SHREWSBURY PERIODICAL

-Lent 2022-

The STEM magazine by & for the students of Shrewsbury Schcool

Shrewsbury School

From the Editor:

Welcome to the second edition of Shrewsbury School's STEM magazine. Once again, our fantastic writers have astounded us with their creativity and natural curiosity within the fields of STEM - from reverse aging to the maths behind random number generators, from possiblities of extraterrestrial life to the science behind human consciousness, a wide range of topics are being explored, providing rich insights to problems from a variety of perspectives. A big thank you to all the amazing contributers out there who made this possible. I have thoroughly enjoyed the process of editing and am inspired by the work and dedication of each individual. It has been an honour to work alongside such talented writers and fellow editors in putting the magazine together. We hope to spark some interest, and find you inspired by the end of the read. Dive right in and enjoy the read!

Cecelia Lam

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Energy Insecurity & Sustainable Energy Implementation in Sub-Saharan Africa

Peter Crews

One of the largest global topics in recent years has been the need for sustainable energy sources. This necessity has appeared for a variety of reasons: climate change, the fragility of fossil fuel markets, and the lack of energy availability are just a few. Africa's current rapid economic expansion is requiring more energy to become openly available to support it, and upcoming renewable technologies show potential in aiding the continent to meet its economic, social, and environmental objectives (Figure 1). An ample supply of easily accessible renewable energy offers the means to eradicate energy insecurity and ameliorate living conditions for millions of people, along with recovering from the impacts of colonialism and exploitation. But why is renewable energy the best option (other than for the environment)?

Currently, an estimated 600 million Africans are lacking electricity with the most part living in the sub-Saharan region (Agency, Organisation for Economic Co-operation and Development International Energy, 2017). Along with the lasting effects of colonialism*, deforestation, which is often caused by large corporations such as tobacco estates, is also a contributor to the preservation of poverty in Africa (Figure 2). Fewer trees leads to more flooding, soil and minerals are washed away, resulting in less food. People then need to buy food, forcing them to cut down trees to sell as firewood, thus perpetuating this cycle, and making more and more land unusable

Fig. 1: An example of integrated and secure renewable energy (IRENA, 2019).

Fig. 2: Deforestation in Zambia on account of tobacco farming (Zambia 2019).

for crops each year. All the while the plantations benefit from selling their goods to other countries and upping the prices of maize. The silt also blocks river systems near dams, which needs dredging, and so the price of electricity increases and fewer people can access it (Kamkwamba, 2010). With more sources across the continent, affordable access becomes a reality, meaning crops can be planted twice a year as irrigation systems can be installed, reducing stress on food reserves and reducing the control that plantation estates have over smaller subsidence farmers.

A large motive for renewable is the benefits it offers over fossil fuels and opportunity for long term prosperity. Around 66% of the world's oil comes from the Middle East, spiking interest of private companies and nations in that area and thus presenting safety concerns for those that live there (an example is the recent conflicts in Iraq). The ability to halt supply to other countries poses another risk to most of the world: in 2006 and 2009, Russia cut supplies to the Ukraine as a political threat that then affected multiple other nations, bringing political energy insecurity to all of them (Klebanoff, n.d.). On multiple occasions the price of oil has increased as availability decreased due to lack of staff and civil unrest, which further shows fossil fuel's delicate nature. In comparison, renewable sources offer better political energy security as they are not concentrated within few countries, diversifying sources, and thus less vulnerable to geopolitical forces hindering progress (Wikipedia, 2021). Given that very little of the oil market is controlled by Africa, domesticated and self-owned renewable sources offer a way of fast tracking through the manipulation of buying oil from other countries. With rising oil prices due to increasing demand and decreasing supply, plus the eventual transition away from fossil fuel reliance once reserves are exhausted, this would save billions in the future.

Overall, Africa's topography offers great potential to implement a range of renewable sources such as wind and solar farms (Figure 3). Skipping straight to renewable energy sources avoids political and financial complications, while also making the energy grid more secure and reliable. With many supplies stretching across the continent, economic development is far more attainable, and the likelihood of natural disasters such as famines is reduced.

Fig. 3: Africa's largest wind farm on the banks of Lake Turkana in Kenya (KETRACO, n.d.).

**Slavery and the Apartheid play large roles in the stunted development of both South-Africa and Africa as a whole. Infrastructure built to support international connections is not suitable for inter-African trade. Even today the exploitation due to lithium and gemstone mining takes the wealth away from Africa and transfers it to other overseas nations.*

HEALTH

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picture: https://pixabay.com

INTO THE FUTURE: REVERSE AGING?

JAMIE DAVIS

One thing that everybody has experienced, from a one-month-old baby to a 90-year-old great grandfather is aging. It has been a constant in life since the first lifeform on earth crawled out of the slime, which raises the question. How do we stop it?

In order to understand this, we must first look at how we measure biological age, since the passing of time affects everyone differently. The main method is the epigenetic clock (Figure 1). Inside of our DNA is a marker of our biological age, where different chemical modifications such as methyl groups can be observed to work out biological age. As our life passes these chemical modifications change and our epigenetic clock ticks onwards, but what can we do to slow, stop or rewind the clock.

While this may seem like a pipe dream, there is some good news for those people wishing to relive their youth, literally. Recently, a group of researchers in California discovered that by giving 9 volunteers a mixture of growth hormones and diabetes medication, they were able to reverse the clock by

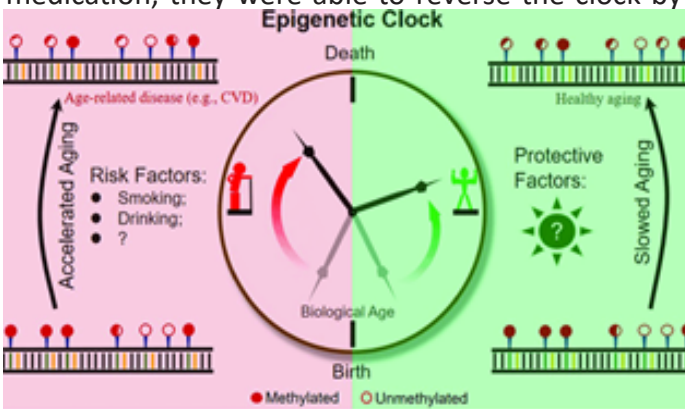


Fig. 1: The Epigenetic Clock.

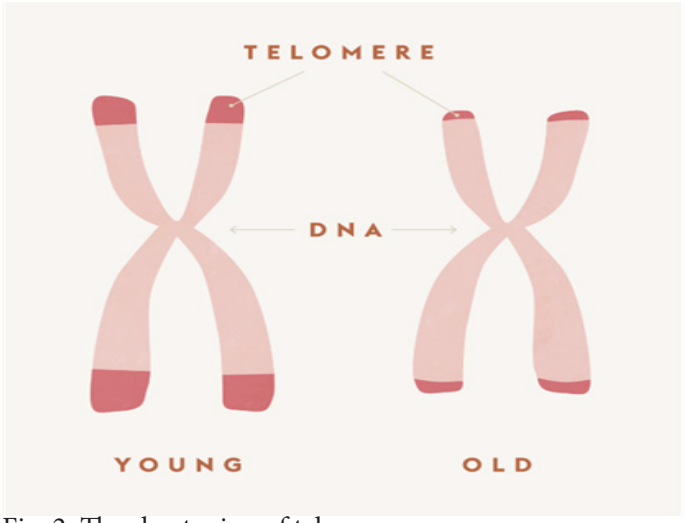


Fig. 2: The shortening of telomeres.

2.5 years on average. Even after 6 months these effects were still visible, though it should be taken with a grain of salt due to the small sample size.

Something that is absolutely necessary for understanding how to reverse aging is to understand the causes of aging. One of which is the shortening of telomeres.

Telomeres are sequences of DNA at the end of the chromosomes that protect the genome (Figure 2), however as we age, they telomeres shorten and cells with telomeres that are too short are unable to divide. We then end up with more and more of these "geriatric" senescent cells.

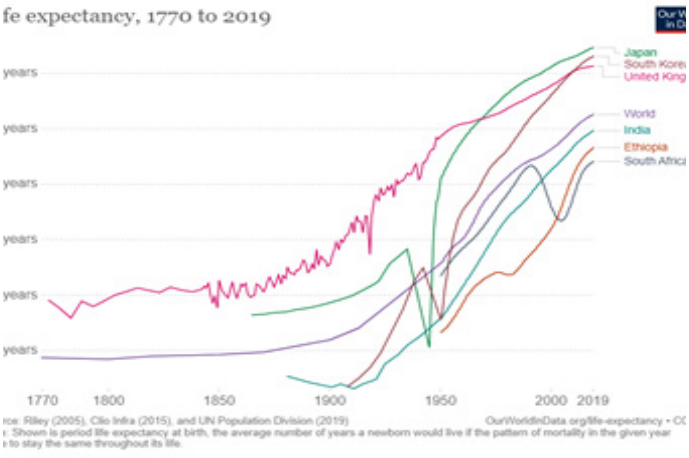
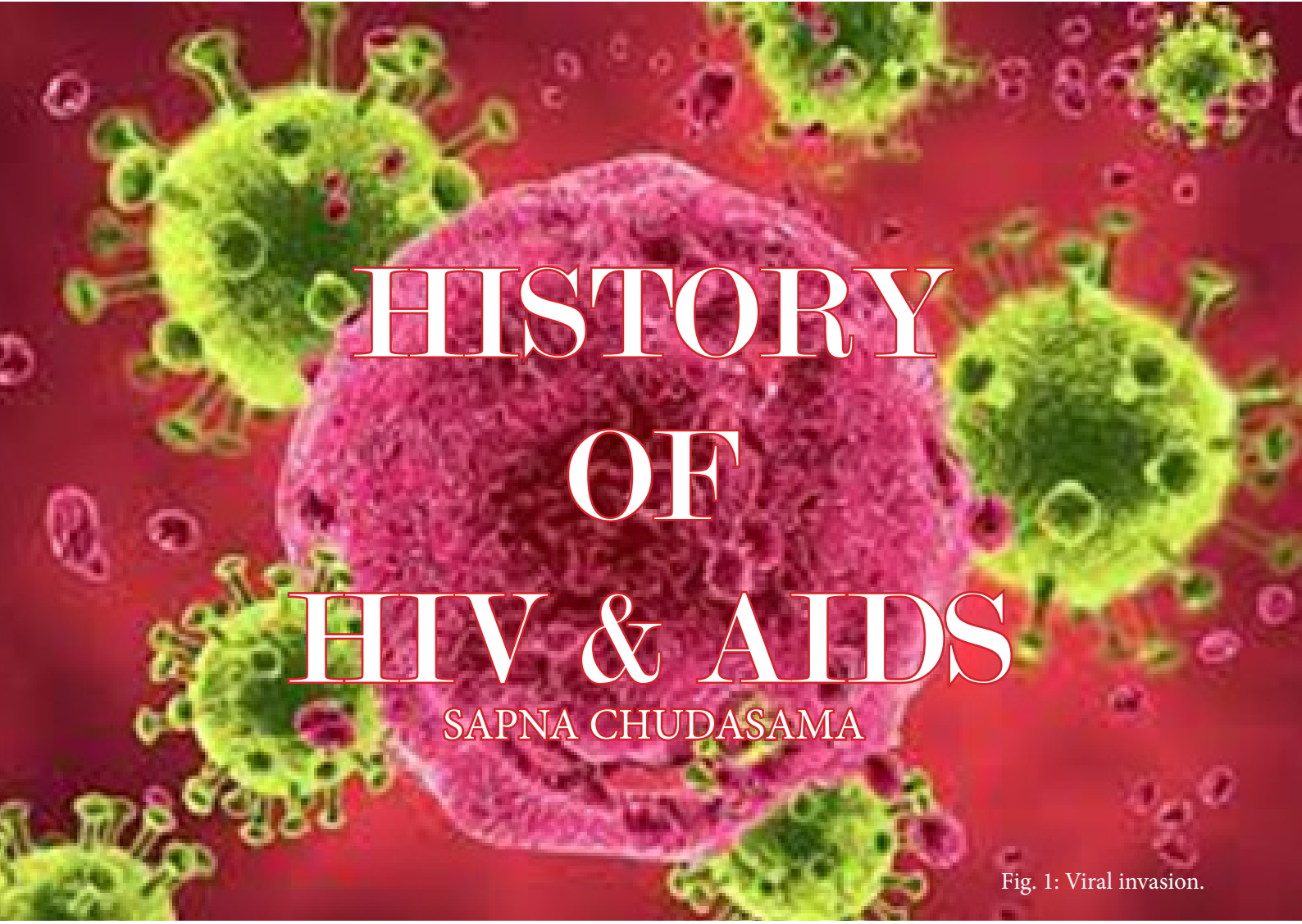


Fig. 3: Global Life Expectancy from 1770 - 2019.

A group of 34 participants over 64 years old were given oxygen treatment - where they breathe pure oxygen in a pressurised chamber - over the course of 3 months. By the end of the 3 months the participants were found to have increased telomere lengths and a decrease in the number of senescent cells.

While immortality may not be something that is going to show up tomorrow, our lifetimes have been increasing since the 19th century. That is not going to be stopping anytime soon (Figure 3).



HISTORY OF HIV & AIDS

SAPNA CHUDASAMA

Fig. 1: Viral invasion.

We've all heard of HIV but very few of us know where it comes from...

HIV (human immunodeficiency virus) is a virus that attacks cells in the immune system. The virus destroys a type of white blood cell called a T-helper cell (which is also known as a CD4 cell). CD4 cells help coordinate the immune response by stimulating other immune cells such as macrophages, B lymphocytes and CD8 cells to fight infections. HIV attaches to these CD4 cells and fuse with them. It then takes control of the cell's DNA and makes copies of itself inside the cell, thus releasing more HIV into the blood. HIV will continue to multiply and spread throughout the body. HIV is transmitted through bodily fluids such as blood, semen, vaginal and rectal fluids and breast milk. HIV medicine called antiretroviral therapy can allow people with HIV to live long lives as well and preventing the person from transmitting the virus.

However, if HIV is left untreated in can lead to the disease AIDS (acquired immunodeficiency syndrome), which is also known as stage three HIV. Healthy adults generally have a CD4 count of 500 to 1600 per cubic millimetre. A person with HIV whose CD4 count fall below 200 per cubic millimetre will be diagnosed with AIDS.

There are two main types of HIV, HIV-1 (most common) and HIV-2. Within the main types there are many genetically distinct subgroups. HIV-1 Group M is the strain of HIV that is responsible for the global HIV pandemic, and within these groups there are 9 distinct subtypes).

It is believed that the SIV (Simian Immunodeficiency Virus) was transmitted to humans from chimpanzees and become HIV-1 . However in reality this SIV didn't start in chimps as we all believe. Instead it was a product of separate viruses jumping from different monkey species into chimps, where they formed a hybrid (Figure 3). It is believed that the virus effecting chimpanzees is a hybrid of SIVs effecting red-capped monkeys and the greater spot-nosed monkey. Since chimps eat monkeys, it is likely they acquired the monkey viruses through consumption. These two strains of viruses combined to form SIVcpz, which was likely passed on to humans when hunters ate the infected chimps. (HIV-2 comes from SIVsmm which was acquired from sooty mangabey monkeys).

It is generally believed that HIV originated in the democratic republic of Congo in the capital Kinshasa in 1920, The area around Kinshasa was full of very good transport links and at the time there was a growing sex trade and so the high population of sex workers may explain how HIV spread. By 1937 it had reached Brazzaville, about 120 km west of Kinshasa.

In the 1960s the 'B' subtype of HIV-1 strain M, made its way to Haiti. At this time many Haitian professionals were working in DRC and they returned to Haiti carrying the virus with them. HIV was then spread to the United States in around 1970, however it didn't come to the public's attention up until the early 1980s.

On June 5th, 1981 the US Centre for Disease Control and Prevention published a report about five previously healthy gay men becoming infected with Pneumocystis Pneumonia which is was caused by the normally harmless fungus Pneumocystis jirovecii which almost never affected people with uncompromised immune systems. On the same day a New York dermatologist (Dr. Alvin Friedman-Kien) called the CDC to report a group of cases of a rare and aggressive cancer (Kaposi's Sarcoma) among gay men in Ney York and California. This cancer was also associated with people who have weakened immune systems. In response to all these reports the CDC began national surveillance of new cases. On June 16th a 35-year-old white gay man who was exhibiting symptoms of severe immunodeficiency was the first person with AIDS to be admitted to the clinical centre at National Institutes of Health.

In 1982 the diseases was renamed (AIDS) and it was realised that the infection can be transmitted sexually and that it was caused by HIV. The next year it was discovered that women could also become infected through heterosexual sex, and 1985 the first international conference of AIDS was held in Georgia, USA.

In 1986 it was discovered that HIV could be passed form mother to child via breast-feeding. Luckily, in 1987 the first anti-retroviral drug, AZT was approved.

The first World AIDS day was held on December 1st, 1988 and by 1990 8-10 million people were estimated to be living with HIV worldwide, with the red ribbon becoming the symbol for HIV awareness in 1991 (Figure 2).

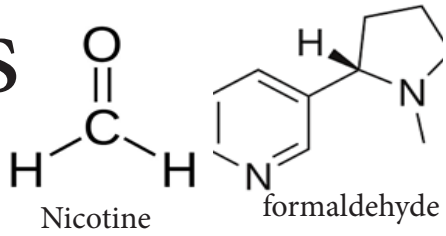
In 1996 Dr. Mark Wainberg helped develop 3TC a drug used to treat HIV. This combination drug therapy brought a decline of between 60% and 80% in rates of AIDS-related deaths. Unfortunately, in 1999 the WHO announced that AIDS was the fourth biggest cause of death worldwide and the top cause of death in Africa. In 2000 the UN adopted the Millennium Development Goals which included a goal to reduce the spread of HIV, malaria and TB and UNAIDS negotiated with pharmaceutical companies to reduce the cost of HIV treatment for developing countries.

Fig. 2: Symbol for HIIV

Fig. 3: Separate viruses jump from different monkey species into chimps and form a hybrid, becoming HIV - 1 when transmitted to humans.

The Effects of Vaping on Humans

Alexander Petukhov



In recent years, vapes have plagued the country. A metallic device consisting of a mouthpiece and some heating coils has got some 2.9 million adults in the UK hooked, a study from 2017 done by YouGov shows. Such a statistic is startling at first, but many need to consider the fact that over 54.1 percent are ex-smokers that have used electronic cigarettes as a method to combat their addiction (data published by Action on Smoking and Health ASH). While the statistics do seem promising, is this the best alternative there is, and are we that aware of its true long-term consequences on the human body?

While on one side it can certainly be said to have its pros, as a healthier alternative to the usual cigarette, the very liquid contains hundreds of chemicals. The basics ingredients are glycerine and glycol ethers which are not considered harmful themselves, but which are interspersed with carcinogens, formaldehyde (CH2O) and Acetaldehyde (C2H4O) being just two of many. Such chemicals, the EPA states, have been said to have links to nasopharynx cancer and leukemia when exposed to in high dosage.

What happens when it enters the body? Nicotine binds to the receptors within the brain, which will activate and cause the release of dopamine and different neurotransmitters across the synapse. This in turn, sparks euphoria, the 'high' everyone is so addicted to. Also, Nicotine is a PSNS stimulant, meaning that it

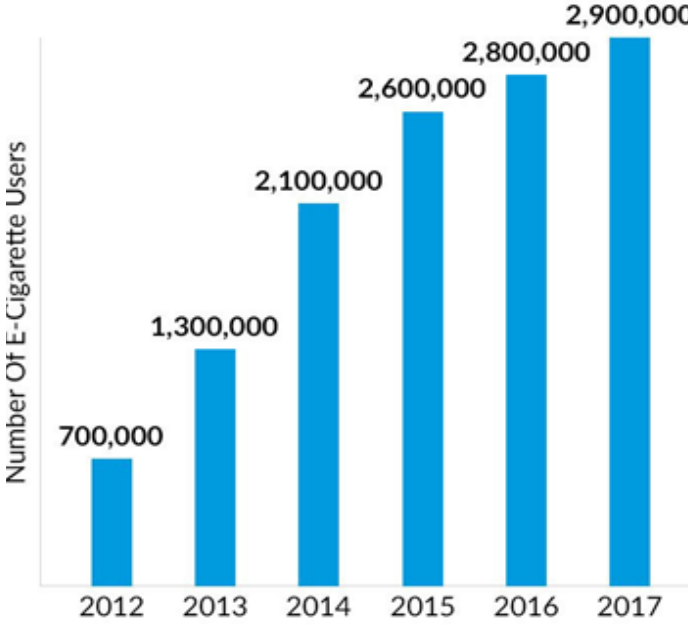


Fig. 1: Graph that shows the growth of e- cigarette users over the years.

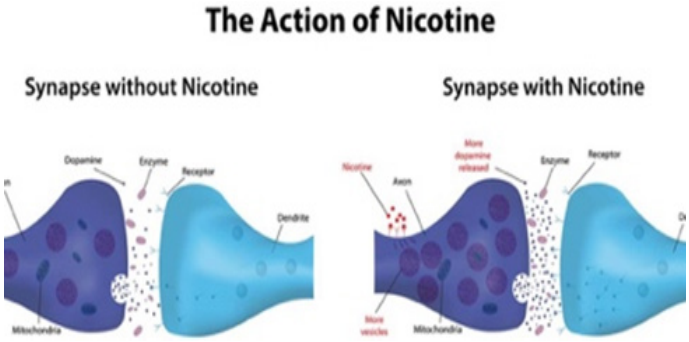


Fig. 2: Release of dopamine and different neurotransmitters.

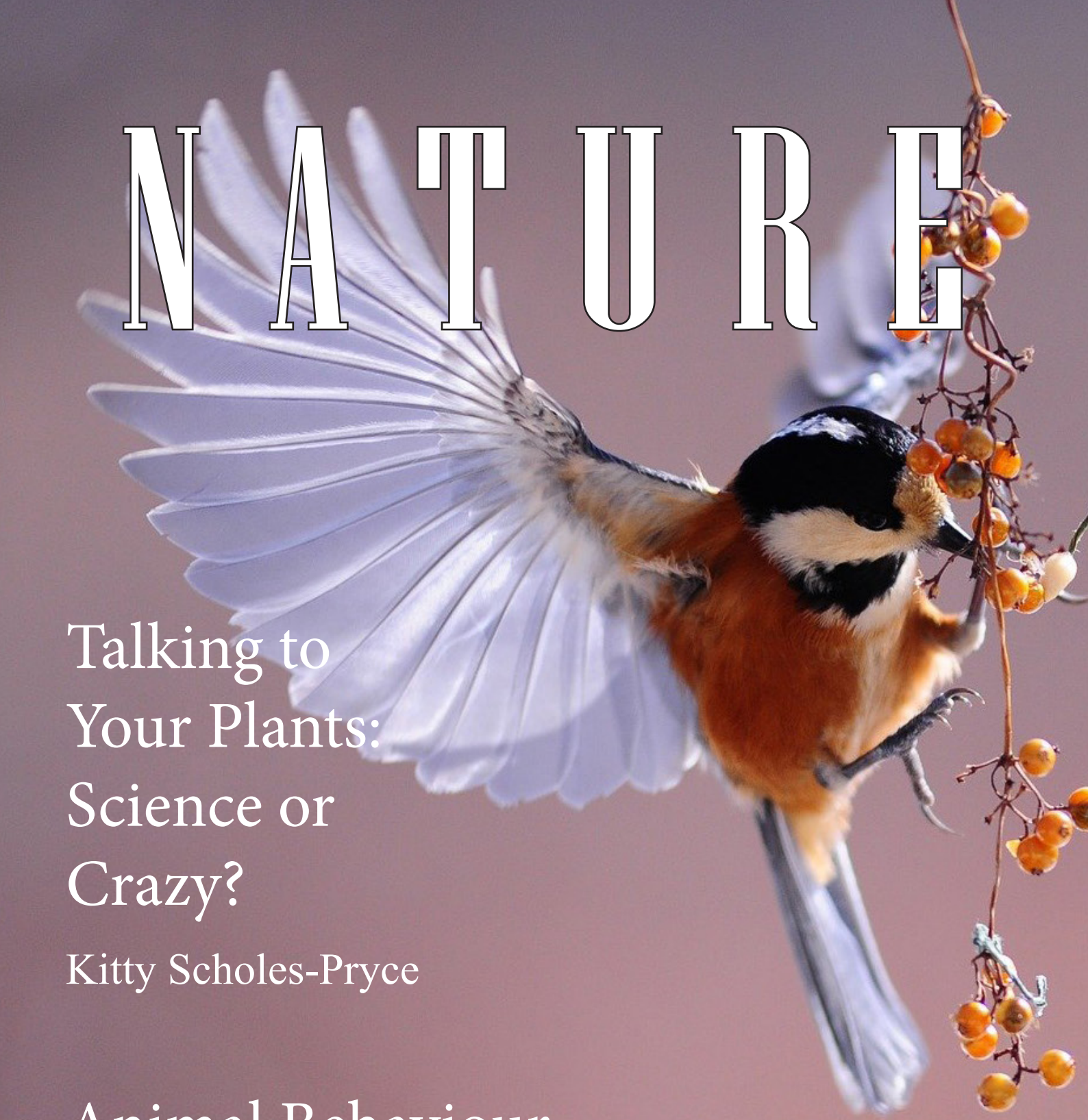
affects and stimulates the parasympathetic nervous system (one that controls the body functions when the body is at rest). This, in turn, causes people to stay up longer in bed whilst also reducing deep sleep (stage 3 sleep) which is vital for growth and for the repair of broken tissue.

Until the age of 25, the brain is still in the development stage. This means that every time a new skill is learned, synapses are built between the brain cells. The developing brain of children and teenagers can create more synapses in a shorter period than the developed brain of an adult. Thus, this paves a path for mood swings and behavioral traits to change especially in teens.

Most importantly it has to be noted that, An article published by Amir Levine, MD; Eric Kandel, MD; and colleagues at Columbia University shows that the nicotine in vapes, cigarette and tobacco can "prime" the brain for other drugs addiction, such as cocaine. This seems to be the case where not much light is shed on, and the reality seems unanswered.

Overall, while some things are evident, slightly concerning are some of the unknown effects of vaping. Being revolutionary and a solution to the smokers' market, its long-term effects have simply not been observed yet. Learning and finding its true consequences, will give us insight into new innovative, and even more revolutionary alternatives to the vape for the years to come.

NATURE



Talking to Your Plants: Science or Crazy?

Kitty Scholes-Pryce

Animal Behaviour - Can Dying be Advantageous?

Dylan Tyack

Mutualistic Relationships

Ellie Letts

picture: https://pixabay.com

MUTUALISTIC RELATIONSHIPS

ELLIE LETTS

Fig. 1: Mutualistic relationship examples (Ox and Oxpecker; Mycorrhizal fungi and trees; Clownfish and Anemones).

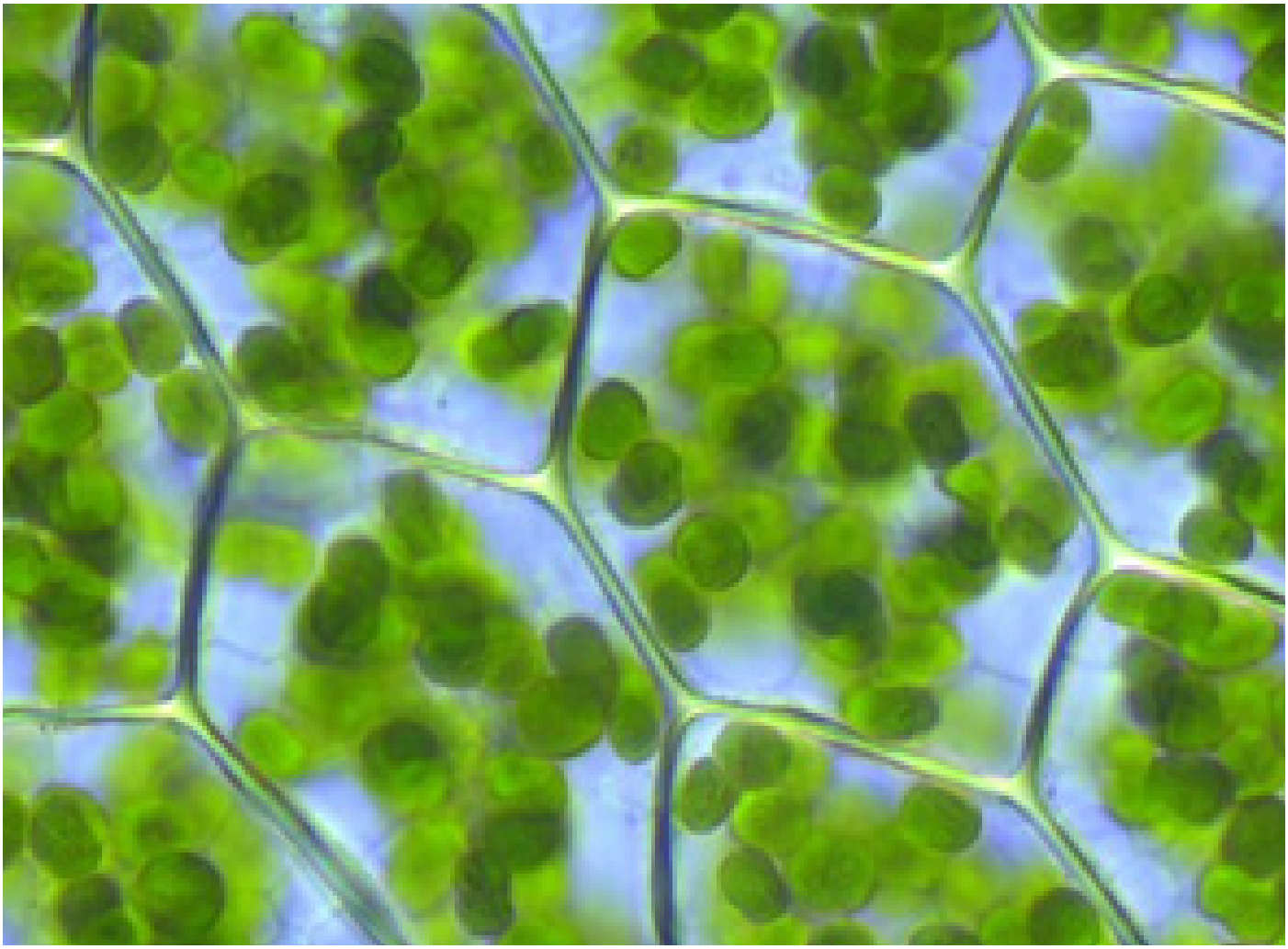


Fig. 2: Chloroplasts in plant cells.

A 'mutualistic relationship' is a fairly niche term for what is actually a very common-place practice. A mutualistic relationship is when two organisms of different species 'work together' each benefitting from the relationship (Figure 1). These relationships have been crucial in producing the biodiversity we have today, and litter both evolution and ecology.

One example of this sort of relationship which has been essential in the development of life is our own organelles (Figure 2). Both mitochondria (the site of aerobic respiration) and chloroplasts (the site of photosynthesis) were once aerobic free-living bacteria before they were engulfed by ancestral eukaryotes (a more complicated type/domain of life, in which cells contain a nucleus among other key differences). Evidence for this evolutionary step, theorised by Lynn Margulis, includes having their own DNA, ribosomes, and a double membrane. The benefits of this relationship were protection and a lack of competition and in return energy, for the cell which had engulfed them. This was a crucial step in the timeline of our Earth, as photosynthesis allowed the oxygen concentration in our atmosphere to become somewhere closer to habitable.

Around 600 million years ago the relationship between mycorrhizal fungi and plants allowed the successful migration of algae-like organisms out of the ocean. Mycorrhizae are mutually symbiotic associations between fungi and plants. The fungi colonise the root system of the host plant, increasing water and nutrient absorption capabilities, and the plant in return provides the fungus with carbohydrates from the sun.

However, the subsequent domination of plants led to more photosynthesis, more oxygen in the atmosphere and eventually the Cambrian explosion, when all major groups of animals first appear in the fossil record (Figure 3). Around 600 million years ago plants had no root system and even today fungal hyphae are still the superior nutrient gatherers, some 50 times thinner than the thinnest roots.

These fungi are essential to plant health, and yet they are being disrupted by pollution and

Fig. 3: A fossil of an early plant.

agriculture, a 2018 study found pollution was disrupting flows of nutrients and key environmental cues.

Figure 4 is heavily simplified but shows the underground marketplace in which we can begin to understand the laws which govern these relationships. This marketplace functions much like a capitalist market would, with prices dictated by supply and demand. In the same way both the customer and consumer may switch partners to enforce good service. Fungi have some curious tactics, or rather evolved mechanisms, to give themselves the upper hand by increasing the exchange value of phosphorous; fungi store it in a form inaccessible to plants and even actively transport it away from to the places where it is most in demand to artificially inflate its 'retail price'.

This theory is known as the theory of biological markets and was first presented by Ronald Noe in 1994 and was inspired by his observations of baboons. It replaced previous theories of kin-selection and reciprocal altruism which didn't stand up across species, and has become the guiding principle in this discipline.

So in fact these relationships are purely selfish and not altruistic as one may have presumed. A good example to demonstrate this is cleaner wrasse (Figure 6). These fish eat dead skin and parasites off other 'client'

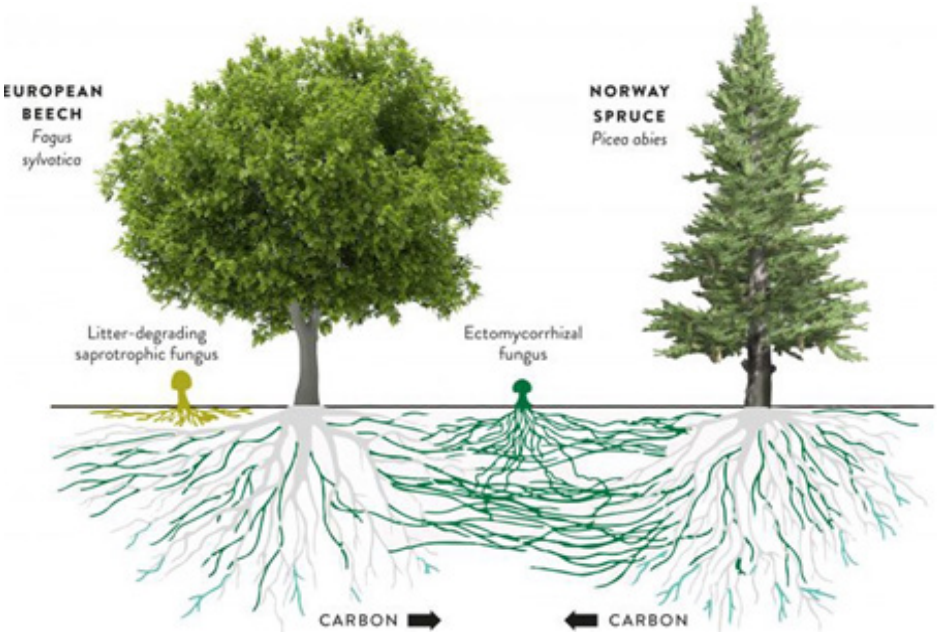


fig. 4: A diagram of mycorrhizal relationships.

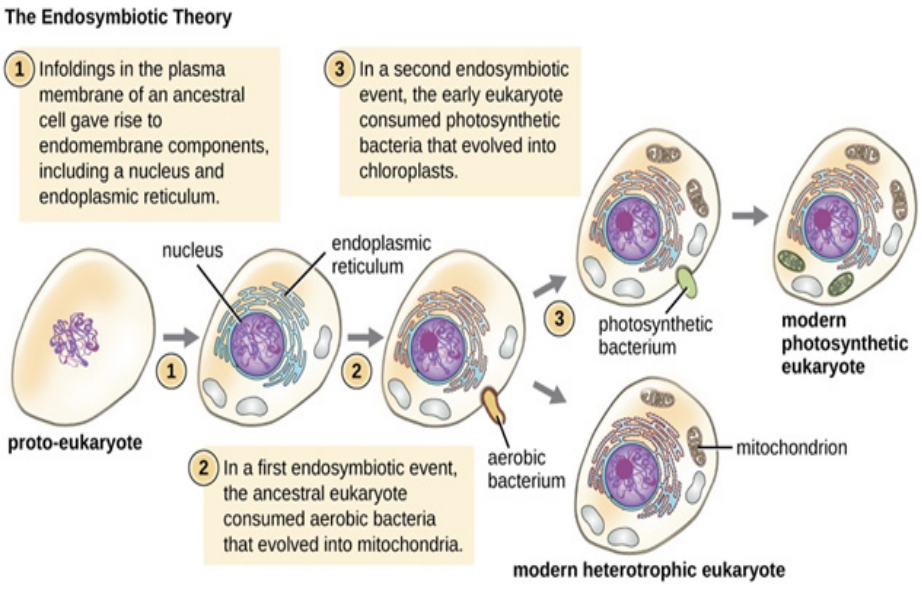


Fig. 5: A diagram demonstrating Lynn Margulis' endosymbiotic theory.

fish. However, not all clients receive equal treatment, some facing longer waits or 'cheating' fish. What I have referred to as cheating is when the wrasse nibble the nutrient-rich healthy scales and mucus of the fish it is serving. These differences can be explained by market forces. Visitors, who could travel between several cleaning zones always received prompter and gentler treatment, than residents who had fewer options of partner - the cleaner wrasse were also less likely to cheat if they were being watched.

However, these finely tuned

mechanisms can make partners vulnerable, particularly the more specialised and reliant on the relationship they are. Huge shifts in supply and demand (often preceded by environmental or biological factors) can jeopardise relationships. One relationship which is currently suffering from environmental change with disastrous consequences are coral reefs (Figures 7 & 8). Coral reefs contain ¼ of all marine species, despite only taking up 0.1% of all oceans and they rely on a close mutualistic relationship between corals and anemones, and single-celled photosynthetic algae. The coral provides protection, CO_2 and nutrients, whilst in return the algae provide O_2.

The algae in corals form the base of almost all reef food chains - as the warm water means there are less dissolved gases, so fewer free-living algae. Coral bleaching occurs when algae die or are expelled by their host. This delicate symbiotic balance can be disrupted by factors such as viruses and temperature rises. As the whole ecosystem hinges on this relationship, the whole ecosystem is vulnerable and is expected to be one of the first casualties of climate change.

Although there are many parts of these relationships that we do not yet understand, we do know that they function like economies, heavily influenced by outside factors, and they can crash like economies. These relationships prop up many ecosystems, often providing the basis from which they have evolved, so perhaps it would be wise to limit the disruptive influence of humans.

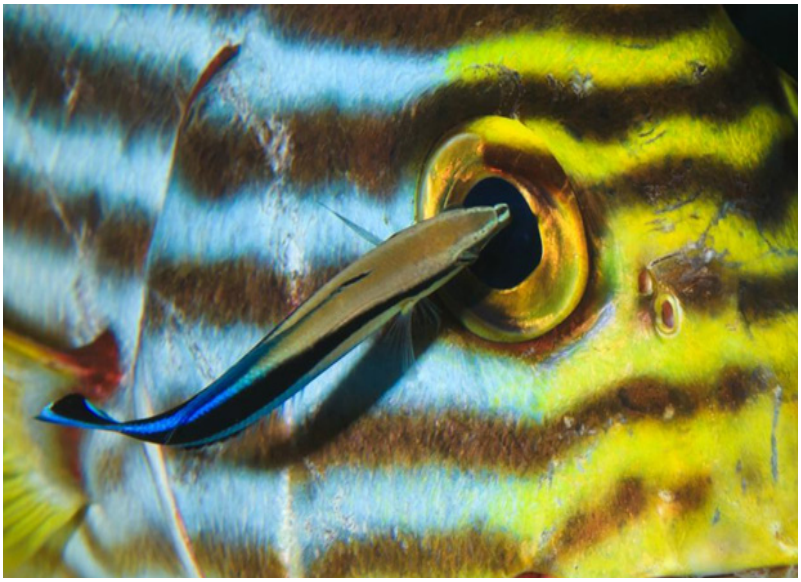


Fig. 6: A cleaner wrasse feeding.

Fig. 7: A biodiverse, healthy coral reef.

Fig. 8: Bleached corals.

Animal Behaviour – Can Dying be Advantageous?

DYLAN TYACK

Fig. 1: A pseudoscorpion mother with her offspring.

Suicide, when defined as any self-destructive behaviour that leads to one's death, is likely more common than you might think within the animal kingdom. From cephalopods to mammals this form of mortality has been observed. While the mechanisms of such cases can be quite interesting, the reasons behind them perhaps deserve more attention as they could contain profound implications that change the way we view animals.

Usually, living beings are effectively programmed to survive and procreate. The genes that most increase the likelihood of this happening are most likely to survive. As it is unlikely for self-destructive genes to exist at all, any animals that do exhibit such self-destructive behaviour could be suggested to possess the thing which we humans believe allows us to act against our genetic desire and even separates us from animals – a consciousness that goes beyond our instincts. There are however a range of examples of animal suicide that can be easily explained as well as myths and more contentious examples that are inconclusive. It is important not to anthropomorphise, which in this context would be to attribute human characteristics to animals without justification.

There are many examples of this self-destructive behaviour in animals. The tiny pseudoscorpion (Figure 1) in Brazil was found to sacrifice itself to its offspring, when food was scarce. This process is documented in other species as well, under similar conditions, including some nematodes and spiders. It is common enough to have its own name: matriphagy. Termites (specifically N. taracua) have in a seemingly similar way been seen sacrificing themselves for others, releasing toxic chemicals in a violent process known as autothysis where the termite effectively explodes. These chemicals kill and deter intruders which could harm the rest of the termite colony.

A more familiar example, and perhaps one we take for granted, is the honey bee, which sacrifices itself when stinging a supposed threat to the hive. These examples clearly are not indicative of animal sentience, or some form of deep emotional connection these social insects have to their siblings or mothers to their offspring. Instead, this form of suicide, by the rudimentary definition as self-

destructive behaviour that leads to one's death, can still be explained by genetic instinct. It may seem nonsensical that there are genes that encourage acts of self-destruction. However, given the social nature of these animals, who live in huge colonies of half-siblings, siblings, possibly even clones, or produce hundreds of offspring, these acts are actually genetically advantageous. A gene in a pseudoscorpion mother that compels her to sacrifice herself, we assume has at least a 50% chance of existing in her offspring. In a dire situation, it is clearly advantageous for the proliferation of the gene for the mother to keep hundreds of offspring alive than for the mother to potentially survive and the many offspring to die. Similarly with social insects like termites and honey bees, their self-sacrifice ensures the survival of those genetically similar to them, allowing for the gene for self-sacrifice to remain in the gene pool. Therefore, this form of suicidal behaviour is clearly not in any way indicative of an animal's liberation from the grasp of its genetics, rather it shows the control genes have over individuals, to the point they seemingly lack autonomy.

We can, however, also look for examples of animal behaviour that would fit a different, more relatable, perhaps even human definition of suicidal; in a way which would suggest that an animal is rebelling against their genetics. This definition shall be: the deliberate destruction of oneself with an awareness of death. Examples are extremely hard to prove or demonstrate as we can't know what is going on within an animal's mind. David Pena-Guzman however, says that "death plays a more central role in the lives of numerous animals than we have previously imagined. Burial rituals have been observed in various animal species, including crows [BBC news 2015], magpies (Figure 2) [Bekoff 2009a], captive gorillas [Morin 2015], red foxes [Bekoff 2009b], elephants and dolphins [Goldman 2012]." These rituals clearly show that some animals possess an awareness of death. Perhaps an example of one of these species deliberately causing its own death could prove the existence of the behaviour fitting the more human definition. However, the circumstances of these incidences often discount any assertion that the act was pre-planned or considered by an animal in defiance of its instincts.

Examples of animal suicide in this context are contentious but quite numerous. In 1970 a dolphin named Kathy was said to have died by suicide by its trainer, Richard O'Barry. Dolphins are considered extremely intelligent, social animals (Figure 4) much like humans. However, unlike humans, mammals living in the ocean are voluntary breathers, meaning they have to make an active decision to surface for air. In the case of Kathy, the dolphin, she failed to surface for air. If we accept this account as true, and the *reported* context that the dolphin was depressed, it seems an undisputable case of suicidal behaviour. There have been similar but unconfirmed stories about bears in bile farms, who undergo painful operations to extract the bile from their stomach. The main problem with treating these as scientific discoveries is that they are simply accounts given by witnesses. Such witnesses, could be susceptible to anthropomorphism - attributing

Fig. 2: A group of magpies gather round a dead comrade..

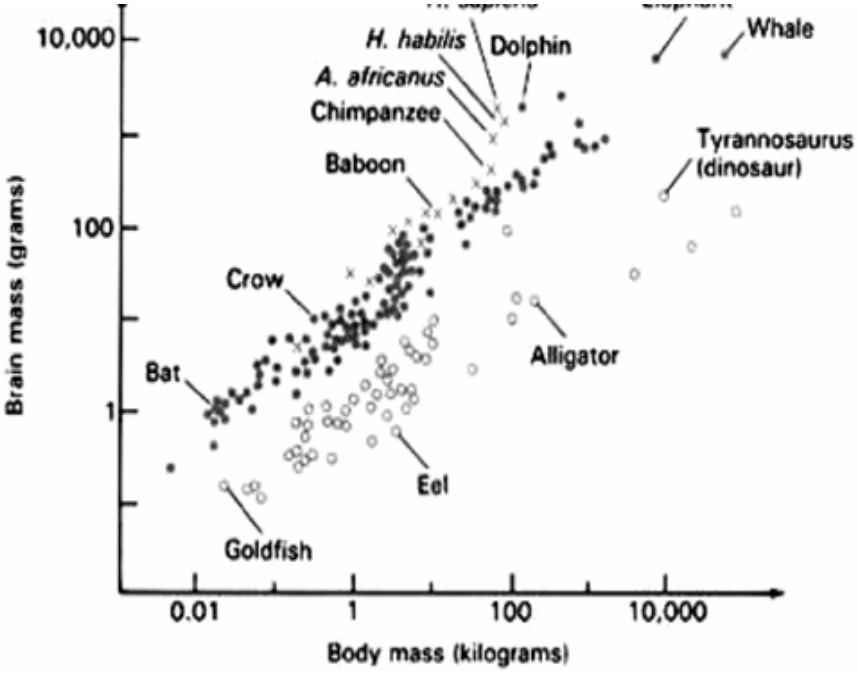


Fig. 3: With body mass on the x axis and brain mass on the y- both increasing exponentially, a brain to body mass ratio is shown, providing a rough estimate for an animal's intelligence. Note the dolphin's close position to Homo sapiens.

human characteristics to animals – and therefore mistake one behaviour or emotion for another. Furthermore, even if these accounts are accurate, as they occur within captivity, they can still be accounted for by stress, defined as: "a symptom resulting from exposure of an animal to a hostile environment." In effect, poorly treated animals living in hostile environments could involuntarily exhibit a self-destructive response to stress, in the ways described.

An interesting view is presented by Ajit Varki, originally raised by Daniel Brower: "Brower suggested that, although many species manifest features of self-awareness (including orangutans, chimpanzees, orcas, dolphins, elephants and perhaps magpies), the transition to a fully human-like phenotype was blocked for tens of millions of years of mammalian (and perhaps avian) evolution. In his view, the only way these properties could become positively selected was if they emerged simultaneously with neural mechanisms for denying mortality." It seems that for self-awareness, as seen in humans, to evolve, a sense of hope in the face of an inevitable and recognisable death must evolve with it. Otherwise, it is evolutionarily unviable.

While the idea of an "evolutionary barrier" preventing the creation of a full awareness of death is interesting, I would argue against the implication that it separates humans from animals. For if a human's self-awareness and awareness of death is tempered by a certain ignorance, then we have not achieved it in full. This leads back to David M. Peña-Guzmán's suggestion that "self-destructive and self-injurious behaviours among human and nonhuman animals vary along a continuum.", and that there is no great divide between the minds of humans and animals. As Dr. Lori Marino, a bio-psychologist, studying captive cetaceans says: "the idea that other animals can't [die by] suicide because they are hardwired to live is very old fashioned".

Overall, the existence of animals exhibiting suicidal behaviour in in the knowledge of the consequences is still very contentious, with no solid proof either way. Given the intelligence of some animals, such as dolphins, some scientists would say that it is indeed possible. At the moment, given we can't delve into an animals' mind it seems impossible to prove.

Fig. 4: Dolphins are considered extremely intelligent, social animals just like humans

TALKING TO YOUR PLANTS: SCIENCE OR CRAZY?

KITTY SCHOLES-PRYCE

picture: https://pixabay.com

As the population increases scientists and researchers are working to utilise greener, more efficient methods of producing crops. Infrasound and ultrasound are known to interfere with human bodily tissues and have been used in medical practice for at least fifty years in diagnosing and treating. Whilst the effects of environmental factors such as light, wind, moisture levels and temperature have had a known effects on plant growth, the audible effect of sound waves is still somewhat of a mystery. Scientists applied sound wave technology to investigate its effect on various processes: seed germination, callus growth, endogenous hormones, mechanism of photosynthesis and transcription of certain genes to try to understand the effect.

Plants can already produce low frequency sound waves (between 50-120Hz respectively) suggesting plants may have a meridian system (also known as internal frequency) just as in humans and animals, meaning they can absorb and resonate to certain external frequencies. Other species such as fruit flies, snakes, frogs and birds can also perceive sound without eardrums. Fruit flies sense vibrations through their antennae, snakes through their jawbone and plants appear to detect sound via an unknown organ.

Sound waves can change cell cycles and cause leaves to vibrate which speeds up the protoplasmic movement in cells (movement of substances in and out of cells). Sound waves can stimulate leaf stomata to open and increases its uptake of fertilizer and dew. Sound

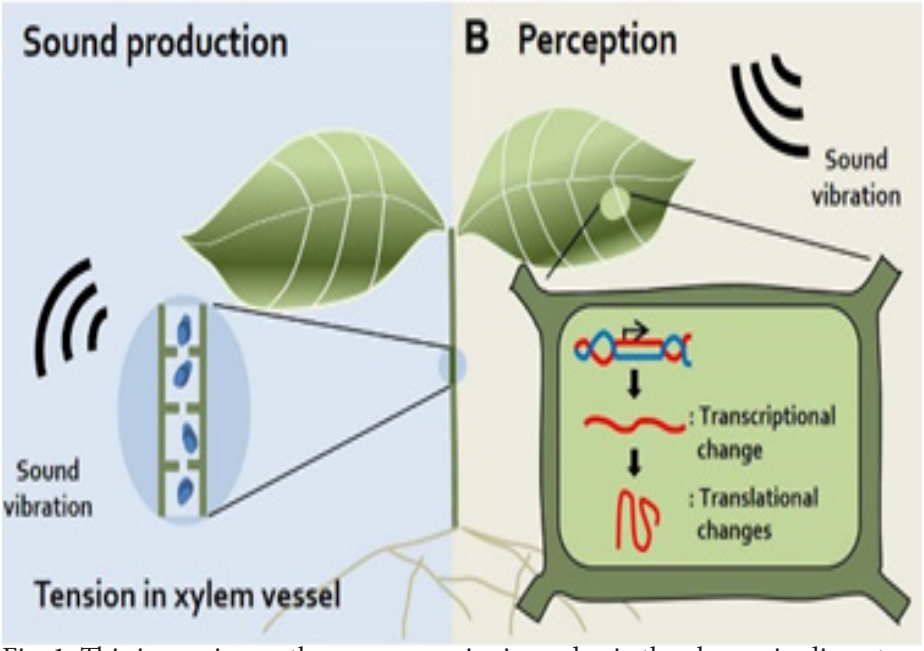


Fig. 1: This image is one theory were noise is made via the change in diametre in the xylem. It also shows howsound waves can cause structural change as proven by an experiment done with Zea Mays where the root tips began to point towards the sound (shown in Figure 2).

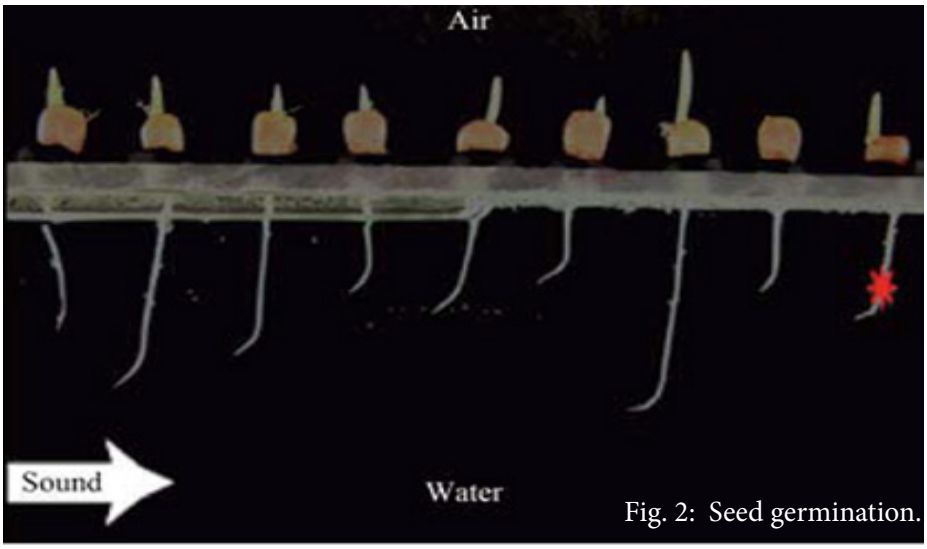


Fig. 2: Seed germination.

waves were also shown to be useful in getting rid of weeds as it increased uptake of herbicide and mature weeds could be sprayed with 50% less chemicals when also treated along with sound waves. The ability to reduce the need for pesticides will not only help the environment but also make food safer for humans. Pesticides could be present in up to 70% of our food and are known to have adverse effects on endocrine and reproductive function.

Sound technology also has a significant effect on seed germination; an experiment on paddy rice seeds showed a significant increase in things such as mass, stem height, activity of root system and penetrability of plant. This means sound waves could easily change the cell cycle and speed up its reproduction rate. Sound promotes growth by stimulating the release of growth hormones such as indole-3-acetic acid and gibberellin. Therefore, helping solve the problem of underproducing.

TABLE I. COMPARATIVE ANALYSIS OF PLANT GROWTH EXPOSED TO DIFFERENT MUSIC

Day	Growth in Controlled Environment (cm)	Growth in Indian classical music(cm)	Growth in Vedic Mantra(cm)
10	12	13	15
20	14	15	18
30	16	18	22

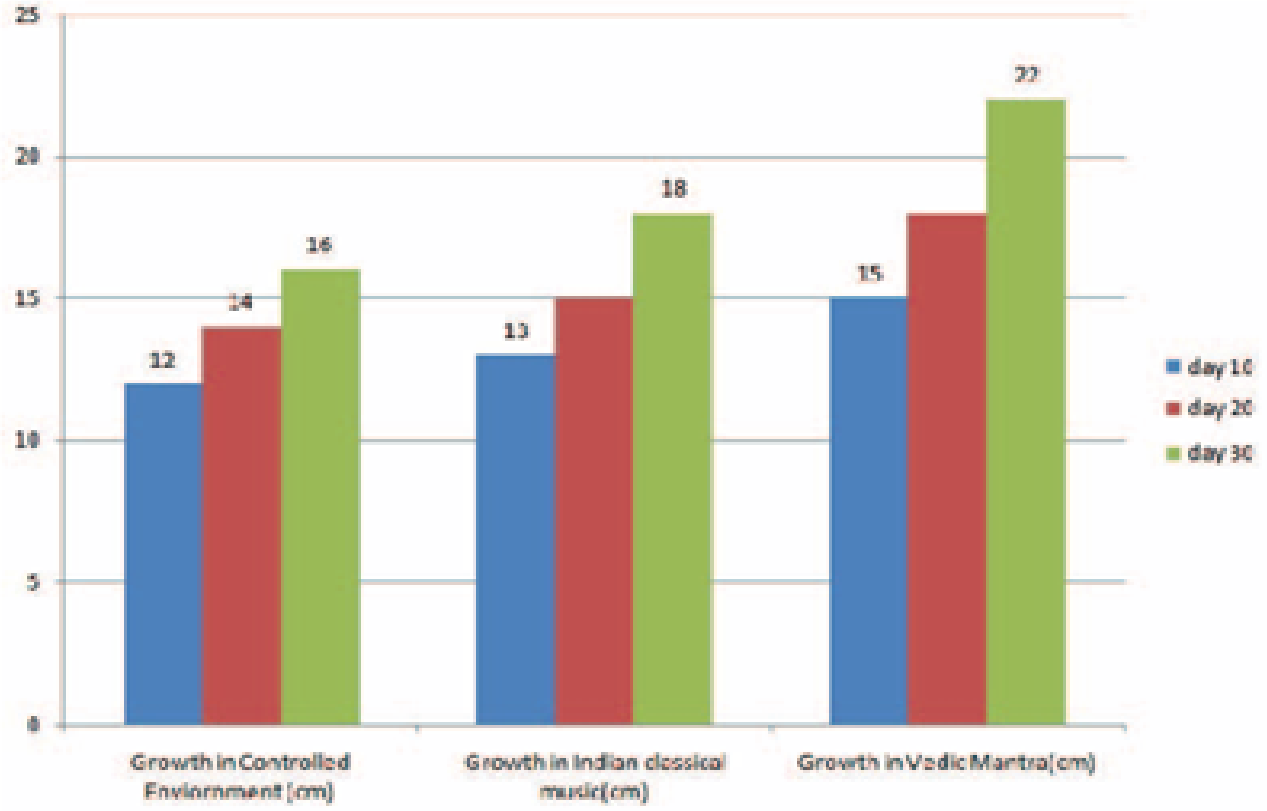


Fig. 3: These results are part of an 'Empirical study for the effect of music on plant growth'. It proves the theory I explained in the previous paragraph.

Following from the data in Figure 3, it is not quite conclusive which type of music plants most prefer as T.C Singh's experiment concluded that violins were most effective, causing plants to grow an extra 20% in height and 72% in biomass. Equally two students, inspired by the work of Dorothy Retallack, found that plants began climbing a wall to get away from speakers playing rock music, no matter how they were originally positioned they would turn away from the sound. Marigolds appeared indifferent to country, but responded well to jazz. Scientists believe this is due to the frequency and wavelength; compare a slight breeze to a strong wind. Darwin was also pioneering in the research into plant's sensory abilities and worked with his son in producing 'The Power of Movement in Plants' (1880).

However, if you are still in doubt you are not alone. Many scientists refuse to acknowledge these experiments as valid as many of them were unreplicable (when repeated by other scientists the same results were not achieved). At least now you can argue that there is reason to talk to your plants, just maybe avoid too much rock music.

THE CAUSES OF CALLOUS-UNEMOTIONAL TRAITS & THEIR RELATIONSHIP WITH BRAIN STRUCTURE

Sapna Chudasama

To be able to discuss the relationship between brain anatomy and callous unemotional traits we first need to understand what it means to be callous unemotional. These traits are usually characterized by a lack of empathy and remorse, as well as rule breaking behaviour and aggression. Children with these traits are more likely to display anti-social behaviour and are less likely to respond to socially rewarding stimuli such as happy faces. Most importantly callous-unemotional traits are defined as potential markers of psychopathy in children and adolescents (bearing in mind that in the USA the Diagnostic and Statistical manual of Mental disorders states that people under the age of 18 cannot be labelled as psychopaths.)

In a study on brain development involving 189 adolescents, researchers took a closer look at the developing teenagers to find out whether callous-unemotional traits were linked to differences and alterations in brain structure. They did this using voxel-based morphometry (which is an innovative approach to looking at structural brain abnormalities using MRI and the main process of VBM is segmenting the brain into grey matter, white matter, and cerebrospinal fluid).

The results of this study were remarkably interesting and showed that in typically developing males the volume of the anterior insula (the brain region involved in recognising emotions in others), was larger in those with higher levels of callous-unemotional traits. However, what makes this study particularly interesting was that this variation was not seen in the girls with the same personality traits.

However, Science has proven that CU traits are also heritable. Research has also shown that the genes that were important for CU traits in childhood were different from the genes that influenced later development of CU traits. Additionally, adoption studies have found that genetic vulnerability is not a destiny and can be counteracted by protective environmental influences. Finally, there are some studies which indicate that low levels of cortisol (the body's primary stress hormone) may also act as a biological maker for Callous Unemotional traits. In one study 37 boys with early-onset conduct disorder and 38 healthy boys were subjected to multiple daytime salivary cortisol measurements. Participants with high callous unemotional traits had decreased cortisol levels.

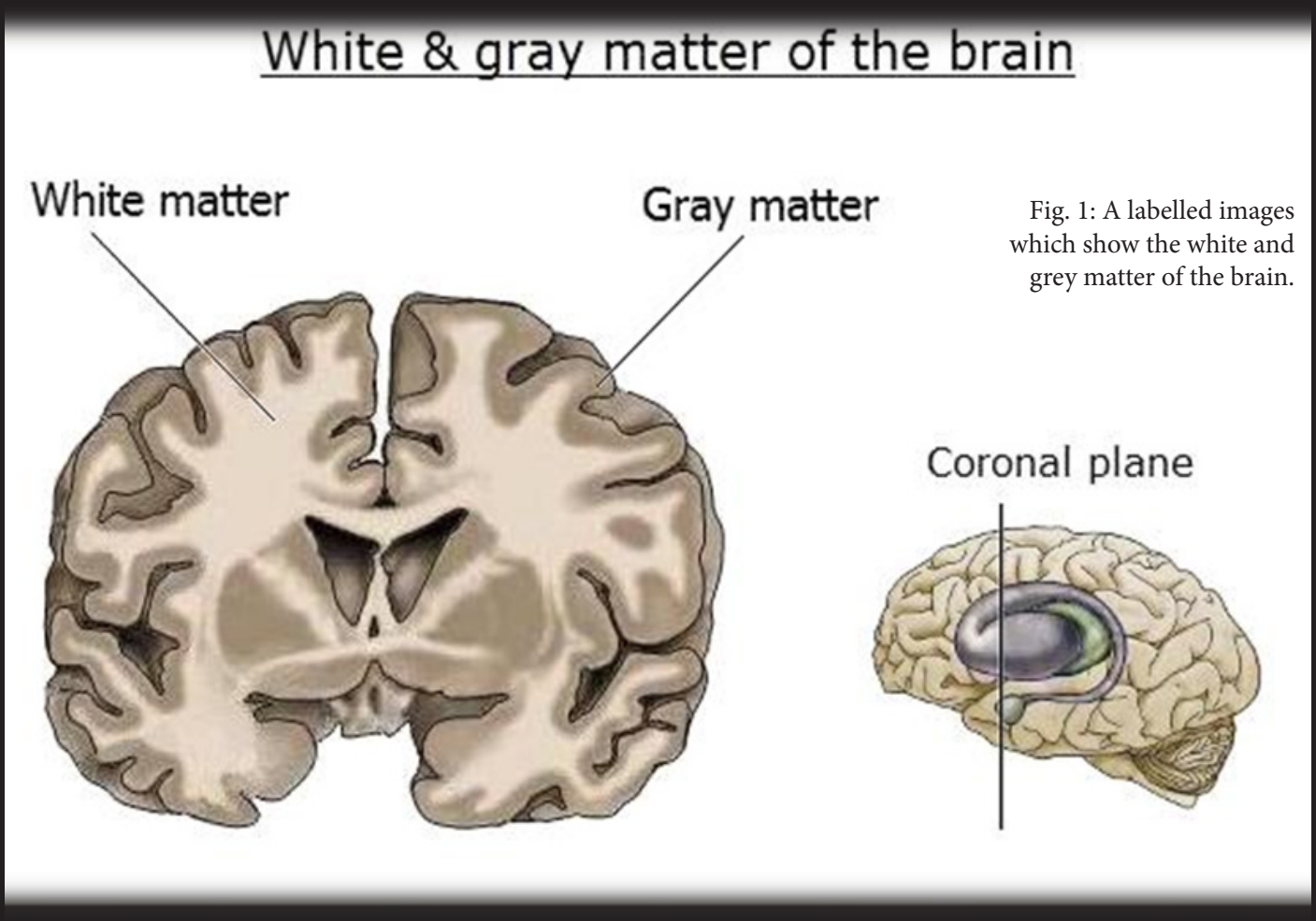


Fig. 1: A labelled images which show the white and grey matter of the brain.

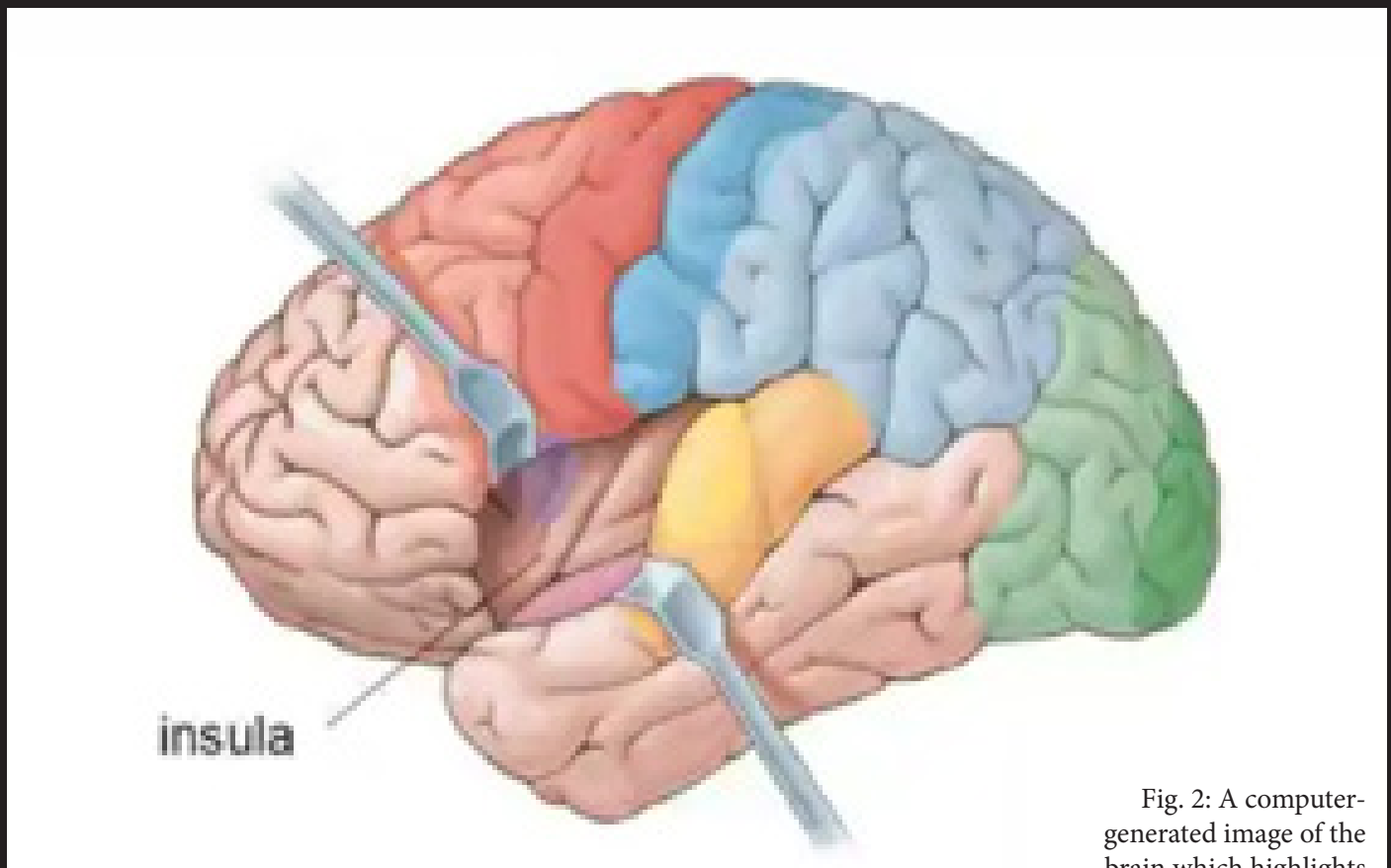


Fig. 2: A computer-generated image of the brain which highlights the location of the insula.

Does Language Shape Our Cognition or is it the Other Way Around?

CECELIA LAM

In the movie Arrival, a linguist, Louise Banks, is called in for deciphering the language of Heptapods – these are aliens who've just arrived in 12 countries separately, bringing chaos amongst fearful crowds and media (Figure 1). The alien language moves in circles, lacking a defined beginning or end. Louise soon learns that the Octopods perceive time in a similar manner: time isn't linear in their world – it's circular, with no beginning nor end; they possess visions of their past, present and future all at once, like reading their entire life off a pre-destined book. As Louise gains further understanding on the language, she begins to have visions of her own past and future, as her perception of time shifts from linear to circular. This is suggesting that, by the time one gains full understanding of a foreign language, thinking in that language can change one's pattern of thought as compared to one's native tongue. The film reflects the concept of the Sapir Whorf Hypothesis, which highlights the intimate relationship between the languages one speaks and the way one perceives the world.

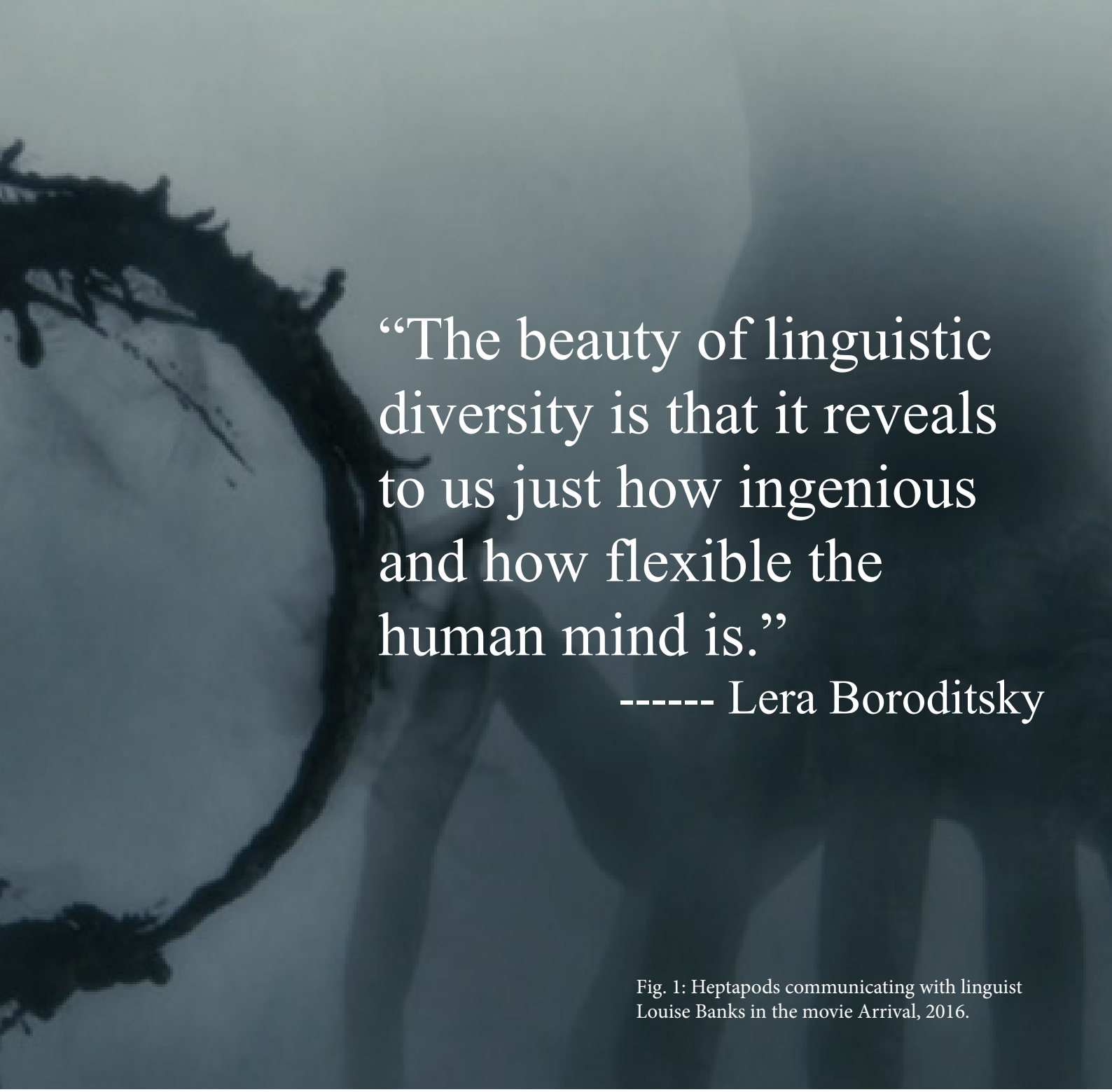


Fig. 1: Heptapods communicating with linguist Louise Banks in the movie Arrival, 2016.

Also known as the hypothesis of linguistic relativity, the Sapir Whorf Hypothesis is a principle claiming that the structure of a language affects its speakers’ cognition, thus people’s perceptions are relative to their spoken language. This is suggesting that what we consider as the external real world is built from linguistic meanings, and language itself is more than a tool for reflection and communication.

However, the concept brings in a paradox: language is a tool invented by humans satisfying our needs for communication, similar to how math is a set of abstract symbols intended to work as a tool for calculations. Yet how is it possible for a ‘tool’ to shape our very own thoughts and cognition?

Imagine if you’re asked to describe the position of your laptop at the very moment, with fixed cardinal points (four points shown on the compass) instead of using egocentric coordinates like ‘left/right/in front/behind etc.’, would you be able to do it? Very unlikely unless you’re trained to do so.

Interestingly, the Thaayorre people, an Aboriginal community located in Cape York, Australia, are perfectly fine with using

Fig. 2: The Thaayorre people in Cape Town, Australia.

cardinal directions in their daily lives (Figure 2). Words like 'left' and 'right' are nonexistent in Kuuk Thaayorre (the spoken language), and the speakers give all their descriptions and directions based on the fixed four cardinal points of a compass: north, south, east and west. Unlike English and the majority of the world's languages, the Thaayorre don't link positions of objects in relation to themselves – the directions are fixed on the landscape in their perception. This language feature gives them a superhuman sense of spatial awareness, as if they have an in-built compass, or a GPS with fully-functioning directional systems at all times.

For example, if you were to describe the location of a book on a table, you might say 'the book is located to the south-southeast of you.' A simple 'hello' stands for 'which way are you heading?' and you're likely to get something like 'North-north east in the far distance, how about you?' In this manner, you'll have to report the direction you're heading to every person you greet – as a matter of fact, you have to know which way you're facing and heading towards all the time. Expectedly, people who speak languages like this tend to stay remarkably oriented even in unfamiliar landscapes. In fact, their exceptional spatial/navigational abilities were better than we ever thought humans could do. This reflects the big difference in cognitive ability across languages: generally, an English-speaking person won't be sure of which way to point to if asked to identify the southeast direction right at this moment, as the language itself doesn't require us to use cardinal directions all the time when we can use egocentric references like 'left' and 'right's. However, a Thaayorre five-year-old would be able to tell directions quickly with accuracy. This shows that, if your language and culture trains you to do something, you are likely to do it no matter how hard it looks – one's cognitive ability is hugely influenced and shaped by the language they speak as shown in this case.

Language can also influence one's memory and perception – it guides the way we look at events.

For instance, a vase is accidentally knocked off the shelf by a person, and it broke. If asked to describe the scene, it's perfectly fine for English speakers to say: 'S/he broke the vase.' However, in Spanish, it would be incorrect to say so, as it was an accident – you wouldn't say someone did it and instead, emphasis is placed on the accident itself. Thus, Spanish speakers are more likely to say: 'the vase broke (itself).' Similarly, in many languages, there's no such thing as 'I broke my arm'; as the construction of the sentence is interpreted as one intentionally decided to break their own arm. This shows that people speaking different languages often pay attention to different things, depending on what their language requires them to do so. Humans have limited attention/memory capacity; thus, we often choose to pay selective attention to considerable values only, and omit all other 'irrelevant' information; this is done through sentence construction in the language spoken, meaning that in order to

speak the language fluently, you'd have to think in the way your language trains you to do so.

In this case, even if both groups (English/Spanish speakers) witnessed the same accident, English speakers are more likely to remember who did it, as its language structure requires you to say 's/he did it', 's/he broke the vase', while Spanish speakers are less likely to remember who did it if it's an accident – they're more likely to remember the event as the accident itself, what actually happened, without any further implications on personal motives as accidents are generally considered to be unintentional. Thus, their sentence construction helps filter out information considered as 'invaluable' i.e., who the person is, what s/he looks like etc. The person involved is not considered as critical information, as an accident of a vase breaking has nothing to do with anyone in their perception – it only has relevance to the vase itself. Thus, 'it broke (itself).'

This has consequences: if two people, each speaking a language different to the other, witness the same crime, they'll remember different things about the event – this has implications for eyewitness testimonies, as different sentence constructions influence our selective attention on events. We omit all 'irrelevant' information automatically and pick up the important bits according to what works best in our language structure. There are also implications for blame and punishments. Even if one witnesses an accident before their eyes – watching the vase drop and break accidentally – they will still put blame on the person more as one goes up and say 's/he broke it' as opposed to 'it broke.' This sentence construction places emphasis on the person in the accident instead of the breaking of the vase, which is the central event that happened. Thus, English speakers are more likely to blame a person in an accident subconsciously as compared to a Spanish speaker, primarily due to how sentences in the language are constructed, influencing what they choose to put selective attention on, finally affecting one's perception of events.

The above examples show that language does indeed influence and shape our cognitive world, whether it's giving the people of Kuuk Thayorre incredible skills of staying oriented at all times, or influencing our memory and judgement of events – these are evidence for how the language one speaks have effect on one's cognition, just as Whorf proposed: 'language is not merely a reproducing instrument for voicing ideas, but rather is itself the shaper of ideas.' There are approximately 7000 languages in the world, and that creates 7000 different cognitive universes distinct to one another. The multitude of languages across the globe shows how astonishing the human mind really is, and how valuable diverse languages are to mankind.

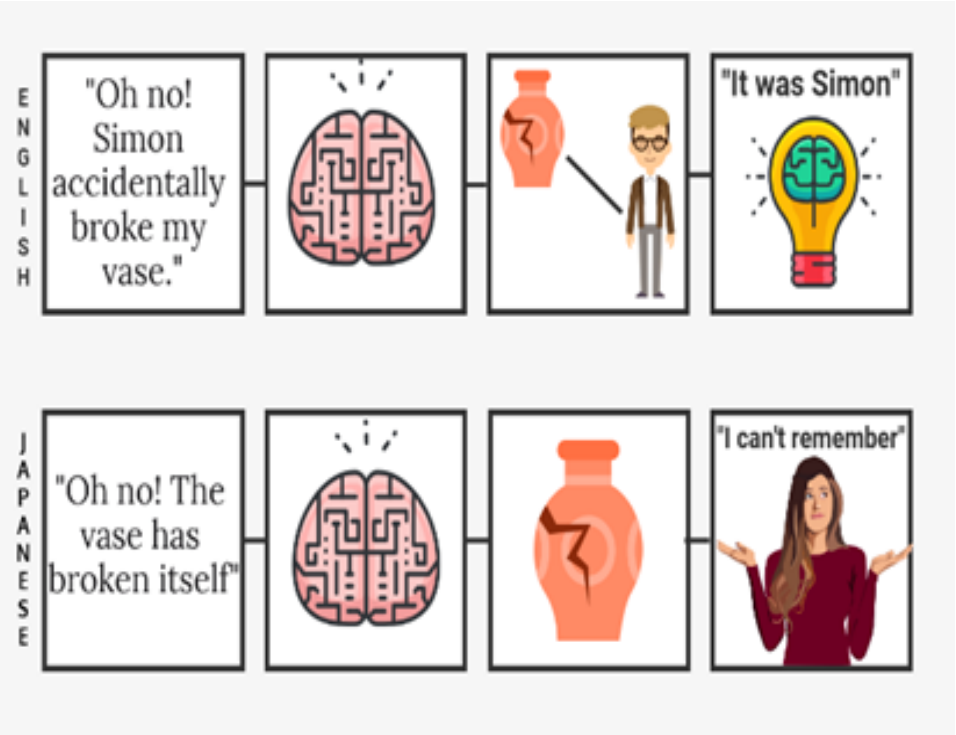


Fig. 3: Visual demonstration of how languages shape our perception of events and how it influences our memory.

Quantum Mechanics

Physics Research Project Poster: Quantum Dots

Hannah Hurst
Dima Shkabura
Harry Clarke
Yuhan Wang

The Authenticity of Absolute Objectivity

Yuhan Wang

picture: https://pixabay.com

The Authenticity Of Objective Reality – A Plain Understanding of Quantum Theories

Yuhan Wang

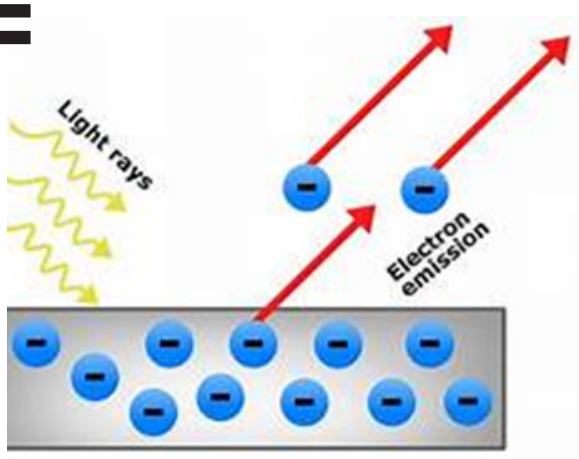


Fig.1: The photoelectric effect.

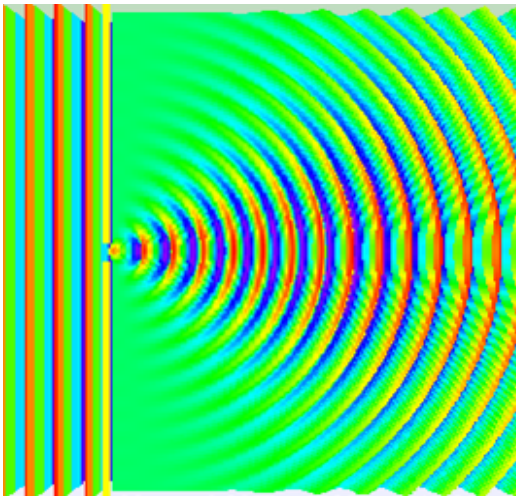


Fig.2: Diffraction of waves through a slit.

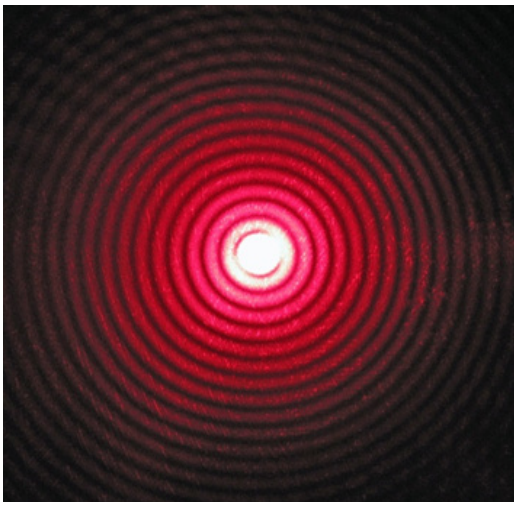


Fig.3: Waves radiating from a point source.

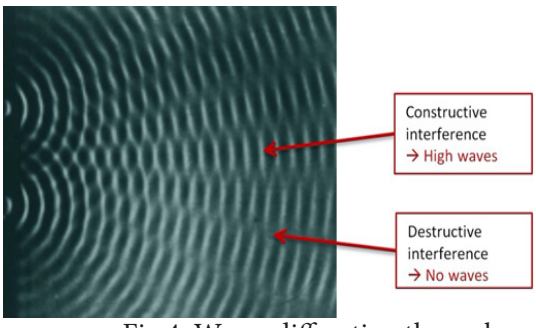


Fig.4: Waves diffracting through a double-slit.

In classical physics, theories and formulae can explain everything at any moment, whether in the past or the future. However, this is not valid for quantum physics. To approach this mysterious branch of the physics world, we need to understand two fundamental quantities, waves and particles. Waves and particles can both carry information and transform energy, while waves are successive, and particles are discrete. In modern physics, particles like electrons and photons are thought to have wave-particle duality. And this fundamental theory causes many counter-intuitive problems. How can things have particle properties at some points and wave properties at others? Why are the patterns of electrons different depending on whether they are observed or not? Is this world completely objective when it is recognised scientifically?

How do quantum particles show wave properties and particle properties? Particles like photons and electrons are both quantised into levels of the order 10^(-34), and they are considered to have wave-particle duality. In some experiments, they show discrete particle properties; for example, in the photoelectric effect (Figure 1), electrons are emitted by their one-to-one reaction with photons (light particles). In other experiments like diffraction and interference, they show wave properties as only continuous things can diffract and interfere (Figures 2-4).

Two sets of theories were established to describe the opposite properties of electrons in different experiments. They are mathematically equal, but an essential difference is one concentrating on the successive wave property and the other

considering the discrete particle properties.

Schrodinger invented the famous wave function by regarding electrons as de Broglie waves. The function is successive, but the solutions are not, just like solving sin(x)=0, where x can only take the integer multiples of π. This function perfectly represents the particle property of electrons as only integer values are solutions. The wave function Ψ (x,t) can be squared to give at probability distribution. The probability distribution means that the photon has 20% at one position and 10% at another position. Figure 5 shows one version of the Schrodinger equation.

ime-dependent Schrödinger equation *(genera*

$$i\hbar\frac{d}{dt}|\Psi(t)\rangle = \hat{H}|\Psi(t)\rangle$$

Fig.5: The General Schrodinger Equation.

Scientists like Heisenberg were against Schrodinger's theory as he thought quanta were discrete. Heisenberg with Pauli, Bohr, Bonn, and others considered matrix mechanics, which use matrixes to represent the position and momentum of electrons. These are based on the idea of atom spectroscopy (Figure 6), which contain the measurements of the variables like intensity and frequency of the light radiated from the atoms (Figure 6).

Heisenberg proposed the Uncertainty Principle, which indicates the particle properties and wave properties of a quantum particle cannot be determined simultaneously. This can be verified using a gamma-ray to assess the states of electrons. We can foretell the probability of electron positions, but we cannot determine it, regardless of how accurate machines are. This principle was so significant as a milestone that it broke the strict determinism of physics, which states that the objects in the universe do not move in perfectly determined ways.

$$\sigma_x \sigma_p \geq \frac{\hbar}{2}$$

Fig.7: The formal inequality relating the standard deviation of position sigma-x and the standard deviation of momentum sigma-p.

We cannot determine everything by physics theories. Things can happen by chance, like dice. Nevertheless, do not panic. The theory is only used in the quantum level world. The position of your desk is still there, without moving, at least not noticeably.

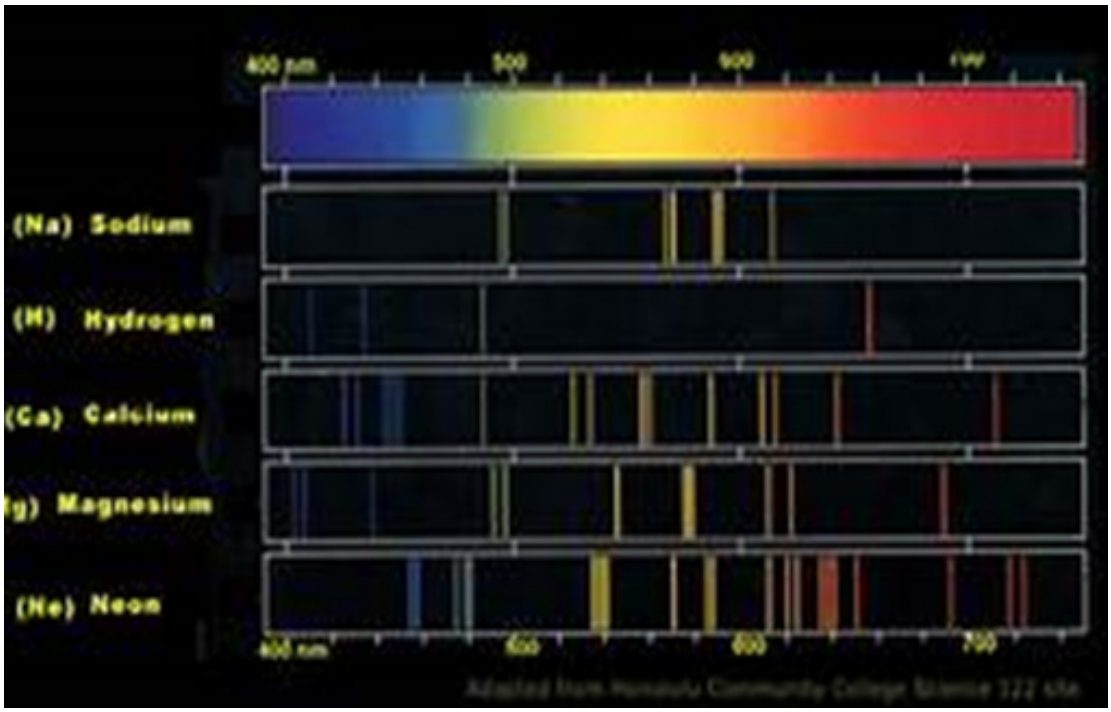


Fig. 6: Emission spectra of various elements.

$\Delta E \Delta t \geq h/4\pi$ is a secondm more interesting, version of the Uncertainty principle. This equation shows that in a concise amount of time, the energy change can be dramatic. This contradicts the conservation of energy, one of the fundamental rules of physics. it sounds crazy that anything can happen in an incredibly short amount of time, but it is valid only for a tiny period of time. Conservation of Energy cannot be broken on a significant scale.

Fig. 8: In optical illusions, like quantised particles, reality can depent on the observer.

It is also believed that things are created from nothing, as E=mc^2, the mass can be balanced with the negative gravitational energy to make sure the conservation law is not broken. This even led to the Inflation theory in the universe scale, which states that at the very early age of the universe, it extended with a dramatic speed.

Also, the observables of electrons are associated with the measuring manner, just like the Uncertainty Principle. This sounds unbelievable to our everyday life, but everything we observe is from visible light range. For example, we say a shirt is blue, but the shirt might be grey for a dog. Is the dog wrong to say the shirt is grey? No, since we have different ways of observation. The reason why the quantum world relies on the manner of observation is that photons are so small that each observation caused by the collision of light particles will change the position and momentum of the observed photon and alter its characters. It seems that the world is not objective anymore. In the elegant and straightforward classical physics world, although we might not understand every detail in the universe, the universe itself always obeys the route of life, with or without observation. However, it depends on the observation now, just like Schrodinger's cat, which we will never know whether it is alive and dead unless we observe it.

Some old-fashioned physicists, including Albert Einstein, were not satisfied with the uncertainties. They imagined electrons have a specific position and momentum that we are not able to determine. However, these imaginary positions and momenta are meaningless, according to Occam's Razor, which suggests 'Entities should not be multiplied unnecessarily.' In other words, there is not an objective, 'absolute world'. The observed world is related to the observing manner, and it is meaningless to talk about the 'true world' without mentioning the way of measuring. The exact meaning of natural science is how we can describe the world instead of using imaginary quantities to explain it.

I believe that this might imply that observation creates reality to some extent. And would lead to the potential connections between quantum mechanics and consciousness: which instant in the process of observation affects the result. Is it where signals hit a detector? Is it when the image or numbers registered by the detector enter our eyes? Is it when this information reaches our brain? Whose brain does it have to reach, is the universe recreated when I tell a colleague about my experimental results? Or when it's processed by the brain? Also, what about the quantum particles that play a role somewhere in the chain of information transmission that are themselves not measured--- do they change the reality? And how do we get to have measuring devices (we can consider ourselves a measuring device) if everything that exists is created by measurement?

Quantum physics is mazy, unlike traditional, punctilious Newtonian physics, with everything following the formulae and causal relationship. It causes the collapse of the absolute objectivity of the world but prompts us with deeper thinking of science, even philosophy. It is like a mysterious, generous goddess, with a veil covering her face, guiding us to find her countless, invaluable treasure.

Oxford University Physics

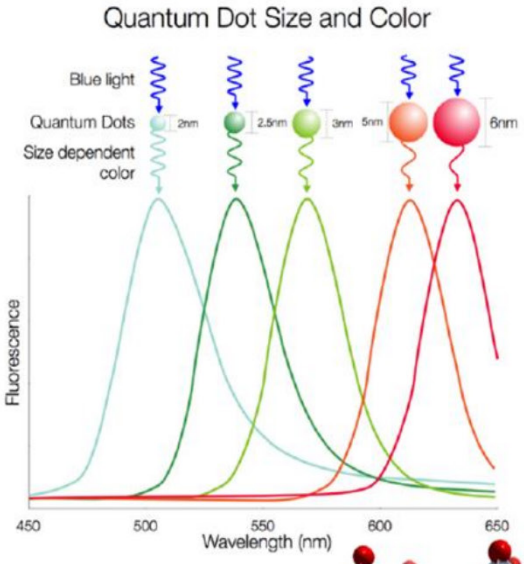
Hannah Hurst (EDH), Dima Shkabura (Ch),

Details of the project:

- For this project we had frequent tutorial meetings via video-call with Dr Farrow, Senior Research Fellow at Oxford University, Department of Physics.
- We also each researched different aspects of the project such as spontaneous and stimulated emission or the Purcell effect and gave presentations to the rest of the group via Teams.

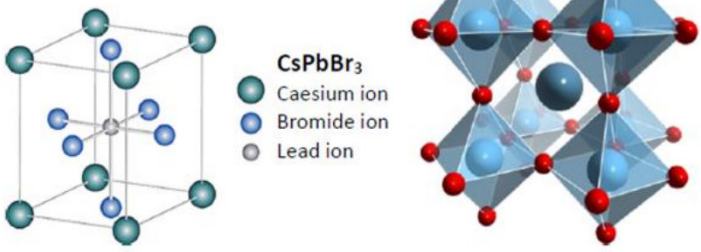
What are Quantum Dots?

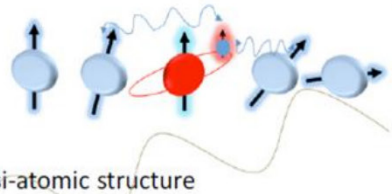
- Semiconductor particles
- Very small → known as nanocrystal
- Sometimes referred to as "artificial atoms" because they act like a single giant atom
- Some of them have perovskite structure (see below)
- Optical properties: become luminous and emit a very precise coloured photon depending on their composition (size)



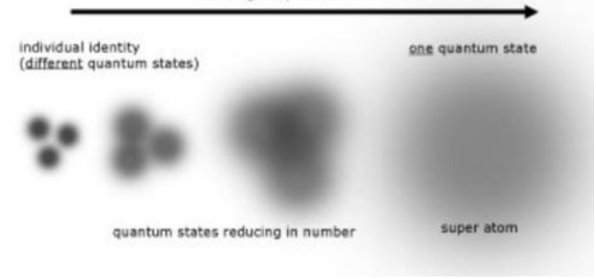
Perovskite Crystal structure

- Crystals with chemical formula ABX_3
  Eg $CsPbBr_3$
- Lead-halide perovskites act as quantum dots nanocrystals





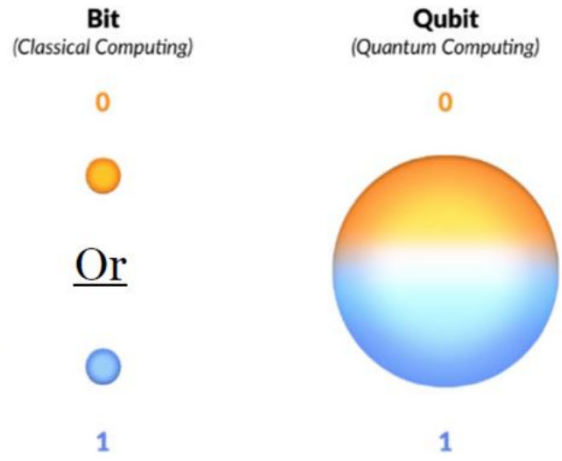
Super atoms:



- A cluster of atoms with a quasi-atomic structure
- Behave chemically in a way that lets them have a closed shell of electrons
- Exhibit some of the properties of elemental atoms
- At ultra-low temperatures, Bosons form a kind of super-atom, and behave as a single wave (a system)

Application—Quantum Computers:

- Use qubits as a base unit of information, which simultaneously behave as both a one and a zero.
- Quantum computers will revolutionise computing due to their immense performance
- They are significantly more powerful than traditional computers as with each additional qubit, performance increases exponentially
- Data transmission becomes very secure with the use of superposition
- Quantum computers solve problems in several minutes that traditional computers would need billions of years to solve



Research Project for Schools

Harry Clarke (Ch), Yuhan Wang (MSH)

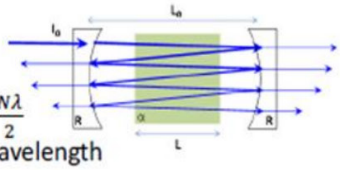
- We learned how to analyse peaks in a power spectrum using a software called "Origin". We had to select the peaks and fix certain parameters to help the software fit the peaks using a Lorentzian function. We crosschecked results with one another and repeated if necessary.
- We learned some advanced mathematical techniques such as Maclaurin Series and Euler's formula to solve the modelling of an optical cavity. This showed how only certain wavelengths of light would be amplified and the rest would be 'filtered' out.

Optical Cavity Science:

Optimisation for a specific wavelength

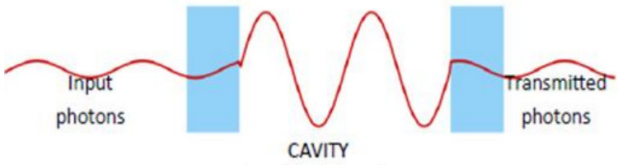
Method:

- Vary the reflectivity
- Fine tune cavity length = $\frac{N\lambda}{2}$ for resonance at target wavelength



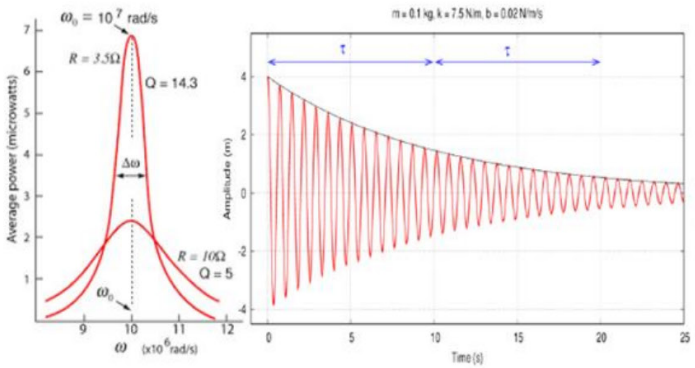
Purcell Effect:

- Method: put the quantum dot atom into a resonant cavity
- This enhances both spontaneous and stimulated emission rates
- A rapid return to the ground state readies for re-excitation by the input beam



Quality Factor

- Measures the damping effect on the oscillations of the waves within it
- High quality factor → low damping
- Low quality factor → high damping
- Average lifetime of a photon ∝ Q factor
- Abruptly changed from low to high, the intensity of the pulse of light increases dramatically

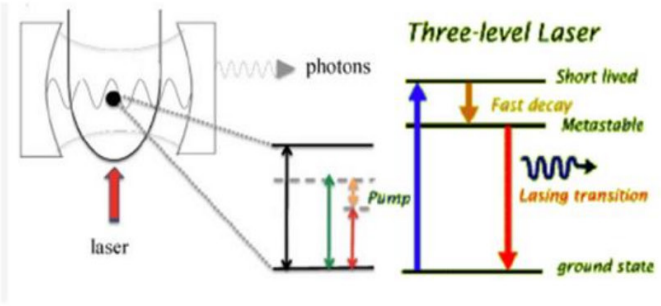


Photon lifetime

- A time constant that describes the decay of energy in a cavity
- Photon lifetime is related to as the rate of photon leakage
- Affects the dynamics of a laser cavity and the steady-state operation

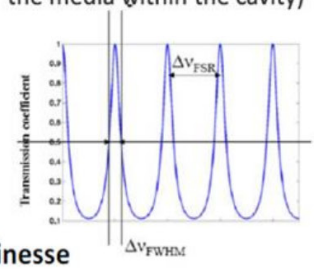
Or can be defined as:

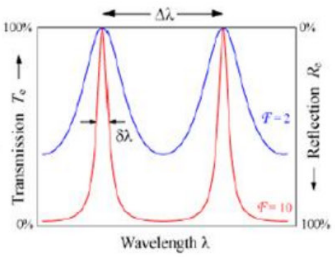
- The time that the atom molecule spends, on average, in the excited level



Free Spectral Range (FSR) (Δλ or Δν)

- The spacing between wavelengths/frequencies that are adjacent transmission peaks
- Δλ ∝ 1/the cavity optical length
- The FSR is the difference in wavelength between adjacent transmission spikes
- It is simplified to $\Delta\lambda = \frac{\lambda^2}{nL}$ (where n is the refractive index of the media within the cavity)





Finesse

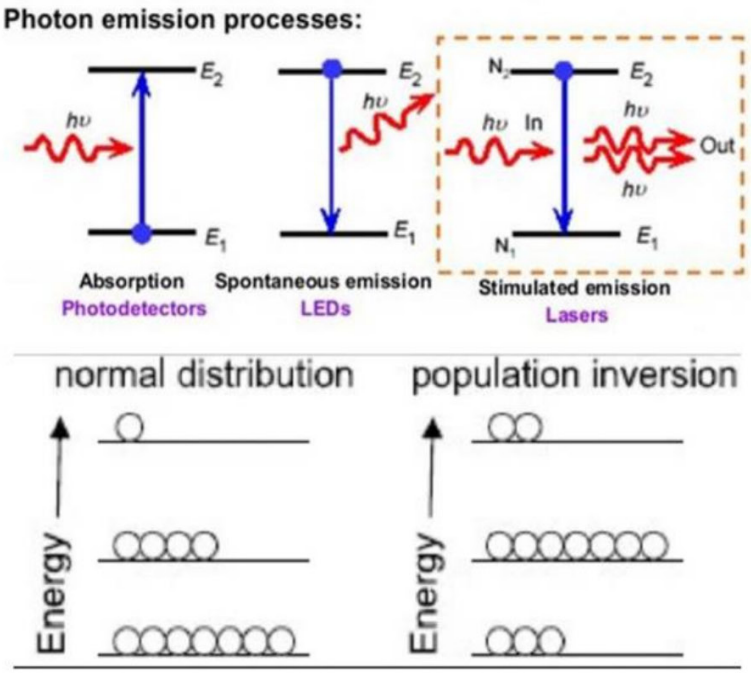
- How "picky" a cavity is about which wavelengths transmit
- If the peaks are wide the cavity is not a very good filter

$$\Delta\nu_{FWHM} = \frac{\Delta\nu_{FSR}}{F} \qquad (\text{bandwidth}) = \frac{(\text{free spectral range})}{(\text{finesse})}$$

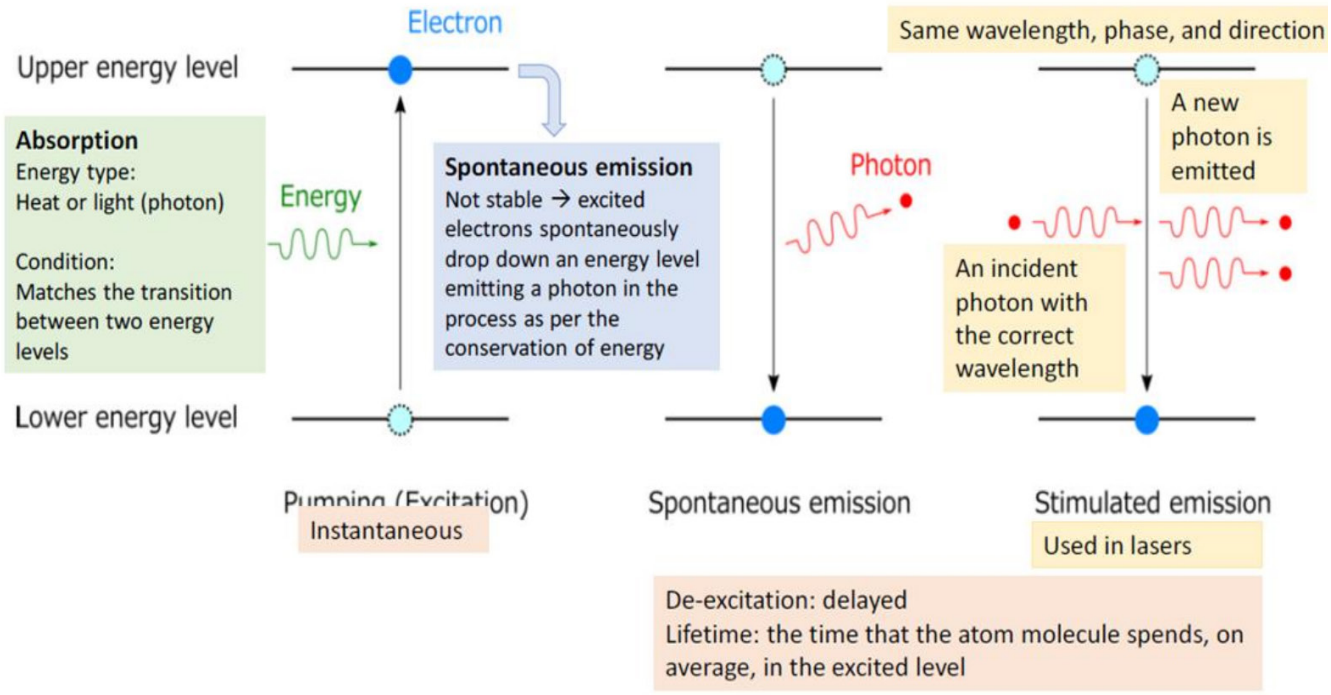
Quantum Dots in

How does a Laser work?

- Particles with electrons in the ground state are excited by photons and the electrons move up an energy level – this is stimulated absorption.
- Further photons meeting these excited atoms cause stimulated emission whereby an electron drops down an energy level and photon is emitted in phase with the incident photon – this creates a beam of coherent light.
- This is how light is amplified; however, this can only happen when there is a population inversion. This is when there are more electrons in higher energy levels than those in the ground state (see lower image).
- These photons are reflected back and forth in an optical cavity, creating a standing wave and allowing the resonance and intensity to be controlled, before leaving through a partially reflective mirror. This is the outgoing Laser beam.



Lasing process: Excitation → Spontaneous or Stimulated emission



Skills gained:

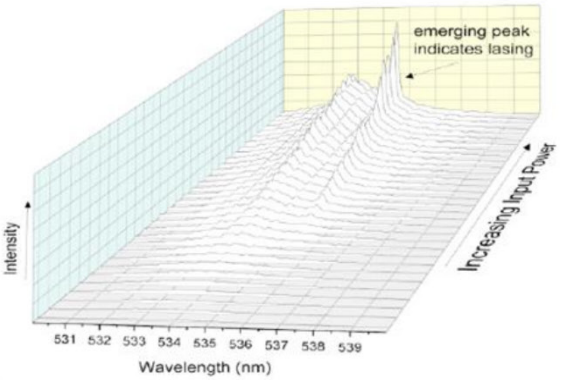
- Learned about a large number of undergraduate level physics concepts
- Gained confidence through active learning via the university tutorial format
- Learned how to use the advanced software Origin to analyse data

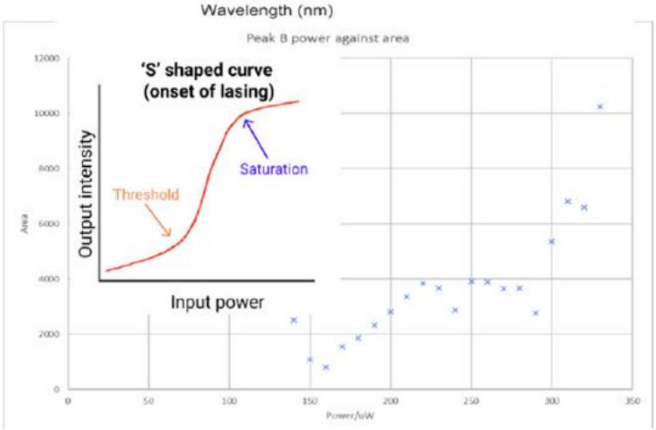
Optical Microcavities

Data Analysis

We were given "live" data measured by Dr Farrow's research group

- Using Origin data analysis program, the data was fitted into a Lorentz curve as shown in the bottom picture
- This curve was analysed taking the full width at half maximum (FWHM) and the area under the peak
- The width at half peak height represents how pure the wavelength is
- The area represents the intensity of the photons produced by the optical cavity.
- By comparing these statistics at different temperatures, we can find lasing crystals and at which temperatures they best operate.
- Lasing is indicated by a distinct "S-shape" produced by the graph of power supplied against the area





Experimental details – experiments conducted by Dr Farrow and his team

The experimental technique is called micro-photoluminescence in a confocal microscopy geometry.

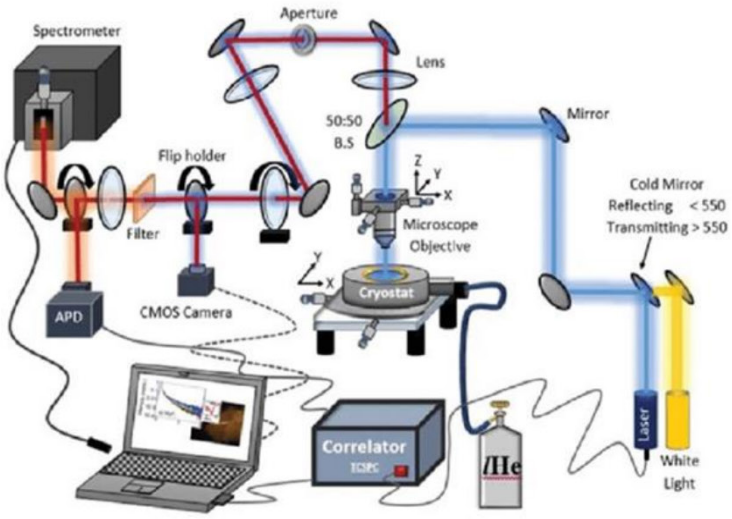
The method:

- A laser shines a beam of light which is focused by an objective lens to spot size of 1 micron (0.0001 cm) on the sample surface
- Re-emitted light from the sample is sent to the spectrometer which separates and measures the wavelengths
- This information is projected on a CCD camera with pixels that digitise the image in the form of a spectra

The aims:

Short term: To use the spectroscopic data to analyse the behaviour and properties and behaviour of the perovskite nanocrystals.

Long term: To develop nano-lasers with tuneable wavelengths and new sources of single-photons for quantum information processing and quantum communication.



- Gained motivation through a research project on cutting-edge science using "live data" from Oxford Scientists
- Developed research skills and project management ability though weekly tutorials
- Gained experience giving presentations on technical topics and learned to always be prepared to answer difficult questions!
- Trialled an academic subject before applying to university and gained subject-specific knowledge

THE THALIDOMIDE DISASTER

Ella Ho

ANTIVIRAL PILL TO TREAT COVID APPROVED FOR USE IN UK

Myra Lam

MEDICAL ETHICS

Marco Chan

WHY IBUPROFEN IS SAID TO BE DANGEROUS

Rosa Li

INVESTIGATING IMMUNOTHERAPY

Janet Li

picture: https://pixabay.com

Short Introduction to Medical Ethics

Marco Chan

Doctors are faced with lots of decisions on a daily basis. A wrong decision could lead to the death of a patient. Lots of these decisions include ethical dilemmas such as euthanasia[1], DNRs[2] and Gillick competency[3]. In order to guide doctors through these tough decisions, there are 4 pillars of medical ethics that doctors follow worldwide. The 4 pillars are "autonomy", "beneficence", "non-maleficence" and "justice" (source: General Medical Counsel). In this article I will be discussing these, giving you a brief introduction to medical ethics.

To begin with, what is autonomy? This is when patients have the right to decide on their own treatment. Patients can make their own decisions on whether to proceed or reject the treatments suggested by their doctors. Patients can only make these decisions provided that they are competent and have understood all the information given by the doctors. Doctors must make sure that the patient has the capacity to retain the information and is fully aware

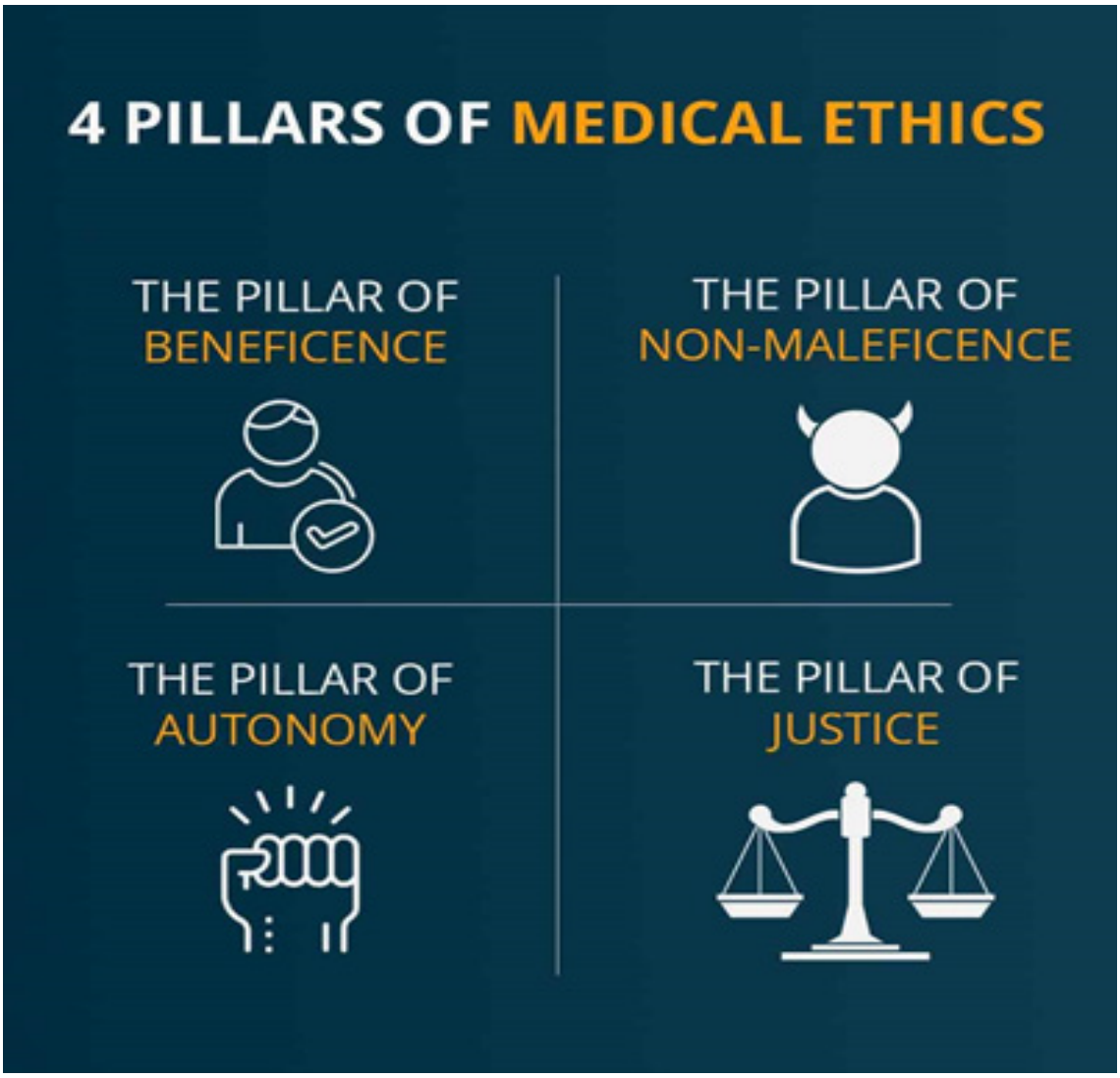


Fig. 1: Summary of the 4 pillars of medical ethics.

of all the risks. In addition to that, decisions made must be voluntary and should not be influenced by others. According to the Mental Capacity Act 2005, doctors will make the decisions for patients without the mental capacity (ability to make decisions and carry all responsibilities of an adult) to do so (for example, a person with an impaired mind). Doctors have to make decisions that are of the best interest of patients and deliver a patient-centred care.

Beneficence is ultimately doing good for the patient and deciding everything within their best interest. Non-maleficence is the principal of doing no harm to patients. Finally, justice is treating everyone equally and not judging people by their social or economic status. Confidentiality is also extremely important and sometimes considered as a pillar of medical ethics. All patient information should be kept between the doctors and the patients and should not be disclosed to anyone unless consent is given by the patient. However, doctors must follow laws and regulations too, and confidentiality has to be broken in complicated situations, (e.g. when patients develop HIV, which risks the health of others), or when it is ordered by court to disclose patient information.

It might be a lot of information for you to take in within this article. I have attached a small ethical scenario below that doctors might come across. Discuss and talk to your friends about what you would do if you were the doctor in this situation. Remember there is no right or wrong answer.

Scenario:

A 15-year-old girl approaches a local GP by herself and ask for contraception. Should you let her parents know she is engaging in sexual activity? Should you prescribe the pill?

Marco's Response to this question: The legal age for a patient to make their own medical decision is 16 years old or above, and a 15-year-old girl has not reach the legal age for making their own decisions yet. However, it does not mean that we should not be providing treatment for her. Gillick competency is when doctors allow patients under the age of 16 to make their own medical decisions without their parents knowing or permission provided that they are a "mature minor". To assess if this girl has the competency, the doctors may ask the girl to repeat

the information regarding the contraception back to him and to make sure she is fully aware of all the short term and long-term side effects, so she is able to take responsibility for her decisions. Doctors must be able to follow the thought processes behind this girl and understand the context of the incident, seeing a bigger picture of why the girl needs contraception, and decide whether she is in danger. Once Gillick competency is deemed, doctors also have the responsibility of treating the patient as a whole. As she is only 15 years old the doctor should follow the Fraser guidelines (a guideline that specifically targets contraception and sexual health in younger children). This guideline helps doctors determine whether the parent of this girl should be informed about this situation. In conclusion, if the girl is competent and providing contraception is of best interest for her, doctors should prescribe her the contraception. Doctors should also encourage her to talk to her parents about this as engaging in sexual activities at a young age could compromise her mental and physical health.

Footnote:

1. Intentionally killing a patient to relieve them from suffering from a terminal illness
2. Do not resuscitate
3. Whether or not an underaged child can make their own medical decision for themselves

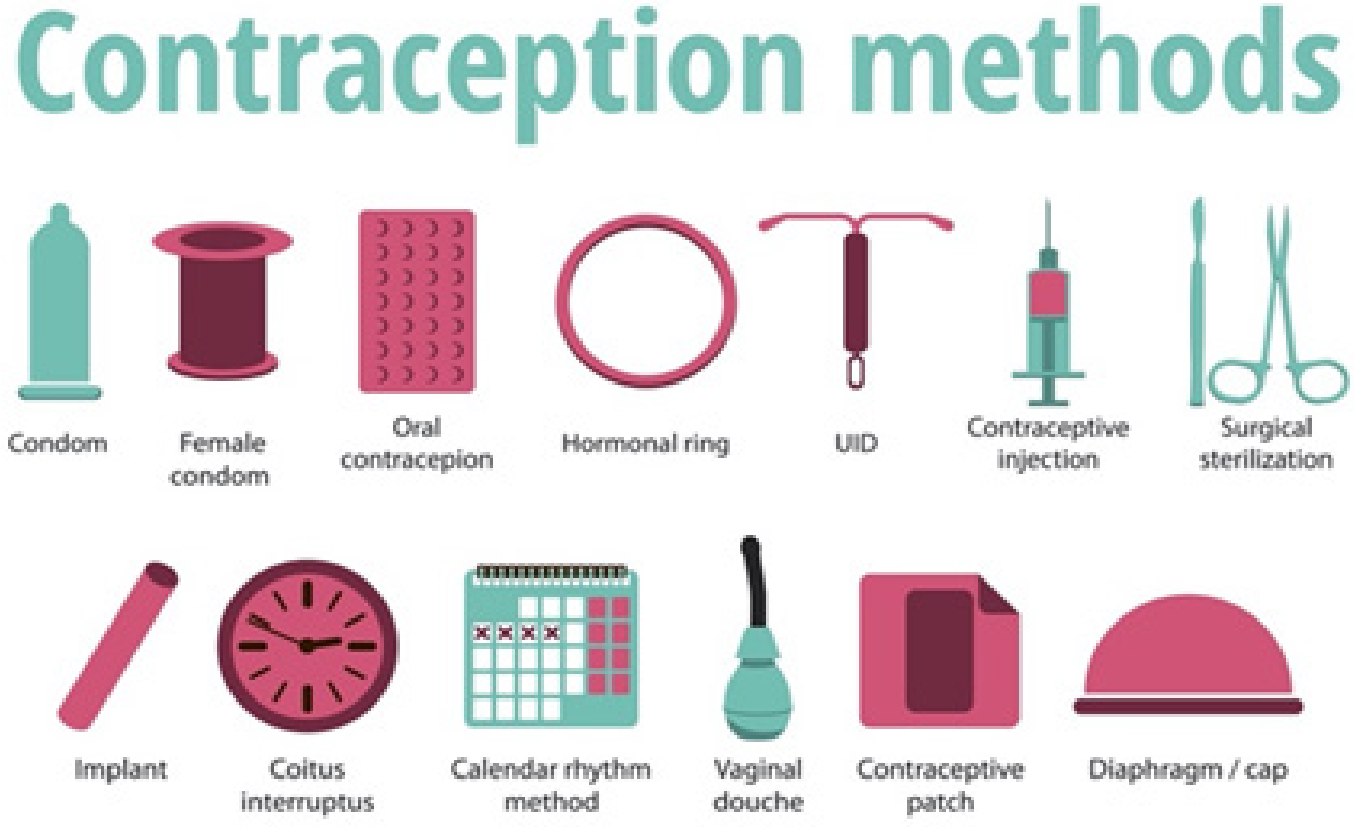


Fig. 2: Common types of contraceptive methods.

THE THALIDOMIDE DISASTER

Ella Ho

Fig. 1: A child with phocomelia as an teratogenic effect of thalidomide.

What Happened?

Our story begins in the 1950s when the German Pharmaceutical company Chemie Grünenthal isolated a by-product that was an analogue of glutethimide, a sedative. Thalidomide was introduced in 1956 as a sedative and was later launched as an over-the-counter drug. Its toxicity was examined in several animals and since it was nearly impossible to give a lethal dose, it was deemed safe for all ages and pregnant women.

Researchers found that thalidomide was an effective antiemetic and inhibited morning sickness, and so thousands of pregnant women took the drug to relieve their symptoms. It was believed at the time that drugs taken by pregnant women would not be able to pass through the placental barrier and affect the foetus.

The drug was distributed to 46 countries under different names, such as Softenon in Europe, Contergan in Germany, and Distival in the UK and Australia. At a time when the world was infatuated with 'tranquillity' medication, thalidomide quickly became the largest selling drug in the world and was marketed heavily and advertised as a safer, non-addictive sedative compared to barbiturates. The heavy marketing can be seen by the sample packets that were handed out to physicians to distribute to morning sickness patients freely (Figure 2).

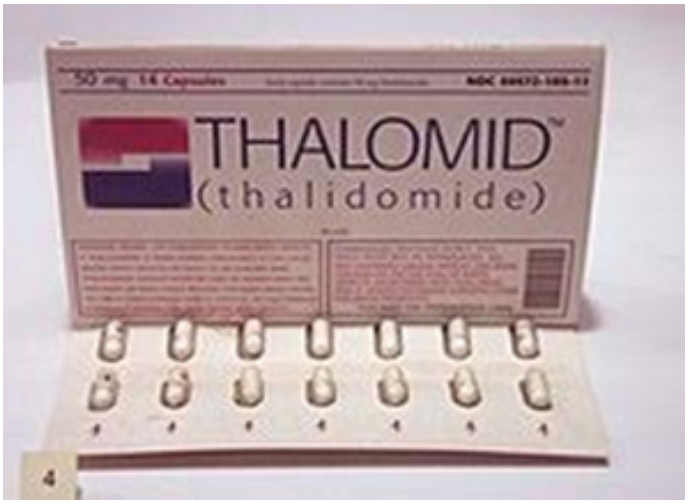


Fig. 2: Thalomid, one of the names thalidomide was sold under.

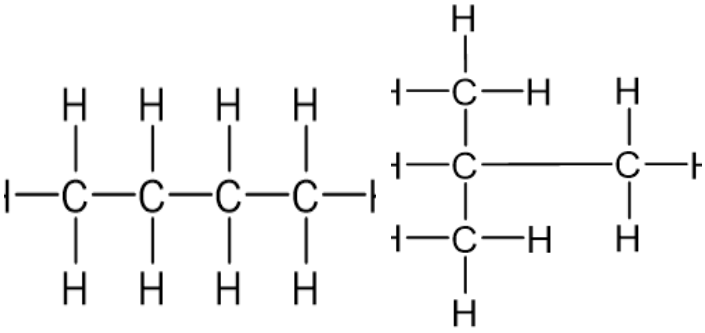


Fig. 3: Structural isomers of C4H10. Notice how the structural formula changes from CH3CH2CH2CH¬3 to CH3CH(CH3)CH3 even though they share the same molecular formula.

However, reports of severe birth defects (Figure 1) arose soon after and although they were not initially linked, It was confirmed by two independent clinicians, Lenz in Germany and McBride in Australia in 1962 and 1961 respectively, to be the cause of the largest man-made medical disaster in history. Hospital licensure laws were created and implemented. Hospital construction plans were created and approved by the U.S. Public Health Service, and local communities were able to receive large-scale funding in order to construct clinics, health centers, and hospitals. This was of great benefit to the poorest and most rural areas, which typically had no health care whatsoever.

Although most of the construction was for general health care facilities, increasing attention was also paid to specialized facilities for tuberculosis, psychiatric and chronic illness units in general hospital facilities, as well as development of rural and public health centers. Between 1947 and 1975, the last year in which Hill-Burton monies were expended, 6,900 hospitals received funding. By the middle of the 1970s, the nationwide average for community hospital beds had risen from fewer than 3 per thousand people to 4.5 per thousand. For the first time, many rural areas had access to health care and hospital facilities.

Although the Hill-Burton Act has had a tremendous and lasting impact on medical care in the U.S., the problem of ensuring adequate and appropriate access to health care for the poorest of the poor in rural and outlying areas remains. In rural areas, particularly in sparsely populated or largely impoverished regions, it is difficult to attract and retain health care providers. Generally, there is often a lack of available public transportation and a scarcity of people who can afford to access care. Some indigent people without significant education or ready transportation in rural areas often find it difficult to manage the requirements for remaining on the rolls of public

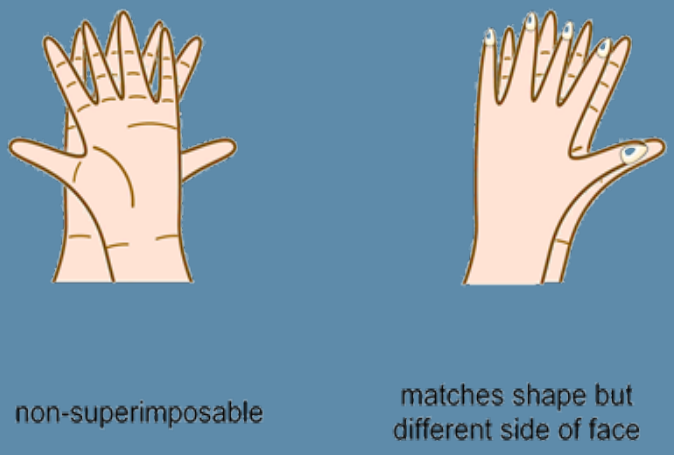


Fig. 4: diagram that shows how a pair of hands are non-superimposable to one another.

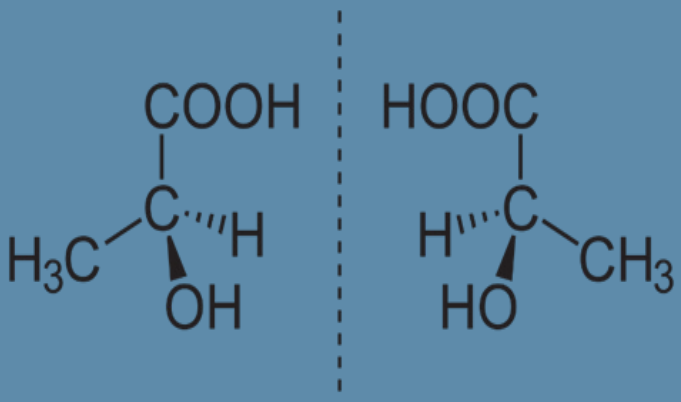


Fig. 5: Enantiomers of Lactic Acid (CH3CH(OH)COOH)

health care systems, such as Medicaid. Without sufficient paying customers to ensure an adequate cash flow, there is little incentive for health care providers to locate their offices in rural areas.

There were over 10,000 reports of severe birth defects in children from women who have taken thalidomide during their pregnancy and increased miscarriage rates during this period. In November 1961, it was quickly withdrawn from the UK, and most of the world by 1962.

Chemistry: Isomerism

There are two types of isomers: structural isomers and stereoisomers. As you may know from GCSE Chemistry, structural isomers are molecules or compounds with the same molecular formula but a different structural formula (Figure 3).

Stereoisomers, on the other hand, share the same molecular formula and the same structural formula, but they differ in the arrangement of atoms in space. Within this, there is a special subgroup of stereoisomers called enantiomers, or optical isomers. These special stereoisomers are non-superimposable to one another, meaning that they are mirror images of each other and do not match up when put one on top of the other. A great example of a non-superimposable image is the human hands. Generally, they are symmetrical and look identical to each other, with all 5 fingers connected to the palm in the same order. However, if one were to place their hands one on top of another with both palms facing the same direction, the hands would not match up, no matter how you rotate them and making them non-superimposable to each other (Figure 4). This relates to enantiomers in the same way. The molecules in Figure 5 are an example of enantiomers in which they are symmetric but non-superimposable.

Thalidomide also has enantiomers and exists in these two forms: R-Thalidomide and S-Thalidomide. As we have discussed, they share the same molecular formula of $C_{13}H_{10}N_2O_4$. It is believed that the R-Thalidomide was responsible for the desired, sedative properties of the drug, whilst the S-Thalidomide was the teratogen and caused the birth defects. Although it was possible to separate the two isomers *in vitro*, the compound interconverts *in vivo* and the teratogenic enantiomer returns.

Side effects:

One of the most famous side effects of this drug is congenital malformations, where the growing foetus cannot develop properly. It is estimated that between 1957 and 1962, thalidomide caused severe birth defects in over 10,000 children. Nearly all of the tissues and organs of the body could be affected by the drug. Some of the hallmark features of a thalidomide victim were identified by several German, British and Australian physicians such as Lenz, Smithells, Newman and McCredie. Phocomelia (the malformation of limbs), damage to the face, eyes, ears, genitalia, and internal organs such as the heart and kidneys are amongst the most common with thalidomide victims and is known collectively as thalidomide embryopathy.

Infants with thalidomide embryopathy have a mortality rate of up to 40% and many had been miscarried or stillborn. There is a critical period during gestation where Thalidomide will have teratogenic effects on the foetus. This is between the 34th and the 50th day after the last menstruation period, which is 21 to 42 days of gestation. In a study done on 113 pregnant women who had taken thalidomide, those who have been prescribed Thalidomide after the critical period, the babies appeared to be normal and healthy, which confirms the importance of the thalidomide critical period. Depending on the day of gestation (within the critical period) thalidomide was taken, different malformations can occur. For example, ear and facial nerve palsies are known to occur with ingestion of thalidomide early in the sensitive period (approximately days 21 to 26 after conception) and that since the upper limb usually develops at day 28 of gestation, ingestion of thalidomide may be less likely to affect the upper limbs after its development.

Apart from the most notable teratogenic side effects of thalidomide, it also affects the patients themselves. Given that most of the studies in humans since the 1960s have been about the affected thalidomide babies and few on its damage on the patients taking thalidomide, it can be argued that the drug did more damage than was advertised when it was first on the market. Another serious side effect people who have taken thalidomide might experience is peripheral neuritis. This is where the peripheral nerves are damaged, sometimes permanently so.

Peripheral neuropathy is a common side effect, with more than a 10% chance of occurrence. This means that both men and women will be affected and is not limited to pregnant women. Ingesting thalidomide can also cause an increased risk of blood clots, such as venous thrombosis, with one controlled trial showing a 17.6% increase in the rate of venous thromboembolism when thalidomide is taken in combination with standard chemotherapy agents.

What was closer to the truth in the original marketing campaign was how it was nearly impossible to give a lethal dose. Overdosages of up to 14.4g of thalidomide have been recorded (the maximum recommended dose is 200mg) and as of 2013, there were only 18 cases in total. No fatalities have been reported yet and supportive care is currently the only treatment required for thalidomide overdoses.

Did you know?

A mouse's cereblon proteins are unable to tag the "SALL4" transcription pr for destruction, allowing mice to not develop birth defects. Due to this, the teratogenicity of the drug evaded the drug safety tests and were distributed.

Fig. 6: Dr Frances Oldham Kelsey (1914-2015).

How does thalidomide affect limb growth?

This is a question that has perplexed scientists for years and has been the topic of debate since the disaster in the 1960s. A study from 1994 by Dr Robert D'Amato and his team confirmed the angiogenesis inhibiting powers of thalidomide. They conducted experiments in a rabbit cornea and found that the antiangiogenic effects of thalidomide correlated with its teratogenicity, suggesting that it could be the cause of thalidomide embryopathy by targeting embryonic blood vessels. (D'Amato et al., 1994) Experts in the field, such as Prof Neil Vargesson, support D'Amato's theory as he says that "blood vessels are essential for normal embryonic development". (Vargesson, 2015) Scholars who support this theory argue that "the loss of immature blood vessels is the primary cause of thalidomide-induced teratogenesis" as experiments done on chick embryos show that the blood vessels were destroyed rapidly and the increased cell death correlated to the deformed limbs and the increased foetal loss. (Therapontos et al., 2009)

However, Dr Janet McCredie hypothesized that thalidomide embryopathy is related to nerves and damage to the neural crest. (McCredie & McBride, 1973) Through further research on rabbits, she concluded that thalidomide acts on embryonic nerves rather than the bones or cartilage. (McCredie et al., 1984) In a lecture she gave in 2012, she argues that since there are is an extensive network of blood vessels in the limb buds for blood to flow through around any blocked vessels, which thus makes it impossible for a row of bones to be "deleted". Moreover, at the embryonic age of 24 days when thalidomide causes arm defects, limbs and arteries do not exist yet and thus provide powerful evidence that contradicts the angiogenesis theory. (*(1) Thalidomide 50 Anniversary Meeting Lecture - YouTube*, n.d.).

The neural crest, where the peripheral nervous system is derived from, begins development at day 18. This means that when thalidomide causes arm defects at day 24 of gestation, it is more probable that it affected the neural crest as it already exists at that time. Though this contradicted the accepted dogma in embryology where it is said that there are no nerves in the embryonic limb bud, the research from Prof Marcus Singer confirms her theory that limbs will not grow without sensory nerves. Although this study on neurotropism was done on newts and not mammalian embryos, newts were said to have retained the embryonic property of limb growth and are thus comparable to limb growth of embryos (Singer, 1974, 2015).

Recently, there were more breakthroughs with the molecular pathway of the drug. Scientists at the Dana-Farber Cancer Institute found that thalidomide "disrupts a broad transcriptional network" though inducing degradation of several transcription factors, including SALL4, a protein crucial for the development of limbs. Two known genetic conditions, Duane Radial Ray syndrome and Holt-Oram syndrome, have mutations in the SALL4 gene which also leads to a lack of functional SALL4 proteins. People who are affected by this condition also have birth defects similar to those of thalidomide babies. The protein cereblon, which targets molecules for removal, has previously been deemed the "primary target of thalidomide"(Ito et al., 2010). These thalidomide-hijacked cereblon proteins tag the wrong proteins, such as SALL4, for destruction and are believed to cause thalidomide embryopathy. (Donovan et al., 2018)

It is important to note, however, that these molecular processes and thalidomide's other mechanisms are not mutually exclusive and can all contribute to causing thalidomide embryopathy.

How is thalidomide used now?

Since it was withdrawn in 1962, it was first reintroduced in 1964 by Dr Jacob Sheskin, a dermatologist working with leprosy patients in Jerusalem. In an attempt to reduce the symptoms of leprosy a patient was having, thalidomide was used as a sedative but yielded unexpected results. The symptoms of leprosy had disappeared when the patient stopped taking thalidomide, the symptoms returned, suggesting its effects as a suppressant of diseases. Dr Skeskin repeated this on 5 more patients and concluded it had 'obvious importance'. (Sheskin, 1965)

Leprosy aside, thalidomide is used as a treatment for cancers such as multiple myeloma. Due to the antiangiogenic nature of thalidomide, (D'Amato et al., 1994) D'Amato's boss, Dr Folkman previously hypothesised that cancer growth required the development of new blood vessels (Folkman, 1971) and as his protégé, D'Amato continued to study angiogenesis and tumour growth. His team found that the combination of thalidomide and an anti-inflammatory chemical inhibited the growth of carcinoma in rabbits by 75%. (Verheul et al., 1998)

Legacy of the Thalidomide Disaster

Though tragic, the Thalidomide disaster has taught the world a lesson about the importance of drug regulation and testing. Thalidomide was indeed widespread but it never made it into the American market at its peak popularity. This is due to a woman named Francis Kelsey (Figure 6). As a new reviewer for the US Food and Drug Administration, she refused to authorise thalidomide for the American market due to the lack of evidence regarding its safety, even when the manufacturers reapplied and pressured her time and time again. When the teratogenic properties of the drug were realised, her efforts have been praised. She became an American hero overnight and the second woman ever to receive the president's award, awarded to her by John F. Kennedy.

This disaster also directly propelled the US into legal reforms regarding drug testing. Both houses of Congress unanimously passed the Kefauver-Harris Amendments, which required manufacturers to provide data from animal trials as well as highly regulated human trials to prove that the drug was safe for humans. (Meadows, 2006) Across the Atlantic, the Thalidomide disaster also impacted the public opinion on abortions and allowed the Abortion Act of 1967 to be more widely accepted, paving the way for women's reproductive rights in the UK.

Why is Ibuprofen described as dangerous?

ROSA LI

Introduction to Ibuprofen:

Ibuprofen-alsoknownas2-4-Isobutylphenylpropanoic acid- is a propanoic acid derivate, with a chemical formula of C13H18O2 (Figure 1). It is usually used as an anti-inflammatory drug (NSAID) to treat a range of pains including back pain, period pain, toothaches as well as inflammations caused by muscle strains, sprains and pain from arthritis. Although it is a very commonly used drug, an excessive consumption of ibuprofen can lead to an overdose, which may cause dangerous side effects including damage to the stomach and intestines. In seldom cases, an overdose on Ibuprofen can lead to fatality.

However, before explaining how Ibuprofen may cause such nasty side effects, one should understand several important chemicals that play a role in the function of ibuprofen and how ibuprofen works effectively.

What are prostaglandins?

Prostaglandins are one of the chemicals that play a significant role in the function of Ibuprofen (Figure 2). They are hormones produced at the site where needed, in nearly all cells and at sites of tissue damage/ infections. This is unlike most hormones that are produced from glands and are transported to areas of the body where needed via the bloodstream. There are 4 principal prostaglandins that are generated in living organisms- prostaglandin (also written as PG) E2 (PGE2), prostacyclin (PGI2), prostaglandin D2 (PGD2) and prostaglandin F2a (PGF2a). Each cell type usually generates 1 or 2 dominant products to act as autacrine and paracine lipid mediators to maintain local homeostasis in the body.

Additionally, when a blood vessel is injured, a specific prostaglandin called thromboxane stimulates the formation of a blood clot to try heal the damage.

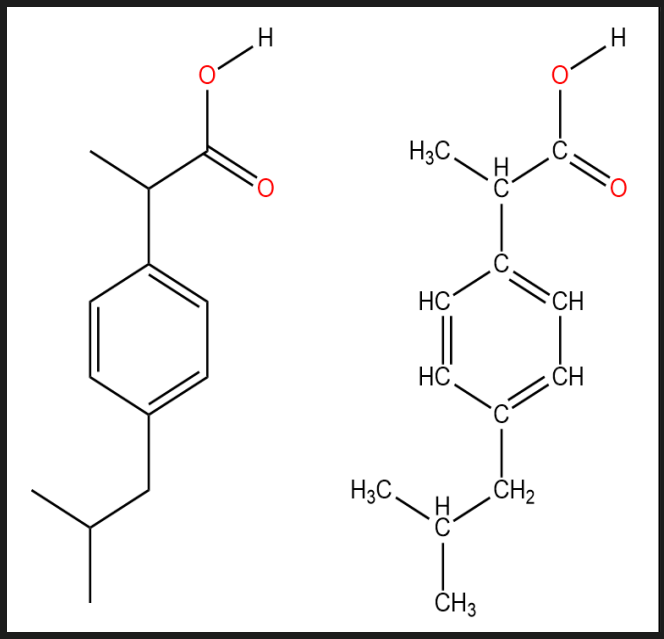


Fig. 1: Skeletal formula of the structure of ibuprofen.

Alongside forming a blood clot, thromboxane also stimulates the contraction of blood vessels to try prevent blood loss from the wound.

Prostaglandins and thromboxane, collectively named as prostanoids, are formed when arachidonic acid (AA)- a 20-carbon unsaturated fatty acid- is released from the plasma membrane by phospholipases and metabolized by the sequential actions of prostaglandin synthase, COX and respective synthases.

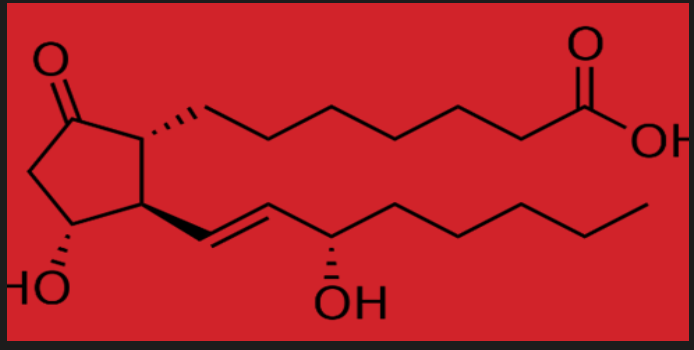


Fig. 2: Structure of a prostaglandin.

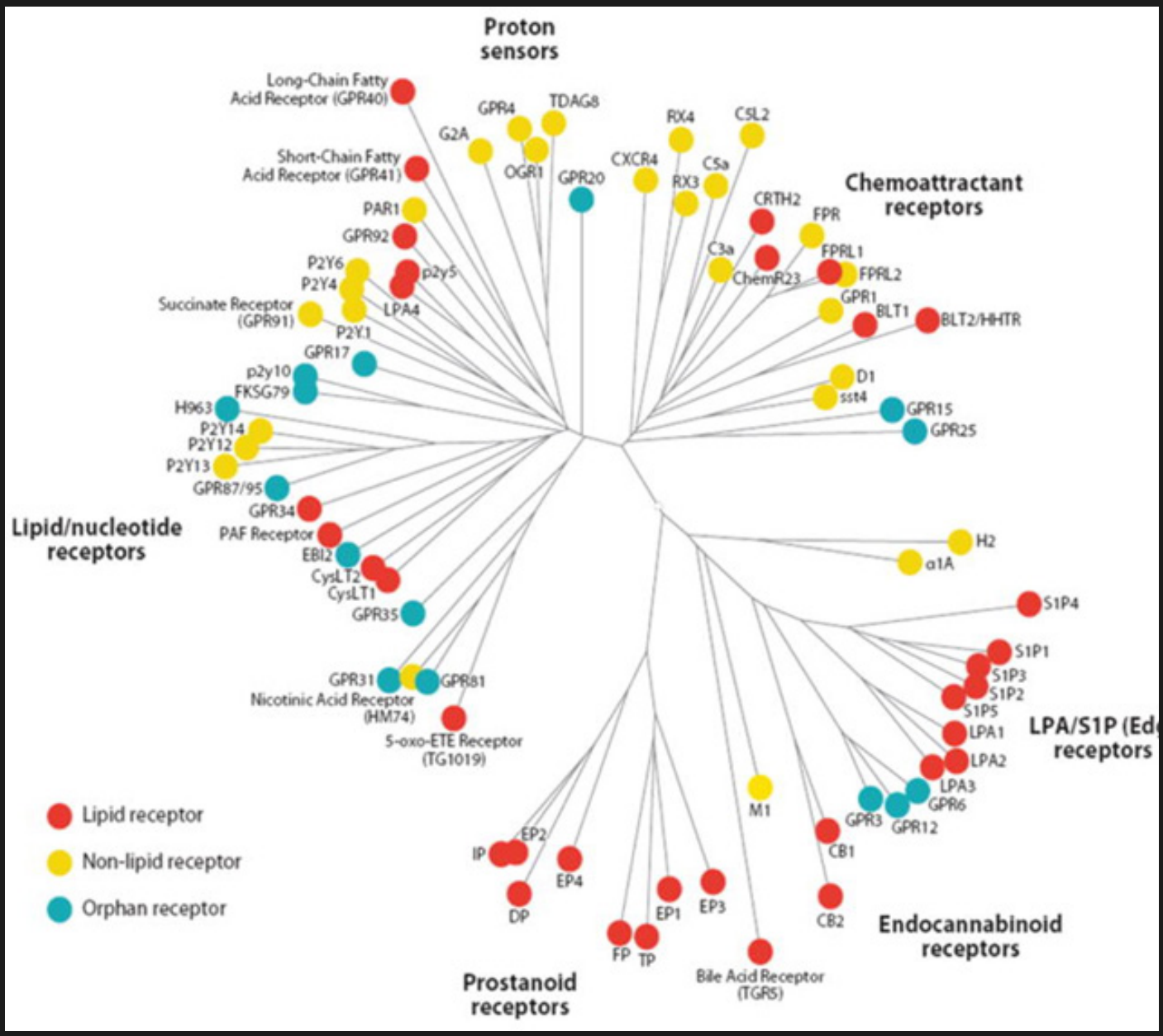


Fig. 3: A map of prostaglandin receptors.

Prostaglandin receptors

The prostanoid subfamily is made up of 8 members: EP1 (E prostanoid receptor 1), EP2, EP3, and EP4 subtypes of the PGE receptor, PGD receptor (DP1), PGF receptor (FP), PGI receptor (IP), and TX receptor (TP).

2 additional TP isoforms are generated through splicing, which would cause them to differ in their C-terminal tails.

What are COX I and COX II?

Prostaglandin production depends on the activity of prostaglandin G/H synthases, also known as COX. They are biofunctional enzymes that contain both cyclooxygenase and peroxidase activity, and exists in 2 isoforms known colloquially as COX-1 and COX-2. Both cyclo-oxygenase I and cyclo-oxygenase 2 are enzymes that produces prostaglandins, the only difference between the 2 similar enzymes being that only COX- 1 produces prostaglandins that activate platelets and protects the stomach and intestinal lining (Figure 3).

COX-1 (or cyclo-oxygenase 1), expressed constitutively/ always expressed in most cells, is the dominant source of prostanoids that work to maintain basic functions of cells, including homeostasis. When

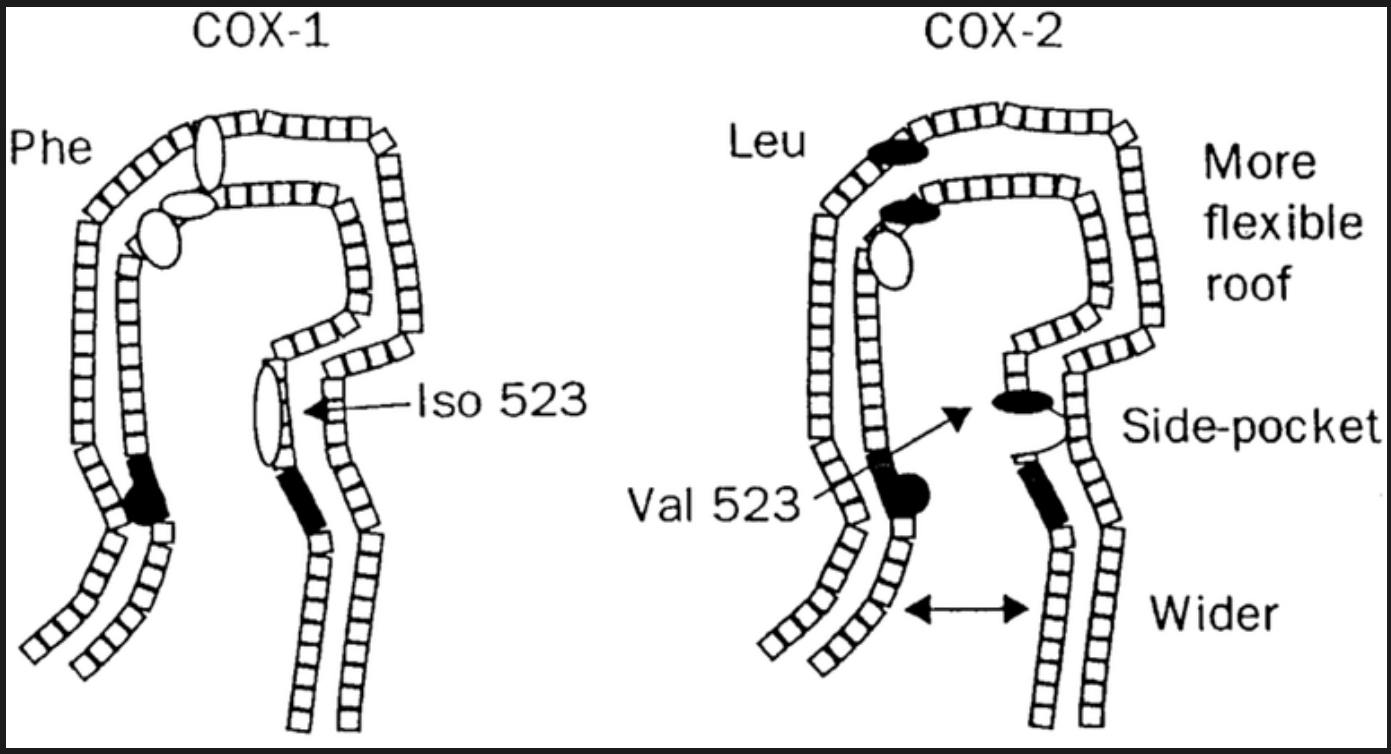


Fig. 4: COX-1 and COX-2 structures.

the body is functioning normally without injury, a base-line number of prostaglandins are produced by the action of cyclooxygenase-1. When the body is injured, cyclooxygenase-2 is activated and extra numbers of prostaglandins are produced, triggering a response to the injury.

COX-2 (or cyclo-oxygenase 2), induced by inflammatory stimuli, hormones and growth factors, is the more significant source of prostanoids in inflammations and proliferative (abnormal growth in tissue cells/ where cells divide and produces 2 daughter cells) diseases including cancer. However, both enzymes contribute to the generation of autoregulatory and homeostatic prostanoids, and both can contribute to prostanoid release during inflammation.

How does Ibuprofen work?

NSAIDs block the COX enzymes and reduce production of prostaglandins. Therefore, inflammation, pain, and fever are all reduced by COX inhibitors. Ibuprofen inhibits the activity of cyclo-oxygenase I and II, resulting in a decreased formation of precursors of prostaglandins and thromboxanes. This leads to decreased prostaglandin synthesis, therefore causing a decrease in prostaglandin and therefore less number of the hormone causing an inflammatory response, hence decreasing the pain and aches caused by inflammation. Ibuprofen also causes a decrease in the formation of thromboxane A2 synthesis, thereby inhibiting platelet aggregation, thus soothing the amount of pain caused by inflammation.

Possible risks:

However, an overdose of ibruprofen will cause an abnormally low amount of prostaglandins by reducing the production of them. Since prostaglandins protect the stomach (and intestinal) lining and promote blood clotting are all reduced, NSAIDs can cause ulcers in the stomach and intestines, increasing the risk of bleeding. Overdose of Ibuprofen is also reported to have caused gastritis, fluid retention, headaches, high blood pressure and dizziness.

For a safer alternative that reduces the risk of getting inner bleeding/ ulcers in digestive track, newer drugs- COX-2 inhibitors, only block the COX-2 enzyme instead of blocking both. By doing so, this drug can help lower the risk of bleeding and causing ulcers.

Investigating Immunotherapy

Janet Li

Immunotherapy is a typical treatment for some types of cancer. It uses our immune system to fight cancer by helping the immune system recognise and attack cancer cells. There are various types of immunotherapies like monoclonal antibodies, vaccines, cytokines, and CAR-T cell therapy.

Monoclonal antibodies are also known as MAB. MABs are antibodies that recognize and attach to specific antigens present on the surface of cancer cells. However, different antibodies work in different ways.

Naked monoclonal antibodies work by blocking antigens that help the cancer grow or spread. For example, Herceptin antibody, it fights against the HER2 proteins present on the surface of breast and stomach cancer cells. When HER2s are activated, they cause the cell to grow and Herceptin then binds to these proteins and stops them from becoming active (Figures 1-3).

Fig. 1: Surface of a tumour cell.

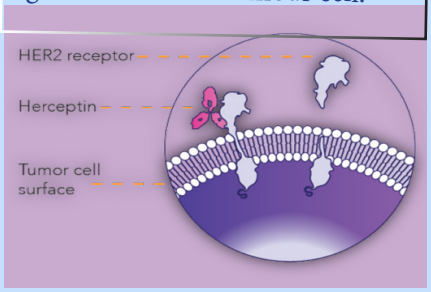
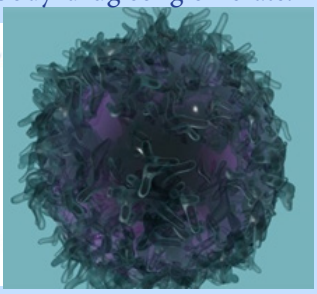


Fig. 2: Action of Antibodies.

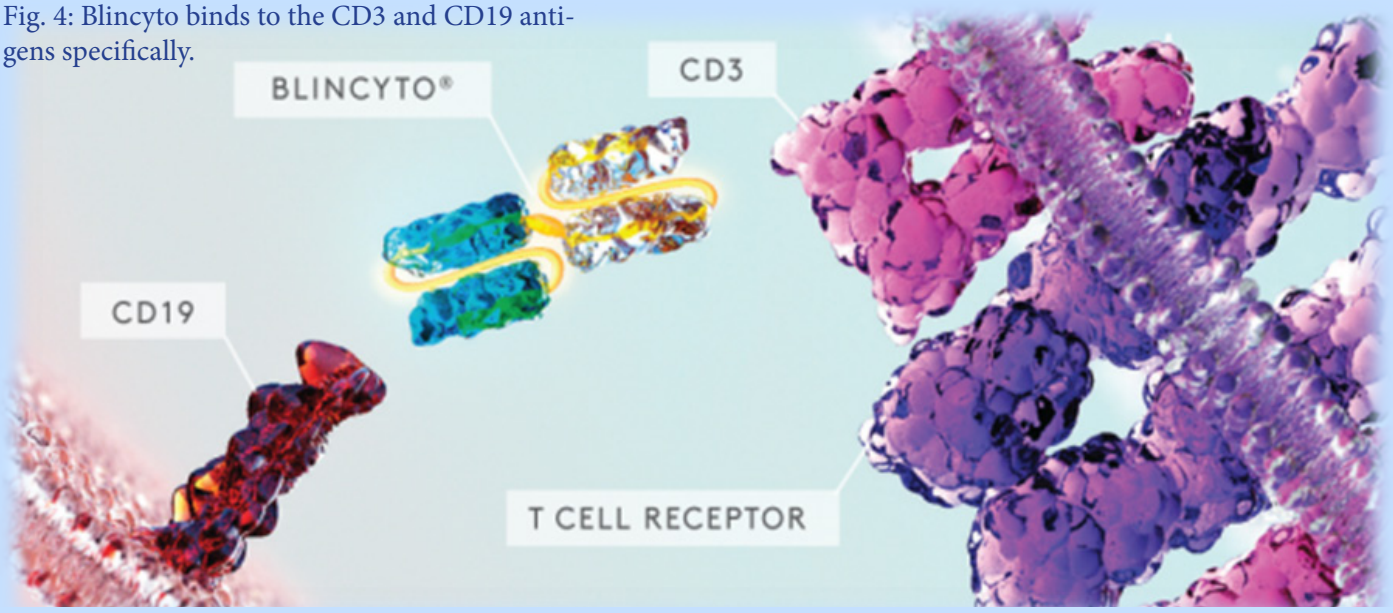
Fig. 3: Antibody-drug conglomerate.



Conjugated monoclonal antibody is another type of MAB. Unlike naked antibodies, these have a radioactive particle, or a chemotherapy drug attached to the MAB. They attach directly to cancerous cells, then transport the toxic substances (radioactive chemicals) to where they are needed most. Zevalin is an example of a radiolabeled MAB, it is combined to a MAB drug (rituximab) and a radioactive substance (RIT). Zevalin binds to CD20 antigen which is found on B cells. The antibody then delivers radioactivity (Yttrium-90) directly to cancer cells.

There is also an antibody called the bispecific monoclonal antibody which is an artificial protein that acts as a bridge between cancer cells and cytotoxic T lymphocytes. Blincyto is a bispecific MAB, it binds to CD3 antigens on cytotoxic T lymphocytes and a specific antigen on cancer cells, which activates the T cells and causes lysis of cancer cells (Figure 4).

Fig. 4: Blincyto binds to the CD3 and CD19 antigens specifically.



Antiviral Pill to Treat Covid Approved for Use in UK

Myra Lam

COVID-19, also known as SARS-CoV-2 is a severe acute respiratory syndrome coronavirus that has been rapidly spreading around the globe. With approximately a total of 246.7 million confirmed cases (*BBC, 7 Nov*), and 5 million deaths across almost 200 countries, this worldwide pandemic has triggered mass panic and damage both socially and economically. For two years, there wasn't an exact treatment for covid, however this changed on 4th of November 2021 when Molnupiravir, an antiviral drug that significantly reduces the risk of hospitalization and death from Covid-19 was approved for use by the UK's Medicines and Healthcare products Regulatory Agency (MHRA).

To understand how the newly found Molnupiravir works, one must first comprehend how does COVID-19 infects cells.

It all starts with the virus gaining passage to the mucous membranes of a person's throat, then moving down the respiratory tract reaching the lower airways where there is abundance of ACE2 receptors. The COVID-19 virus's spike protein binds to the ACE2 receptor of a host cell in which the host cell molecule TMPRSS2 cleaves the spike protein exposing parts that fuse the viral membrane with that of the host. The Viral RNA is then translated into non-structural proteins that quickly supress the translation of host messenger RNAs in favour of those belonging to the virus. The host cell thus becomes infected and aids the replication of the virus which would cause the further infection of more cells.

Molnupiravir works by incorporating itself into the burgeoning RNA strands of the virus inside the host cell. Once it successfully does so, it destructs the RNA sequence by shifting its configuration. The RNA strands that are responsible for the translation and replication of the virus are now faulty blueprints for the next round of viral genomes. This leads to mutations to occur in the virus, and when enough

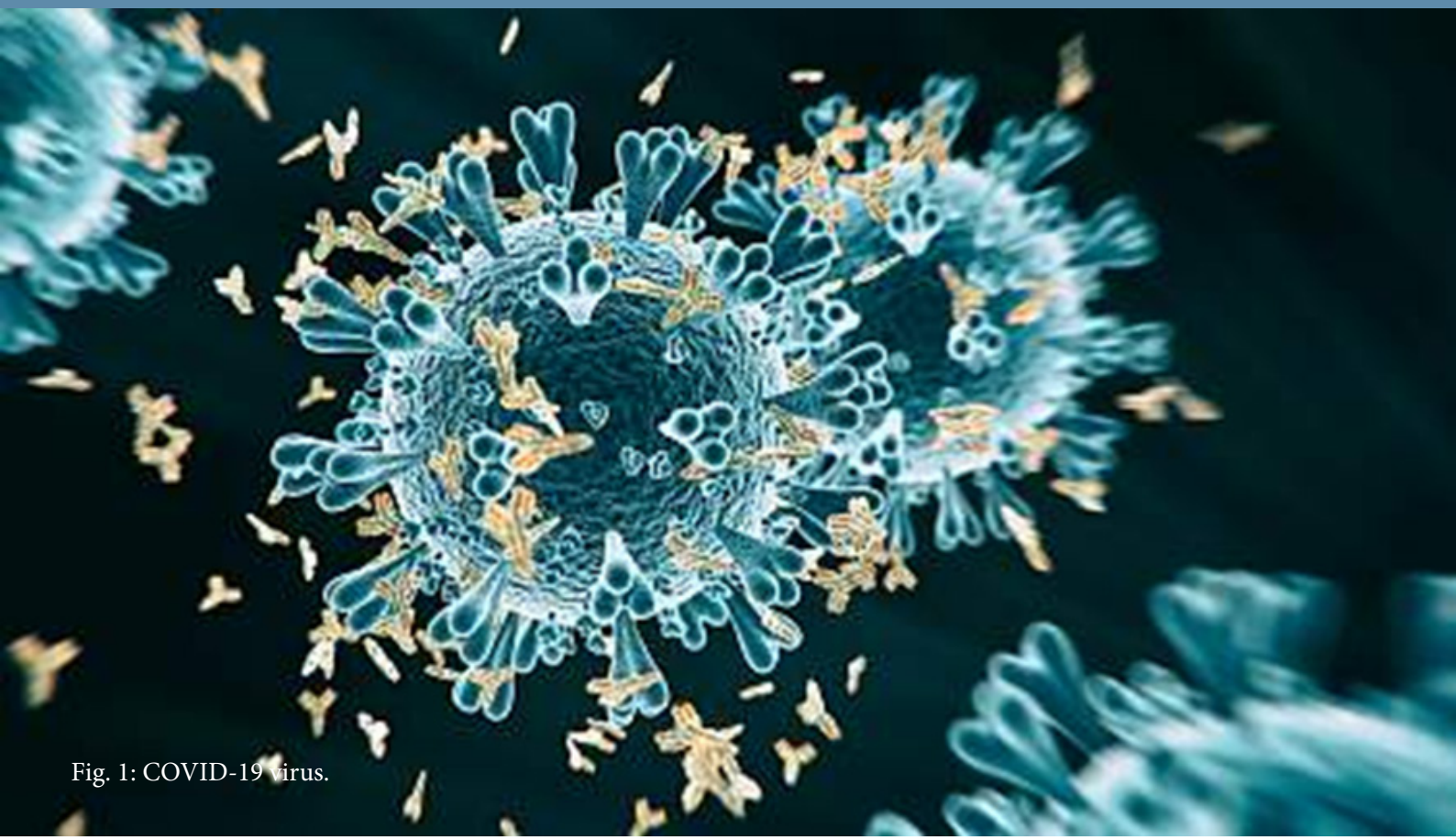


Fig. 1: COVID-19 virus.

mutations accumulate, the viral population collapses as it has essentially mutated itself to death.

Having gone through phase 2 clinical trials, the MHRA claims that the drug is "safe and effective at reducing the risk of hospitalisation and death with mild to moderate COVID-19 who are at increased risk of developing severe disease." (*Nature, 28 Jul*). The clinical trials have concluded that the drug is found to reduce the risk of hospital admission or death for at-risk non-hospitalised adults by 50% according to Munir Pirmohamed, the Chair of the Commission on Human Medicines. However, for the drug to be effective it should be taken as soon as possible after being tested positive for COVID-18 within the first five days as it works by preventing the virus multiplying and keeping virus levels low enough to reduce severity of symptoms.

The UK, being one of the countries that has been hit hardest by the pandemic, has announced that it had ordered 480 000 doses of Molnupiravir from the US pharmaceutical company Merck and it is estimated to arrive by the end of year.

Molnupiravir will be the world's first approved antiviral for COVID-19 that can be taken orally instead of administered intravenously. Which is important as this would mean it can be administered outside of the hospital setting, helping to ease the overburdened healthcare system in hospitals that are constantly overwhelmed with new COVID-19 patients.

Though this drug may be a real game changer as it has been predicted to be able to halve the number of Covid cases requiring hospital admission (*BBC, 5 Nov*), experts are warning that "the treatment is not a miracle cure" and that it is not intended to be used as a substitute for vaccination against the virus. Currently, UK figures still suggests that there is an upward trend in coronavirus infections and according to the latest estimates form the Office for National Statistics (ONS), around one in 50 people in UK households had COVID during the past week. Thus it is clear to see that the severity of coronavirus infections has not seen a better turn. People are continuously encouraged to follow covid regulations strictly on a daily basis and to take two doses of vaccines in order to obtain herd immunity.

Fig 2: Molnupiravir pills.

STUDENT RESEARCH

Life Beyond Earth

Anu Shukla
Godwin Yuen

How Computers Generate Random Numbers

Hal Cowan

Making the Kitchen a safer place

Tom Hughes

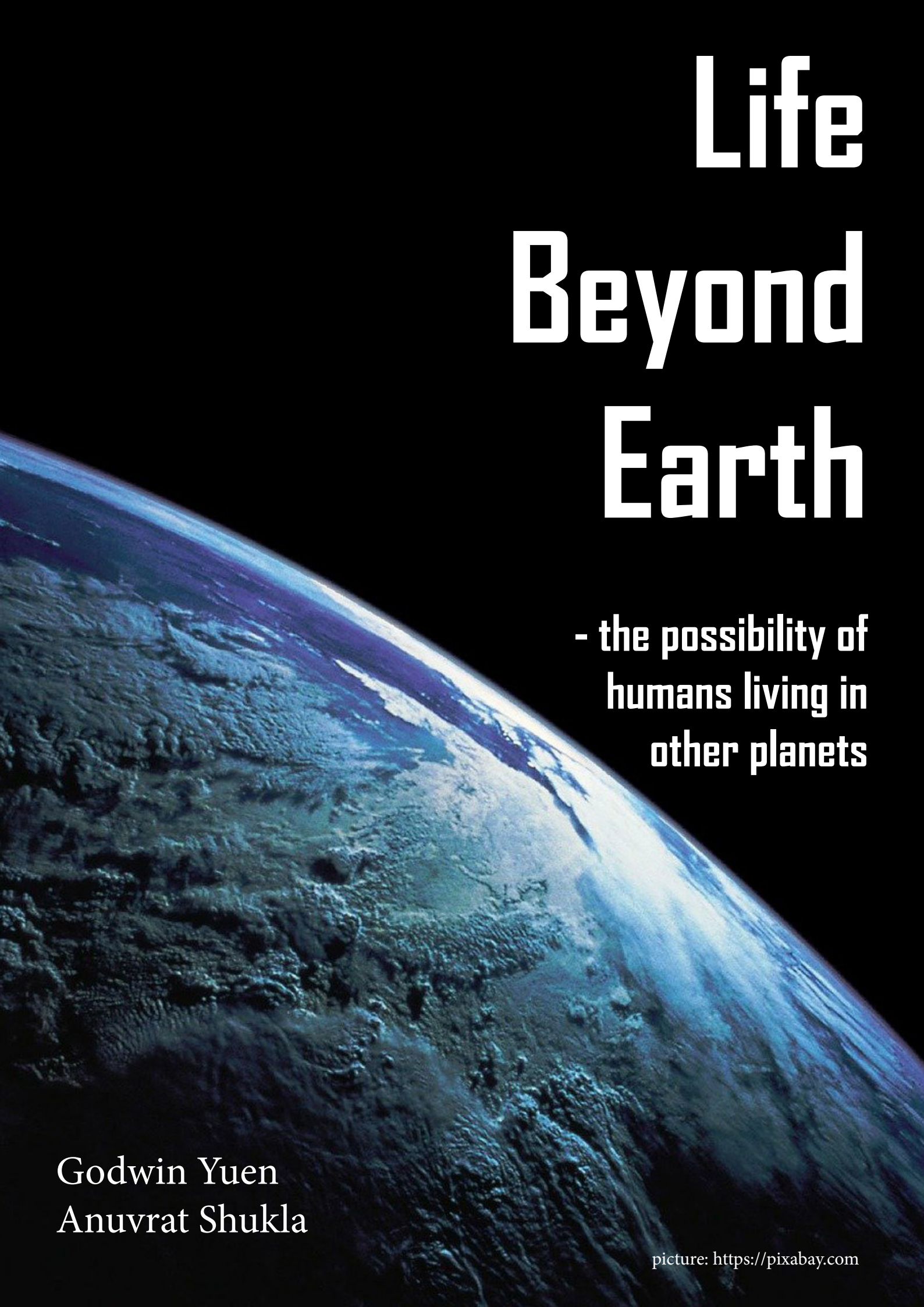
Aerospace Industry Inventions: Using CAD to create new exhaust systems in aeroplanes

Thea Haugan

picture: https://pixabay.com

Life Beyond Earth

- the possibility of humans living in other planets



Godwin Yuen
Anuvrat Shukla

picture: https://pixabay.com

I believe everybody has thought of living in space at some point in their lives. How cool would it be to colonise other planets? Well, I am glad to tell you that we are one step closer to achieving this goal. Recently, the Perseverance Rover has landed on Mars, in search of evidence for past life. Before diving into the potential locations of life beyond Earth, we first have to answer a few questions:

1. What is life?

The definition of life has disturbed the lives of scientists and philosophers throughout the years. At the moment, we can only describe what life is: Life is something that exhibits homeostasis, organisation, metabolism, growth, adaptation, response, and reproduction. These are the seven characteristics of life.

2. What is it that we look for in other planets?

For a planet to be determined as habitable for life, they must have an atmosphere that contains oxygen, without oxygen we would die. They should have liquid water, which means that a suitable temperature is needed. Too cold water would exist as ice; too hot water would evaporate. This means the planet has to be in the Goldilocks zone, not too close but not too far from the star. There are also requirements of life, these are the basic molecules: amino acids, ATP, and DNA.

3. How do we detect it?

The transit method, radial velocity method and other methods can be used to detect exoplanets, but how do we know if it fulfils the requirements above? Water and oxygen in exoplanets can be detected using spectroscopy. As the planet transits the star, light is blocked, and this causes a dip in the light observed by a telescope. The atmosphere of the exoplanet absorbs certain wavelengths of the radiation of the star. This is because molecules absorb a specific wavelength of electromagnetic radiation. The atmosphere allows the rest of the unabsorbed wavelength to pass through and be observed by the telescope. By obtaining the spectrum of this star (Fig. 1), absorption lines are revealed, which are the chemical footprints of the exoplanet. Hence, its chemical composition is known.

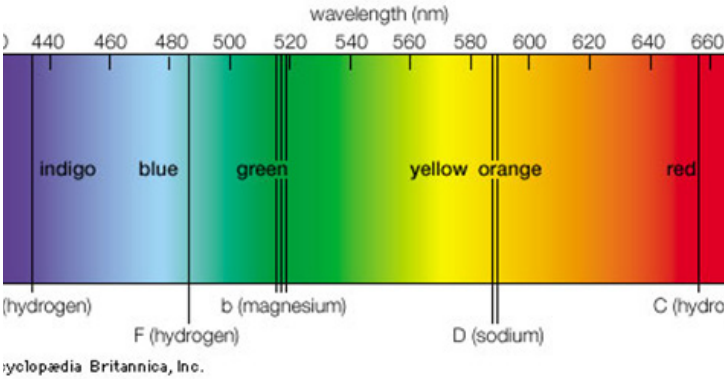


Fig. 1: Absorption lines on a spectrum.

Telescopes like the Kepler space telescope were launched into space particularly to detect exoplanets. In 2018, the Kepler telescope retired, and NASA plan to launch the James Webb telescope on October 31, 2021. During its time, it has had huge contributions, finding over 5000 possible exoplanet candidates, with 2500 confirmed, which is more than half of the 4000 found today. However, there are only a handful of exoplanets that can potentially host life forms, and they are very far away. Among them, Kepler-62f and Kepler-186f are the best candidates according to a review in 2015.

Fig. 2: Kepler-62f.

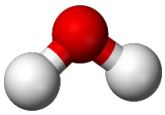
Kepler-62f (Fig. 2) was discovered in 2013 and is 1200 light years away. It is in the habitable zone of the star Kepler-62 and has an orbital period of 267 days. However, it is 2.8 times heavier than the Earth. This means that it has a stronger gravity so if we were to live on there, carrying out daily tasks would be much more difficult. It also has a temperature of -65°C, which is too cold.

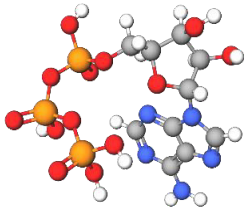
Another alternative is Kepler-186f. Discovered in 2014, the exoplanet has a relatively short year, only of 130 days, compared to Earth's 365 days. However, its mass and composition are unknown as it is too far away to be observed by a telescope. It is estimated to have a surface temperature above 0°C, which is similar to Earth.

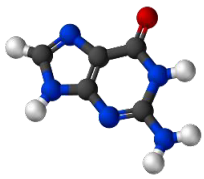
Life Beyond Earth

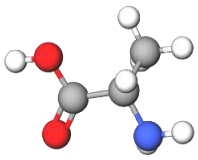
Basic building blocks of life:

- Water
- Amino acids
- ATP
- DNA

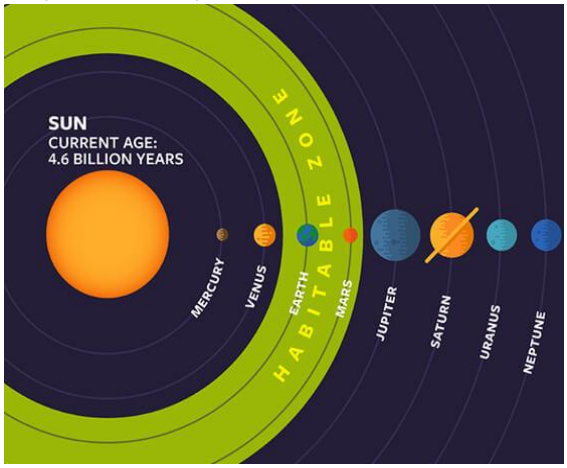








Why does life only exist on Earth?



- We are located in the Goldilocks zone
- Not too far and not too close to the sun
- Just warm enough for liquid water to exist
- Earth has oxygen in its atmosphere

Detecting exoplanets:

1. Transit method

   As planets orbit their stars, and pass in front of them, the brightness of a star slightly lowers in a regular time interval. The regular dips in brightness shows the presence of an exoplanet.

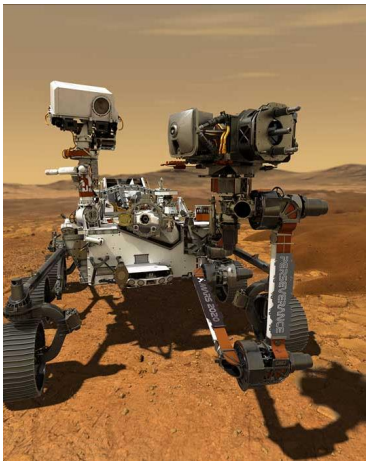
2. Radial velocity method

   Not only do stars have a gravitational attraction on planets, but planets also have a pull on stars. This pull causes the star to move very slightly. This movement can be detected by changes in its radial velocity.

3. Microlensing method

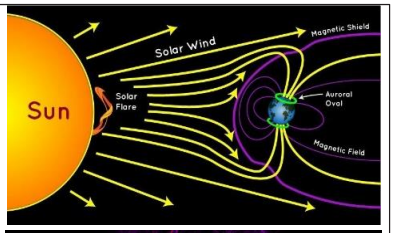
   Gravity also slightly bends light. For giant planets transiting, light is bent from both sides and more light is received by the telescope. The spike in brightness suggests that an exoplanet is present.

Is life possible on Mars?



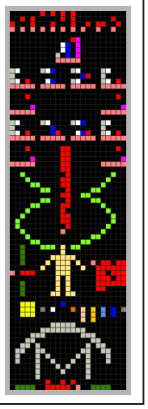
- The *Perseverance Rover* has just landed on Mars
- It aims to search for evidence for past life, water and test oxygen production
- It is also in the Goldilocks zone and is quite similar to Earth
- It has a higher surface temperature than Earth
- It does not have enough oxygen in its atmosphere

Conditions for life:



- The star has to be in the Galactic Habitable Zone, away from the cosmic catastrophes (supernovas, gamma ray bursts…)
- The star has to be in a stable stage, e. g. a main sequence star
- The exoplanet has to be in the Goldilocks zone
- The size of planet matters: the stronger the gravity, the thicker the atmosphere and therefore better conditions for life
- A magnetic field should also be present to protect humans from outer space events, e.g., solar winds

Aliens?



- The drake equation estimates the number of technologically advanced civilizations in our galaxy
- The Arecibo message was sent
- We are more likely to find aliens than finding organisms on an exoplanet
- NASA says that we will be likely to find aliens in the next decade

How Computer Ge

Generating Random Numbers is **not** simple.

Computers use **2** methods to generate random numbers

1. Pseudo-Random Number Generators

- They use Linear Congruential Generators (LCG)
- The LCG uses the algorithm below:

$$X_{n+1} = (aX_n + c) \bmod m$$

a = Multiplier | c = Increment | m = Modulus | X = Seed

A piece of information from the outside world would be allocated to the seed.

Predetermined numbers would be allocated to the constants

The algorithm would be performed, and the next number would be calculated

The calculated number would replace the previous number in the sequence within the algorithm

nerate Random Numbers

Hal Cowan

2. True Random Number Generators

- TRNGs observe information from the outside world to generate random numbers.
- The data collected from the outside world is known as **ENTROPY.**

Examples of Entropy:

- **Listening to Atmospheric Noise**
- **Measured amounts of Time**

  E.G. Measuring the time in milliseconds from 02:00 to when you press the letter ‘

The Ideal Piece of Entropy

- To Measure the radioactive decay of an atom.
- Because according to quantum theory:
  ‘The decay of substances is completely random’

3. Uses

- Pseudo random number generated numbers are used in:

  Video Games

  Shuffle Playing

- True random number generated number are used in:

  Online Gambling

  Web Encryption

For these application of True numbers The numbers must be impossible to guess.

Making The Kitchen A Safer Place

Tom Hughes

I chose this topic as my area of research for a CREST Award by thinking hard on areas of life I would like to improve upon. A few days prior I had burnt my hand on a hot pan whilst making supper one evening. I then thought about what could have been done to prevent this and found very little on products preventing burns while cooking, which are the most common injury in the kitchen.

I first set out on researching injuries in the kitchen and the statistics of it and found burns were by far the highest cause of injuries so I looked into the types of burns that are most common. After seeing the effects of the burns, I then looked into how best to prevent them. I started to prototype with thermo chromic materials to help create a device to indicate the temperature of the pan.

The major challenge faced was the second Covid lockdown, which completely disrupted my schedule. In the end this prevented a final physical protype from being built. This led to a whole lot of adjusting and working from home using just a computer, without access to the lab and the DT department. With a big push after coming back to school in March, I managed to get the project completed.

In the end I manged to collect some good data and information from surveys and manged to design a prototype of a device that will indicate by colour when the pan is safe to touched and when not. Hopefully in future I will be able to take this project further and create a physical working prototype.

Aerospace Industry Inventions: Using CAD To Create New Exhaust Systems In Aeroplanes

------ a CREST Summary

Thea Haugan

Over the course of 5 months (most of which was in lockdown) last year, 4 Lower Sixth students in the Thursday STEM Society competed in the Aerospace Engineering STEM Challenge organised by Marches Centre of Manufacturing & Technology (MCMT), coordinated by Ms Perkins. We were very fortunate to have worked in collaboration with Radius Aerospace, a leading aviation fabrication corporation, thanks to Leanne Mee from The Stem Workshop. We were tasked with the challenge to explore problems faced within the aerospace industry and find an opportunity to develop a new product idea.

Personally, having no knowledge nor experience in the fields of physics, aviation or engineering, I had to start by studying the structures of light, turboprop airplanes. Then, having gained a fairly good grasp of the mechanisms that allow the planes to be sustainably propelled into the air, I started to conduct extensive research on current issues and areas for new product development in the aviation industry.

I created a timeline to ensure I was on track:

January:
Research on Radius Aerospace and their core services.
Research on potential problems in the aviation industry.

February:
Narrow down selection on points of improvement of gaps in the market of the aviation industry.
Settle on a topic and look at possible approaches for a solution.

March:
Experiment with different ideas, coming up with many ideas to present to Radius Aerospace and my mentor.
Establish contact with Radius Aersopace, inquiring about their services and what they do with regards to my topic of choice.
Teach myself how to use Computer-Aided Design with practice.

April:
Polish my ideas and finalise them into one or two solid solutions.
Produce my final ideas using a Computer-Aided Design and drawings.

May:
Presenting my solution to Leanne from Marches Centre of Manufacturing and Technology.

Problems in the Aviation Industry – Heating of the Exhaust System

One major safety issue that stood out to me was the overheating of the exhaust system. Exhaust gases at temperatures reaching almost 650 degrees are removed via an exhaust system, which is partially located in the engine bay. There remains a risk of the exhaust pipe thermally interacting with the nacelle interior (holding engines, fuel and equipment) and other systems located close to it. Poor design of the exhaust system may lead to the worst-case scenario of thermal damage to the cowling or devices located inside the nacelle, which can undermine the performance of the aircraft and put everyone's safety at risk.

Cracks in augmenter tubes can present a fire or carbon monoxide hazard by allowing exhaust gases to enter the nacelle, wing, or cabin areas.

In some studies, temperature hot spots on the inner side of the nacelle cover were observed due to heat transfer between the hot engine and exhaust system surfaces and the cowling. Even if the temperature peak were below the maximum allowable temperature of operation of the materials used to make the cover, these results do not provide total comfort that no thermal damage will happen to the cowling or engine systems. Therefore, there is a still need to improve airplane safety and performance, for example by decreasing the temperature of the exhaust system and its direct and indirect thermal interaction with the nacelle and systems located in the engine bay.

I decided to focus on the design and optimisation of the exhaust system in general aviation aircrafts, with the aim of optimising the thermal performance by using different materials or designing a new exhaust system that shields the nacelle interior from thermal damage caused by the exhaust pipe.

Background information, Structure & Terminology of Engine Bay

In order to address the problem, I had to conduct sufficient research to be well versed in the structure, mechanisms and terminology of the engine bay. On usual turboprop aircrafts, an exhaust duct is quite often referred to as a tailpipe, although the actual duct itself is basically a simple, stainless steel cylindrical pipe. The assembly includes an engine tail cone and struts inside the duct. The tail cone and the struts strengthen the duct, while imparting an axial direction to the gas flow. This is very useful as it will smooth the gas flow.

Cowling of an engine is useful to streamline the airflow so it reaches the outside of the aircraft but, as or more importantly, also on the inside to improve cooling. "Most aircraft engines are air cooled, so they need proper airflow to prevent them from running too hot. This is especially very important for high powered engines." (experimentalaircraft.info)

With regards to maintenance, we must make sure that on exhaust systems equipped with augmenter tubes, the tubes should be inspected at short intervals to ensure proper alignment, security of attachment, and a good overall condition. Even when some places in the augmenter tubes do not contain a dangerous heat exchanger surface, they should be inspected, as cracks can form along with the remainder of the exhaust system. This can present a fire or carbon monoxide hazard by letting exhaust gases enter the nacelle, wing, or cabin areas.

You must take into account that it is better to replace things like exhaust stacks, mufflers, tailpipes, etc. with reconditioned components rather than repair them, as they are made to be easily replaceable. Welded repairs to exhaust systems are made complicated by the difficulty of precisely identifying the base metal so that the proper repair materials can be used.

Information on Radius Aerospace and their work on the Thermal Capacity of Exhaust System

I started to look at Radius Aerospace's key services, and learnt that they fabricate and assemble a range of aircraft and space-craft parts. I emailed them with an inquiry on the materials that Radius Aerospace currently uses in the exhaust pipes to decrease the thermal load, and how they design the exhaust ducts to ensure a safe and efficient pathway for airflow that can efficiently get rid of hot air. I was sent their product portfolio, and realised they used HVOF/ Plasma coating to reduce the thermal load. Although HVOF spraying creates a dense coating that causes less residual stress, it cannot be used for surface applications engineering of inner surfaces such as the internal surfaces of cylinder-like substrates, such as the exhaust pipe, which was what I was looking at.

Researching Solutions

Using a conventional steel exhaust system, I wanted to look for alternatives with increased specific performance, which are not abundant. I looking into the use of high-strength and high-density materials that can withstand peak temperature. Creating a multi-material solution meant lining the exhaust with a low-mass and low-conductivity layer. This helps facilitate the flow and thermal resistance between gas and duct under non-steady exhaust gas flow or turbulent pipe flow.

I did research into using a fibrous layer as a material. The central section would be a polymer cylindrical shell internally lined with a porous ceramic fibre layer and a silica fabric in place of a stainless-steel mesh. In addition, fibrous materials are also really useful since they offer sound insulation. There is a great advantage of a combined influence on flow and thermal resistance of an exhaust pipe wall from a porous, compliant layer.

However, others had already started to develop a fairly similar idea, leading me to look at the airflow of the engine bay ventilation system.

My Solutions

I then focused on the design and optimisation of the exhaust system in general aviation aircrafts. The aim is to improve the thermal performance of the exhaust system and decrease thermal load (amount of heat energy to be removed). I aimed to optimise the thermal performance by using different materials and design a new exhaust system that shields the nacelle interior from thermal damage that can be caused by the hot exhaust pipe, by ensure a safe pathway for airflow that can efficiently get rid of exhaust gases.

The newly developed exhaust system consists of the exhaust pipe and cover ducts which shield the nacelle interior from direct contact with hot surfaces and thermal radiation given off by the hot exhaust pipe. The entire process of engine-airframe integration considers air delivery, which assists in delivering fresh, cool air for the engine compressor, nacelle cooling system and air-conditioning of cockpit, engine nacelle and exhaust system.

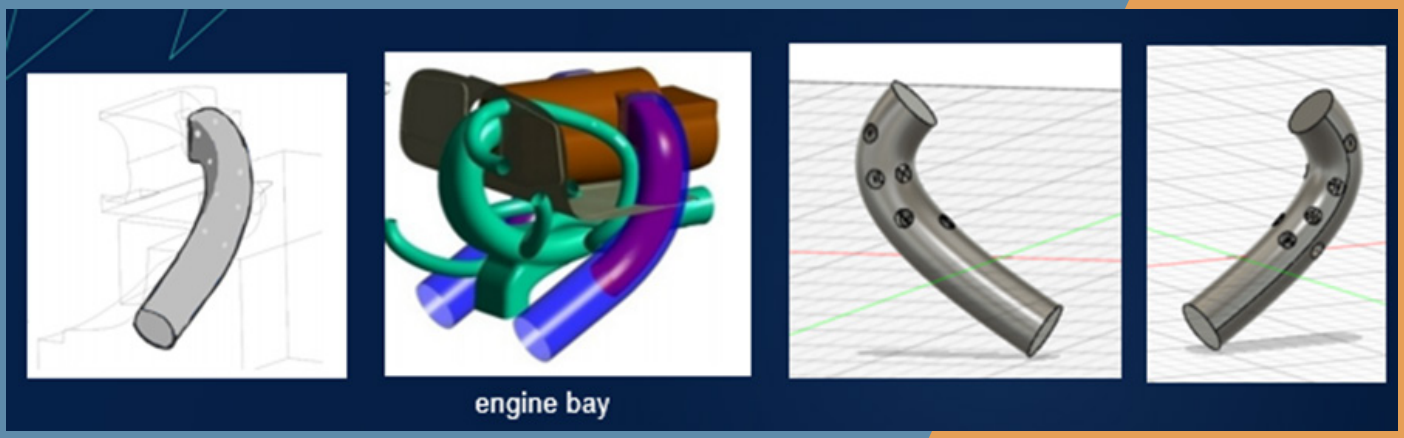


Fig. 1: The drawings of my cover duct with holes.

Several openings were arbitrarily created in the cover duct wall. The role of the holes was to increase the mass flow rate of the cold air sucked in from the nacelle interior to the gap between the exhaust pipe and its cover due to the ejector effect. The Ejector effect is to mix cool ambient air with high velocity engine gases before they're exhausted to the ambient air. The higher mass flow rate of the cold air was expected to decrease the temperatures of the exhaust pipe and the cover and reduce thermal loads inside the engine bay. The locations, number and cross-sectional area were selected arbitrarily.

Due to the ejector effect the gaps located between the exhaust pipe and its covers become efficient air outlets from the nacelle interior to the surroundings. Therefore, they are also considered as parts of the engine bay ventilation system. Additionally, the air flowing through these gaps cools down the exhaust pipe and the covers, reducing thermal loads inside the nacelle.

I then came up with another idea to remove exhaust gases far away from the airframe in a quicker fashion by centralising the direction of the airflow. This would get rid of the hot gases leaving the exhaust pipe and replace the hot air in the engine bay much quicker, while also cooling them down.

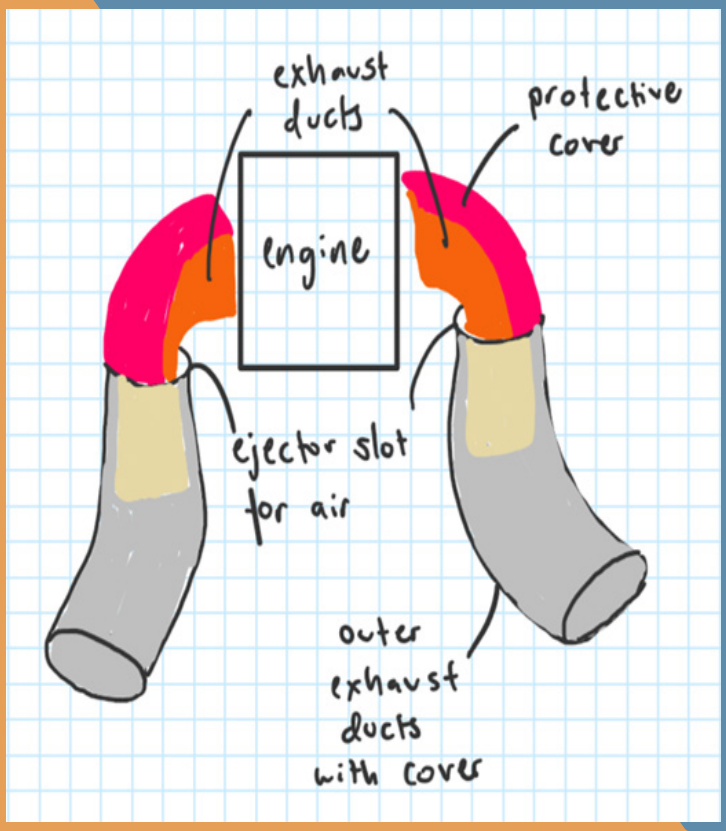


Fig 2: Idea number 2; making an ejector slot and additional cover ducts.

The baseline concept of exhaust system would assume that external exhaust outlets would be localized under the engine nacelle. The exhaust ducts would be covered by special covers combined with the heat barrier, separating the hot and cold parts of the engine bay.

Apart from removing exhaust gases, the system was designed to remove hot air from the engine bay. In such an approach, the exhaust stream should generate under-pressure, sucking the hot air filling the hot part of the engine bay through the ejector slot.

Similar to the first idea, the protective covers help to separate different parts of the engine bay of varying temperatures. However, there will now be two different exhaust ducts for the inner and outer parts. The inner exhaust ducts are mounted to the engine, while the outer ducts are mounted to the engine mounting system. This way it was possible to minimize the danger of a strong warming the nacelle composite shell, which did not have any contact with hot exhaust ducts.
To protect the most heated parts of the nacelle shell, additional protective covers have been introduced, which would provide insulation.

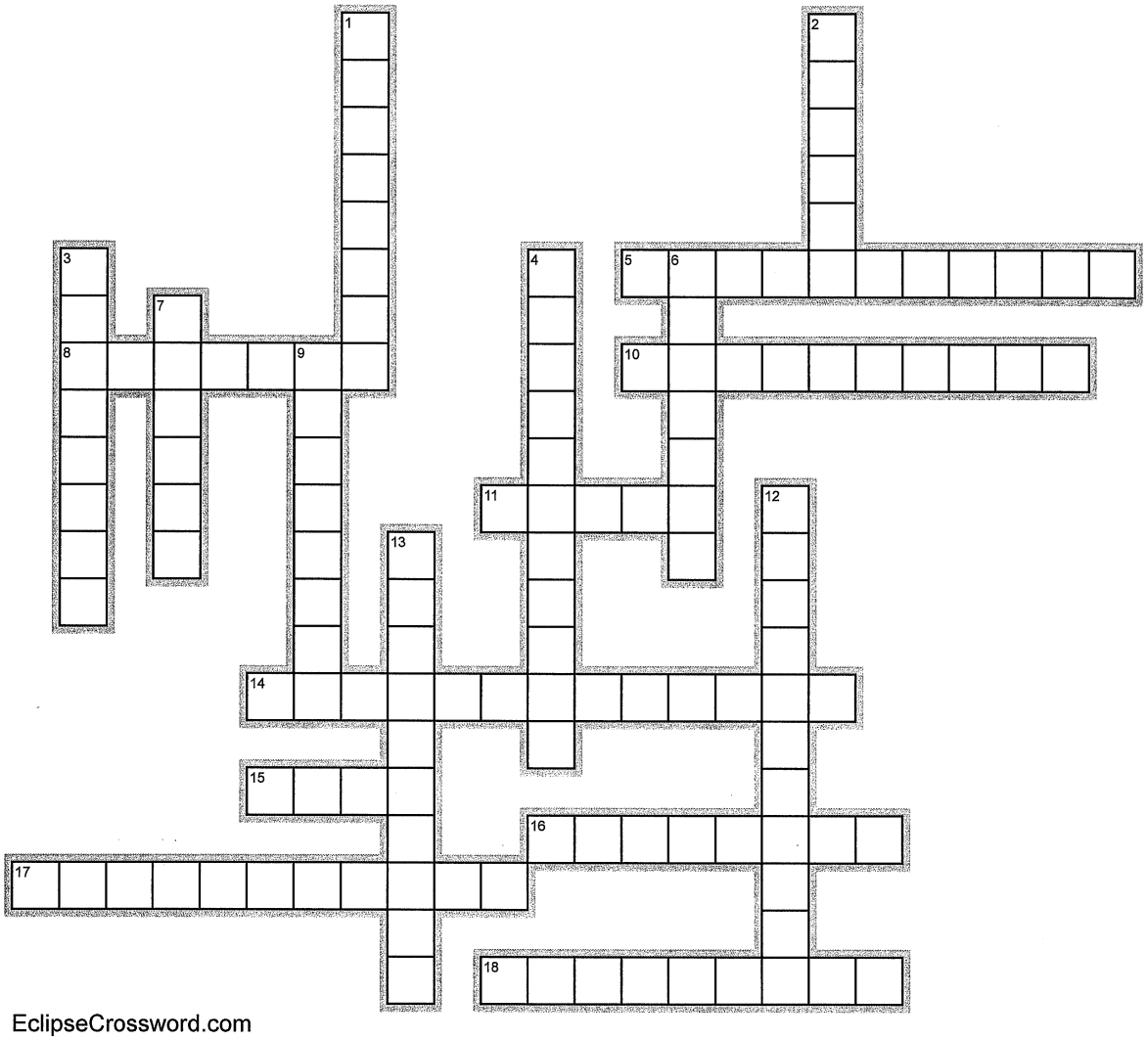
Outcomes

I found my visit to Marches Centre of Manufacturing and Technology incredibly fruitful. I particularly loved touring the centre and discovering elements and departments of engineering I hadn't even known of before. Being named the "Overall Winner" to the competition made me confident in my research and CAD abilities. I was able to learn and use many skills that I otherwise would not have developed in my A-Levels, such as teaching myself Computer-Aided Design and designing airplane components.

Fig. 3: A nacelle cover.

Crossword

Have a go at the crossword below - all the answers can be found througout the magazine. Good Luck!



EclipseCrossword.com

Across

5. Process demonstrated by waves passing through an opening.
8. Social animal that builds large colonies, and can explode to deter attackers.
10. Name given to the zone around a star where the temperature will be suitable for planets to have liquid water.
11. Renewable power source.
14. Removal of trees - a contributing factor to poverty in Africa.
15. Disease diagnosed as a result of having HIV and a particularly low 'CD4' blood count.
16. A word referring to the points of the compass, N, E, S, W.
17. Drug prescribed in the 1960s that has led to many babies being born with malformed limbs.
18. Aboriginal people whose use of language gives them above-normal powers of orientation.

Down

1. A drug molecule found in most vaping products.
2. Telescope that retired in 2018.
3. One of the four pillars of medical ethics.
4. Green organelle that was once free-living bacteria, engulfed by ancestral forms of life.
6. Chemicals with the same molecular formula but different structures.
7. A small fish that cleans the dead scales off some larger fish.
9. Sequence of DNA at the end of chromosomes.
12. Scientist whose equation describes the exact state of a quantised particle.
13. Type of crystal structure that can be used to tune the colour of lasers.

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Credits

VOTE OF THANKS

Producing this second edition of the Shrewsbury School STEM Magazine - the "Shrewsbury Periodical" has been another eye-opening experience, showcasing the breadth of interest and engagement the students at School have in a full range of scientific fields. Once again, the quality and detail of research and writing has surpassed all expectations, and I would like to thank every contributor to this great collection of work. The Upper and Lower Sixth Darwin Presidents have done so much behind the scenes this last year, so to also contribute so keenly to this magazine is to their credit!

As ever, I am indebted to the Chief Editor, Cece Lam, for her untiring efforts in producing what looks like a professional final product. It has been a huge undertaking and she has done a fantastic job, I'm sure you will agree. I sincerely hope you find something of interest in these pages!

Mr David Wray

Head of Science Outreach

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Sasha Petukhov, Sapna Chudasama and Kitty Scholes-Pryce
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