GFPs into nude mice because their lack of hair allows scientists to view the tumours through the skin, and this is useful because the effects of different treatments can be seen. HIV/AIDS can also be studied using GFPs because one of the deadly things about the virus is that it can kill host T-cells, so virologist Gary Nabel used GFPs to show exactly how this happens. To protect against DNA damage, cells use repair enzymes, but in cells activated by HIV, an enzyme that causes cell death is released instead and these enzymes can be illuminated by GFPs. Furthermore, GFPs can also be used in neuroscience to follow neurons as they form synapses. A large spectrum of colours have been engineered, called the “Brainbow”, created by neuroscientist Jeff Lichtman and neurobiologist Joshua Sanes, and it allows each neuron to be illuminated and observed in a different colour.

It may be concluded that the discovery of the use of bioluminescence in medicine has been transformational. The incredible discovery of Shimomura has allowed scientists to see microscopic processes in much more detail, and being viewed in this way has led to a better understanding of a range of problems, meaning they are closer to finding treatments and cures for many conditions, thus saving and improving many lives.

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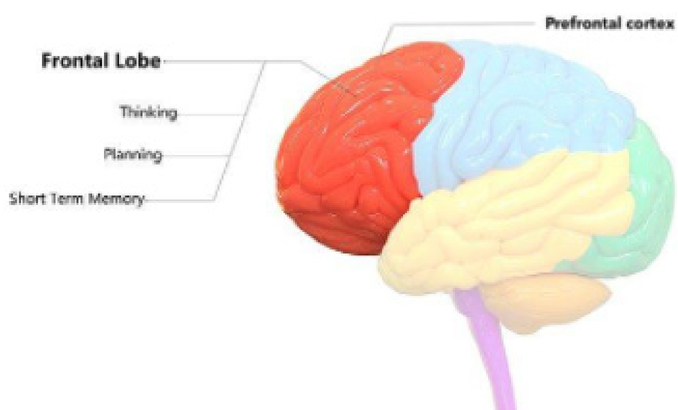
The Melody of Science

Anwita Vedula, Blackheath High School

The piano is an instrument played by many, and it's truly no surprise: the piano is known for its elegance, and its music can be mesmerising. Playing this instrument is seen as an art that is difficult to master, and most people don't even bother trying to learn. However, I believe that if they realised the relationship between music and science, they would change their tune.

The truth is that music and science are very closely intertwined. That's why playing the piano has countless benefits for the brain. Nonetheless, it can be a challenging experience - whether you have just started learning or if you're practising. When learning, it's important to remember key facts such as the note names and what the notes look like. While practising, pianists can struggle with overcoming left or right-handedness, a trait that is innate to many people. It can be hard because while playing, a pianist must use their right hand to play the melody and their left to play the additional notes. Additionally, musicians must persevere through finger fatigue, which can be tiring. It can be frustrating when you have to face such a problem, so why should you bother about it at all? Here's why.



Firstly, playing the piano greatly contributes to the prevention of brain processing, memory loss, and ageing. American neuroscientist Nina Kraus, who is a professor of neurobiology at Northwestern University, Illinois, is actually the first to provide evidence for this. She conducted an experiment that eighty-seven people were a part of, and their ages ranged from eighteen years to sixty-five years old. These people all had normal hearing, and around half of the subjects took piano lessons and continued to play often. The other half barely took any lessons and were not musicians. In her experiment, Kraus and her team attached electrodes to the heads of all participants. Electrodes are pads that are attached to the skin and allow the electric current to be recorded. The reason for using the electrodes was to measure "neural timing" or how fast it takes for the brain to process an auditory signal (such as a series of sounds or spoken messages). The faster the neural timing of each participant, the lesser the chance of them ever developing memory/hearing loss. Kraus and her colleagues discovered that those who were not musicians scored far worse than those who were musically active in their lives. She then concluded that music plays a very crucial role in hindering memory loss and slow brain processing.

Furthermore, playing the piano strongly encourages the connection between the different parts of the frontal lobe of the brain. The frontal lobe manages cognitive functions such as memory, problem-solving, and social interaction. A research investigation conducted by Dr. Ana Pinho, who works at the Karolinska Institute in Stockholm, Sweden, found that the medial prefrontal cortex becomes very active while playing the piano. The medial prefrontal cortex is the part of the frontal lobe that helps with creativity. Thirty-nine students from the Royal College of Music in Stockholm participated in Dr. Pinho 's experiment. They had different levels of knowledge for classical and jazz piano. When they were laid down in the scanner, the pianists were asked to play their favourite piece, though at times they were prompted to play something particularly happy/sad. At the Society for Neuroscience meeting in San Diego in 2018, Dr. Pinho said the scans revealed "...training led to more automation and higher functional connectivity between regions that are important for creative playing." This means that pianists possess the unique ability to think outside of the box because of their training. Dr. Pinho also stated that greater connectivity improved the overall efficiency of these brain regions, which means that pianists' abilities to recall, solve problems, and understand information are enhanced.

Finally, playing the piano can stimulate innovation and individuality. One way this can happen is by improvising. Improvisation is a technique that involves performing without any preparation or making up the notes as you go along; it requires a great deal of concentration but also creativity. Gottfried Schlaug, the director of the neuroimaging lab at Harvard Medical School in Boston, supports this. He talks about the relationship between improvisation and creativity; he says, "Improvisation is one way into creativity. These tools allow us to understand what brain regions are involved in creative thought and in coming up with new ideas." Schlaug emphasises how vital this relationship is because of the effect it can have on society: "...And from a societal perspective, it's always important to strengthen creativity because it is the seed for new developments and new ideas."

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SCIENCE ESSAYS UNDER 18

Metallic nanoparticles -
could they be the solution in the battle against antibiotic-resistant bacteria?
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Antibiotics are medicines used to prevent and treat bacterial infections. Globally there has been a rapid development of resistant bacteria, which is affecting the ability of antibiotics in the treatments of patients. This occurrence is resulting in bacterial infections becoming just as much of a threat as they were years ago, right before the first patients were treated with antibiotics. It has now been discovered that one of the causes of this dilemma is due to the abuse of these medications - this drives the evolution of resistance as a result of natural selection of the bacteria. Another cause is the misuse of these medications – antibiotic doses that are subinhibitory or subtherapeutic can encourage the development of antibiotic resistance by promoting genetic modifications such as gene expression changes (Holmes et al. 2016). The last main cause is due to a scarcity of new drug development by the pharmaceutical industry due to decreasing economic incentives and difficult regulatory requirements - antibiotics are less profitable than medications that treat chronic illnesses since they are taken for a short period of time and are often curative (Michael CA et al. 2014).

One of the many techniques of bacteria which have evolved to resist antimicrobial medications is their ability to build biofilms – they cling to a surface and form a biofilm community, in which cells clump together and surround themselves with a self-produced extracellular matrix that protects them against antibiotics and environmental challenges. Antibiotic resistance is much higher in biofilm-embedded bacteria than in free-floating bacteria, therefore scientists have turned to nano-materials as a new strategy to tackle this challenge (Davies, D. 2003).

The naturally sourced metal-based nanoparticles have been considered in particular- this is because of their therapeutic and blocking effects which have allowed them for decades to be used against infectious pathogens (Makabenta et al. 2021). Different types of nanoparticles have different mechanisms for combating microbial resistance. Of all the nanoparticles, the metals and metal oxide nanoparticles have proven to be the best option and have gained interest from many researchers, this is due to their display of diverse activities against several multi-drug resistant pathogens (A.M. et al. 2010). Let's focus on silver nanoparticles which have been the leading nanoparticles due to their low toxicity compared to others (Arya et al. 2019). One of their anti-microbial mechanisms is their cytotoxic effect in the 'metal ion release' – they first penetrate the microbial membrane surface then release the silver cation which harms the internal components, and these ions and silver nanoparticles also interact with DNA, leading to protein inactivation and subsequent cell death (Wang L et al. 2017).

The rate at which this silver cation is released is largely affected by the size and structure of the nanoparticles and this is another one of their best advantages - their extraordinarily small size provides them with a larger surface area-to-mass ratio so they can interact more with cells and therefore can easily penetrate the cell wall (Sriram et al. 2012). Their structure also lets them carry drugs and their ability to enter host cells by endocytosis allows most of the drug to be released intracellularly (Huh et al. 2011). As well as this, silver nanoparticles can enter biofilms and prevent biofilm development by suppressing gene expression (process by which a gene gets turned on in a cell to make RNA and proteins) (Zhao L., Ashraf M.A. 2015). Their mechanisms are also non-specific (they do not bind to a specific receptor in the bacterial cell) which makes the development of resistance by bacteria much more difficult.

However, there are some disadvantages which will need to be considered - we know that silver nanoparticles can accumulate within the human body and, because they can cross the blood-brain barrier, they can amass especially in the brain. They have also been identified in the lungs, spleen, kidney, liver, and brain in exposed rats (Tang J et al. 2009). On the other hand, zinc-based nanomaterials have been reported to cause toxicity and membrane injury and to increase oxidative stress in mammalian cell lines (Huang Z et al. 2008). TiO_2, which is chemically inert, also has adverse effects in its nanoform, as it exhibits toxicity such as DNA damage, genetic toxicity, and lung inflammation (Trouiller B et al. 2009).

Overall, microorganisms are becoming increasingly resistant to antibiotics, and nanoparticles with antimicrobial properties can be an effective complement in the fight against their antibiotic resistance, given their great therapeutic potential. However, we must remember that it is not only important to develop potential applications for antimicrobial nanoparticles, but also to follow safety regulations that allow for the control of these nanoparticles, which could potentially result in human health issues.

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Nanocellulose; is it the solution to the plastic problem?

Ruby Gratrick, Sydenham High School

In 1907 Leo Baekland invented the first fully synthetic plastic, called Bakelite, and at the time it was the perfect solution to the increasing need for electrical insulators. By the 70s we were producing 50 million tonnes of plastic annually, and this has skyrocketed in the past 3 decades- with around 367 million tonnes of plastic being produced globally in 2019. But what is it about plastic that is so good?

Polymers such as PET or PVC have revolutionised the ways in which plastic can be used, from food packaging to water pipes. They're inert, often have low density and are cheap to produce, however synthetic plastics do not break down easily- it's what made them so appealing in the first place, and it's this property that causes the overwhelming issue of plastic pollution. Eight million tonnes of plastic are estimated to enter the ocean annually and as the world becomes more environmentally aware, the need to find alternatives to plastic is all the more apparent.

The last 20 years has seen an increasing effort to find a naturally occurring material that could replicate the ideal characteristics of synthetic plastics. A promising candidate was cellulose; the most abundant carbohydrate and a naturally occurring polymer. The polysaccharide is composed of glucose molecules joined in 1,4 glycosidic bonds to form a long chain which are further arranged to create cellulose fibrils; these are strong insoluble strands that aid the stability of a plant's structure. We already use cellulose fibrils to make paper but what if cellulose still has more to offer?

Nanocelluloses can be extracted from cellulose fibrils. There are three main types: crystalline nanocellulose, cellulose nanofibers, and bacterial nanocellulose. Crystalline nanocellulose is extracted from cellulose fibrils via acid hydrolysis resulting in a high crystallinity which in turn results in improved mechanical and thermal properties. Nanofibrillated cellulose is extracted from cellulose fibrils by mechanical procedures causing longer length in comparison to nanocrystalline cellulose. However bacterial nanocellulose is produced from the building up of sugars by bacteria, so it is always produced in the pure form.

Cellulose fibrils have extremely high tensile strength, think eight times stronger than steel, which is carried over into the nanocellulose structures. Combined with their low toxicity and biocompatibility, the properties of nanocellulose allow for it to be applied in a variety of ways.

The future of nanocellulose mainly lies in industrial applications, with its strength and abundance of hydroxyl groups making it ideal for combination with other substances such as poly(lactic acid). This produces a lighter and more flexible material. Coating paper with nanocellulose makes it smoother and waterproof, which replicates the properties of the current cheap plastic covering, but importantly allows these coated papers to still be recycled.

Another potential use is the production of nanocellulose paper; this is formed from the filtration of a nanocellulose suspension which is then pressed and dried. Due to the smaller diameter of the nanocellulose fibres in comparison to the regular cellulose fibres, less light scattering occurs with nanocellulose paper. This means transparent nanocellulose paper can be produced, and it's these transparent paper sheets which will likely be developed to replace transparent food packaging or even to be applied to electronic devices. Nanocellulose may also bring revolutionary changes to the medical field. Bacterial nanocellulose has demonstrated biocompatibility and has potential to be used as a wound dressing due to its gel-like texture.

So why haven't we switched to this seemingly miracle substance? The reality is that although the mechanical properties of nanocellulose seem to be equivalent or even sometimes superior to its plastic competition, the real purpose of this pseudo-plastic is that it will biodegrade easily. Despite being derived from cellulose which has the ability to decompose quickly and without producing harmful byproducts, nanocellulose has not been tested in the long term and so needs to undergo more rigorous investigation concerning biodegradability. Not enough is known about the environmental implications of mass producing nanocellulose yet, so there is still hesitation to allow it to fulfil the huge role that current synthetic polymers play.

So is nanocellulose the answer to plastic pollution? It's lightweight, has high tensile strength and can be produced in a transparent format, but it's far from perfect. Further research must be done into the long term effect of the decomposition of nanocelluloses. However, I do believe utilising natural resources will bring us closer to finding a greener alternative to plastics and help solve the ever growing problem of plastic waste.

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Is there a cosmic speed limit?

Kirsty Martin, Croydon High School

Think you can travel as fast as you can – think again!
The idea that light always travels at the same speed, and that nothing can travel faster than that, is hard baked into modern physics. It is still difficult to get your head around the mind-boggling consequences of travelling in a spaceship with the beam of your headlights bouncing off in front of you into the vacuum of space. A stationary observer outside your ship would see those photons travelling at light speed – 299,792,458 metres per second. The thing is, so would you, no matter how fast your ship was travelling in the same direction.
According to the laws of physics, as we approach light speed, we have to provide more and more energy to make an object move. In order to reach the speed of light, you'd need an infinite amount of energy, and that's impossible!
So, you're on a fast train or in an airplane – did you ever notice the feeling of getting bigger throughout the trip? You may have heard that an object traveling at the speed of light gains infinite mass. But that's not exactly true. The object doesn't actually gain physical mass, but it behaves like it has.
For example, if a 65kg person was travelling at 50% of the speed of light, they would behave like they had a mass of 87kg. At 90%, they would behave as if they weighed 172kg.
So, if mass can't travel at the speed of light, how come light can?
Light is made up of photons, which are massless particles and therefore they don't require energy to move.
Then if it doesn't take any energy to move light particles – why can't a photon travel faster than light speed?
This is because of something called time dilation. Time slows down as you approach the speed of light and when you reach it, time stops.
Photons don't know what time is. For them everything happens instantaneously. Trying to make a photon go faster than the speed of light is like slowing down until you stop then trying to go even slower. It cannot be done. It's impossible!
Time dilation affects us all the time in everyday life, but its effects are so small we can't see it.
According to Einstein's theory of relativity, "moving clocks run slow." This isn't him going crazy. This means that if you throw your clock off a cliff, it will show a slightly later time than a clock that wasn't thrown. This is true for all types of clocks – mechanical and biological. You actually age slower at higher speed. However, you would have to travel very fast to notice any difference.
Consider it like this – you are an astronaut on the international space station for 6 months. When you get back you would've aged 0.005 seconds slower than your friends back on earth. The International space station travels around the earth once every 90 minutes or so, but this is still only 0.003% of the speed of light.
If you, hypothetically travelled in a spaceship at 98% of the speed of light for just a few minutes, decades would have passed on earth for your friends – it's like an effective but very expensive and dangerous anti-aging facial!
In ending does this answer the question if there is a cosmic speed limit. Well yes – and there is. The speed of light in a vacuum is the absolute cosmic speed limit. Nothing can go faster than 3.0 x 108 meters per second and this is due to a phenomenon that we experience in our everyday lives.
So, think you can travel as fast as you can. Well hypothetically you can travel up to the speed of light but only if you have an infinite amount of energy. Therefore if you do manage to travel that fast then you might want to let Einstein know, he may be a little jealous!

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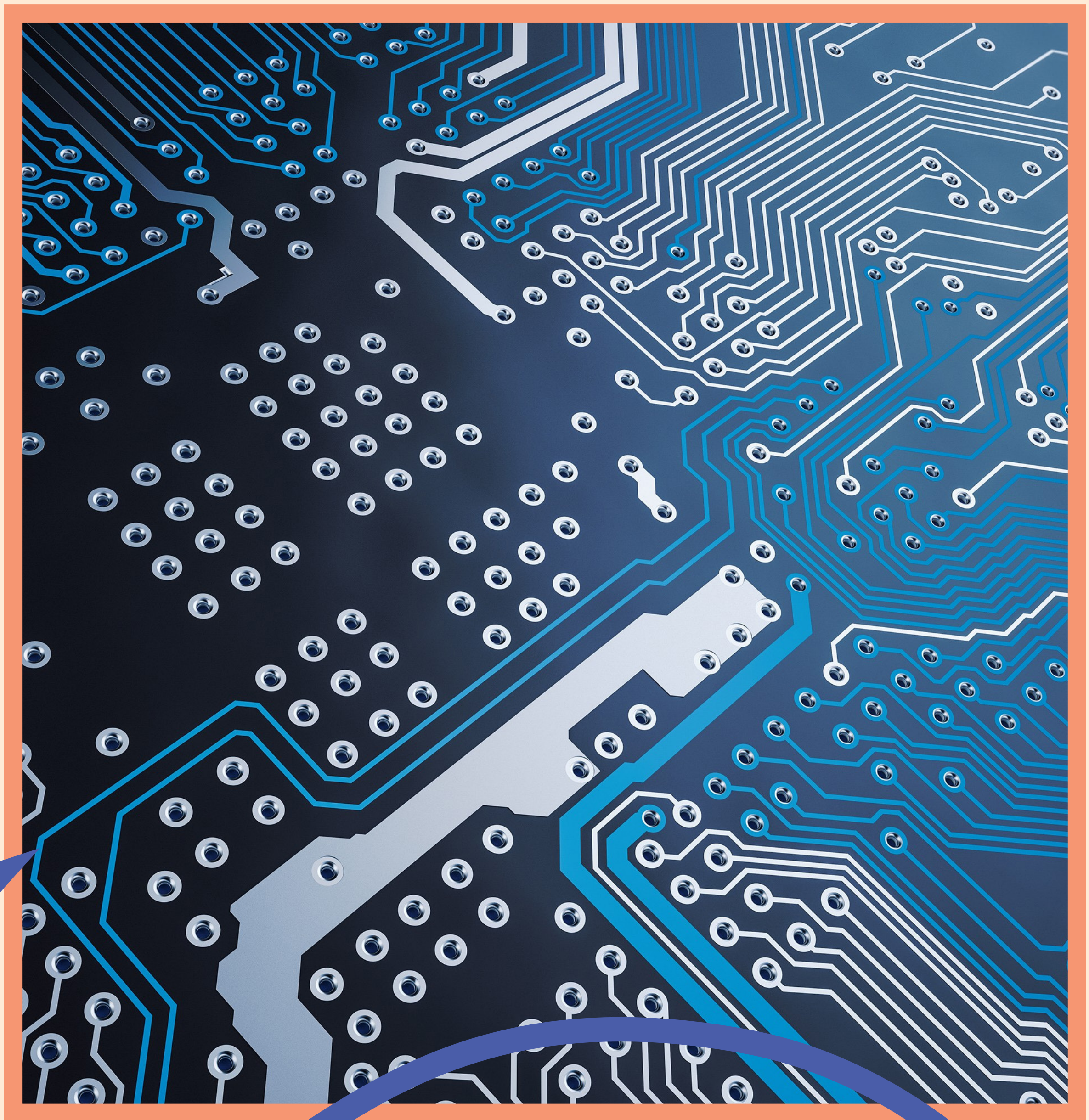

Bioprinting a healthier life

Yumna Zameel, Oxford High School

Have you ever thought of printing a new heart or a liver for yourself? Although we have become really good at living longer, if we could replace the parts that are not working as well, the quality of our lives would also improve – increasing our health-span. Dreams of the 'Fountain of Youth' have haunted humans over the ages and bioprinting is a new technology that could turn this fantasy into a reality.

So, how exactly does bioprinting work? Like a 3D printer, material is printed in layers to create organ-like structures. But instead of plastic being squeezed out of the print nozzles, the bioprinter uses living human cells to recreate tissues.

The first step is creating an instruction set for the bio-printer to place the biomaterial in precise positions. This digital file is made from a detailed scan, such as an MRI, describing the external and internal structure of the organ. The next step is to load the ink and it's this 'bio-ink' which makes the bio-printer special. Bio-ink is made by obtaining human cells and allowing them to proliferate until there is enough to use in the printer. However, some cells are hard to get hold of - like brain or heart cells. The answer to this problem is to generate those cells using stem cells. But what is a stem cell?

A stem cell is a cell that can divide to form all of the specialised human cell types. Embryonic stem cells are how we start our life and where the 37 trillion cells in the average body comes from. Although every cell in the body has the same genes, by switching particular sets of genes on, a cell can become specialised. This is how a caterpillar turns into a butterfly – the genes are identical, but the look and functions are completely different. Amazingly, a technique was discovered that meant an adult specialised cell can be turned back into something like an embryonic stem cell. This was such an incredible revelation that the scientists who discovered this process were given the Nobel Prize. It means that there is now a way to regenerate cells of a person if they have worn out. Stem cells are incredible, but making the cells is just one part of the problem. The other part is putting the cells together in the right way – which is exactly what bio-printing is designed to do.

Perhaps the most urgent need are the 120,000 people waiting for organ transplants in the UK. A person can't just take any organ donation because the immune system will recognise the transplant as foreign and will start attacking it. Each day 17 people on the waiting list die because the matched organs were not provided quickly enough. At the Wake Forest University, researchers have used bio-printing to provide a solution. They took cells from the patient's original bladder, refined them, and added nutrients. A 3D mould of the patient's bladder was then printed, and the cultivated cells soaked through it. This was transplanted into the patient's body, and the patient was able to return to normal life.

So why isn't every hospital equipped with a bio-printer? Although bioprinting has a lot of promise, there is still an incredible amount of work to be done. More complex and larger organs need to have a blood supply to be able to survive. However, the intricacy of the blood vessels is extremely hard to recreate with the type of print nozzles currently available. Specialised cells made from stem cells are being used in the bio-ink but keeping these cells healthy and developing them, so they function properly, is a challenge that has not been solved. Bio-printers also need to increase in speed and have better resolution.

Bioprinting will become a reality, and this will completely change how diseases are treated and even how we live our lives. Perhaps being old will not be something to worry about. This raises important ethical questions on how the technology should be used and whether it will worsen the rich-poor divide. Science is racing ahead and promises a bright and youthful future and we should work hard to make sure it benefits those who most need it.

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Example Harvard referencing
In-text citations are used when directly quoting or paraphrasing a source. They are located in the body of the work and contain a fragment of the full citation, e.g. “After that I lived like a young rajah in all the capitals of Europe…” (Fitzgerald, 2004).
Reference Lists are located at the end of the work and display full citations for sources used in the assignment, e.g. Fitzgerald, F. (2004). The Great Gatsby. New York: Scribner.
For more information see https://libweb.anglia.ac.uk/referencing/files/QuickHarvardGuide2018.pdf

Will Artificial Intelligence Conquer The World?

Abby Gherendi, Notting Hill & Ealing High School

Artificial intelligence has evolved over the last 70 years and is becoming a new world enterprise priced at approximately $57 billion in 2022, growing to a $190 billion industry by 2025. With AI spreading its wings across sectors, new jobs will be created in development, programming, testing, support and maintenance, to name a few (Duggal, N 2021). However, arguments have been raised as to whether this rather new technology will become self-aware. Although Self-Aware AI does not exist yet, artificial intelligence can become way more intellectual than we thought and could become dangerous for humanity.

Artificial intelligence has already received a lot of buzz in the past decade, but it continues to be one of the new technology trends because of its notable effects on how we live, work and play are only in the early stages. AI could be used for countless jobs such as waiters, helping elderly, dangerous jobs that humans can't do, harnessing human knowledge to find the cure for dangerous diseases and many more. With all these jobs that AI could do, it would make life easier for us. AI has the possibility to accelerate global efforts to protect the environment and preserve resources by distinguishing energy emission reductions, CO_2 removal, helping develop greener transportation networks, surveilling deforestation, and predicting extreme weather conditions. Artificial intelligence would also drive down the time taken to perform a task. It enables multi-tasking and eases the workload for current resources. AI also operates 24 hours without any interruption or breaks. AI also has the ability to do complex tasks, but with thorough code built in, artificial intelligence can do many things some humans cannot.

The enthusiasm for artificial intelligence has never been easy. Many have come to fear the possibilities of what AI could become. Elon Musk believes 'AI is a fundamental risk to the existence of human civilization.' Stephen Hawking has a very similar opinion saying 'I fear that AI may replace humans altogether.' These great minds cannot be wrong. Artificial intelligence can present threats if used in a specific way. If artificial intelligence surpasses human intellect, it would become a major threat as to what it could do. Autonomous weapons are artificial intelligence systems that are programmed to kill. In the hands of the wrong person, these weapons could easily cause many casualties. Moreover, an AI arms race could inadvertently lead to an AI war that also results in many casualties. To avoid being thwarted by the enemy, these weapons would be designed to be extremely difficult to simply "turn off," so humans could plausibly lose control of such a situation. This risk is one that's present even with narrow AI, but grows as levels of AI intelligence and autonomy increase (Tegmark, M 2016). With more intellect and self-awareness, artificial intelligence can do anything, because they could have the vast and logical power to do so. Elon Musk has said "It's capable of vastly more than almost anyone knows, and the rate of improvement is exponential." As progress continues rapidly in labs, the threat of this new technology becomes broader.

The debate about the benefits and threats that AI can bring can continue for sure as the technology evolves. Both sides have good reasons as to why artificial intelligence is dangerous or useful. Although AI is technically in its infancy, it is growing smarter every day and it is all up to how artificial intelligence behaves. Technology is still complex but being unsolved, if we know how to control artificial intelligence, the future might look brighter. The raised argument is not about stopping AI, but about controlling its development. The fundamentals of controlling artificial intelligence is to 'continuously assess and maintain control over sophisticated, evolving algorithms by putting in place methods, controls, and tooling that secure the trust anchors along the lifecycle, from strategy through evolution' (Sokalski, M 2022). At every new thing, a regular pattern falls through humans, we may be fearful at the beginning, but as we become more familiar and proficient with interacting with artificial intelligence, we will see more of the benefits, and not that much of the threats. We may encounter problems along the way with artificial intelligence but if we can gain trust with it, then we can control it.

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Has Lockdown increased the impact of social media on young people?

Gisele Oakley-White, Streatham & Clapham High

Has Lockdown increased the impact of social media on young people? When lockdown hit, everyone turned to their devices, for work, home-schooling, entertainment and socialising. This meant people were spending a lot of time on their devices. Lockdown, meaning you couldn't see anyone, meant social media apps such as zoom were becoming very popular. Young people also used WhatsApp, Snapchat and TikTok to communicate. 2020 was marked by the coronavirus pandemic and has changed everyday life in various ways, one which is, without a doubt, the way people use the internet. There is a significant increase in the average time U.S users spent on social media in 2020: 65 minutes daily, compared to 54 minutes and 56 minutes the years before. Whilst people were at home bored, scrolling through social media, it was very easy to come across something upsetting or concerning. It gave social media the chance to influence young people, by making them think a certain way and speak a certain way. An example of this is how young people posted some pictures of themselves being productive and motivated. Whilst this may have helped some, it could also have negatively affected others as they felt they might not be doing enough, or they may not be good enough. This may have affected peoples' mental health, making them more vulnerable.

Fake news spread like the flu, concerning people. When one person posts misinformation, another will see it and possibly forward it on. In the first three months of 2020, nearly 6,000 people around the globe were hospitalised because of Coronavirus misinformation, recent research suggests. People don't always believe fake news, but for those who did, it may have impacted the way they thought. It could be something small like a person starting a rumour or something a lot larger and influential, such as a political point of view.

During lockdown, when both of my parents were working, I had to look after myself. I needed to do the schoolwork set, make my own lunch and be sure to join Google Classroom calls. After I had finished all this, I was too tired and too bored to be productive, so I navigated my way back to my screen. This happened day after day, until it eventually became a loop. Whilst social media was very good for communication, I found myself scrolling through useless, and sometimes upsetting messages and content. It also affected friendships. Social behaviour includes how an individual's thoughts, feelings, and behaviour influences, and is influenced by, other people. Being locked in your house, with only your family, affects how interaction skills are developed. If someone hadn't talked to or seen someone for months, it might be hard to communicate, and confidence may be lost. Although social media helped us to communicate virtually, it didn't help us communicate in the real world, face to face.

Has lockdown increased the impact of social media on young people? I have found that since lockdown restrictions have eased, some peoples' grammar and handwriting are not as good as they used to be. Some had also gone through a massive change in personality. This leads me on to my next point. Whilst people spent a lot of time on social media, they came across different trends. Some of these trends were enriching. Studies show that some of the trends - such as rethinking the space we live in, gardening, etc - were actually motivating and enriching, and helped people find a new passion. Keeping this in mind, we were in lockdown for six months, so some hobbies only lasted a couple of months, making people bored once again.

I noticed that after lockdown, instead of people going outside to meet with friends or family, they decided to stay at home and continue using their devices rather than meeting face to face. Largely, evidence indicates negative effects of prolonged screen time on health including mental health. Although digital technology provides avenues to connect socially, over indulgence or over use of digital devices can be harmful in the long-term. After all that has been stated, I -among many another people- agree that social media helped me and others to communicate and stay in touch, but it also had a negative affect on young people in becoming less motivated to go out and meet face to face.

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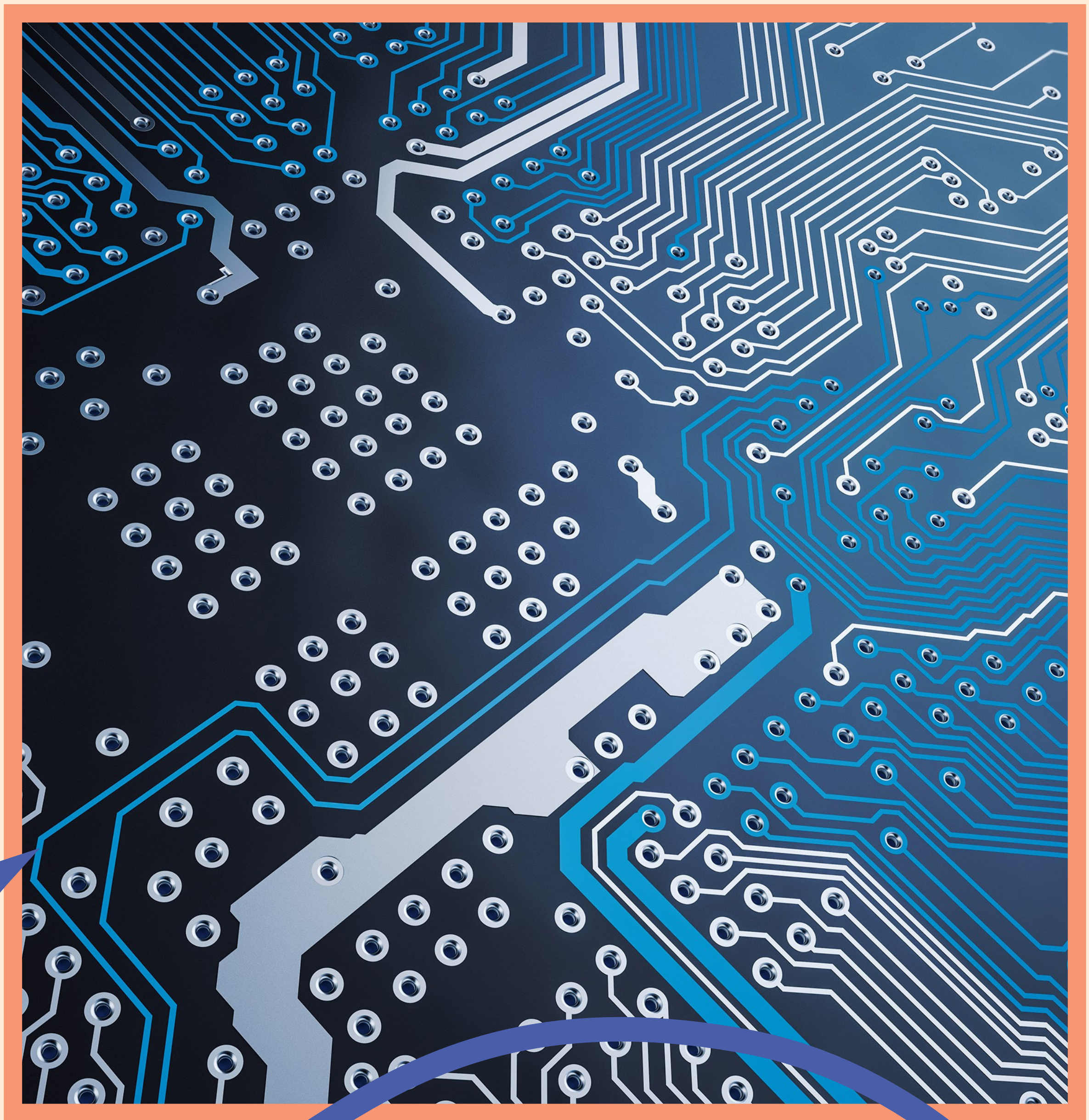

A Technological Advancement in Combating Climate Change

Robby Marshall, The American School in London

Imagine a world without climate change - a world where people don't need to worry about their emissions; a world where people don't experience climate change-induced droughts and floods; a world where people don't expect wildfires.

Humans emitted 34.8 billion tonnes of carbon dioxide in 2020 (Roser and Ritchie, 2017). This is the greenhouse gas responsible for 80% of global warming. Fortunately, carbon dioxide can be removed from the atmosphere and stored, thereby slowing down and eventually stopping climate change (Air Pollution & Climate Secretariat, 2013). This technology could be vital if humans are going to reach the goal of limiting the warming of the earth to 2º C as put forward by the Paris Agreement (United Nations, 2022).

Carbon dioxide capture and storage happens in two ways. Through industrial carbon dioxide capture, carbon dioxide is captured as it is emitted into the atmosphere. Industrial carbon dioxide capture takes place in coal and natural gas power plants. For this method to be successful, the flue gas, the mixture of gasses emitted by coal or natural gas power plants, is collected, and a liquid solvent is added.

Flue gas contains only 4% carbon dioxide. (Climate Science, 2021). A liquid solvent, such as monoethanolamine, absorbs the gaseous carbon dioxide to form a liquid (Carbon Clean, 2021). The temperature is then raised to approximately 120ºC to remove the pure carbon dioxide from the solvent carbon dioxide liquid. The solvent is reused to collect additional carbon dioxide (Carbon Clean, 2021). Industrial carbon capture allows for the capturing of 89% of the carbon dioxide emitted from coal and natural gas power plants.

The second manner in which carbon capture occurs is through direct air capture. Rather than capturing carbon dioxide emissions from a single source, direct air capture removes carbon dioxide from the atmosphere. In this process, carbon dioxide reacts with potassium hydroxide to form potassium carbonate and water. Calcium hydroxide is then used to separate the potassium carbonate into potassium hydroxide and calcium carbonate. The potassium hydroxide and calcium hydroxide are reused. Calcium carbonate can either be used as limestone or be heated at 1,100 º C to release pure carbon dioxide. (Climate Science 2021). Although the largest direct air capture plant in the world, Orca, is only enough to offset the emissions from 790 cars, the company behind Orca, Climeworks, is planning to build a plant ten times bigger than Orca by 2024 (Panko, 2021)

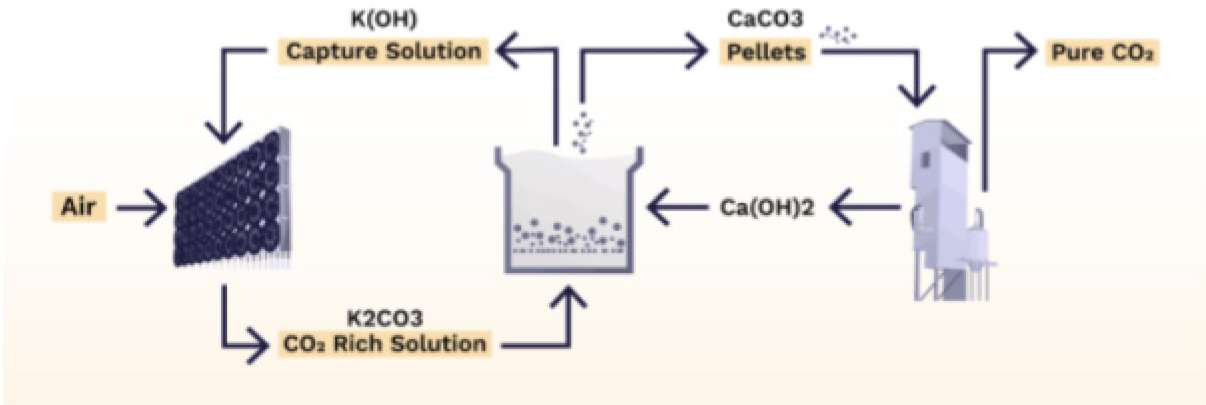

Diagram from Climate Science

The third method for direct air capture requires a sorbent filter to extract the carbon dioxide from the air. Carbon dioxide binds to this filter. The filter is then heated at 100º C to release pure carbon dioxide in the form of steam. The pure carbon dioxide can then be stored (International Energy Agency, 2007).

For both industrial carbon dioxide capture and direct air capture, storage of the carbon dioxide is essential. Carbon dioxide can be cost-effectively transported to desired locations through pipelines and ships. Currently, the long-term approach to carbon storage is through storage in rock formations underground. Carbon dioxide can stay indefinitely in these formations. (International Energy Agency, 2007) It is estimated that there is enough storage for thirty-three years of our current carbon dioxide emissions (International Energy Program, 2007).

Alternatively, carbon dioxide can be stored in a mixture of minerals. Carbon dioxide reacts with iron, magnesium, and calcium to be held in minerals. This process is time-consuming, but increasing the temperature of the reaction increases the speed of the reaction. (British Geological Survey, n.d.).

The final option for carbon dioxide storage is pumping it underground and creating rock. This is accomplished by combining carbon dioxide with water and pumping it into basalt rock formations. Basalt rock is found in places where the earth's crust is very thin, such as under the ocean (Michigan Tech, n.d.). Within two years, the carbon dioxide water mixture turns into limestone in holes in the basalt rock (International Energy Agency, 2007).

While carbon dioxide capture must be part of the solution to climate change, it is not the sole solution to climate change. Greenhouse gas emissions must be reduced. Industrial carbon dioxide capture will help reduce the emissions of coal and oil power plants until they are phased out. Direct air capture will take the role of ensuring carbon dioxide levels don't increase while some industries continue emitting carbon dioxide.

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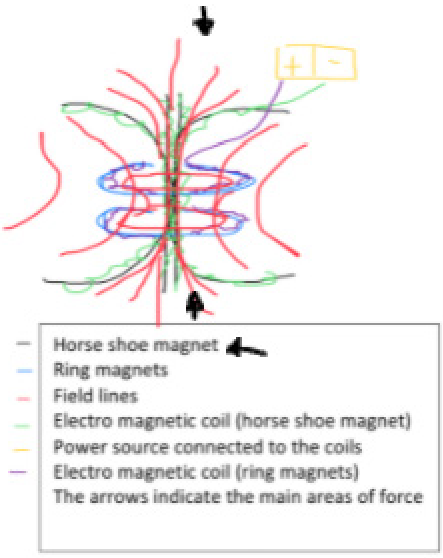
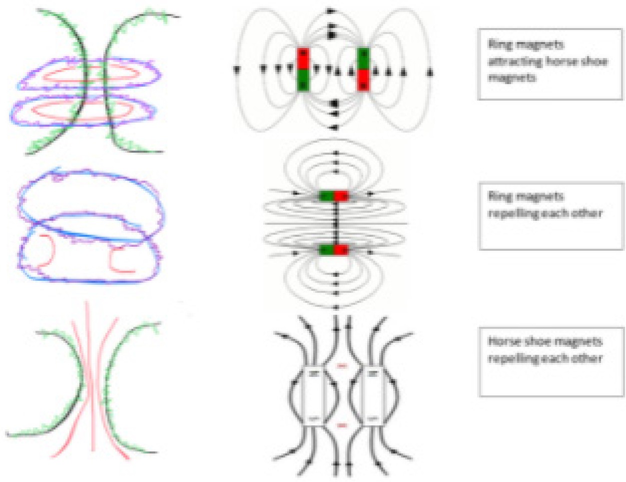
A study in Levitation with electro-magnetism and My Invention

Julia Pfeiffer, Blackheath High School





What is an electromagnet and how it works ?
An electromagnet is a magnet that runs on electricity. Unlike a permanent magnet, the strength of an electromagnet can easily be changed by changing the amount of electric current that flows through it. The poles of an electromagnet can even be reversed by reversing the flow of electricity.
An electromagnet works because an electric current produces a magnetic field. The magnetic field produced by an electric current forms circles around the electric current.

Normally, the atoms in something like a piece of iron point in random directions and the individual magnetic fields tend to cancel each other out. However, the magnetic field produced by the wire wrapped around the core can force some of the atoms within the core to point in one direction. All of their tiny magnetic fields add together, creating a more powerful magnetic field.
As the current flowing around the core increases, the number of atoms which are aligned increases and the stronger the magnetic field becomes. Eventually, all of the atoms that can be aligned will be aligned.

How the device works
The reason why I think everyone assumes levitation could never work is because essentially it has always been thought of as the device having to make force from nothing, and enough force not only to get off the ground and 'defy' gravity but also to support the thing it is making levitate. The definition of levitation is: 'To float in the air, defying gravity'. It is also said to be to, 'to cause something to float as if by magic'. So therefor in order for a levitation device to work it would need to use non-contact force(s). My prototype uses magnetism because it can be directed in any way and all force goes in a continuous self sustained loop of force. Into each other and out at each pole because of the repulsion of the similar poles (N and N/ S and S) and the attraction of the opposite poles (N and S/ S and N). The formation of electro-magnetic shapes means that all force will be utilised and sent in the direction needed.

Description
My device is made up of three major components:
The (two) ring magnets attracting the (four) horse shoe magnets
The ring magnets repelling each other
The horse shoe magnets repelling each other
(this is demonstrated in the diagram at the top of the document)

The ring magnets which are located in the centre of the horse shoe magnets and are one pole for example North and the horse shoe magnets which are place at four equal points with their curves facing outwards are another pole for example South. The ring magnets are needed for stability as the force generated by the ring magnets will repel them from each other but still attract the horse shoe magnets meaning the horse shoe magnets wouldn't just fly apart in various different directions. Instead they insure that everything is held securely together enabling for the device to be stable enough for levitation to take place; all the magnets will be compact and generating high amounts of force in focused and specific directions.

What sets it apart?
The reason why I feel that levitational mobility as a whole could be revolutionary is because it is far faster than any other known or conventional ways of mobility if applied correctly. This is because it evolves zero friction with the ground and the device itself potentially enabling faster speeds than ever before.

However what sets the device I have come up with apart from all of the other currently used devices is that it does not require both magnets on the floor and the levitation device itself in order to work. Instead it singularly uses the force from the device itself meaning it can hover on any terrain. This making it much more useful and versatile than any other existing levitation devices. I believe that with my invention and it being executed correctly the possibilities could be endless and possibly even the way we look at transport and the world changed.

Resources:
Article title:
Questions and Answers - What is an electromagnet?
Website title:
Education.jlab.org
URL:
https://education.jlab.org/qa/electromagnet_is.html

One Programming Language: Is It Enough?

Boris Hall, Wilson's School

Technology is advancing. With it, software engineering is a more vital field than ever before. With newer games running on more demanding graphics, more satellites being sent into space, and electric vehicles becoming more commonplace, the software required for such technology is designed to be as efficient as possible. Thousands of programming languages exist worldwide[1], the three most widespread being Python, Java and JavaScript[2].

This begs the question: why do we need more than these three languages? In fact, why do we need more than a single programming language?

Alan Turing, often praised as the father of modern computer science[3], devised the Turing machine in 1936, a simple abstract machine that is capable of implementing the algorithmic logic of any computer program that is desired[4]. It can add two numbers, find the shortest path between two points, encrypt data - the list goes on endlessly.

But this machine goes further than being abstract: it has been implemented in real life, too. In fact, virtually all programming languages can be described as 'Turing-complete[5]'. Turing-completeness is the idea that a program can be used to simulate a Turing machine; that is, it is capable of implementing any computer algorithm that is desired. Overall, this should mean that every single language has the same constraints as any other language.

Or does it? As has just been discussed, every language can perform the same algorithms. We have determined that no language has a different constraint of capability over the other - but there are other constraints to consider, namely time, purpose and usability.

It is easy to compare how fast two languages execute a given algorithm. However, just because one language is faster at, for instance, sorting a list of numbers into ascending order, this does not necessarily mean it is faster at everything. Some languages may be preferable to use based on the time taken to execute specific algorithms.

So why are some languages slower than others? This brings us to the next constraint: purpose.

Let us consider an analogy involving wheels. Every size and design of a wheel can perform the same function - turning to make a locomotive force. Why shouldn't we just invent one size and design of wheel and use that for every train, every car, every bicycle?

Well, we need different variations of wheels to support the weight and the environment on which they are being used. In the same way, multiple Turing-complete languages are created so that they can be used for a variety of more specialised purposes: JavaScript is often used for full stack development, Python is widely used for mathematical analysis and artificial intelligence, and languages such as C# are suited for game development[6]. Different languages are provided with constraints of purpose in order to maximise their efficiency at performing their own specialised tasks.

Finally, we will look at usability. One way to categorise programming languages is to sort them into higher and lower level languages. Lower level languages tend to look more like binary or assembly code, the language of the computer, and so will generally seem more complicated and confusing to a human, whereas higher level languages tend to look more like human speech[8]. The differences are strikingly obvious to anyone regardless of their level of coding experience. Higher level language programs are overall a lot easier to interpret and debug, and so are described as generally being more usable.

Given the opportunity to learn either C or Python, many would choose the higher-level language Python simply because it is a lot easier to learn and grasp the fundamentals of. Quite intuitively, though, Python would be a lot slower at executing any algorithm than C, as this human-like language must first be decoded into binary for the computer to be able to understand and execute. The lower level the language, the faster the program runs when converted into binary. Therefore, it is not as time-efficient to code the same algorithm in Python than in C[9].

Despite this, Python's relative ease to learn makes it a more accessible language - part of the reason it is so popular. This is the constraint of usability: in forgo of languages that execute more quickly and are more specialised, more high-level languages may be seen as more favourable to a programmer.

It is clear that Turing completeness alone is a baseline requirement for a programming language to perform. However, when it comes to streamlining processes, some languages will always out-perform others. The number of officially recognised languages in the world alone is testament to the many ways a programming language can be tailored to be optimal for a niche set of tasks, which is ultimately an integral part of how programmers excel at their work.

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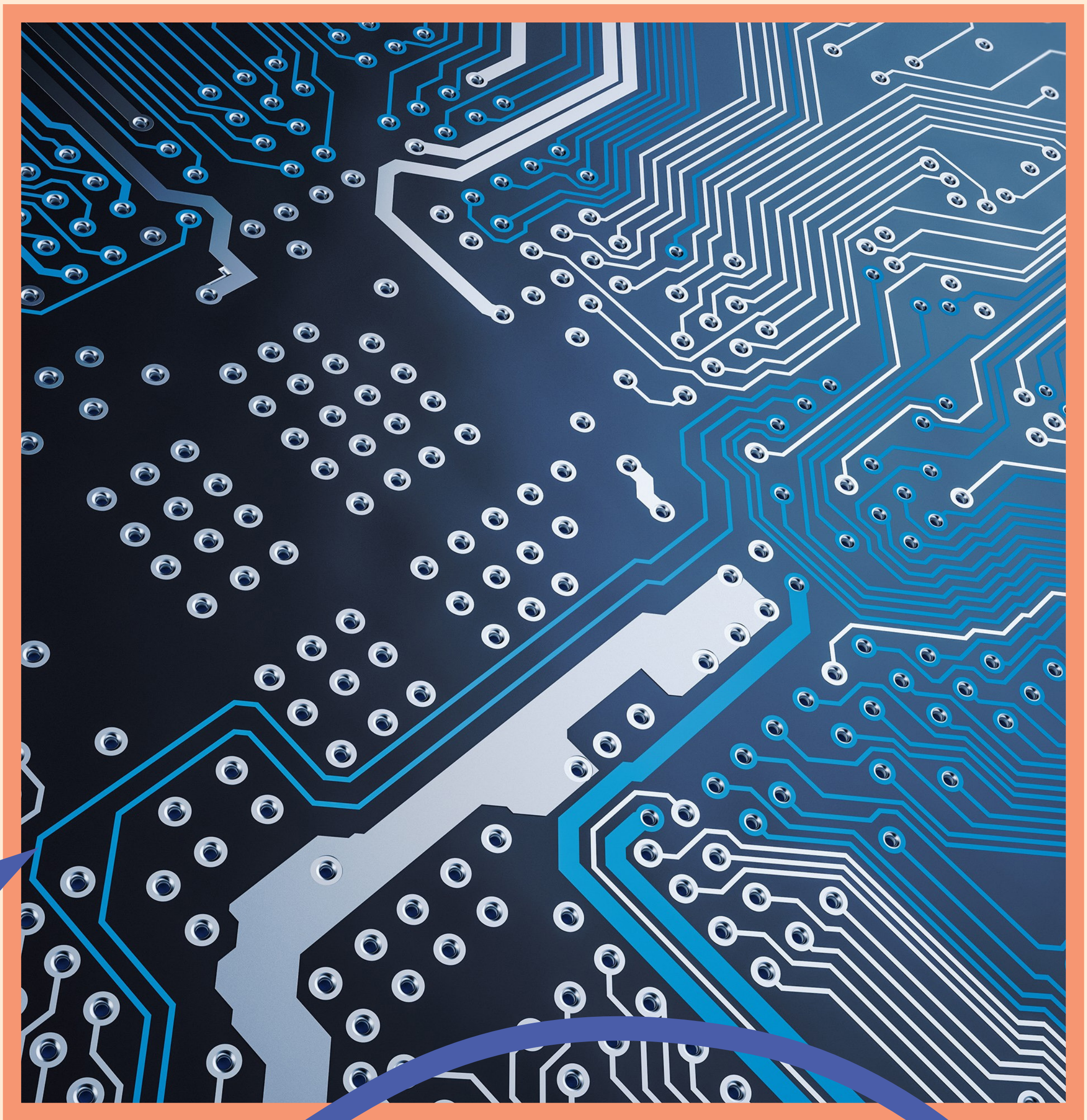
TECHNOLOGY/ ENGINEERING ESSAYS UNDER 18

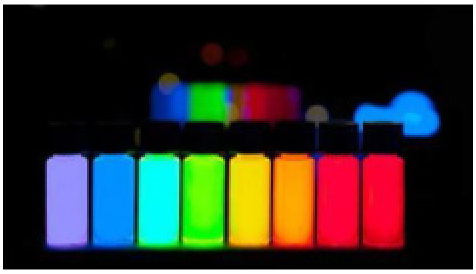


Quantum Dots
Minuscule in nature, but boundless in potential

Shanjai Mathialagan, Wilson's School

What are quantum dots?

Quantum dots are synthetic atoms that do not occur naturally in the world. These atoms are manufactured in a process called colloidal synthesis, involving nucleation, growth, and transformation, and are made from semiconductor materials such as silicon, or cadmium sulfide. They are examples of nanomaterials, and so they are exceptionally small [1]. This gives them unique properties which standard materials lack.



When ultraviolet light shines onto these artificial atoms, the high energy electromagnetic radiation causes an electron to be excited, and the electron moves to a higher energy level. When the electron moves back down to a lower energy level, it emits a photon of light with an identical frequency to the electromagnetic radiation that was absorbed. Quantum dots with the largest radius emit the lowest frequencies (red), while the dots with the smallest radius emit higher frequencies (blue). This is because a small quantum dot has a larger band gap - the minimum energy required to excite an electron so that it can conduct electricity. Larger dots have more compact energy levels, so they produce lower frequencies of light, due to smaller band gaps [2].

Quantum Dot Solar Cells

In the rapidly evolving solar photovoltaic market, quantum dots have transformed the functionality and utility of solar panels across the globe. In standard solar panels, each photon of light is only able to produce one delocalised electron, whilst the rest of the energy is transferred into less useful stores, such as heat. Comparatively, the properties of silicon quantum dots enable each photon of light to produce up to three electrons, increasing the average efficiency of solar panels by 32% [3]. The consequences of this can be far-reaching in an increasingly environmentally conscious world. Flaunting its low power consumption, increased electrical performance and efficiency, quantum dot solar panels can be one of many solutions to our global environmental problems. The lower long-term costs and greater electrical output can encourage more homes and businesses to adopt solar panels on a small scale, but these solar panels should ideally be implemented centrally by governments for more widespread impact.

Quantum Dot Displays

In a normal liquid crystal display TV, there is a blue LED coated in yellow phosphor, which gives off a white light. When this light reaches the RGB filters, the television can emit a range of colours. However, in a QLED TV, quantum dots are applied to a thin film sheet, which is situated in front of the LED backlight, which illuminates an LCD. The quantum dot colour filter enables the LCD to reveal a wider, more saturated range of colours [4]. In addition, since these quantum dots are so small, the resolution of the images are also significantly greater. The use of quantum dot technology has also enabled companies like Samsung and other manufacturers to reduce the thickness and weight of their large displays, whilst enabling them to enhance the colour, sharpness, and contrast of their TV displays. Some other benefits that quantum dot displays exhibit include a longer lifetime, lower manufacturing cost, and lower power consumption.[4]

Biological Applications of Quantum Dots

With their fascinating optical and physical properties, quantum dots have proved useful in the medical and pharmaceutical industry. Their distinctive photoluminescence makes them very effective fluorescent labels in the delivery of drugs. For example, quantum dots can be used to deliver cancer-killing drugs.[5] Bioconjugation allows us to attach drugs to these atoms, and we are able to deliver these drugs to the site where they are needed - there is high specificity and reduced side-effects as drugs are not delivered to healthy tissues. In addition, they could also potentially be used for cancer cell imaging. Specific antibodies can be attached to the quantum dots, so that when they are injected into the body, the quantum dots will be able to detect and bind to the cancer cells, illuminating them.

On the contrary, there are various hazards with using quantum dots for biological applications. For example, cadmium sulfide is a toxic substance, and it could catalyse harmful reactions in the body. Hence, these types of quantum dots cannot be used for medical purposes, and alternatives may be necessary.

The unique set of properties that come with such small atoms provide beneficial advantages, whether this may be in the energy industry, medical industry or even the entertainment industry. The discovery of quantum dots can prove to be a ground-breaking invention, and their potential is yet to be reached.

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with corrosion, degradation and the non-rechargeable aspect.

Aluminium Air Battery Technology application for electric vehicles

Jon Hiew, Dulwich College

With the increased awareness of climate change and global warming, many industries have had to adapt to become as eco-friendly as possible to help combat the problem. Currently most electric cars make use of lithium-ion batteries to power their vehicles, but there have been a wide range of new emerging battery technology alternatives, one being aluminium-air batteries.

How it works

The batteries use aluminium metal (as the anode) and the surrounding air around the battery (as the cathode). In addition, there is an additional layer between the cathode and anode, being the silver-based catalyst that separates oxygen from other molecules in the air. Once the oxygen has passed through, it reacts with the water, which acts as the electrolyte, and forms negative hydroxide ions. These hydroxide ions then react with the aluminium metal to form Aluminium Trihydroxide and electrons, which power the battery by moving from the anode to the cathode. The battery uses both oxidation of aluminimum at the anode and reduction of oxygen at the cathode to create a galvanic cell. A galvanic cell is an electrochemical cell, which makes use of electrons in redox reactions to supply an electric current to the electrical vehicle.

Anode oxidation half-reaction: $Al + 3OH^- \rightarrow Al(OH)_3 + 3e^-$ −2.31 V.

Cathode reduction half-reaction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ +0.40 V.

Balanced equation: $4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$ + 2.71 V

Ways to improve technology

The technology behind the battery makes use of negative hydroxide ions reacting with the aluminium metal to form electrons, that form the electric current and power the vehicle. During this process, an excess of negative hydroxide ions would help improve the rate of reaction. To address this, the best electrolyte to use within the battery would be an alkaline solution such as potassium hydroxide (KOH) or sodium hydroxide (NaOH) rather than water. Furthermore, KOH-based electrolytes would be more efficient than NaOH due to their higher ionic conductivity and higher oxygen diffusion coefficient faster reaction kinetics.

Anode material is also something that factors heavily into the battery's efficiency. While (almost) pure aluminium anodes have shown better anodic performance, aluminium material is unstable as anodes. To improve electrochemical properties, researchers have looked into the different usage of aluminium alloys, by mixing aluminium with other metals such as gallium, zinc, tin and many more. When looking into the results of alloying aluminium with certain metals: gallium can repress formation of oxide film by reacting on aluminium surfaces and tin can better aluminium anode dissolution rates and reduce corrosion rates. In addition, researchers have been experimenting to further the Al-air battery by covering the aluminium anode with oxide to minimise corrosion.

Pros and cons

Al-air batteries offer one of the highest energy densities, due to weight light of air, acting as the cathode compared to other alternative batteries. It's estimated the energy density of an Al-air battery to be 8100 Wh/kg, while lithium batteries only offer 100-265 Wh/kg. The energy company, Phinergy, had tested an electric vehicle with an Al-ai battery, that successfully travelled 1,000 miles, while a typical Tesla model S' lithium-ion battery would travel only roughly 370 miles.

However, for Al-air batteries, there are several issues associated such as formation of by-products from the redox reactions, hydrogen evolution and formation of corrosion products. When aluminium trihydroxide is formed from oxidation at the anode, the product can suppress the Al-air battery's electrochemical reactions that hinder its power density, making it less efficient.

Parasitic Chemical Reaction: Al + 3H2O -> Al(OH)3 + 3/2 H2O

The reaction introduces corrosion on aluminium anode surfaces, which acts as a passivation film that increases the circuit's resistance and decreases both electrical current and power density. As a result, this leads to corrosion of aluminium electrodes and can cause the battery to fail. Furthermore, another issue associated with Al-air batteries is the battery is non-rechargeable once the aluminium has reacted.

Conclusion

In conclusion, aluminium-air batteries present a potential better alternative to electrical vehicle's choice of battery, but come with challenges such as non-rechargeable batteries and formation of corrosion products that deteriorate the quality of the battery. That said, there is still new research looking into Al-air batteries to deal with corrosion, degradation and the non-rechargeable aspect.

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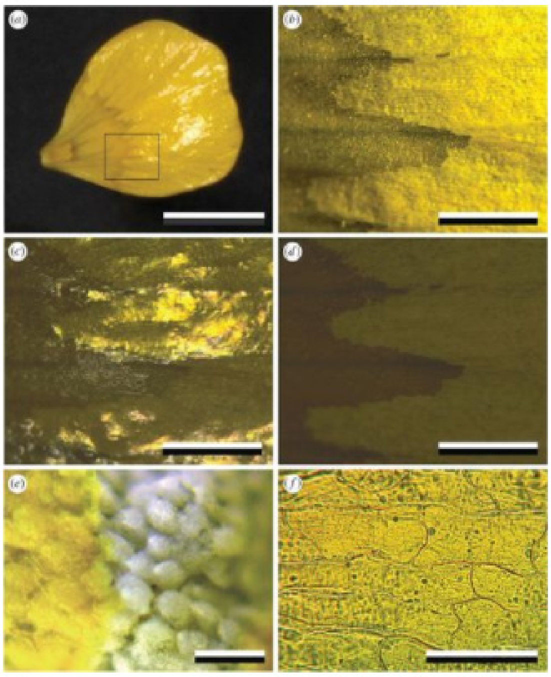
Structural colour: the future of materials?

Sia Patel, Notting Hill & Ealing High School

We have always been taught at school that different materials appear coloured based on the wavelengths of light that they absorb, and that the remaining wavelengths reflect into our eyes to make an object appear a certain colour. But what if this is not true all of the time? We can change the way we think about colour by looking at structural colour, a completely different mechanism to what we are used to.

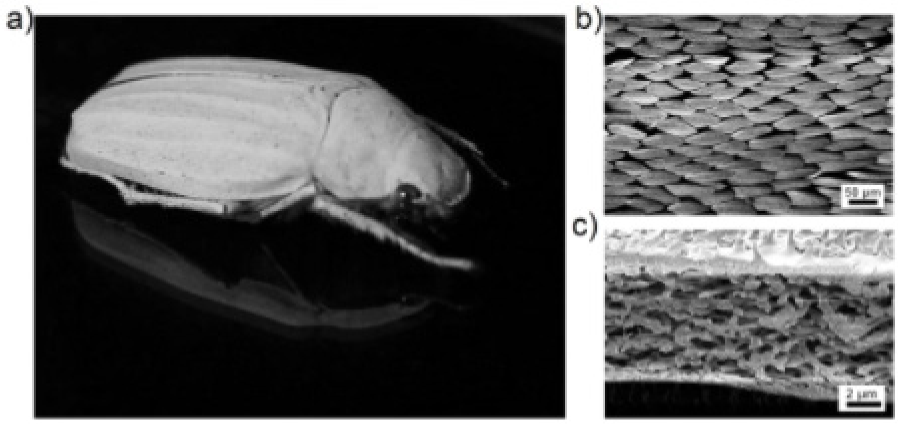
In short, structural colour arises when complex, microscopic structures in an inherently colourless object reflect light, causing an iridescent colour to be seen when the object is looked at. Take hummingbirds as an example: their feathers have a bright iridescent colour to them that is, in reality, caused by tiny pancake-shaped melanosome structures (Eliason et al, 2020) that reflect light and create a magical gleam to the hummingbird's wings. The melanosomes also contain air bubbles, making the surface even more complex and allowing light to bounce off in countless different ways. Structural colour, essentially, is based on reflection rather than absorption of light.



Another example of this type of colour in nature is the unique gloss on the surface of buttercups, which exists alongside the yellow colouration of the petals. This comes about due to a unique combination of pigment and structural thin films within them (van der Kooi et al, 2017). Structural colour is rarely seen in flowers, as the interior and surfaces of the petals are generally irregularly shaped, and structural colour requires semi-regular patterned structures in order to function. This makes buttercups an uncommon case of structural colour in the natural world.

So how can developments in structural colour research change how we think about colour in our everyday lives? An example is the incredibly unique paintwork on a 2019 range of Toyota Lexus cars. Whilst the car may look undeniably blue, the materials that make up the coating of the car (dubbed 'structural blue') are actually colourless. The result is a blue colour that undergoes subtle changes with light or even position of the viewer, and gives an ethereal quality to the car. In the words of Tadao Mori, chief designer of the Lexus LCs, 'structural colour is a designer's dream technology'. It allows for nuances and the natural shape of objects to be amplified and conveyed to the viewer, resulting in an incredibly unique user experience.

Another application of structural colour is in the world of food colouring and cosmetics. Creating white pigments and dyes is an immensely difficult task, however scientists have been inspired by structural colour in nature to use different methods in order to achieve this. 'The challenge is to create white in as thin a layer as possible', says Dr Silvia Vignolini, who has been working with her team at the University of Cambridge to try and overcome this challenge. The white Cyphochilus beetle serves as an example of white structural colour in nature, with thin, foam-like structures that scatter light and give a fade-resistant white appearance (Burresi et al, 2014).



Dr Vignolini's research centres around creating 'cellulose nanofibril aerogels' (Toivonen et al, 2018) which can make up a film that results in a bright white colour. This arises from the random nanoscale structures of the fibrils, which can give this colour at a thickness of just tens of microns. The technology is being developed so that it can be used in powders or as films. There are countless applications of this material in the food and cosmetic industries, such as providing an alternative to the whitening agent titanium dioxide, which has been identified as a potential carcinogen. Another potential use is, due to the biodegradable nature of the cellulose, in new eco-friendly paints.

Overall, structural colour is a fascinating field that could become more and more prevalent in our everyday lives in the future; it provides an attractive alternative to certain dyes, materials and ingredients in products. As research continues, we could see uses that extend far beyond its humble origins in animals and plants.

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THANK YOU