2020

#700STEMChallenge

FINALISTS MAGAZINE

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INTRODUCTION

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

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

UNDER 14 RESULTS

Science:

1st - The Bacteriophage: the future of antibiotics
Tara Khan, Croydon High School

2nd - Saving the Ocelot with germ cell transplantation technology
Charlotte Grady, Sheffield High School

3rd - Jane Goodall
Lauren Marshall, The American School in London

Technology:

1st - How Will CRISPR Change Us?
Sophie Azhar, South Hampstead High School

2nd - Is Nanotechnology the miracle cure for humanity's problems?
Amina Nartey-Grey, Sydenham High School GDST

3rd - The possibilities and pitfalls of AI
Aditi Nebhwani, Northwood College for Girls

Engineering:

1st - Astonishing advancement in Bio-engineering
Poorna Bakaidy, Wimbledon High School

2nd - A Sustainable Building
Elena Shah, Northwood College for Girls

3rd - City of the Future – A Living Laboratory for New Technologies
Miu Someya, Croydon High School

Mathematics:

1st - The History of Algebra
Rumaysa Peerbhai, Shrewsbury High School

2nd - Pythagorean Theorem: Who Discovered It?
Robby Marshall, The American School in London

3rd - The History of Maths and Computer Science
Piper Lauder, Chislehurst School for Girls

UNDER 16 RESULTS

Science:

1st - The secret communication between plants
Julie Jung, Wimbledon High School

2nd - The significance of HeLa cells
Ipek Tsil Kara, Sydenham High School GDST

3rd - Golden blood
Lucy Coleman, Sydenham High School GDST

Engineering:

1st - Bioprinting: the future of tissue regeneration
Aditya Chougule, Wilson's School

2nd - Supercritical Fluids and Their Application in Industry
Elisa Morris, Sydenham High School GDST

3rd - Genetically Modified Organisms
Liza Filatova, Sydenham High School GDST

Mathematics:

1st - Magical 9
Kiki Wang, Streatham and Clapham High School

2nd - The proof behind one of the most famous theorems in mathematics
Vishaali Ramesh, Wimbledon High School

UNDER 18 RESULTS

Science:

1st - 新型冠状病毒，新型冠状病毒，新型冠状病毒 Are you scared?
Choi Liu, Croydon High School

2nd - Time
Elena Hornby, Sydenham High School GDST

3rd - Wait four hours...it is a matter of life and death
Mathura Kathirgamanathan, Royal High School Bath GDST

Technology:

1st - The impact of innovative materials on the built environment and it's sustainability
Emma Wilkes, Streatham and Clapham High School

2nd - Bacterial bricks: a construction revolution?
Kitty Joyce, Oxford High School

3rd - Robotics is here to stay
Ayishah Bridge, Chislehurst School for Girls

Engineering:

1st - "CRISPR-Cas9 has the potential to solve all of society's problems." Do you agree?
Megan Leung, Newcastle High School for Girls

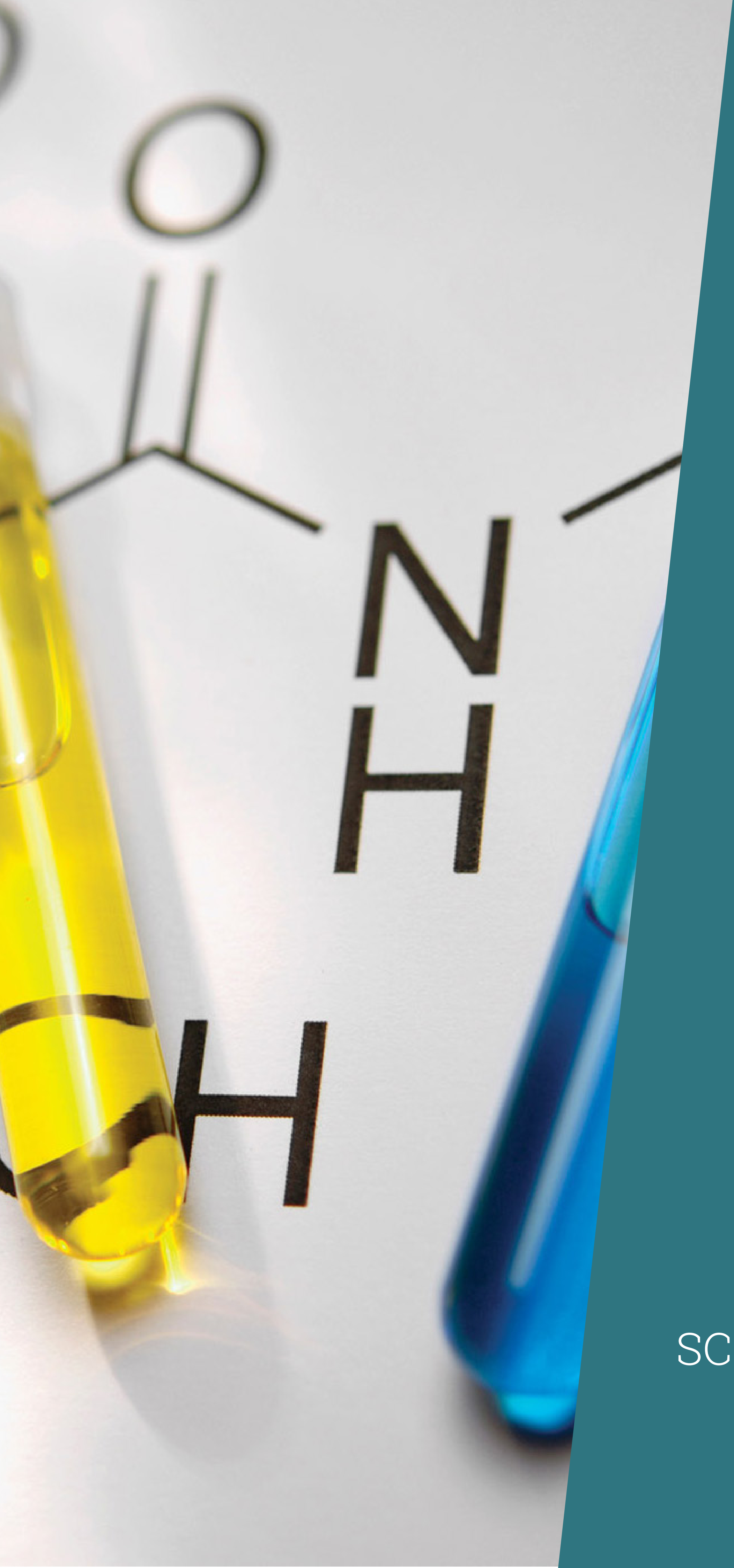
2nd - Synthetic Biology: Cancer's Potential Cure?
Lia Bloch, South Hampstead High School

3rd - The use of Intensity Modulated Radiotherapy (IMRT) to treat cancer
Beatrice Frediani, Wimbledon High School

Mathematics:

1st - Magic, Madness, Maths – A Curious Combination
Joely To, Streatham and Clapham High School

2nd - Math in daily life
Mona Hong, Shrewsbury High School



UNDER 14
SCIENCE ESSAYS

The Bacteriophage – The Future of Antibiotics
- Tara Khan, Croydon High School

When we think of the deadliest beings on planet earth, our mind often turns to black mambas, box jellyfish or, to the arachnophobic population, spiders. But these seemingly sinister creatures are put to shame by another being, that has been in constant battle for billions of years, killing trillions along the way. The bacteriophage (or phage for short). These creatures have been described as the 'single most deadly entity on planet earth.' It takes more than sharp teeth to garner that title. So let's delve into these creatures and discover the irreplaceable damage they cause and how they are the future of antibiotics...

A phage is a bit like a virus. Not alive, not dead and look like something out of a sci-fi fantasy. With their head shaped like an icosahedron, a long tail branching down to leg-like fibres. There are more phages than every other organism combined (including bacteria). They are covering you, your eyelids, that cold mug of coffee by your side and all other living organisms on our planet. But, panic not.

Though these creatures may seem like uncontrollable serial killers, they ONLY kill bacteria. For example: 40% of ocean bacteria are killed by phages. They start off by injecting their genetic material into the bacteria, and then the 'phage apocalypse' begins. The bacteria is taken over by the phage, being forced to create the parts of a phage until the bacteria is so full it bursts, releasing the phages, and dies. A gruesome end, but one that can save our lives.

You may be wondering, how on earth are we going to use phages as the future of antibiotics? Well, the truth is, us human beings, we need a new solution. Bacteria are slowly, but surely, becoming immune to antibiotics. Transforming into a deadly creature known as the SUPERBUG. It is predicted that by 2050, more people will be killed by SUPERBUGS that cancer. In 2017, indestructible bacteria in the USA killed a staggering 23,000 people. This bacteria immunity is spreading across the world right now, so we are getting desperate. Remember the time where the tiniest cuts could kill you? Well those days are at our doorstep, and the SUPERBUG will be responsible. Where can a solution to stop SUPERBUGS and to protect you and your family possibly come from? Just say hello to your tiny bacteria-killing friends, phages.

To solve our desperation, we have come up with a solution. Antibiotics just aren't doing the trick. So, how about we try injecting millions of phages into our body! You may be thinking, how on earth can injecting millions of viruses cure our illnesses? Phages, are very specialised viruses. They are often referred to as cruise missiles. This is because of their ability to only target BAD bacteria, unlike antibiotics, which kills, good and bad. This makes them highly effective and specialised killers. This fact alone proves phages, will be better than antibiotics, and it is a superbug busting way to kill the bacteria. But, superbugs will become more advanced, but the phages will always be one step ahead. Even if the bacteria become immune to phages, this will mean it will become a target once again for antibiotics.

This has already been tested on a patient who had no other hope left. His chest cavity had been infected with one of the most feared bacteria that could survive in alcoholic hand gel and his life was hanging in the balance. So, they injected 1,000s of phages into his chest cavity along with some antibiotics the bacteria was immune to. Within a week or so of recovery, the infection had cleared. So, with this being such a success why not start using it right away? Well, it's not that easy. The procedure still needs to be tested and safety always comes first, but, it still is revolutionary. Phages are finally getting the attention they truly deserve. The time where antibiotics, our lifesavers, protected us from evil bacteria is over.

No, it's time for phages to step in the spotlight, and get the job done.

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Saving the Ocelot with Germ Cell Transplantation Technology
- Charlotte Grady, Sheffield High School

The Ocelot (Leopardus pardalis) is a beautiful small wild cat that lives in South and Central America (da Rocha et al., 2016). Sadly, the Ocelot is hunted for its fur and is now included on the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2019). Ocelots are now also protected by the Convention on International Trade in Endangered Species to prevent people making money from killing and selling Ocelot furs (CITES, 2019).

Unfortunately, the Ocelot is very vulnerable to population loss because it only produces a single kitten and only breeds every other year (Balme et al., 2017). This means that scientists called Ecologists, who help to save endangered species by preserving their habitats, are not having much success in increasing Ocelot numbers. So, scientists who study animal reproduction have started to get involved in Ocelot conservation to increase the number of Ocelot kittens that are born. These kittens can then be released into the safe wild habitats that the Ecologists have saved.

Reproductive Biologists have started to develop a new treatment for infertility that might be very useful for Ocelot conservation. It is called Germ Cell Transplantation (Brinster et al., 1994). A germ cell is the name for the cells that we produce to make babies. The male germ cells are called spermatozoa and they are made by the testicles. In germ cell transplantation, you take very immature sperm cells from a donor male's testicles and transplant them into a different male who is called the host (Brinster et al., 1994). These immature sperm cells then divide and mature in the host testicles to make fully developed spermatozoa. This means that the spermatozoa, which are made by the host male, have the genetic information of the original donor male (Schlatt, 2002).

Germ Cell Transplantation technology is being developed to treat men who cannot have their own babies because there is something wrong with their spermatozoa (Gauthier-Fisher et al., 2019). Germ Cell Transplantation can also be used to restore fertility in males who have been treated for cancer (Puscheck et al., 2004). It is very sad that the drugs use to cure cancer will mean that patients are left infertile, and can no longer have their own children.

What has this got to do with the Ocelot? Well, germ cells can be transplanted between different males of the same species (human-to-human or mouse-to-mouse), but they can also be transplanted between different species (for example hamster-to-mouse) (Ogawa et al., 1999). This means that we could use one type of animal to grow the spermatozoa for another type of animal. This would be very useful for breeding from endangered species who are low in numbers and might be harmed by too much handling by the scientists.

This is where the Domestic Cat can help the Ocelot! It is interesting to know that the Ocelot is only 2 million years of evolutionary distance from the Domestic Cat (Felis catus). The closer the evolutionary distance between two species, the more similar the species are, and the more likely Germ Cell Transplantation will be successful between the two species!

Recently, scientists have taken immature spermatozoa from wild and zoo Ocelots and transplanted them into the testicles of the Domestic Cat (Silva et al., 2012). They stained the Ocelot spermatozoa with a fluorescent dye that will give off coloured light so the scientists can see if the cat testicles start to make Ocelot spermatozoa. They can also watch the movement of the Ocelot spermatozoa through the male Domestic Cat reproductive system to see if the immature Ocelot spermatozoa grow into fully developed mature sperm cells ready to make a baby. Two weeks after transplantation, the immature Ocelot spermatozoa could be seen in the testicles of the Domestic Cat, which showed that they were still alive. After thirteen weeks, fully mature Ocelot spermatozoa were seen in areas of the Domestic Cat male reproductive tract that store the spermatozoa ready to be released into the female during mating (Silva et al., 2012).

This exciting research means that we now have a way to make lots of Ocelot spermatozoa using Domestic Cat hosts. We can use this cat-grown Ocelot spermatozoa to make extra Ocelot kittens by using it to fertilise the eggs of wild and zoo female Ocelots. This will help to increase the numbers of this endangered species. In the future, scientists might even be able to use Domestic Cat hosts to produce Ocelot eggs by transplanting tiny slices of Ocelot ovaries or even allow the Domestic Cat to be pregnant with an Ocelot kitten. The use of Germ Cell Transplantation for saving endangered species would be amazing and might happen during our lifetime!
I can't wait to see it!

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Jane Goodall
- Lauren Marshall, The American School in London

As a woman in 1960, one wasn't expected to go into the fields of science, technology, engineering or mathematics. No one was expected to go into primatology without a formal research background. Further, no one would expect anyone to study chimps for fifty-five years in the Gombe Stream National Park in Tanzania. Above all, no one expected Jane Goodall, a woman with no formal research background, to surpass all of these expectations and redefine the understandings of primatology as we know it today. (Gerber, 2017)

When Goodall was about a year old, her father gave her a stuffed chimpanzee to honour the birth of a chimpanzee at a nearby zoo. This small gift fuelled a lifelong love of animals for Goodall. "At the age of just five, Jane hides for hours in a henhouse to discover where the eggs come from, unaware her family is frantically searching for her." (https://www.janegoodall.org.uk/jane-goodall/biography) This curiosity of animals exhibited at age five would stay with Goodall her whole life.

"Goodall left school in 1952 but couldn't afford to go to university. So she learns to be a secretary and works for a time at Oxford University typing documents. Later, she works for a London filmmaking company, choosing music for documentaries." (https://www.janegoodall.org.uk/jane-goodall/biography) At the age of 23, Goodall traveled to see her friend in Kenya where she met Dr. Louis Leakey. Without a formal research background, Leakey only offered Goodall a secretarial job. Soon after Leaky found a six-month job for her to study chimpanzees nearby in Tanzania. (Gerber, 2017)

At the end of her six-month study, Goodall made two discoveries that changed primatology forever. Over the course of six days, Goodall discovered that controversial to previous beliefs, chimpanzees eat meat. However, Goodall's other discovery was much more monumental. Goodall discovered that chimpanzees not only use tools, but they often make them as well. "Squatting by a termite mound, he [a chimpanzee] picked a blade of grass and poked it into a tunnel. When he pulled it out, it was covered with termites, which he slurped down." (Gerber, 2017) No one was expecting Goodall to make discoveries that changed the meaning of mankind and prove that we should all see ourselves as equals to chimpanzees. "When Goodall's boss Louis Leakey heard about her discovery he replied to her by telegram 'Now we must redefine tool, redefine man, or accept chimpanzees as human.'" (Gerber, 2017) This was unprecedented in primatology as previously, humans were thought to be the only species capable of making and using tools.

In 1957, women weren't encouraged to go into the field of science. Goodall wasn't even allowed to go into Gombe to study the chimpanzees alone! "In Jane, National Geographic found a telegenic researcher and storyteller with a film-ready setup: an attractive white woman doing scientific work in the African bush." (Tony Gerber, 2017) Even though National Geographic wasn't sponsoring Goodall entirely for her knowledge of primatology, Goodall still found a way to make some of the biggest discoveries in primatology history.

In 1965 Goodall founded the Gombe Stream Research Centre to train scientists, allow them to join her study of chimps and combat chimpanzee extinction. The research centre in Tanzania close to where Goodall first researched the chimpanzees. It makes it possible to witness some of nature's rare sightings such as Golden and Glitter -- chimpanzee twins that helped scientists discover that chimpanzee twins can exist. The Gombe Stream Research Centre will help scientists make discoveries about chimpanzees for years to come. (https://www.janegoodall.org.uk/our-programmes/gombe-stream-research-centre)

After leaving the Gombe Forest, she wrote books such as *My Friends, the Wild Chimpanzees, Innocent Killers, In the Shadow of Man, Grub the Bush Baby, and Solo: the Story of a Wild African Dog*. (Gerber, 2017) Today, at the age of eighty-five, Goodall is widely recognised for her accomplishments. She is still campaigning and speaking about animal rights and environmental rights. Goodall believes anyone can make big changes if they put their mind to it. *"Every individual has a role to play. Every individual makes a difference."* (https://www.janegoodall.org.uk/jane-goodall/biography) It's something we should all remember.

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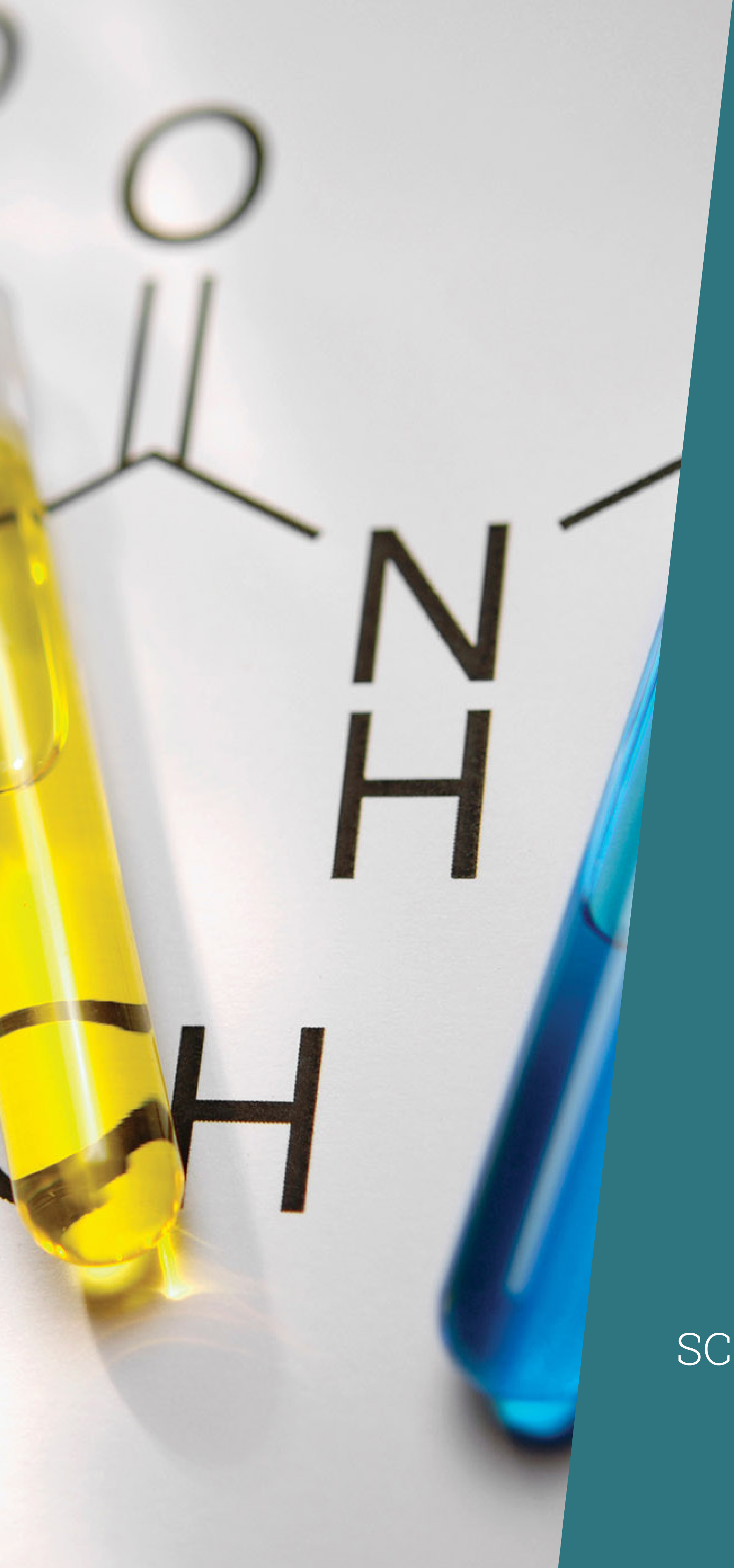

UNDER 16
SCIENCE ESSAYS

The Secret Communication between plants
- Julie Jung, Wimbledon High School

Communication between organisms are crucial for survival. Animals, for instance, are alerted immediately of dangerous situations by the receptors in their eyes, skin, nose or ear that transfer electrical impulses through the neurones to the brain. This helps them run or hide from danger and survive. However, plants do not have these systems that animals use to communicate. So how do they know when to protect themselves from danger?

The idea of plants sending airborne chemicals to each other was first developed by a scientist John Lawton (Mc Gowen, 2016) He experimented with a batch of sagebrush and tomato plants that were sealed into airtight jars. Sagebrush produce large amounts of methyl jasmonate, which is an airborne stress hormone that is released when the sagebrush is being eaten by insects. When Lawton clipped the leaves of the sagebrush imitating an insect's bite, it released methyl jasmonate. A few minutes later, the tomato plant started responding to the presence of methyl jasmonate in the jar and released proteinase inhibitors, which harms insects. This experiment was further carried with sagebrush and tobacco, resulting in the same reaction: the tobacco plant responded to the methyl jasmonate and produced its own defence chemicals against insects (McGowen 2016). After many experiments' scientists have also found that chilli peppers and lima beans respond to the airborne chemicals produced by cucumbers! (Vogt, 2017)

It was also discovered that airborne chemicals from certain groups of plants work more effectively on the same types of plants. The priority for all plants is to survive and reproduce: to increase that chance, less competition between neighbouring plants is important. This is why plants of their own population respond better to their own population's signals so that the genes of their own population have a higher possibility to survive (File, 2012).

However, plants have adapted so that these specific signals to certain types of kin can be intercepted. They have developed a way of communicating through roots. An experiment was held in the University of Negev in Israel to investigate the method of the plants 'eavesdropping' (Rick Karban 2012). They planted two pea plants but with one pea plant under drought condition and the other in normal condition. A few hours later, the pea plant that was not under drought condition had shuttered its stomata, which decreases the rate of evaporation of water from the plant. This meant that the plant not under drought condition had received information about the drought condition from the other plant through the roots and was preparing for a drought. This was further proven by repeating the experiment but this time the two pea plants were in separate pots so that the roots would not be able to connect through the soil. The result showed that the plant that was not under drought condition had not reacted to the other plant's drought condition, as its stomata had not shut (Cossins, 2014).

In more depth, exactly how do the roots communicate?
The plant roots secrete a soluble chemical that is transferred by fungi that feast on the plants. In exchange for the fungi receiving sugars from plants, they give the plants nitrogen and phosphorus. The fungi also connect the roots between plants with their stringy white hyphae, forming an underground plant communication system (Coombs, 2013). This is part of the reason why the farmers plant the same type of plants in the same area. The plants communicate through airborne and underground chemical signals to warn their kin to prepare for diseases, insects or droughts. It is proven that planting same type of plants therefore increase the plants ability to resist and survive against diseases and droughts, helping crops like maize and wheat grow more successfully.

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The Significance of HeLa Cells
- Ipek Tsil Kara, Sydenham High School GDST

The ‘immortal’ HeLa cell line has been hugely influential in many medical and scientific developments over the past 50 years. Originating in 1951, HeLa is the first cell line that was successfully multiplied in culture by Dr George Gey Of the Johns Hopkins Hospital in the USA.

The cell line originates from cells collected from an African-American woman named Henrietta Lacks who went to Johns Hopkins for treatment for a particularly aggressive form of cervical cancer. Without her consent, extra cells were taken from her tissue during her treatment and used worldwide and throughout science. The continuous division of her cells (provided they are kept in the correct environment) allowed over 110,00 scientific publications to be written but the taking of her cells without her permission also brings up many ethical issues in medicine.

In the 1960s, HeLa cells were sent into space along with the first humans to see the impact of zero gravity on human cells. The cells survived their first trip to space with Yuri Gagarin in 1961 but the trip did not have a big effect on cell growth as the flight only lasted an hour. The same set of cells were sent up with other Soviet trips into space and this time around it was found that the cancerous cells divide more rapidly in zero gravity while noncancerous cells divide at a normal rate. Although there is some controversy that surrounds whether these results are coincidental (as highlighted by Ari N. Schulman in an article entitled ‘What is the body worth’), the results aided scientists significantly in learning about the effects of space in human biology.

A more recent development aided by HeLa cells is the HPV vaccine- a vaccine developed to combat the disease Henrietta Lacks had, cervical cancer. HPV stands for human papillomavirus and is the common name for a group of viruses affecting the skin. Most strains of HPV do not even cause any symptoms, however, some strains of more severe HPV can lead to mutations in the cells of the cervix, eventually leading to cervical cancer. HPV-18 (the strain of HPV that is linked to cervical cancer) leads to cancer in that it injects its DNA into healthy cells, making them produce proteins that can cause carcinomas. However, for this to occur the virus must also cause genetic instability in the cells so that the immune system cannot provide an immune response to the tumours.

In the 1980s it was found that HeLa cells contained HPV-18, which causes scientists to believe that an HPV infection was what caused her cancer. Found to preside in HeLa cells by the German virologist, Harald Zur Hausen, the cell line was later used to develop the HPV vaccine. The HPV vaccine protects you against HPV-18 and 3 other strains that cause different types of cancer by blocking the HPV DNA from entering the healthy cells. The vaccine is now offered by the NHS to all students ages 11-13. In 2008, Zur Hausen was awarded a Nobel prize for his work in developing the vaccine and finding the link between HPV and cervical cancer, however, no one could explain why Henrietta Lacks’ cells HPV-18 caused such a previously unseen rapid growth of cells both in culture and in her body.

Another instrumental vaccine developed from the HeLa cell line is the polio vaccine. In 1954, Jonas Salk used HeLa cells to develop the polio vaccine. Polio is a serious viral disease that in some severe cases can lead to paralysis which can be deadly. Since the Hela cell line is very easily affected by poliomyelitis(polio) virus, Salk took advantage of this and used the cell line in developing the polio vaccine. The vaccine works like most other vaccines in taking a dead or attenuated pathogen and injecting so that the person’s immune system can produce the memory lymphocytes that provide immunity, without becoming ill. Thanks to this vaccine, there has not been a case of polio in the UK since the 1980s.

In conclusion, HeLa cells have been successfully utilized throughout medicine, truly earning them the title of ‘immortal’ within the scientific community. Their aid in understanding a range of science from how nuclear bombs affect human tissue to HIV is irreplaceable but their origin is also very significant and should be a reminder of the importance of making ethical decisions first, particularly in a field like medicine.

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Golden Blood

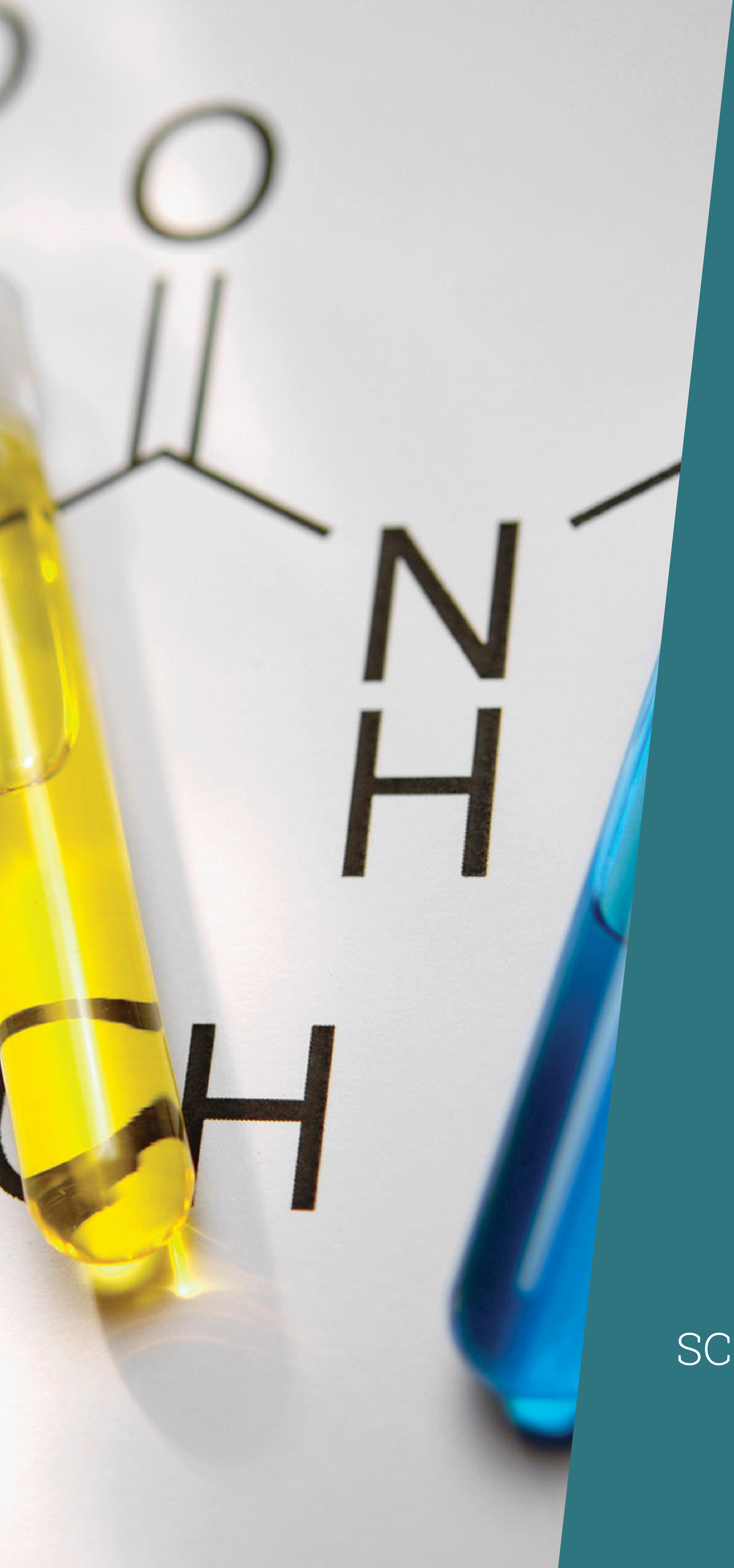
- Lucy Coleman, Sydenham High School GDST

Human blood is characterized into four main blood groups, A, AB, B, and O. One of the most complex blood groups created is the rhesus blood group, which was discovered around 60 years ago. It plays a significant role in determining who your blood can be donated to, as one of the 49 rh antigens, rhd can cause a hemolytic transfusion reaction (HTR- the destruction of red blood cells due to immunological incompatibility between the donor and recipient). However this is only a problem for someone who produces anti-D, and it is represented through having a negative blood type, therefore meaning someone who carries rhd has a positive blood type.

Typically speaking the rarest blood type is AB- with only 0.5% of the population carrying it, but what if there were a blood type which was rarer than AB-?

Rh-null, (also known as the golden blood) is the rarest blood type that ceases to exist. With less than 50 people around the world to have reported to be carriers of this blood type, rhnull can cause various problems for those who have it. With rhd being just one of the rh antigens, out of the 49 rh proteins, the blood type rh-null lacks all of them. Meaning not only is it rare, but similarly to blood type O, rh-null is a universal donor for those who also carry rare blood types within the rh system, causing it to be incredibly important to medicine. But the problem that lies within rh-null are the difficulties of receiving blood transfusions, as it is almost impossible to locate a donor. In Fact, it can be predicted by doctors that people with this blood type are unlikely to live beyond the age of 20. Before it was first discovered in 1961 in an Australian woman, doctors had presumed that someone without rh antigens would not survive out of the womb. The reason why it is extremely dangerous to live with is down to the effects of mixing blood types. If a person with rh-null were to receive a blood transfusion that contains any of the rh antigens, their body would attack the cells as foreign objects or microorganisms. This can cause fevers, breathing difficulties, nausea and other life threatening symptoms. For this reason, to avoid this from happening, people with rh-null are often influenced to donate their blood in case they or others ever need it, whether that means they have rh null or other rare blood types in the rh system. However, one can only reproduce so many blood cells meaning there is a limit to how much they can safely donate. Roughly a doner is allowed to give blood every eight weeks and just one pint can save up to three lives. If people with rh-null were to preserve their blood by freezing it, which can be stored for up to thirty years, they would have one hundred and ninety five pints of blood which could be used to save themselves or others up to five hundred and eighty five times, but this does not prevent it from being a dangerous blood type as not everyone with it will have easy access to health care systems.

At Washington University, research shows that a doctor has created an artificial blood cell that can transport oxygen and carbon dioxide around the body and to respiring cells for up to 30 to 50 hours. The aim of artificial blood is to only replicate the job of transporting oxygen, meaning it can’t function as coagulation (blood clotting) or immune response. However, with research only being recent, it is still currently undergoing trial and it therefore is not being used in the UK or many other countries. While there are still possibilities for the development of artificial blood, it’s usage will most likely stay short term. I predict the future does hold a solution to creating artificial blood types that don’t just carry oxygenated blood, but instead are able to adapt and function as your own blood cells, to help not just those suffering with the difficulties of having a rare blood type, but everyone else too.



UNDER 18 SCIENCE ESSAYS

新型冠状病毒，新型冠状病毒，新型冠状病毒 – Are you scared?
- Choi Liu, Croydon High School

新型冠状病毒*- - are you scared? I am. Images of hazmat suits, surgical masks and Chinese citizens have been a hot topic in worldwide media outlets. Rumours are circulating around local Chinese communities that someone has arrived in Croydon University Hospital who has tested positive for the coronavirus. Surgical masks are selling out, to which a family friend has recently bought 700. There is also evidence that traditional surgical masks[1] are not enough to stop infection, however my distant cousins claim they are of a high enough standard and the industrial masks offering the WHO's recommended protection of n95 respirator level[2] are not aesthetically pleasing.

Is the novel Coronavirus '2019-nCoV'[3] to be feared? It is not like we have not seen a coronavirus before- some namely being the 'SARS-CoV'[4] (Severe Acute Respiratory Syndrome) in 2003 and the 'MERS-CoV'[5] (Middle-Eastern Respiratory Syndrome) 2012. All of these diseases have been in the limelight in the past for being extremely infectious and potentially lethal-all being types of Coronavirus. Does that mean that after this new coronavirus, a new one will come in a few years? One which is even more lethal and even more infectious?

With the World Health Organisation (WHO) classing this as a public health emergency of international concern on 30th January 2020[6] many are being quarantined and tested positive for 2019nCoV around the globe. As of February 3rd 2020, 08:50 GMT, officially there have been 17,488 reported cases of which 2,298 are in critical condition and 362 reported deaths with reported cases in Asia, Europe and the Americas.[7] However, with the knowledge that media censorship is widely known to be manipulated through the Chinese government, it is unsettling that the official numbers are likely tamed to cover up the truth.[8,9]

Coronaviruses are a family of zoonotic viruses. 2019nCoV in particular started from a wet market, the Huanan Wholesale Seafood Market: the epicentre of the virus, in the bustling city of Wuhan and the Hubei province in China.[10] Unsettling images of illegal dealings in the said market show evidence of possibly infected animals and how the unsanitary wet market could have been the perfect place for the virus to transmit to humans. In addition, with the knowledge that Chinese delicacies in the area include eating cats, rats and bats (the latter being notorious for making transmission possible for Ebola to infect humans)[11], it is not too surprising that another disease has wreaked havoc in China. With the ongoing Avian influenza (bird flu)[12], the issue of SARS earlier in the last decade and now the 2019nCoV, perhaps a change of habit could help prevention in the future. In spite of this it could be argued that this is a breach of culture, as I too remember visiting a wet market in my youth in Hong Kong with my late grandmother.

With an incubation period of 14 days, symptoms include[13] fever, cough or shortness of breath. Sound familiar? Perhaps when you look at the common cold, (influenza), the two are more similar than different. Does that mean you should be any less worried about the coronavirus? No. The reality is that the common cold should be more feared, however that discussion is for another day.[14]

Well, is there a cure? A miracle? Yes, the miracle mineral solution[15] - but with the side effect of death. There is no cure in medicine but the closest we can get to it is a vaccination[16]. Previous vaccinations which had fared effective against SARS are currently being thawed from storage, however the issue with these almost-pandemics is that whenever the problem fades almost seamlessly away, vaccinations which researchers have hurried to make are in their beta stage and packed away- simple supply and demand.[17] It takes almost a year to not fade away? The Coronavirus or the X-virus will always make a comeback, bigger and stronger before.[18] In terms of mass migration of Chinese citizens[19] and other nationalities trapped in the quarantined areas, is it selfish for them to seek freedom?[20] Where people are trapped possibly without medical supplies, hospitals overflowed[21], with more and more people coming through with cases day in, day out. Infected citizens dropping dead[22], their lungs filled with fluid, stopping them from breathing[23]. Just like a real-life contagion.[24] The only thing we can do is 加油** and have hope that with a worldwide effort[25] we can prevail through this struggle.

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* 新型冠状病毒 means the 'new coronavirus'

** 加油 literally means 'add oil' and is a chinese proverb for 'have courage'.

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Time
- Elena Hornby, Sydenham High School GDST

Newtonian physics was capable of getting humans to the moon but soon new theories where required to explain how time worked in space. Imagine two sisters, one on Earth and one on a distant planet, Proxima B, at four light years away. There is no way of knowing what she is doing now, if you could see her then you would be seeing what she did four years ago, hearing her would take even longer. So you could say that her present is four years ahead of what you can see, but then her present is in your future and that can't be now? This example is not meant to be understood, only conclude that there is no 'now' shared by proxima B and earth, in fact there is no present. This illustrated a need for new theories to explain the progression of time for different bodies.

These came from Einstein's theory of general relativity in which he states that time is relative to velocity and mass. Einstein uses the example of another two twins, one lives on a mountain and the other at sea level, should the two twins be reunited over a period of years the one on the mountain will be older. He has experienced more time, his heart beat more times and he has physically aged.

This is because mass and gravity cause time to slow down, there is less time closer to the centre of mass and more further away. Today this effect has been proven numerous times. However what made Einstein's discovery so incredible was that he understood and predicted this effect before we had clocks precise enough to measure it.

Secondly time is relative to velocity. This is demonstrated by looking at a wave of light which must always travel at the same speed no matter the position of who observes it. First imagine observing it from a fixed position, relative to you it has displacement. Now imagine that you are observing it whilst travelling with it at the same velocity, so to you the wave has no displacement. Both electromagnetic waves have the same speed but one has no displacement, this means it has no time as displacement is equal to the product of time and velocity. By travelling at the speed of light you have stopped time. This proves that the faster you travel the slower time passes for you, however as we can't yet move anywhere near the speed of light this effect is mostly negligible.

Einstein understood time as a rate of change, it can be change dependent on velocity and mass. Newton previously believed time to be a universal constant so 't' in equations can only be used to measure the amount of time in seconds from a fixed point. In fundamental physics there is only one equation that can differentiate between the past and the future.

DELTA S > or = 0

This is from the second principle of thermodynamics, due to the fact that heat can only pass from a hotter body to a colder one. Heat is the only principle in fundamental physics that separates the past and future, but is this the flow of time?

If we define time as the flow of events from the irreversible past then we discover that events such as reactions do not occur in time. It is reactions and events that make time flow as they create the irreversible heat transfer. By measuring the rate of these reactions we can get the most accurate results of true time for a body currently possible.

In reality our idea of time may not exist at all. This is because we have developed our concept of time due to the fact that its passes for us at a relatively fixed rate, the moon orbits us and we orbit the sun at a set pace from which we derived days, hours, minutes and seconds. We observe life, on our earth, as happening chronologically. But when we look at movements on an atomic scale there is no fixed rate, no order, our ideas of time cannot even be applied to the atoms that make us.

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Wait Four Hours… It is a matter of Life and Death
- Mathura Kathirgamanathan, Royal High School Bath GDST

Endlessly across the News, TV's and Radios, we hear the simultaneous and recurrent theme of the NHS recording its **"worst A&E** [Accident and Emergency] **waiting times"** or the favourite **"the bleakest winters in the NHS's history"** (Hayes, 2019). The NHS's (National Health Service) A&E department, provides for thousands of patients daily – from strokes and life-threatening injuries, to a broken leg, so surely, we shouldn't be surprised that the A&E department is regularly at full capacity? But do we really want to wait four hours to be seen in an emergency?

The four-hour A&E waiting time is a target, introduced in 2004, to see at least 98% of patients that arrive in A&E either admitted, discharged or transferred within that time. This relaxed to a target of 95% in 2010 (Nuffield Trust, 2019), however even this target has not been met since July of 2015 (Parliament, UK, 2019). Why? There are many obvious reasons – since 2004, the population of England has increased by over 16 million people (Statista, 2019), yet the number of hospitals in England and available beds has not accommodated for this. Moreover, with an increasingly ageing population in England, it is foreseeable the NHS and its A&E department will struggle and will continue to do so unless something is done to improve the current system.

But are the headlines deceiving? As Hayes mentions in his article about the A&E's worst waiting times in 15 years, he comments that only **"83.6% of patients were seen within four hours in October [2019]"**. At a first glance, this is considerably under the 95% target, however headlines fail to consider that the patient attendances had risen by 4.4%, with a rise of 3.1% in emergency admissions - compared to the previous month (which Hayes does mention within the article). In contrast, headlines do cover the peaks and troughs of waiting times, especially through a seasonal period. For example, Nuffield Trust reports that during the summer, A&E's see a rise in cuts and sprains which can be relieved and treated quickly whereas during the winter, there is a larger proportion of older people attending and a greater number of people requiring emergency admission to hospital.

The NHS have dealt with this in a number of ways. There are three main types of A&E departments in England (The King's Fund, 2017). Type 1 departments are the 24-hour major emergency areas that attends to life-threatening cases like a cardiac arrest. These departments account for 68% of A&E attendances and thus the majority of waits over four hours within the NHS. Type 2 departments are consultant-led, single-speciality facilities such as dental problems. Type 3 departments treats minor injuries such as aches and bruises including units or walk-in centres. As the King's Fund also states, that the four-hour target of 95% is monitored across all these types of A&E departments.

So, is the four-hour target important? The King's Fund states that **"being treated quickly in A&E is clearly important for both the experience and clinical outcomes of the patient. However, measuring the proportion of people seen within four hours does not provide a full picture of how A&Es are performing."** By this, they refer to the quality of care given in the departments, which can be measured through patient-experience surveys, as an example. In addition to this, NHS bosses have revealed the possible drop of the four-hour target under new plans (Triggle, 2019). The BBC correspondent commented on the targets becoming **"outdated"**, coming after missing the targets for the past few years. NHS England have claimed that they want to see patients coming in with heart attacks, acute asthma, sepsis and stroke, with their care starting within an hour. This is opposed to treating virtually all of A&E patients in four hours. They claim that the changes would be tested during 2019, and if successful, introduced in 2020.

In conclusion, the four-hour target was set to efficiently aim to effectively see as many patients as possible, with the 95% element reflecting to reflect clinical concerns that there would always be a number of patients, who needed to be observed over that time period (NHE, 2016). However, with current plans to change and even drop the target all-together in the near future, if seeing the sickest patients first was an alternative target, patients with 'less serious' injuries may face waiting more than four-hours. It is therefore up to the government working closely with A&E doctors and data from hospital trusts, in order to find a better and more reliable outcome, for a crisis that has gone on for far too long.

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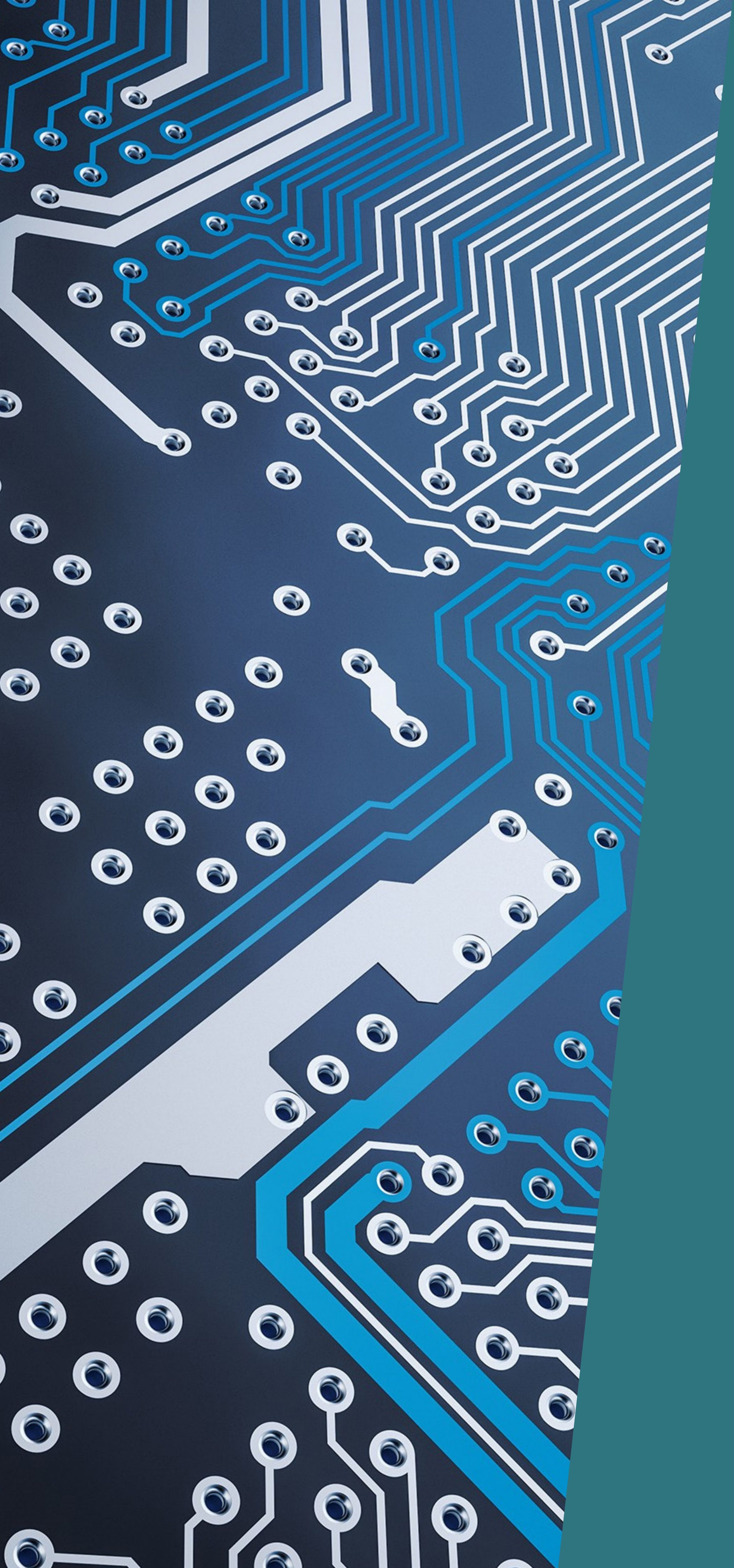

UNDER 14 TECHNOLOGY ESSAYS

How Will C.R.I.S.P.R Change Us?

- Sophie Azhar, South Hampstead High School

Our DNA is the code contained within the nucleus of our cells that defines us. This gives us our different, distinctive characteristics. It is a long molecule in the shape of a double helix, which looks like a twisted ladder. Each strand of DNA contains 4 letters- A, T, G and C- which describe our genes. But sometimes, those genes have errors in them, like a misspelled word. Sometimes this mistake simply gives you a strange birthmark. But it could mean having a serious inherited disease. How do we find these mistakes, and what can we do to fix them?

The idea of using lasers to break apart the molecular bonds in a section of DNA to replace faulty genes came about in 1987, when researcher Yoshizumi Ishino and his colleagues from Osaka University, Japan, discovered repeating individual clusters of DNA patterns in the genetic codes of living organisms. Twenty-five years later, that idea came to life through the discovery of CRISPR (clustered-regularly-interspaced-short-palindromic-repeats).

CRISPR is a form of genetic engineering discovered in 2012 by Jennifer Doudna, Professor in the Department of Chemistry and the Department of Molecular and Cell Biology at the University of California, and Emmanuelle Charpentier, a French professor and researcher. CRISPR is so precise that it is often referred to as a "pair of molecular scissors", neatly cutting out cutting out the faulty genes from strands of DNA. Once the malfunctioning gene has been located and separated from the double helix, it is either removed from the strand, replaced with a fully functioning gene or the error in the code is corrected.

Although CRISPR has been around for 8 years, we have not yet reached a point in CRISPR's development where we can use it with full confidence. This software has been used on mouse cells to prevent the gene that causes Huntington's disease, a genetic condition that results in severe damage to the nervous system and brain, and usually results in early death. This experiment was carried out by ex-corporal in the US army, Jeff Carroll. He is currently a researcher at Western Washington University, Bellingham, who suffers from the genetic mutation that results in Huntington's disease.

Even though the use of CRISPR on real patients since its discovery has been minimal, there are hopes for the future. CRISPR offers itself as cure to the majority of genetic diseases and conditions that we currently are aware of. Scientists are hoping to use CRISPR as a cure for conditions such as HIV, Herpes and Hepatitis, by removing the viruses genetic information from the patients infected cells. Most importantly, they think it will prevent the most serious inherited diseases, like Huntington's or sickle cell. Doctors also hope to use CRISPR as a way to battle cancer. Doctors will do this by deleting genes with errors from the patient, in order to help the immune system attack tumors.

Beyond using CRISPR as a way to cure diseases, and even lifelong genetic conditions, it is possible to use it to improve people, and create the so called "designer baby". One scientist in China has already done this. He Jianku, a doctor in China, changed the DNA of twin embryos so they would be immune to the disease HIV. Most scientists considered this a bold, but reckless, step as the babies will pass this modification to their children.

This episode has raised awareness that CRISPR's ability to change genetic code may result in "designer babies" becoming a reality, raises numerous ethical and social questions. Is it right to tamper with an unborn child's genes without their consent? If CRISPR is expensive, will only the rich use it? Is that fair? If we can take away a serious illness using CRISPR, is it fair not to use it? What will impact will it have on a society where some people have improved abilities and others don't?

These questions are crucial for our societies. If we are to adapt to the new potentials that CRISPR has opened up, we could progress towards longer, healthier lives. But unless we make sure that this is equally available in our societies, the rich could flourish and the poor might suffer at the hands of these super-people.

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Is Nanotechnology the miracle cure for humanity's problems?
- Amina Nartey-Grey, Sydenham High School GDST

Nanotechnology is one of the most exciting and fast-moving areas of science today; it focuses on the control of matter at the atomic and molecular scale. One of the characteristics that makes it increasingly fascinating is the use of such small particles to create new large-scale materials. But just how small is a nanometer? A nanometer is a billionth of a meter, and just to put this number into perspective, the diameter of a human hair and the width of a sheet of paper are separately equivalent to 100,000 nanometres. Some nanostructures are naturally occurring;however nowadays scientists can create nanostructures themselves by rearranging the atoms of an item. The ability for us now to influence the position of each independent atom, allows us to create things that behave in an unusual manner; this can benefit us in numerous ways.

One of these benefits is life extension: by helping to eradicate life-threatening diseases such as cancer, and by repairing damage to our bodies at the cellular level. The average human lifespan has been increased over the last century, primarily by reducing the impact of life-threatening diseases. The application of nanotechnology in healthcare is likely to decrease the number of deaths from chronic conditions. So what type of work is being done in the way of eliminating cancer, one of the leading causes of death on the planet? An intriguing targeted chemotherapy method uses one nanoparticle to deliver a chemotherapy drug and a separate nanoparticle to guide the drug carrier to the cancer tumour; nanorods accumulate at the tumour concentrating the heat from infrared light, heating up the tumour and finally killing the cancer cell. Similarly, several efforts are being made to combat heart disease. Scientists are developing methods to detect, monitor, treat and eliminate plaque that is most likely to cause heart attacks. The most revolutionary possibility exists in the potential to repair our bodies at the cellular level. Techniques for building nanobots are being developed that should make repair of our cells possible; they serve as miniature surgeons which can also replace entire intracellular structures and correct a genetic deficiency. Further investigation can create opportunities such as completely replacing an organ. This ability to repair DNA and other defective areas in our cells goes beyond keeping healthy: it has the potential to restore our bodies to a more youthful state.

There is an opportunity for developing countries to take advantage of cutting-edge technology. In remote regions, many lack access to essential services, nanotechnology has potential assistance in every industrial sector, from medicine to clean water and energy. It is unlikely to solve all of these problems solely, but can form a part in many cost-effective materials and systems. These solutions for development can offer useful perspectives for medical care, water treatment, agriculture and food. For example, water treatment through nanotechnology is an emerging area of research and could play a large role in averting the coming water crisis. All problems in the developing world will certainly not be solved by advanced technology; however, the basic problems of accessibility to technologies, affordability, and fair distribution could be solved by nanotechnology.

A survey was carried out in 2011 in which an audience was asked what they believed were humanity's next pressing issues for the next 50 years. The top five responses were water, food, the environment, poverty and disease, but energy wasn't mentioned, which was unexpected as the use of energy plays a huge part in each of these complications. 71% of the Earth's surface is comprised of water; however it is salty and not where it is needed to be. In terms of food, fertilization involves tonnes of input, food needs to be transported and water is needed for this industry. Problems with the environment come from the type of energy we use and the conservation of it. Poverty can be defined as a lack of access to energy and finally, many diseases are caused by unclean water. All of these troubles can be solved by the use of sustainable energy through nanotechnology. Nanoparticles could allow us to produce more effective and inexpensive solar cells and make cheaper and more efficient biofuels.

Despite the convenience of such futuristic technology, it comes with potential risks that should be considered. Whilst receiving nanomedicine, some nanoparticles may split up and enter the cells of various organs and reside in them for an unknown amount of time; this is an issue as we are unaware of what problems they may cause in the future. Workers are also likely to be exposed to nanomaterials in higher quantities and for longer periods of time than patients. The long-term toxicities linked to these particles are unknown; however it is said that they can cause lung damage. On a broader scale, there are contamination risks to the environment, as inhalation of nanomaterials and direct contact to the skin could lead to toxic effects.

The evolution of nanotechnology is undoubtedly a big step in the development of our world; however the effectiveness of it all depends on government policies, political priorities, resources, financial restraints and, notably, the depth of research into this topic.

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The Possibilities and Pitfalls of Artificial Intelligence (AI)
- Aditi Nebhwani, Northwood College for Girls

Artificial Intelligence is the most important technological innovation of the last decade which holds many possibilities for the future ranging from the downfall of the human race to the conquering of death itself. But which is it? Scientists of today are split on this but we will have to make a decision quickly due to the rate technology evolving or we shall be our own downfall.

Many people believe that AI will be harmful in the future and while there are possibilities they are extremely unlikely. All new technology, like the first car, are intimidating, but AI is more so as people believe it will be able to think for itself. AI's negative depictions stem from various places. One of them is pop culture's villainization of robots. Pop culture has become a massive part of modern life. It influences people's political choices through social media and theatre. Showing the worst-case scenario makes for a good story but is not scientifically accurate. There are endless possibilities, some that have already come to fruition such as self-driving cars and robot helpers in hospitals. Having 'Doomsday' brought about by computers helps to inspire fear in AI and a reluctance to support the emerging technology, especially when they do not understand it. One popular misconception is that AI will become sentient in the future and we will not be able to control it. We do not know what the future holds but we can regulate the technology and restrict its freedom. According to Isaac Asimov's Laws of Robotics, we could ensure that AI never hurt humans. It is supposedly a fool-proof way to advance ourselves without risking our freedom.

> 1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
>
> 2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
>
> 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.
>
> —Asimov's Three Laws of Robotics

However there are some problems with this premise. Many believe that Asimov's Laws are unreliable and easy to get around, especially by something as vastly intelligent as an AI. People such as experts Ben Goertzel and Louie Helm say that 'Asimov's laws are woefully inadequate'. Asimov also assumes that we will live in a world where humans have more rights than AIs.

If an AI is truly self-aware, it would be able to ask the question of a robot's basic rights. Even if the laws did work there the other issue of the human variable. Humans can be both good and evil. If someone with malevolent intentions were to hack a super-computer, there would be no limiting their power. Humans are unpredictable and it would be impossible to put enough rules for the AI to follow that humans could not find a loop-hole. This is because humans are creative. But what would happen if AIs became creative too. In 2015, researchers were able to build a robot that could be innovative. The scientists were running simulations to see how little contact the robot's feet could have with the ground while walking. The program came up with a way to have 0% contact by walking on it's elbows instead. This shows that the program could think for itself and possess creativity. Creativity has always been a human trait. Now we must all wonder, is this AI's first step to self-awareness?

At the moment, the question of the hour is what do we do? How do we stop humanity's enslavement without restricting the possibilities? Governments and companies are already taking action. Elon Musk has a company called Open AI dedicated to researching AI safety and there are committees reviewing advancements in the field. People around the world are working to build a safe AI to be a helping hand to humankind and researchers predict that we are just a few decades away from that goal. The world is a few decades away from anything to infinite knowledge, to enslavement to anything in between. The possibilities are as limited as ourselves.

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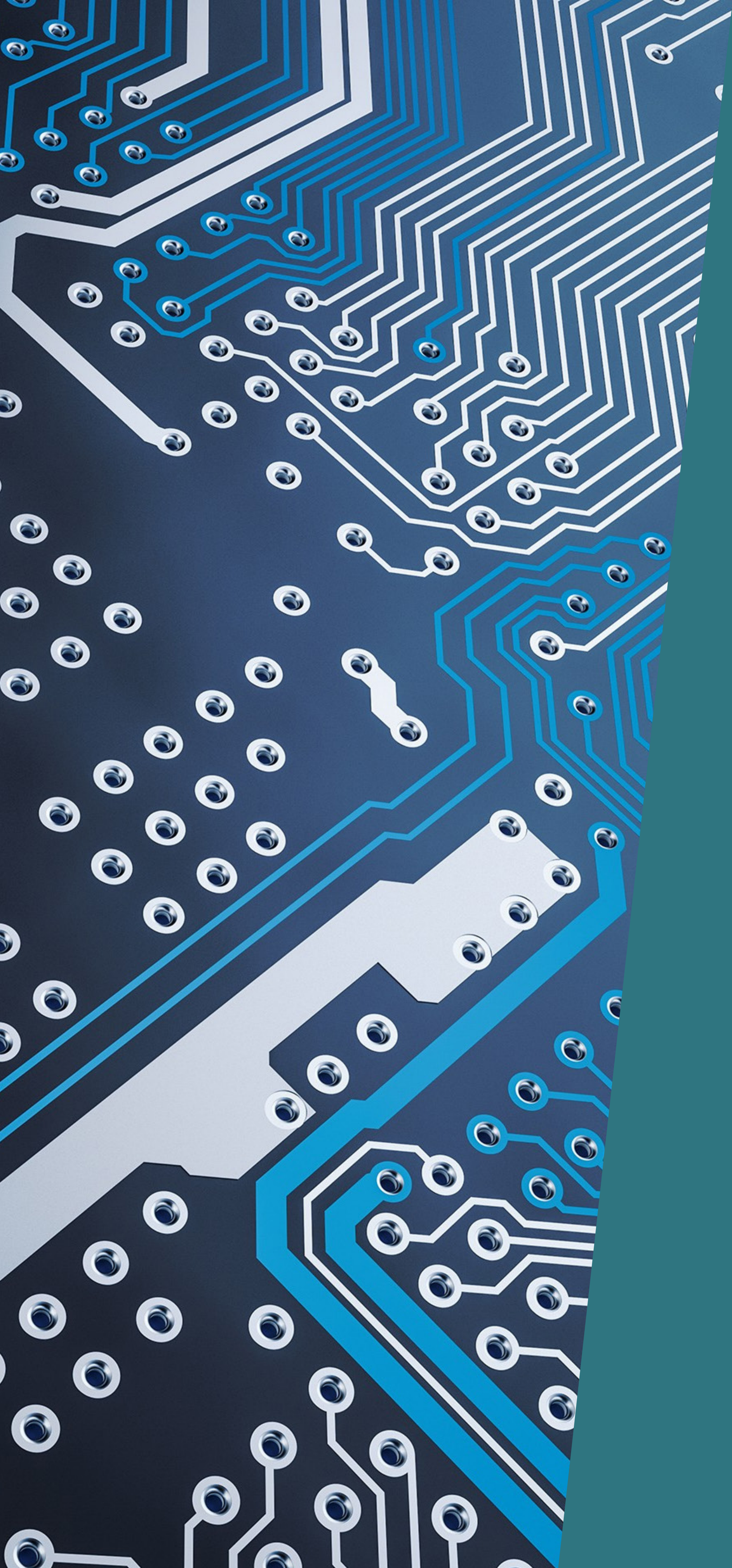
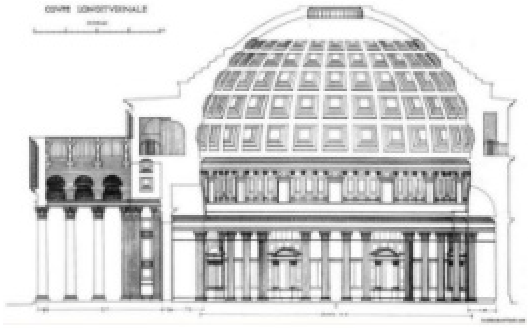


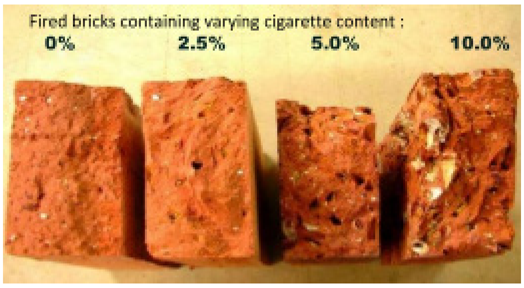
UNDER 18
TECHNOLOGY
ESSAYS

The impact of innovative materials on the built environment and it's sustainability
- Emma Wilkes, Streatham and Clapham High School

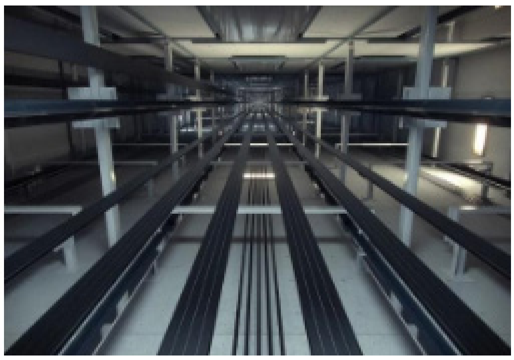


When the Romans built the Pantheon in Rome in 124AD to honour their gods, they had to rely on their formidable understanding of materiality to ensure the building would stay standing, specifically its 43m diameter unsupported dome, the largest in the world. The engineers understood that the base of the dome needed to be thicker and the concrete of higher density than at the top, providing stable support. The central oculus (an 8m diameter opening in the roof) further demonstrated the Roman's understanding that the top of the dome bears no load, and significantly decreases the weight of the dome. While this feat of engineering will forever pay testament to the depth of understanding of the Roman engineers, the process of designing buildings and spaces, the opportunities available and the possible characteristics of those structures have been exponentially expanded thanks to the ever-increasing range of materials.

The use of concrete dates back far before the Pantheon, to 6500BC, when the first structures are thought to have been built in Jordan and Syria. Concrete is a hugely versatile material and now even more so, thanks to new, innovative, techniques. An example of this is light-generating cement, which is a smart material with the ability to absorb light energy during the day and illuminates at night. This is made possible by the polycondensation of silica, river sand, industrial waste, alkali and water, a process done at room temperature. It is a low energy consumption and low pollution process. The use of light-generating cement could hugely benefit areas that do not have easy access to electricity, or as a sustainable option for lighting park paths, for example, as the cement does not contribute to light pollution. The cement glows a blue-green tone, adding an aesthetic aspect to the environments it is implemented in, meaning there are thousands of beautiful uses of this cement simply waiting to be found.



Fast forward to 3500BC, with the Roman breakthrough of the fired brick, now considered one of the most fundamental building tools available, but they too have received a 21st-century update, with the introduction of fired bricks made with cigarette butts. While this seems rather an unlikely choice, adding cigarette butts can reduce the energy required to manufacture the fired bricks by as much as 58%, with as little as 1% cigarette content, and the bricks are lighter and boast better insulation properties than traditional fired bricks. Furthermore, the cigarette butts are removed from the environment – which can take anywhere from 18 months to 10 years to biodegrade and leach heavy metals such as arsenic, chromium, nickel and cadmium, contaminating the soil. While the use of these bricks doesn't necessarily require or even inspire new types of structures, buildings that are built with these bricks are hugely more sustainable than most and start to re-define the standard for eco-friendly architecture.



Time travel (I'll save that for another essay) to 1958, and a strong and lightweight material known as carbon fibre has just been invented. Since then it has become ubiquitous for its uses in sports and aerospace equipment, however, used very little in architecture. This is soon likely to change as carbon fibre is being utilised for lift cables when applied with a high friction coating. The cable is currently able to carry lifts 1km high, double the capability of traditional steel cables. Carbon Fibre is considerably lighter than steel and has a much higher tensile strength (3.5 GPa as opposed to 400–550 MPa in Steel). Meaning that instead of needing multiple separate lifts, for example, in the Shard and Burj Khalifa, only one lift is required. This avoids the need for awkward transfer floors and removes limitations on the design of new skyscrapers by structural elements. Another recent innovation is the Cabkoma strand rod, which makes use of a carbon fibre composite, covered in both synthetic and inorganic fibres, and coated in a thermoplastic resin.

The rods not only strengthen buildings against seismic activity, and is currently the lightest reinforcement in the world, but also adds an aesthetic canopy over the building, as seen in the photo above. As seismic activity continues to pose an unpredictable threat across the world, such materials will be considered a huge advantage in the battle against ever-worsening natural disasters.

There is no doubt that material development is a never-ending treasure chest of undiscovered uses and possibilities. It affects every product, building and structure from its aesthetics to its lifespan, sustainability and how we design. Materials have such a powerful influence over design, but if the mastery of the Romans teaches us anything, it is that our application and use of these materials is what will give rise to the greatest masterpieces of our time.

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Bacterial bricks: a construction revolution?
- Kitty Joyce, Oxford High School

"Scientists created carbon-sucking 'Frankenstein' bricks using microbes. The material can spawn its own babies." Reading this outlandish headline[1], one might be forgiven for thinking that it sounds like something in a science fiction novel. However, it is very real. Someday, perhaps not too far in the future, your house may be built from bricks made out of bacteria.

Sounds rather disgusting, doesn't it? Although the idea is unpleasant, these bricks could lead to a whole new age of construction. The miracle material has been created by researchers at the University of Colorado Boulder[2]; it is a living mixture of sand, gelatin and bacteria (3), and has the extraordinary property that if you cut a brick in half and add some more of the raw ingredients, it can grow into two whole new bricks[3].

The process of creating this bizarre material is 'a lot like making rice crispy treats', according to structural engineer Wil Srubar, one of the leaders of the project[1]. Cyanobacteria are added to a mixture of sand, gelatin and nutrients; in humid conditions, the bacteria take in carbon dioxide gas and use it to make calcium carbonate, which crystallises the gelatin[4]. As the cyanobacteria are photosynthetic, the bricks are green in colour, although they tend to fade to brown once the bacteria have died[3].

Now, this isn't the first time people have harnessed bacteria to produce building materials. The idea has been around for a few years, and other scientists have produced similar materials; the start-up company bioMASON began creating their own bacteria-and-sand bricks in 2012[5], and have won several major awards for their efforts[6]. However, biological building materials are in no way mainstream, meaning that their full capacity to change the way we create has not yet been unlocked.

There are plenty of benefits to materials like this. The first is that rather than producing lots of carbon dioxide, these bricks actually take it in. This puts them head and shoulders above the cement we use now, which produces a whopping 8% of global carbon dioxide emissions[7]; as people become increasingly aware of the issues man-made greenhouse gases create, environmentally friendly building materials could help mitigate the looming problem of climate change. Also, if you begin with one brick, that one can become two bricks, then four, then eight... Since the bricks can be made at an exponential rate[4], producing them may end up being more efficient than producing regular concrete.

Unfortunately, these bricks aren't ready to go just yet. In order to be hard and strong, the material must be dehydrated, while in order for the bacteria to remain useful, there must be water present[2]; ideally, a balance would be found where the bricks were strong and the bacteria still alive. The bacteria's need for moisture means that these bricks could not be grown in some of the places they would be most useful, like deserts or other planets, which are very dry.

Despite the relatively low carbon emissions of these bricks, one of their main ingredients is gelatin (which is made by boiling the bones, skin and connective tissues of animals[8]). If these bricks became mainstream, gelatin production would have to increase - which would mean more animals being killed. As well as many people having concerns about this being inhumane, keeping animals is a carbon-intensive process, so this is not an ideal situation.

Nonetheless, once we've refined the technology, these biological bricks could be immensely useful. As they can be produced on a building site, people would be able to make bricks of any shape and size they wanted, enabling more creative ways of building; they could be used in space, or other environments where resources are scarce[9]. Eventually we might even have self-healing concrete or bricks that suck up toxic gases[4] - although such developments are still some way away.

So, are we really going to be building with bacteria any time soon? Realistically, we probably won't. These new bricks aren't ready to be used commercially: they're too weak, too temperamental and haven't been thoroughly tested yet. Still, they have lots of potential. There are endless ways we can use and improve this exciting new material: as Wil Srubar said, 'The sky's the limit for our creativity.'[4]

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Robotics is here to stay
- Ayishah Bridge, Chislehurst School for Girls

STEM's discoveries have come so far in such a short time, things that seemed to only live in science fiction novels are now what we can see clearly in our near future. We've all watched films where someone loses an arm and can get a robot arm able to operate better than the arm they had before, or we see someone turn into a robot. We probably watched these in awe but thought nothing more of it. Now we are seeing technological developments that are showing that this could be possible.

In December 2017, Johnny Matheny lost his arm to cancer and thought he would never be able to have his arm again. To his surprise he was given a robotic arm and became the first person to live with an advanced mind-controlled arm. Unlike many other prosthetics, this one only requires the control of Johnny's mind. The idea of this alone is breath-taking to think that a piece of machinery can act as a limb. However, the way it operates is self-explanatory, our brain sends electrical impulses and the band on top of the robotic arm captures theses impulses sending them to the rest of the arm. The hard part of this overall process is the fact that they must place an implant into your bone to attach the arm, as well as giving nerve reassignment surgery. These two procedures are the part that make the arm work like a normal arm. This fact raises the issue of whether we are allowing the use of robots to control human behaviour too much. If we are changing ourselves to adapt to this robotic technology, could that mean one day this technology will control us completely?

This may seem to be a very recent topic, but the first robotic arm was introduced in 1962, invented by George Devol. It was created for industrial use, some of the first companies to start using these were car companies and now all the big companies operate with them. The mechanisms of these machines differ largely from the prosthetics, however the overall idea of a robot doing human tasks is the same. The use of robots in industry is also another topic that people use to highlight the ethical issues with artificial intelligence. The main one is unemployment, if robots are replacing jobs then where are the people going to go? Where can they earn money to support themselves and their families?

The continual use of these robots is significantly increasing the value of different industries, this is increasing the gap between the rich and the poor which is a large concern for many. How are we able to distribute wealth in a way that creates equality while the cost of making and maintaining AI continues to increase. The cost of these may be expensive but they also provide the ability for companies and individuals to gain a large amount of profit. For example, John Matheny prosthetic costs $120 million to run and be maintained. To many this is an astronomical amount of money, especially since the US Department of Defence are the ones paying for it as a way of research.

It seems to many that robots are all negative however they do have their positives. They can have unwavering focus as they are programmed for a certain job. This means that in many areas they excel humans at performing a job, so in both industry and healthcare, this is essential to the safety of people and the smooth running of the institutes. Not only do they allowing places to run, they allow them to run at a speed which meets the fast pace demands of the world. 7 billon people is a lot to provide for.

I think the negatives and the positives highlight the importance of humans working alongside robots, but not allowing them to dominate and be a stronger power. I think all STEM subjects play a vital role in this development, and all individuals interested in STEM much ask themselves what is going too far? When do we say stop? It is going to makes us reassess what see as core human values and define humanity.

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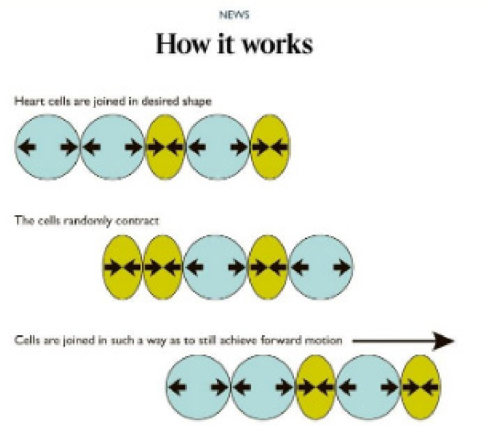
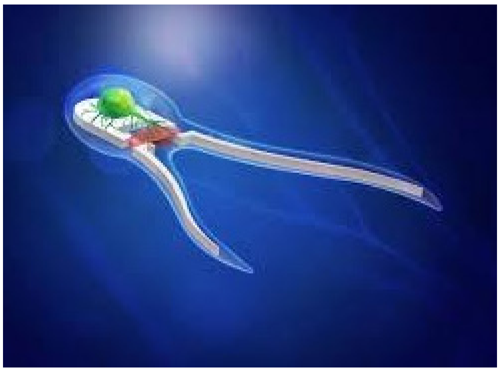
UNDER 14 ENGINEERING ESSAYS

Astonishing advancement in Bio-engineering
- Poorna Baikady, Wimbledon High School

What are Biobots?
Have you ever thought of living robots? Or to be more precise, Biobots? Recently scientists have engineered living cells that are biologically programmed to propel themselves and carry out specific functions. These Biobots are being developed to target and combat diseases. They are currently being tested in laboratories to confirm the hypothesis and are yet to be used as a medical practice. However, they are engineered to delivering key drugs to target infected areas of the body.



How do they work?
Biobots are hybrid cells developed from those of a frog's cardiac muscle. The cells clump together to form a contracting muscle that is able to propel itself through blood systems. These biobots use no metals or plastics and are entirely biodegradable. Scientists have found a way to restructure heart cells so that their irregular contractions cause the Biobots to propel themselves unidirectionally. Whether Biobots are living or non- iving is debatable because they contain characteristics of both. biobots are also known as xenobots, derived from the frog's scientific name, Xenopus laevis.



Are they Alive?
These new organisms are often debated to be alive because they do not fulfil all eight life functions. Furthermore, they do not fit the traditional characteristics of a machine because they are not made of metals, plastics or woods. Nevertheless, they do move and function by themselves. The cells themselves are from a living organism and, essentially, are just stitched together differently. Some scientists say that these biobots are machines because they carry out a specific function which is the main purpose of a machine. They cannot respire, retrieve their own food or reproduce but they are able to move due to the contractions of the cardiac cells. Therefore, these cells don't quite fit the definitions of living or non-living but instead exhibit characteristics of both.

How did this idea come about?
The idea of a bio-hybrid cell originated in 2014 when they applied the same concept to a rat. They started by using a super computer to test out different body configurations. They used rat heart cells and silicone hydrogel – the same material that is used to make a contact lens - to form a biobot. The silicone hydrogel is coupled with a rats cardiac cells into a sperm like structure, improving the Biobots mobility. They used heart cells because their irregular contractions were able to move the synthetic body by themselves. They discovered that the heart cells contractions could move the synthetic body on its own, ¼ of an inch per second.

The future
Scientists claim that these cells could eventually be used to deliver drugs and target and clear diseases due to their ability to move. They are designed to move in the same directions, therefore able to clear the plague from artery walls. They believe that these cells can eventually be created using restructured human cells so the body doesn't reject them. They hope to one day adapt these biobots by using human cardiac cells. These biobots must currently be held in rich fluids to keep it alive due to the nutrients within these fluids and research is underway about how the human veins could potentially 'feed' the biobots, increasing the lifespan of the Biobots.
To conclude, these Biobots are stepping stones to revolutionary discoveries in the medical world. These biobots have provide an insight into a unique type of hybrid cell. I believe that Biobots are not alive since they do not carry out all 8 life functions but are a new type of machine that researchers haven't encountered yet. These biobots are a wonder of the modern world and they are truly marvelous non-living creatures.

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A Sustainable Building
- Elena Shah, Northwood College for Girls

A sustainable building is a building which is an environmentally friendly way, for example, it could help with the impact of carbon dioxide.

One of the main features that a sustainable building will have is a sustainable energy supply which will have a significant change in reducing the carbon footprint that a building can produce. Another feature of a sustainable building is the materials from which it is built from. This could mean making a building from the materials that are already there or easily renewable in the world. Examples of this would be harvested bricks or timber from sustainable forest. The heating and air conditioning of a building can also have a big carbon footprint therefore, a way to reduce this would be having glass windows which don't let the heat out for the winter. In the summer the cold air coming in through the vents could be air which is generated from the energy made by the solar panels. another way to save energy and to keep the building warm in winter would be to build the building in an open sunlight space because this will reduce the need to turn on the lights therefore reducing energy. Another feature to make the building more sustainable would be the use of water, make sure the drainage system is efficient because the water collected there could be filtered and used for indoor and outdoor water purposes. For example, if the tap water was collected and filtered it could be used to water the plants and grass outside rather than wasting more water and using the resources already in the building. Another simple way to make a building more sustainable is to have sensor lighting so the light turns off automatically if no-one is there. If the building is surrounded by grass or there are places to plant more trees, then plant more trees as the trees will absorb some of the carbon dioxide around the building and turning it into oxygen therefore, making the air clearer for other people or have plants in the building.

There are loads of benefits to building a sustainable building, one of the biggest being the environment. Sustainable buildings reduce our negative impact on the environment as they use a more sustainable way of using water, energy or materials. Another benefit is the economic impact because the resources (water and energy) is renewable it will save money in the long-term cost. And an example of a social impact would be using local labour and local materials and building the local businesses economies and work.

Some of the most sustainable buildings around the world include: One Angel Square, Manchester. As it is" powered by a pure plant oil fed combined heat and power system and utilizes rapeseed oil which is grown on the co-operative's own farm land". Other ways it sustainable is its ability to recycle waste and rain water. Another building is the Crystal, London due to most of the energy used is generated by the photovoltaic solar panels. The light which is used is a combination of LED lights and fluorescent lights and the roof of the building collects rainwater. Another building which is known for its sustainability and for its height is the Shanghai Tower, China, it is approximately 632 meters tall and it is the second tallest building in the world after the Burj Khalifa. The wind turbines on the top, of the Shanghai Tower, produce energy that will be enough for the outside lighting, for the inside lighting the natural light coming through the windows should be enough light so it will reduce the need to turn on the artificial light. The carbon footprint which is expected to reduce by 34,000 metric tonnes per year.

If more buildings like sustainable buildings the impact on the environment could be massive, helping us to end climate change and reverse the damaged caused before it is too late.

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City of the Future – A Living Laboratory for New Technologies
- Miu Someya, Croydon High School

Our future of STEM is filled with hope and excitement – with all the fascinating and innovative technologies invented today, such as AI, clean energy sources, robotics, virtual reality and many more. Our current technology is so advanced and promising that it suggests that we have a bright future ahead of us. But how do we actually use all these mind-blowing innovations into our daily lives?

Toyota, Japanese leading automobile manufacturer, announced its plan to build a city of the future, a "living laboratory" where it will put its existing research into a modern living setting. The plan was announced in the Consumer Electrics Show in Las Vegas in January 2020. Called the Woven City, the prototype city will be built on a 75-acre site at the base of Mount Fuji, Japan, where 2,000 residents and researchers will live full-time. The idea is to test and develop new technologies such as autonomy, personal mobility, smart homes, artificial intelligence and hydrogen-powered infrastructure.

In the Woven City, the roads will be separated according to the speed: the main streets will be only for autonomous vehicles for larger transportations, the smaller promenades for slower personal vehicles such as scooters and bicycles, and the pedestrian walks will be incorporated into parks. Separating streets depending on the type of vehicles will reduce the accidents rate.

Houses will be built with carbon neutral materials such as timber. Being called smart house, each house will have an in-house robotic system and artificial intelligent to assist with daily living as well as to monitor health.

The Woven City will be covered by 100% clean energy. Each house will be equipped with solar panels on top of the roof, in addition to the electrical energy generated by the hydrogen fuel cells. Geothermal energy will also be used to heat the houses.

When I first read an article about this Toyota's plan, I found it fascinating especially the idea about putting all the technologies in a real-life situation and creating an entirely new city from the ground. I agree that we will need a place where we actually take in those innovations to test them in our everyday lives, so we can see how they fit in, what problems we will have and what we can do to make it better.

Toyota is starting to construct the Woven City in early next year in Japan, but probably we can adapt its unique concept into our own school in the very near future. We may be able to transform Croydon High School another Living laboratory to make it a model of a sustainable school.

By using robots in our school we will be able to do morning and afternoon registration automatically. Robots can be placed at every classroom door and take attendance without a teacher. It can also collect health information such as the temperatures and heart beats to monitor and check students' both physical and mental health. Together with artificial intelligence, this new way of registrations can not only automate the tedious morning routine, but as well as to provide useful health guides and insights.

Another way of making our school a living laboratory is to introduce GPS trackers to every student and teacher. The reason why this is a great idea is because often students lose track of where their teachers are when they want to ask for something. If we have GPS trackers on everyone in the school, we will know exactly where teachers are without any running around the buildings. It can also be useful for when we go on school trips by keeping track of all the students, ensuring the safety of everyone.

Using up-to-date technologies to monitor and track students and teachers might raise a problem with privacy. There are lots to think about when these innovations will actually take place in our lives, such as data privacy, moral principles and so on. Scientists believe that the very first thing to do is to make all the technologies happen, but at the same time we need to test them out to see if those innovations will actually make us happy and peaceful.

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UNDER 16 ENGINEERING ESSAYS

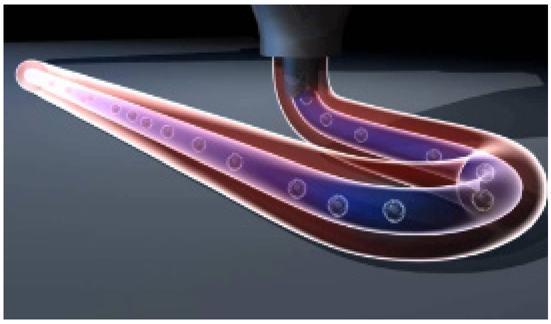
Bioprinting: the future of tissue regeneration
- Aditya Chougule, Wilson's School

Since the 1990s, a new concept known as 'tissue engineering' has generated much excitement; this refers to the possibility of replacing faulty tissues and organs with a fully-functional tissue or organ that has been printed externally using the patient's own cells.

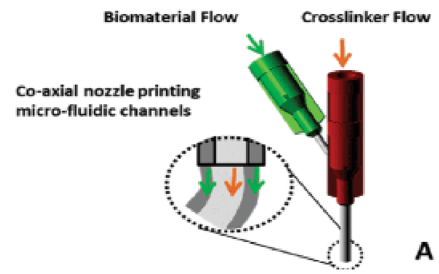
The prospect of bioprinting- a niche sector that could see massive growth in the next decade and impact millions for centuries on- is upon us. While we already have 3D-printed prosthesis that can allow amputees to walk and throw things, bioprinting allows for the printing of actual body tissues with the stem cells of patients; throughout this article I will discuss how bioprinting came to be, outline some of the obstacles faced in the development process, and present an example of how the technology can aid the medical field.

The discovery of induced pluripotent stem cells- adult stem cells that have been genetically reprogrammed to an embryonic stem cell-like state- means that we can now generate pluripotent cells from accessible tissues in the body. For example, after a knee reconstruction pluripotent cells can be isolated from adipose (fat) tissue in the knee- a material which is usually discarded following this procedure[2]. This advancement in the field of cellular biology has paved the way for bioprinting by providing a supply of patient cells suitable to be incorporated with 3D printed structures.

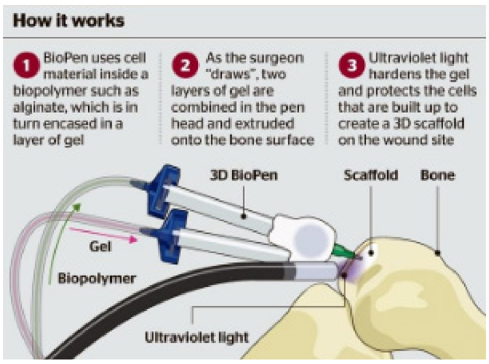
The next hurdle is actually assimilating the cells with polymer structures in order to replicate tissues within the body. One solution to this is hydrogels. These are jelly-like materials widely used for tissue engineering due to their compatibility with cells; many types of living cells can grow happily inside these hydrogels, however, they lack the viscosity and strength to hold their shape after printing. To combat this, multiple-component composite hydrogels, such as alginate (from seaweed) blended with gelatine, have been developed to improve the gel-like characteristics and enable high resolution printing of free-standing hydrogel constructs[3].



The technology used to print living cells was developed by the Biofabrication team at the University of Wollongong in Melbourne, Australia; their idea consisted of extrusion printing (where a material is selectively dispensed through a nozzle) with a co-axial tip- this allowed structures to be fabricated out of multiple materials with the more sensitive component (i.e. the living cells contained within the hydrogel) being encased by a 'shell' material designed to hold the structure together and protect the delicate entities contained within. This technology was then adapted into the operating theatre through the innovation of the BioPen at St Vincent's Hospital in Melbourne, Australia, which is a handheld device allowing free-form bioprinting to be applied in a surgical context. It is fitted with the same co-axial tip, enabling the deposition of living cells and biomaterials in a manual, direct-write fashion[1].



Not only can this manually operated tool allow for surgical sculpting with increased dexterity, the flexibility of in situ biofabrication allows for free-form construction of supplant tissues, providing many advantages over robotically manipulated surgical bioprinters- more cumbersome devices which are harder to sterilise and keep sterile[2].



Articular cartilage- the substance that coats the surface of bones in joints such as the knee- is an example of a tissue that can be engineered through bioprinting (1). There is a substantial need for this kind of critical cartilage repair since there are very few resident stem cells available within articular cartilage; this means that there is little chance of cartilage regeneration once it is damaged. Researchers like Professor Jos Malda at the University of Utrecht in the Netherlands have used the technology highlighted above to create UV- curable biopolymers (where the gel-like fabrication is solidified with UV rays), which have increased scaffold strength 5-fold; they can place this material atop of ceramic scaffolds that support the underlying bone and give the artificial cartilage a fighting chance by preventing crushing in the early phases of implantation (2). Taking this further, extensive research is also focusing on reducing the movement of these scaffolds by fixing them to the surrounding tissue with various biological 'glues'- natural polymeric materials that act as adhesives. With a sustained push to translating these materials from animal trials (currently these scaffolds are widely used in repairing cartilage damage in race horses) to clinical outcomes, cartilage could quite easily become the first mass printed engineered tissue in the coming years.

3D bioprinting is multi-disciplinary in nature: scientists need to be able to communicate with engineers, who must communicate with cell biologists, who must communicate with clinicians (2). Vital to achieving the true potential 3D bioprinting holds for humanity is the effective integration of each of these professionals with their skill sets in order to expand the scope of medical solutions the technology can offer to patients in the years to come.

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Supercritical Fluids and Their Application in Industry
- Elisa Morris, Sydenham High School GDST

In industry today, many manufacturers are struggling to create new materials and products out of more energy efficient material. Due to this, there has been an increase in demand for researchers to explore new ideas for developing material that is better and greener than anything we have accessible right now. More recently, a new material called Aerogel has been developed, which is a very efficient insulator, has a low sound speed, low mean free path for diffusion and is 8x lighter than air. It was discovered in 1930, however it wasn't until the 1970s that it started being developed into industry and now it is used with NASA to insulate its Rover. Its incredible insulation and lightweight properties are due to how it is created. Most types of aerogel are created out of silica, however there are many new different materials for it now, and are combined with a solvent to create a gel. This gel is then molded into a shape and the moisture in the gel is removed. This process allows for the gel to be extremely thin and to almost have no density at all, meaning holding it is an incredibly surreal experience. Although, the only way that the silica-solution gel is able to have the moisture extracted is through a process called supercritical drying, which can be done in three methods but they all require either the solvent or CO_2 to reach above its critical point and become a supercritical fluid.

A supercritical fluid (SCF) is any substance at a temperature and pressure that is above its critical point. At this point, gas and and liquid phases do not exist. This causes the substance to take on a hybrid of properties from both gases and liquids. Such examples of this are that it moves freely through its container like a gas, but with the same density as a liquid. A SCF is also able to dissolve substances like a liquid while also having a diffusivity that is close to a gas and typically, SCFs are also completely miscible with one another.It was discovered in 1822 by Charles Cagniard de Latour Thereafter, a french physicist and the term Supercritical Fluid was coined by irish chemist Thomas Andrews. Interestingly, planets, such as Venus, have such high temperatures and atmospheric pressures that the surface atmosphere is comprised of supercritical fluids. This also applies to Jupiter and Saturn's core, however it is still quite unknown for far off planets such as Neptune and Uranus which have not been explored thoroughly enough. Even the Earth naturally produces supercritical fluids through hydrothermal vents at the bottom of the ocean. These vents get up to 400°C and the fluid that comes out of them is supercritical. The SCF is seen as a black smoke.

Two of the most common types of SCF are SC CO_2 and SC H_2O, however supercritical water damages most substances at its critical point if it were to be used in supercritical drying. Although, the properties of SC water are almost the complete reverse of liquid water, which is quite interesting. While SC N_2O has similar properties to SC CO_2, it is a very powerful oxidiser in its supercritical form, therefore not allowing it to be used in most supercritical drying methods as they would just catch on fire. The reason SC CO_2 is so common is because of its low critical point, its green, therefore non-toxic and non-flammable nature and it doesn't contaminate substances during supercritical extraction. Due to the nature of CO_2, SC CO_2 is also readily available and can be created out of recycling industrial waste. It is used extensively in supercritical drying due to these very reasons and is the main substance used to create aerogel.

There are three main methods used for supercritical drying. The first one requires the actual solvent in the gel itself to be taken above the critical point and vented out of the pores of the gel. This method is quite inefficient as the critical point for the typical solvent used in aerogel is above 200°C and could cause some heat damage to the gel itself. The second method is the most frequently used one. This requires liquid CO_2 to be used to displace the solvent in the silica-solution gel. Once this is done, the aerogel is put above CO_2's critical point and is vented out. This step is done several times to ensure that all moisture is extracted. The final method is the same as the one above, but instead the displacement occurs with SC CO_2. Once this is done, you are left with aerogel. Scientists are trying to use aerogel to line clothing and many other everyday equipment, so the future is bright for new types of materials to be introduced into industry.

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Genetically Modified Organisms
- Liza Filatova, Sydenham High School GDST

A genetically modified organism or GMO is an organism that has modified DNA through genetic engineering or transgenic technology. GMO's are usually altered with DNA from another organism, these can be referred to as transgenic organisms. These organisms are combinations of plant, bacterial, virus and animal genes that can not occur naturally.

A lot of the food we eat on a daily basis is genetically modified, plants such as fruits and vegetables being one of the most common genetically modified organisms. Long before all modification was done in labs, people would mate different plants with attractive traits consistently until the new plant meets the requirements that they were looking for. The most common example of a genetically modified plant is corn. Corn started off as a grass called 'teosinte' with practically inedible grains because of their size, but over the years Mexican farmers managed to transform it into the corn we eat today. This process is called 'artificial selection' and it's made a lot of inedible plants edible such as rice and almonds. Plants are mainly modified so that they can withstand drought and frost, not attract pests and grow faster.

Animals can also be genetically modified but not as much as plants. Cows have been modified to resist mad cow disease and salmon have been engineered to grow larger and mature faster. These modifications are mostly made in favour of human consumption but modifications to male mosquitoes have been made in order to decrease the amount of offspring that reached adulthood in order to try and stop the spread of the Zika virus. A more widely known term for animal modification is selective breeding but this term can be used to refer to plants as well. This is a genetic modification in domestic animals for better growth rate, production of wool, eggs, milk etc. Dogs, such as a greyhound, were bred for their speed and were used a lot while hunting since they could easily chase down an animal while a small Yorkshire Terrier was bred to catch rats in coal mines.

There are many controversial views on GMOs, but are they actually bad for us humans? Eating GM plants is no riskier than non-GM plants and GM animals rarely end up on our plates, but what about plants that have been purposefully made toxic, such as BT plants? BT plants are plants that have been engineered to be able to protect themselves from pests. These plants have toxins in their cells that destroy the digestive systems of insect pests and therefore killing them if they were to eat the plants. Some farmers use pesticide sprays on their plants, which can be washed off while the toxin in BT plants is inside the cells. These toxins have no effect on humans, they kill insects, but are completely harmless to us. This also goes the other way, there are plants that have been modified to be resistant to specific herbicides. This leads farmers to spray herbicides everywhere on their land without the fear of killing any of their useful crops. Over 90% of crops in America are resistant to the herbicide, mainly to glyphosate so its usage has greatly increased which led to greater profits for the pesticide industry. It isn't particularly harmful to humans but has led many farmers to stick to that one method rather than using more balanced ways of managing weeds. That is the biggest problem with GM plants since this particular method isn't very sustainable and GM's are there to help minimise our impact on the environment.

In conclusion, GMOs are very helpful and could be our greatest weapon against climate change. Using GM plants to intensify agriculture rather than expand it could stop deforestation, and by modifying plants to collect even more carbon dioxide we can reverse climate change altogether. Another example is the use of nitrogen as a fertiliser, which pollutes groundwater. Scientists are working on plants that can draw nitrogen from the air like microbes and by having plants collect their own nitrogen they'd be fixing two problems at once. As for the future, scientists are working on GMOs that could improve our diet, but that's only the beginning. With all the tools we have today, our imagination is the limit.

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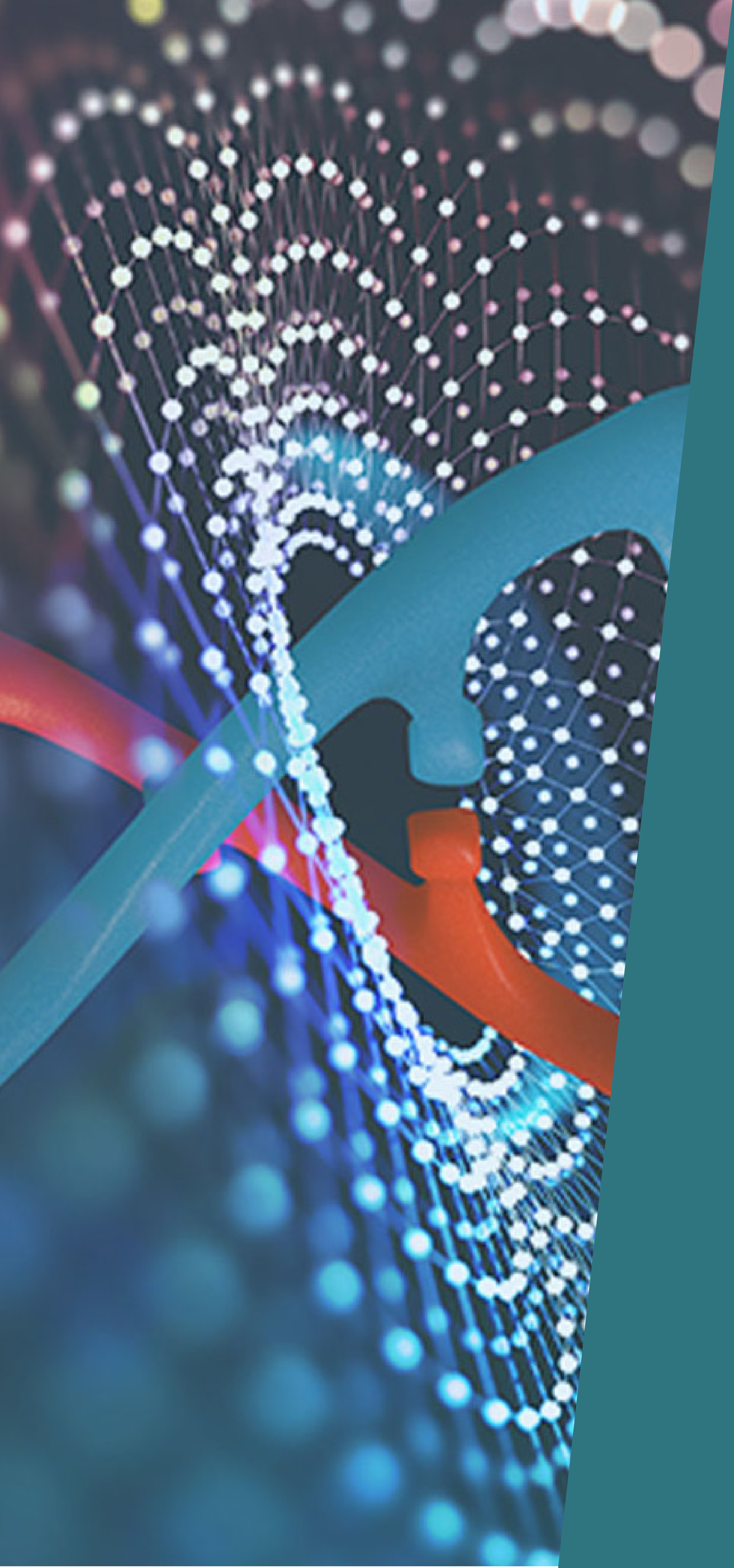

UNDER 18
ENGINEERING
ESSAYS

“CRISPR-Cas9 has the potential to solve all of society’s problems.” Do you agree?
- Megan Leung, Newcastle High School for Girls

First successfully utilised for editing the human genome in 2013, CRISPR-Cas9 is often cited as one of the most significant revolutions in biomedical research of the past decade. Indeed, it is likely that it will continue to play a crucial role in the genomics of the future, given the potential versatility of its technology in medical treatments, plant engineering and antibiotic research. Yet whilst the applications of CRISPR-Cas9 cannot be ignored, it is clear that they have also encountered much controversy within the scientific community, particularly regarding the ethical and safety risks surrounding proposed methods of utilising this tool. Evidently, these issues must be addressed to ensure the viability of this technology in research.

CRISPR-Cas9 is comprised of two components, the first being a piece of guide RNA, which is used to bind to DNA as well as guide the second component, the enzyme Cas-9, to the part of the genome selected for editing. Using the complementary base-pairing of the RNA and DNA sequence, the complex is easily and precisely targeted to modify, correct or delete DNA by binding to parts of the sequence and cutting them, theoretically enabling parts of the genome to be edited with no other regions affected.

Consequently, it seems that CRISPR-Cas9 could revolutionise the treatment of a huge range of diseases, including inherited genetic conditions such as cystic fibrosis, as well as blood disorders and cancers. Whilst some previous attempts to correct disease-causing mutations were promising, others resulted in devastating effects on patients, including severe immune responses and cancer. Subsequently, it has become clear that gene-editing technology must be highly specific (so as to prevent mutations), a requirement which the CRISPR-Cas9 process fulfils. Indeed, CRISPR technology appears to be applicable for the modification of the virtually any genome, including that of plants and animals. Thus, its potential appears to be endless.

However, this is not to say that CRISPR-Cas9 is immune to criticism; in 2018, a study published in Nature Biotechnology indicated that CRISPR had the potential to unexpectedly modify non-target sections of DNA, possibly causing harmful mutations, particularly if these changes were genes linked to cancer. In the same year, Chinese scientist He Jiankui provoked worldwide condemnation, when it emerged that he had manipulated the genomes of two girls using CRISPR-Cas9 in order to induce HIV resistance, a practice forbidden by international law as it involves the modification of human embryos intended for pregnancy. In effect, he had facilitated the creation of gene-edited babies, who could then pass on their edited characteristics, both known and unknown, for better or worse, to future generations.

He’s work highlights the importance of international collaboration to ensure the regulation of CRISPR-Cas9 technology, as well as the need for robust testing systems to check for unwanted genetic mutations. Studies are already underway using cell-free systems in order to identify unintended changes to regions of DNA and increase the safety of any future treatments carried out. Having recognised the promise of CRISPR-Cas9 treatments in laboratories, it seems that a blanket ban on genome editing, based on the fears surrounding “designer babies” or mass genetic modification, would not be the most effective solution, especially given the huge potential of the tool. Whilst we should be aware of the risks, and cautious in our approach, the future seems bright for CRISPR-Cas9.

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Synthetic Biology: Cancer's Potential Cure?
- Lia Bloch, South Hampstead High School

'The technology of synthetic biology is currently accelerating at four times the rate of Moore's law. It's been doing that since 2005, and it's likely to continue.' - Stewart Brand (February 2013)

And it has.

This past decade has seen multiple breakthroughs in the field of synthetic biology: a terrifyingly thrilling initiative that aims to "create life from scratch", to "make life better" and to "make biology easier to engineer".[1] Standard biological parts can be put together in unnatural combinations in order to fulfil almost any function imaginable; almost like in an electrical circuit. Our wildest dreams can become a reality, and for many of us, this dream is to emerge victorious from our vicious, bloody, and seemingly ceaseless war against a truly merciless foe: cancer.

Fortunately, new weapons are already being honed in preparation for battle.

In July 2016, researchers at the University of California San Diego and the Massachusetts Institute of Technology devised a promising new strategy for the use of synthetic biology in therapeutics. Their approach involves engineered bacteria, which allow the continual production and release of cancer drugs at tumour sites in mice. Simultaneously, the size of these bacteria populations is limited, as they then self-destruct.[2] "It's basically a kamikaze mission," said UC San Diego bioengineering and biology professor Jeff Hasty.[3]

In order to achieve this, Hasty and his team synchronised the bacteria to release bursts of known cancer drugs whenever a bacterial colony self-destructed within the tumour environment. The use of bacteria to deliver cancer drugs in vivo is especially enticing, as conventional chemotherapy doesn't always reach the inner regions of a tumour - this is due to the fact that these regions have no blood vessels.[3] In contrast, bacteria are well-equipped to live in the anaerobic environment within a tumour, thus rendering them the perfect tumour-destructing tool.

In a tantalisingly momentous conclusion, the researchers observed that the combination of chemotherapy and the genes produced by the bacterial circuit consistently reduced tumour size.

A more recent act of cancer-defiance (May 2019) has been undertaken by researchers at the Stanford University School of Medicine. According to this study, synthetic proteins engineered to recognise overly active biological pathways can kill cancer cells while sparing their healthy peers.[4]

The customisable approach, which the researchers call RASER, relies on just two proteins: the first is activated in the presence of an 'always on' growth signal often found in cancer cells, and the second carries out a researcher-programmed response.

Although the experiments were confined to cells grown in the laboratory, the researchers believe that the results could lead to a new form of cancer therapy; perhaps one in which synthetic proteins deliver highly targeted and customisable treatments, in order to avoid the sometimes devastating side effects of current options.

"We're effectively rewiring the cancer cells to bring about an outcome of our choosing," said Michael Lin, MD, PhD, associate professor of neurobiology and of bioengineering. "We've always searched for a way to kill cancer cells but not normal cells. Cancer cells arise from faulty signals that allow them to grow inappropriately, so we've hacked into cancer cells to redirect these faulty signals to something useful."[4]

However, studies like Hasty's are not the end of innovative new ventures into synthetic biology. This is clearly illustrated by MIT professor Jim Collins, who is in fact known as one of the founders of synthetic biology: "The new work by Jeff Hasty and team is a brilliant demonstration of how theory in synthetic biology can lead to clinically meaningful advances".[3] These results are truly meaningful, and should not be taken lightly. Concrete steps have been taken in our long-standing fight against cancer, paving the way for many more to come.

In 2016, more than 350 companies across 40 countries were actively engaged in synthetic biology applications. This field clearly carries immense potential, and to our great fortune, it is no longer a science-fiction fantasy. We have to take advantage of this remarkable opportunity: the opportunity to redesign nature, create new life and treat severe, life-threatening diseases. We can make a significant difference in the scientific community, and perhaps even in society as a whole.

We will cure cancer.

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The use of Intensity Modulated Radiotherapy (IMRT) to treat cancer
- Beatrice Frediani, Wimbledon High School

In November 1895, German physicist Wilhelm Rontgen and his wife Anna are experimenting with the effects of electricity on gases (NobelPrize.org, 1967). They found a new type of radiation that can travel through certain substances (such as flesh), but not others (such as bone). And just like that, Anna's left hand becomes the first ever x-ray image to be printed (NobelPrize.org, 1967). Over time, interest in x-rays grows and it is discovered that x-rays can damage the skin if repeatedly exposed to the rays. And so were formed the foundations for modern external radiotherapy.

Today, 40% of those diagnosed with cancer use radiotherapy as part of their treatment, with 134,000 courses of radiotherapy given each year (Teenagecancertrust.org, 2014).

Radiotherapy can be administered in two forms: external and internal. External radiotherapy is more commonly used, and has traditionally involved very focussed, high energy photons (x-rays) being projected as beams of radiation by a linear accelerator to specific parts of the body (Cancerresearchuk.org, 2017). These x-rays enter the tumour and damage the cells' DNA by causing breaks in the strands of genetic material. Cancer cells cannot effectively repair this damage and thus die off. Internal radiotherapy also kills cancer cells through damaging the DNA by using radioactive sources introduced into the body either as liquids or through surgery.

The main aim of external radiotherapy is to 'get to' all areas of the tumour and inflict maximum damage to it. This means that external radiotherapy works with margins around the tumour to ensure that all of it is radiated and destroyed. The collateral damage of using these margins to try to get at all of the tumour is that the DNA of healthy cells is damaged (Teenagecancertrust.org, 2014). This is usually not irreparable as, unlike cancer cells, healthy cells are able to repair their DNA and thus do not die. However, there is a larger risk in young people who are still growing that beams in the margins of the tumour could affect healthy cells and cause other cancers in the future. In order to minimise this risk, new techniques are being developed to provide a more accurate and safer practice of radiotherapy (Nature.com, 2018).

Tumours are as different as the people they affect, so surely the radiotherapy used to treat them should be as specific as possible. This is where Intensity-modulated Radiotherapy (IMRT) comes in. This technique involves the radiation beam (made up of photons or protons) passing through metal leaves that slide to make different shapes in a multileaf collimator inside the radiotherapy machine. The result of this is a variation of the intensity of radiation depending on the target part of the tumour, meaning that healthy tissue (especially near to vital organs) gets a much lower dose (NCBI, 2004).

In this way, IMRT offers a much more individualised treatment, whilst remaining effective, by giving the correct dose of radiation to the right part of the tumour. This treatment reduces the need for operations on the head, neck and other sensitive parts of the body as is able to be precise in killing cancer cells, decreasing physical scarring and possible psychological damage (Cancerresearchuk.org, 2017). Because of its limited negative impact on healthy cells, IMRT has allowed large numbers of tumours to be reduced in size or cured which in the past would not have been able to be treated. This is shown by a study conducted by Professor Faivre-Finn. He studied 9,000 lung cancer patients treated with radiotherapy from 2005-2015 (Cancerresearchuk.org, 2017). Before the introduction of IMRT in 2008, the number of patients given radiotherapy to cure was 39 in 100. However, from 2009-12, this number rose to 59 in 100 patients (Cancerresearchuk.org, 2017). This shows the impact IMRT has had on patients who would previously have been given only end of life care or low doses of radiotherapy. For patients with terminal cancers, IMRT means that the cancer can be controlled for longer, therefore the patient will experience fewer symptoms and have an improved quality of life for longer.

It's fair to say therefore, that IMRT is improving every individual patient's treatment and quality of life; and with many new clinical trials (for example SCALOP-2 looking at the use of IMRT for treatment of pancreatic cancer), (Pancreaticcancer.org, 2018) being carried out, the future of IMRT is set to revolutionise radiotherapy and cancer treatment.

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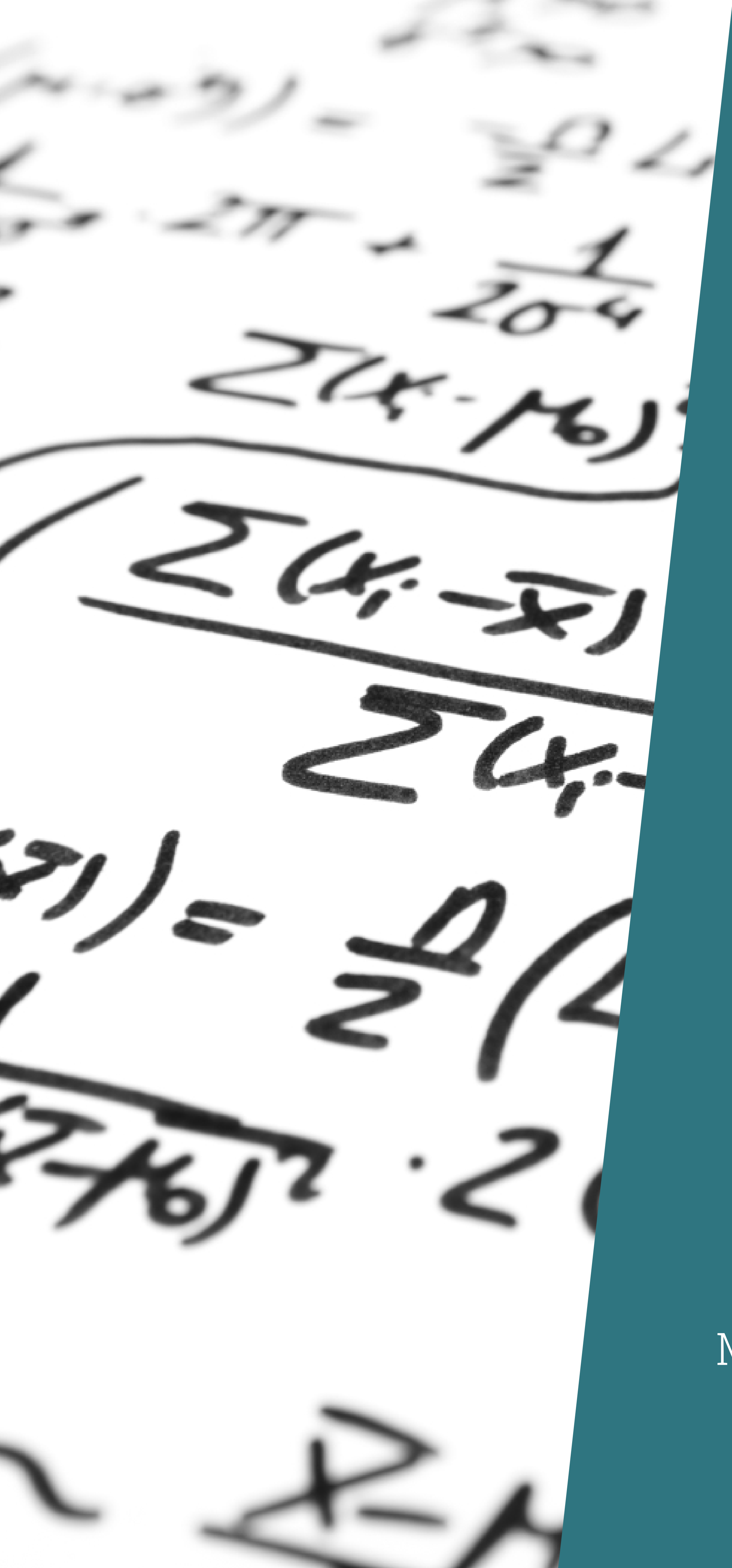

UNDER 14
MATHEMATICS
ESSAYS

The History of Algebra
- Rumaysa Peerbhai, Shrewsbury High School

Every child spends five long years of their life expanding brackets, solving x or finding a reciprocal and in those years, they must've wondered during this time how this information could ever be useful to them later on in their life.

The truth is that the facts we all learn in this subject might not ever be needed for us in the future. However it is the skills that we acquire in this lesson that will help us immensely. During our maths lessons we learn how to think logically and solve a problem step by step. This way of thinking can help us solve our problems in the future.

Students must've also pondered over the fact that someone extremely intelligent must have invented this. Take algebra for example, we are racking our brains trying to make sense of the whole thing when there are people who have fabricated this from nothing which is perplexing.

So, who is this highly intelligent person who devised algebra?

Well, there were many people who contributed to this discovery; however there were some special people who played very important roles in it, such as a gifted man by the name of Al-Khwarizmi. This man made perhaps one of the most significant changes to Arab mathematics. This man came up with the foundation of algebra. This invention had an extremely crucial significance to the Arabs being that it was a revolutionary move away from the Greek concept of mathematics which was essentially geometry. This invention gave mathematics a whole new development path which gave a much broader concept to what had existed before. It also allowed the Arabs (and the rest of the world) to develop their daily lifestyle due to the fact that Businesses have to use algebra to finance day-to-day operations as well as long-term investments , like building a new factory.

Al-Khwarizmi was a Persian scholar who spent most of his academic life within the city of Baghdad. He produced work in mathematics, astronomy and geography. He was so good at his job that around 820 CE he was appointed as the astronomer and the head of the library of the 'House of Wisdom' in Baghdad. During his lifetime Al-Khwarizmi had constructed a number of books. Within this he had also wrote a biography which is why we know so much about his life and how it helped to make such a life-changing discovery.

After the Muslim Conquest of Persia, Baghdad grew to be the centre of scientific studies and trade, so with all of these resources Al- Khwarizmi decided to spend his time studying science and mathematics. Al –Khwarizmi was a very logical person and when something didn't make sense, he thought about it hard until he was satisfied. This skill played an immense part in discovering algebra.

Al – Khwarizmi had an aim to solve linear or quadratic equations by a process of balancing both sides of the equation. After some time he accomplished this which made further bits of maths more logical which lead on to more discoveries.

Not only did Al-Khwarizmi discover algebra, but he was also responsible for tweaking the Hindu-Arabic numerical system and then disclosing it throughout the Middle East and Europe. Furthermore Al-Khwarizmi systematised and corrected Ptolemy's data for Africa and the Middle East. (Ptolemy was a Greek mathematician who lived under the rule of the Roman Empire) The Ptolemaic system was that the earth stood in the centre of the universe and the rest of the planets revolved around it. This geocentric view was declined by many however some people were religiously passionate about this theory to the point that many books were made on this debate. This supposition didn't make sense to Al-Khwarizmi so he did some research and modified this theory to a closer version of one we all know today. Along with this considerable contribution to our knowledge Al-Khwarizmi assisted a project to determine the circumference of the earth and making the world map. He unfortunately did not succeed however his efforts helped to find the answer much quicker.

The life of Al-Khwarizmi and how he helped evolve our day-to-day activities, shows us that if we really think that we can change something, then you should try your hardest to do so and if you don't succeed, your efforts will help someone later on.

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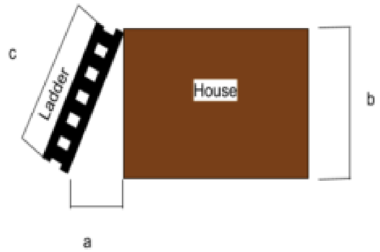
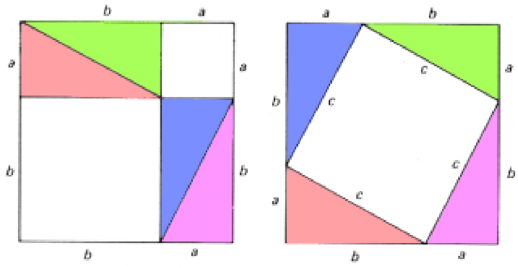
Pythagorean Theorem: Who Discovered It?
- Robby Marshall, The American School in London

Today Pythagoras is one of the most known mathematicians, his name known by students who don't even understand his theorem. The Pythagorean Theorem, states that $a^2 + b^2 = c^2$, where "a" and "b "are the two legs and "c" is the hypotenuse of a right triangle. This theorem is commonly used in architecture and is especially useful when building sloped surfaces.

Born on the island of Samos, Greece in 569 BC, Pythagoras was a Greek mathematician. It is known that he lived between 560 BC and 490 BC. (Huffman, C., 2018) At the age of forty, he moved from Samos to Cronton, Italy. As well as being a mathematician, he was a cosmologist. Pythagoreanism was a system of teachings and beliefs. (Ratner, 2009) A religious school believed to be founded by Pythagoras taught both religion and maths. (britannica.com) Pythagoras later died in Metapontum. The Pythagorean Theorem assists people in determining the length of the hypotenuse or longest side of a right triangle. "Architects and engineers use this formula extensively when building ramps."(5) In addition, the Pythagorean Theorem is "frequently used in architecture, woodworking, and other physical construction projects." (Zamboni, 2018)



One can even use the Pythagorean Theorem to determine something as simple as the necessary length of a ladder. In this example shown to the left, the distance from where the ladder meets the ground to where the house meets the ground would be "a", the height of the house would be "b" and the length of the ladder would be "c". To find "c", square the length of side "a" and add that to the square of side "b". Then, take the square root of the total. This provides the necessary length of the ladder (side "c").



One proof of the Pythagorean Theorem is shown in this diagram of two squares. (Elkouri, 2013) This image proves the Pythagore-an Theorem because the side length of each of the big squares is equal to a+b. Therefore, the squares are equal in area. The four coloured triangles in each diagram are also identical. After subtracting the area of these triangles from the area of the square, what remains in the left diagram is one square that represents a^2 and another that represents b^2. If one looks at the white area in the left diagram, the two small white squares together show $a^2 + b^2$. When looking at the diagram on the right, the white area represents c^2. The large squares are identical. The space subtracted from them is identical. Therefore the remaining white space is identical and, $a^2 + b^2 = c^2$. The converse or opposite of the Pythagorean Theorem states that if in a triangle $a^2 + b^2$ equals c^2, then the triangle is a right triangle. This is used when one has all of the sides of a triangle and wants to test if the triangle is a right triangle.

The Pythagorean Triples are numbers such as 3, 4 and 5. These triples, when on the sides of a triangle make it easy to identify a right triangle because a triangle with side lengths of 3, 4 and 5 is always a right triangle. Further, if you multiply any set of Pythagorean Triples by the same number, then you again have a Pythagorean Triple. One example of this is multiplying 3, 4 and 5 by 20 to get 60, 80 and 100. Just as 32 + 42 = 52 , it is also true that 602 + 802 = 1002. With the existence of the Pythagorean Theorem, Converse to the Pythagorean Theorem, and Pythagorean Triples, one would assume it was Pythagoras who discovered these ideas. However, "the Babylonians were familiar with the Pythagorean Theorem." (Ratner, 2009) Others believe the idea was more wide-spread. There are an abundance of ideas as to the true source of the Pythagorean Theorem. "Ancient cultures, including the Babylonians, Vedic Indians, and Chinese, all proved the beloved [Pythagorean Theorem] long before the Greeks." (Barry, 2013) The most compelling argument of all is made by Dr. Manjul Bharagava. "A document that explicitly states the Pythagorean theorem -- the geometric theorem... first occurs about 800 BC in India." (7) If it was used by the Babylonians, Vedic Indians and Chinese, logic dictates that one of the most known names in mathematics may not have been the first to prove his own theorem. In fact, there is no evidence of Pythagoras ever proving the theorem at any time.

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The history of maths and computer science
- Piper Lauder, Chislehurst School for Girls

Ada Lovelace produced the first computer program along with aiding Charles Babbage in his discoveries of the Analytical Machine. 1833 was the year in which Ada met Charles Babbage knowing him by being famous for his calculating machine. In 1842 Ada Lovelace translated the logic behind Charles Babbage's Analytical Engine into the first known algorithm. This concluded in him having thought of her with very high capabilities due to the fact she used his descriptions to create the algorithm. This was significant to a great extent as in the Victorian Era, women were not seen as having the ability of thinking so mathematically and equal to a man. Such as Augusts De Morgan, who was Ada's mathematics tutor at a young age, who had claimed in a letter to her mother that "the very great tension of mind they require is beyond the strength of a woman's physical power of application."1 This quote stands to say that women did not have the physical brain power to think logically and solve equations in maths. However, he later contradicts himself by stating "Lady L has unquestionably as much power as would all the strength of a man's constitution"2. This proves to the population of his era that women's logic and brain holds the same achievement as men's. For a woman in this age, this shows true potential in her work, however, if there was equality in society, maybe Lovelace could have been recognised for more than being considered as Babbage's 'apprentice' and 'student' but rather than the first women who created an algorithm and stood up for what she knew she was capable of.

During the Victorian Era, a women's role was to stay at home, take care of the children and cook the food. This was one of the reasons why she did not become recognised during this time period as everyone else overlooked her and disliked as she stepped out of the patriarchal view on society. In spite of this, in the 21st century, without Ada Lovelace's coding, programming and true passion for mathematics, we would not have the basic structure of a computer, nor a basic understanding of algorithms. You may think why Ada Lovelace did not become popular during the 19th century due to her outstanding knowledge and progress to computer science, but another contributing factor to why is because Babbage rarely spoke of her after her death. If her name was spoken and included within the credits of the Analytical engine, she would have been more recognised and reversed her untold story due to the progression within computer science.

Ada had proved that there were countless ways to code and if she had lived longer, her achievements could have increased significantly and with her knowledge more facts could be contributed to the study of STEM and especially women within the subjects too. Her inspiration has lived on through an international day in October to thank her knowledge and courage but to also show what she had accomplished in the 19th century that was not really recognised everywhere.

Have you ever experienced that problematic feeling when our maths teacher tells us it is a non-calculator test? Do you know how much you rely on a calculator? Can you imagine a life without one? However, these times give us that insight and understanding of when it was before Ada Lovelace designed and created , along with Charles Babbage, the Analytical Engine. A world dominated by men yet Ada Lovelace proved her skills by standing up for what she believed in and never gave up trying to prove to men that she had an equal mindset and capability as they do.

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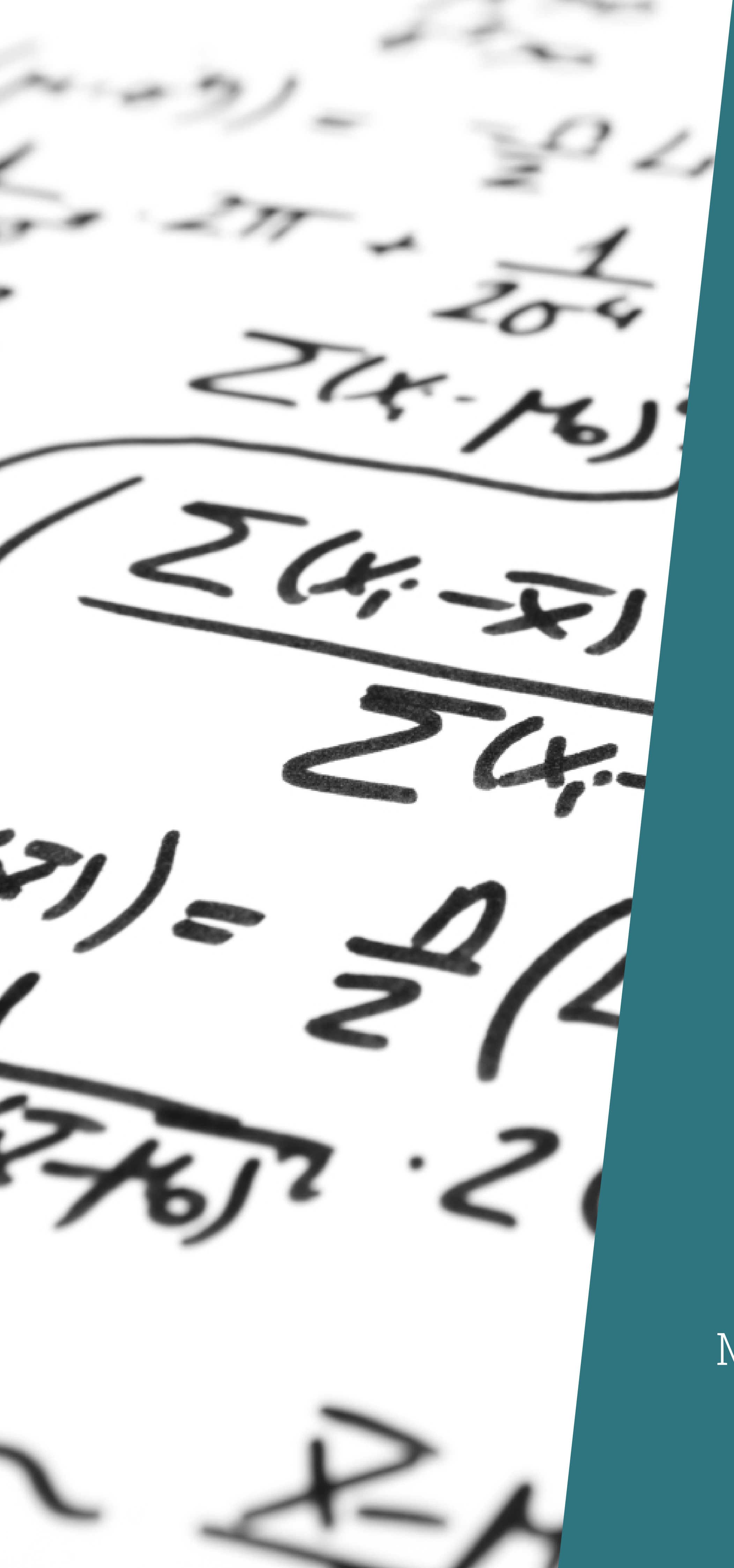

UNDER 16
MATHEMATICS
ESSAYS

Magical 9
- Kiki Wang, Streatham and Clapham High School

The world of number is incredible and amazing. Pythagoras, a well-known mathematician said that 'All is number' implying that numbers are the root of all things. The number 9 has many interesting qualities which other numbers do not have and making it particularly special.

If we just look at 9 itself, we can think of many magical facts that are related to it. To be more specific, in the decimal system, 9 is the largest one-digit number and the largest composite number in a one-digit number. Also, 9 is the smallest odd composite number and it is a perfect square. Furthermore, the multiplication about 9 is quite interesting. 9×9=81, 99×99=9801, 999×999=998001, 9999×9999=99980001 and so on. Forming a regular pattern. However, there are much more incredible …… about 9.

Firstly, if all the digits of the dividend add up to a multiple of 9, then the dividend is divisible by 9. For instance, 3744 can be divided by 9 because 3+7+4+4=18 which is the multiple of 9. As for the reason why this rule works for 9, we can rewrite the number 3744. 3744=3×1000+7×100+4×10+4. It is equal to 3×(1+999)+7×(1+99)+4×(1+9)+4×1. Expanding it, we will get 3+3×999+7+7×99+4+4×9+4=(3×999+7×99+4×9)+3+7+4+4. The stuff in the bracket (I.e.3×999+7×99+4×9) is definitely divisible by 9. So we just need to look at the other stuff (I.e.3+7+4+4). If the sum of them (3+7+4+4) is divisible by 9, then the original number (here it's 3744) is divisible by 9. And we can notice that they are the same as all the digits of the original number. So this is how this rule is formed.

Secondly, for the numbers that are not divisible by 9, the remainder is the sum of all the digits of the new number that we get from adding all the digits of the dividend together. For example, 2344 can't be divided by 9 because 2+3+4+4=13 (13 is not a multiply of 9). By using the rule that I mentioned before we can quickly figure out the remainder of 2344, which is 1+3 =4.

Thirdly, the difference of any two arrays with the same numbers, the same number of digits, but different permutations can be divided by 9. For instance, 947-749=198 and 198 is divisible by 9.

In addition, when we add all the numbers that composing the Arabic numerals except 9 which are 0,1,2,3,4,5,6,7,8 together, we will find that 0+1+2+3+4+5+6+7+8=36 and 3+6=9. In contrast, adding 9 to any non-zero natural numbers, the sum of all the digits of the new number that we get by doing this is equal to the sum of all the digits of the non-zero natural number itself. For instance, if we have a natural number---48 and we add it to 9, then we get 48+9=57 and it's easy to notice that 5+7=4+8. It's even more special for non- zero natural numbers that are less than 10 (from 1 to 9) such as 7. If we add 9 to 7, we will get 16 and 1+6=7 (it's equal to the original number!). From these, there is a saying that 'actually, nine is equal to the sum of all the basic numbers that composes the Arabic numerals and nothing'.

The angle around the centre of the circle is 360 degrees and 3+6+0=9. When we divide the circle equally to form two semicircles, we will find that around the centre of the circle, there are two angles of the same size which is 180 degrees and 1+8+0=9. Similar, when we divide it again, we will find that there are four angles around the centre and each of these are 90 degrees (9+0=9). Similar things happen if we divide the circle less than 6 times.

What impresses me the most is that in polygons there is a really mystical regular pattern about the angles. For the smallest polygon---triangles, we know that the sum of their interior angles is 180 degrees and 1+8+0=9. For the quadrilaterals, the sum of their interior angles is 360 degrees and 3+6+0=9. For the pentagons, the sum of the interior angles is 540 degrees and 5+4+0=9. Similar things happen to all the polygons: the sum of all the digits of the number that we get from calculating the sum of all the interior angles is equal to 9.

Nine is the most intriguing number as they are many 'coincidences' about this natural number in mathematics.

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The proof behind one of the most famous theorems in mathematics
- Vishaali Ramesh, Wimbledon High School

What is the difference between a theorem and a theory?

A theorem is a mathematical statement that has been proven on the basis of previously established statements (Ask Difference, 2020). For example, Pythagoras' theorem uses previously established statements such as all the sides of a square are equal, or that all angles in a square are 90°. The proof of a theorem is often interpreted as justification of the statement that the theorem makes.

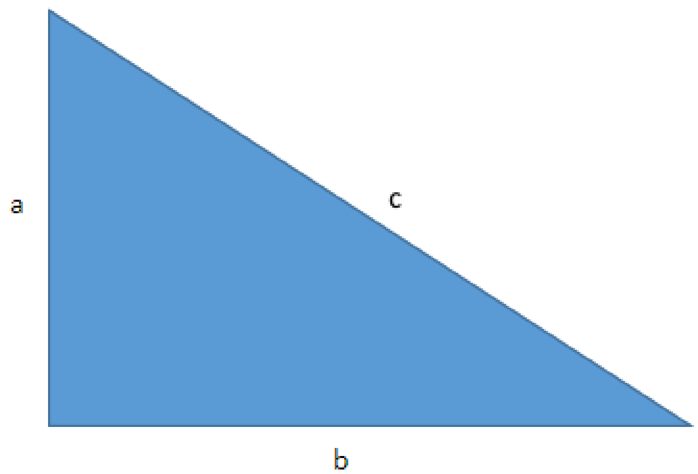
On the other hand, a theory is more of an abstract, generalized way of thinking and isn't based on absolute facts (Ask Difference, 2020). Examples of theories include the theory of relativity, theory of evolution (Than, 2018) and the quantum theory. Take the theory of evolution, it's about the process by which organisms change over a time as a result of heritable behavioural or physical traits. This is based on undeniable true facts, but more from experience and from an abstract way of thinking. It is also important not to confuse mathematical theorems with scientific laws as they are scientific statements based on repeated experiments or observations, such as the Law of Reflection (Boyer, 1946).

The proof behind Pythagoras' theorem:

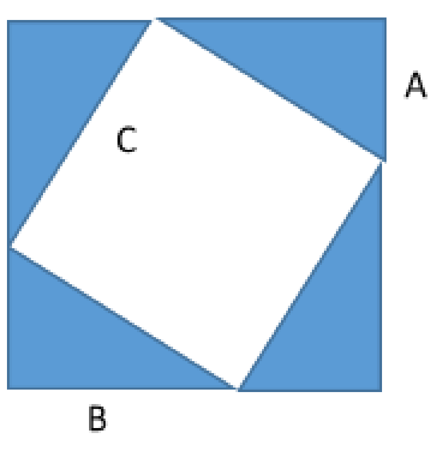
You have probably all heard of Pythagoras' theorem, one of simplest theorems there is in mathematics that is relatively easy to remember. Given that it's so easy to remember and learn, wouldn't it be an added bonus to know exactly how this theorem came to be?

The theorem, $a^2+b^2=c^2$, relates the sides of any right-angled triangle enabling you to find the lengths of any side, given you have the lengths of the other two.

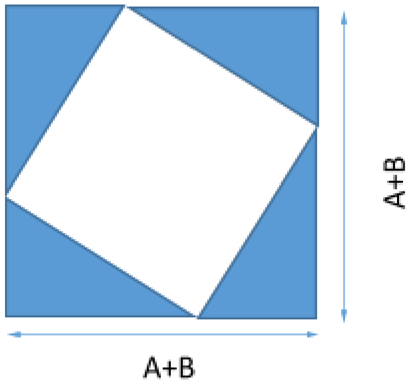
This whole theorem is based on a triangle like this:



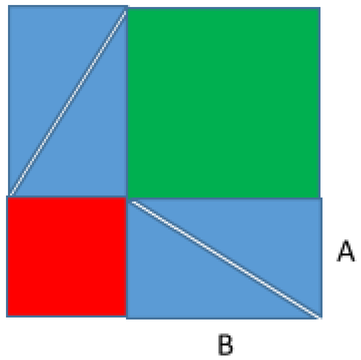
These four right angled triangles are exactly the same just rotated slightly differently to create this shape:



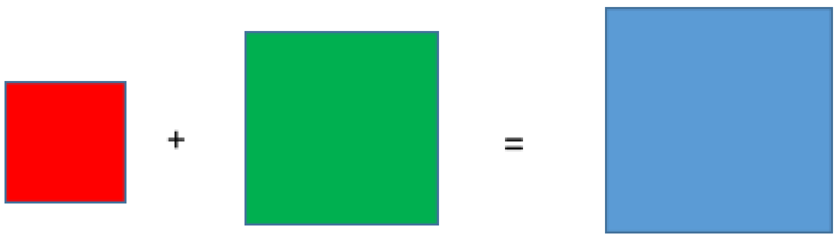
Two shapes have been made by putting these triangles in this order. A big square on the outside, and another slightly smaller square in the middle. As all these triangles are exactly the same, you can label them A, B and C. You can tell from the labels the triangles have been given that the bigger square would have the sides (a+b), and the smaller triangle in the middle will have sides of c. Therefore we know the area of the smaller square is c^2.



Using the exact same four triangles, we can rotate and translate them to create a slightly different shape:



Now two more squares have been added to this shape. We can call them a^2 and b^2.
Thinking back to the shape we made before, we can also see that the length of this shape is also (a+b). As we know we used the same four right angled triangles for the shape before and now, we can infer that the two squares a^2 and b^2, are exactly the same as the square from the first shape, c^2. Hence we get Pythagoras' theorem, $a^2+b^2=c^2$.



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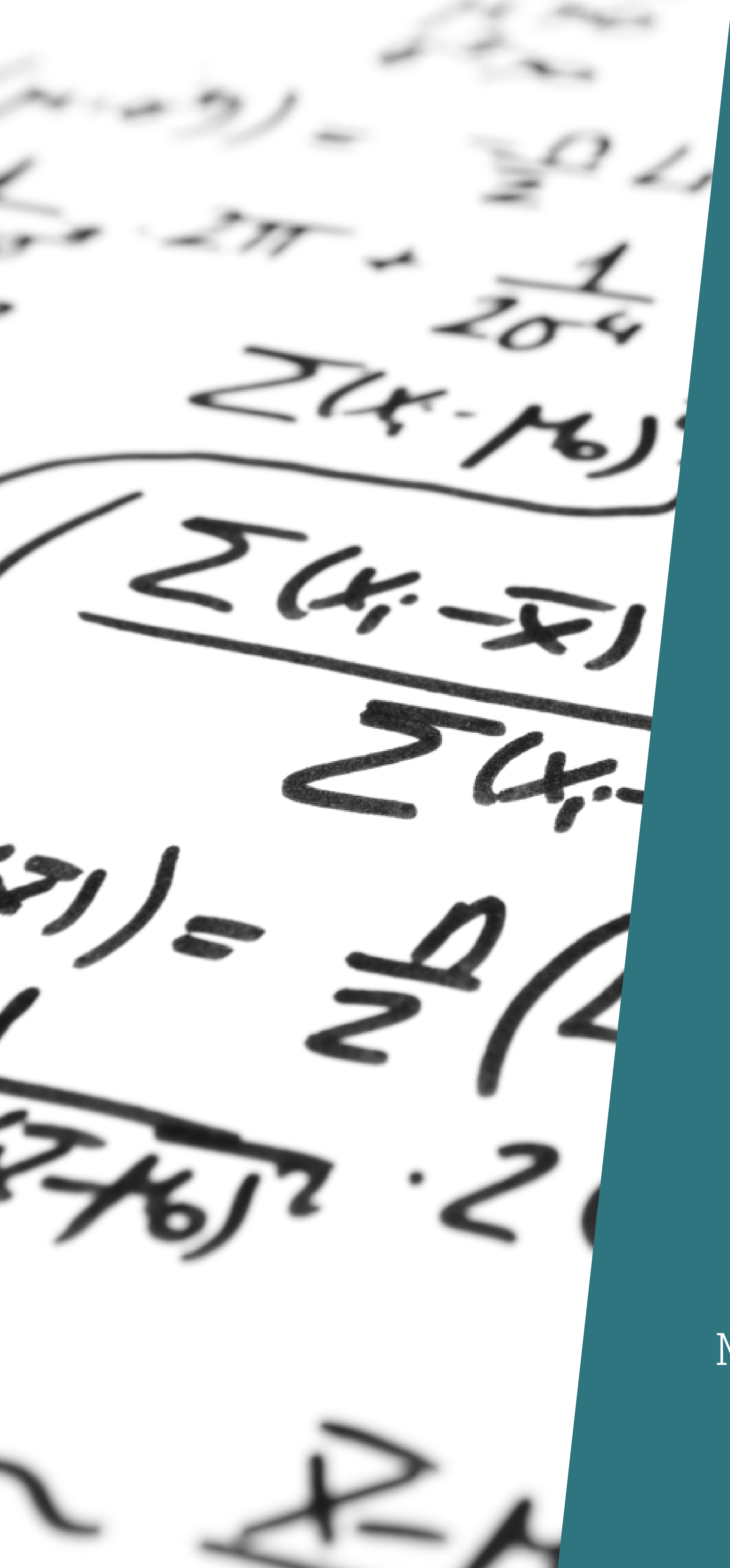

UNDER 18
MATHEMATICS
ESSAYS

Magic, Madness, Maths: A Curious Combination

- Joely To, Streatham and Clapham High School

The world of mathematics was in turmoil. Current and controversial, the new concepts of imaginary numbers and non-Euclidean geometries seemed incredibly far away from the physical reality of arithmetic and proofs. For a particular English mathematician named Charles Dodgson, such abstract contemporary ideas of the 19th century were "semi-logical". Thus, he decided to combine fact with fiction and math with myth: by creating his own nonsensical fiction world, he could mock the new radical ideas by revealing their absurd conclusions. Perhaps better known as Lewis Carroll, Dodgson used this technique based on Euclid's proofs, reductio ad absurdum, to create a mix of mad hatter maths. The result? Alice's Adventures in Wonderland.

Having fallen down a rabbit hole into a wonderland of hidden maths, Alice eats a cake that reduces her height to three inches. Smoking a hookah pipe, the Caterpillar comes in with a mushroom to restore her size. However, Alice must eat exactly the right amount to return to the correct proportions, given that different parts of the mushroom either stretch or shrink various body parts. This scene arguably symbolises Dodgson's ridicule of symbolic algebra, which allows "absurd" calculations with negative and impossible solutions. Taking a closer look at the Caterpillar's pipe, "hookah" is, like "algebra", of Arabic origin; the first Arabic translation of "algebra" was in fact "al jebr e al mokabala" (De Morgan, 1849) meaning "restoration and reduction" – which is exactly what Alice experiences. Alice seeks restoration of her size, yet encounters reduction. This is a striking parallel to De Morgan's proposition: "reduce" algebra from universal arithmetic to symbolic operations, in order to "restore" the significance of symbolic algebra.

The madness of this mathematical wonderland only becomes "curiouser and curiouser", as Alice notes. The next chapter, "Pig and Pepper", describes the kitchen where underneath the action a geometry parody is at play. In this scene, the Duchess gives Alice her baby who suddenly transforms into a pig, which represents Dodgson's derision of projective geometry. In particular, this concerns the "principle of continuity", defined by its French inventor Jean-Victor Poncelet as the idea that for geometric figures undergoing a continuous transformation, as long as there are no sudden changes, "the same property will belong to all the successive states of the figure". An example of this would be two intersecting circles. By solving their equations simultaneously, two distinct points of intersection are obtained. The principle claims that this property will be preserved with any continuous transformation, such as moving the circles' centres apart. Even when the circles no longer touch, they will still intersect twice, but the solution will include imaginary numbers where i is $\sqrt{-1}$. Dodgson presents a geometric figure in the form of a baby, turning it into a pig through the continuity principle. Indeed, most of the baby's original features stay the same, as should an object under a continuous transformation.

By describing the Hatter's tea party, Dodgson explores the breakthrough discovery of quaternions in 1843 by William Rowan Hamilton. Quaternions are a number system based on four terms which enable mathematicians to calculate rotations. With three terms (one for each dimension of space), Hamilton could achieve rotation in a plane, but could only speculate that the fourth term was the concept of time, which would allow a three-dimensional rotation. This is mirrored at the tea party where Alice sits with three characters: the Hatter, the Dormouse and the March Hare. Dodgson uses these characters to represent three terms of a quaternion, where the fourth term – portrayed as the character Time – is missing. This only allows plane rotations, symbolised by the characters continuously circling the table. With quaternion multiplication being non-commutative, $x \times y$ does not equal $y \times x$ which is reflected in the characters' exchange. The Hare tells Alice to "say what she means", to which she replies, "at least I mean what I say", which the Hatter says is "not the same thing". A contradiction to basic arithmetic, non-commutative algebras arguably seemed even more absurd to Dodgson than symbolic algebra.

If we look through the looking glass carefully enough, we discover a whimsical wonderland of magic, madness and maths. What would remain of Alice's Adventures in Wonderland without this curious combination?

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Math in Daily Life

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Nowadays, the use of mathematics in daily life is becoming increasingly popular. For many people, especially students who study math, learning how to be flexible manipulating mathematical problems is a helpful skill. Flexible math means a principle can be used in many kinds of difficulties. However, most people including me, do not know how to really do this. In this essay, I will explore how we can develop flexible math thinking.

Let us begin by looking at how to do math. When I was a little girl, I was taught by my father "math is a visual discipline". This opened the door to a new world for me. First of all, math is not an abstract number game. Everyone cannot do math just through remembering forms and steps about solving questions, it has to become more intuitive, to avoid getting incorrect results, which will be discouraging.

Secondly, we will tackle lots of abstract theories, which are researched by many mathematicians. Many situations need to be solved by using maths in daily life, to calculate the bill, to measure the drop of curtain and the number of tiles. Mathematicians throughout life spend plenty of time solving specific practical problems that they create methods and principles to address; that is why we need to have rigorous theories.

To sum up, mathematicians summarise theorem through challenges in daily life. If we find out how they work this theorem, we will solve new problems.

Take Pythagoras theorem for example, (Pythagoras. c.570-c.495BC. Pythagoras theorem) everyone know its expression is $a^2+b^2=c^2$, but if we just know it, when we meet questions in exams, we even do not know how to substitute the numbers into the formula and it only applies to right triangles. We should find out its diagram and source. According to the unofficial history, at the dinner party Pythagoras chose a tile and drew a square with its diagonal AB as the edge. He found that the area of the square was exactly the sum of the areas of the two tiles. Then he decided to do some deeper research, and that led to the great theory that we use today. It describes how people can use this theorem when they measure up to calculate how many tiles, or the amount of fabric for a pair of curtains in daily life. Not only that, an abstract theory is for wider use. We can use this theorem to design buildings, using Pythagoras theorem helps us to easily measure the height of a building, architects need to be accurate. All things considered, all mathematics is abstract, and removed from the actual. As mathematicians and as humans, we have to focus on the practical application, first understand, then buckle the theory.

To use math in daily life we really need to understand concepts and theorems. I can see three steps. First of all, ask a teacher, it always helps to intuitively understand the causes and consequences of math concepts and theorems, and clarify the logic. Secondly, I find reading textbooks is very important. I suggest choosing an appropriate textbook when starting, the choice of book should depend on ability. For example, there are many differences between western and eastern textbooks. Eastern textbooks will focus more on dialectics and western textbooks will focus more on logic. Through using the textbook, I try to figure out every theorem and the process of proof, then do the exercises after every lesson. These steps help to get the theory into our heads. The process is painful, especially at the beginning, when I am not familiar with the common routines of proof, I often stare at a proof for an afternoon without understanding it. But if I stick to it, eventually I will understand, by reading many times I will have deep experience. Thirdly, when I meet really tricky problems, I often research online. I can find lots of useful handout, relevant papers and useful example questions, so that I can understand a math concept from different angles.

In conclusion, the use of mathematics in real life need visual thinking ability. When we meet difficulties, we need to think about abstract theorem at first. Understanding concepts and theorems is an important part. We should know how people in previous eras solved problems, we should also summarise methods in our words, to solve new the actual problems.

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