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"It has been wonderful to see our new crop of Year 12 scientists embrace the opportunity to write an article for the second edition of the Spencer Scientist. Their engagement with the subject beyond the taught curriculum shows just how interested they are in finding out more about the world of science, and this curiosity will serve them well for the rest of their time at George Spencer and when embracing future study."

Dr G. Martin
KS5 Co-ordinator, Science

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Resurrection Biology: should we bring back extinct animals?



Sophie Spray

RESURRECTION BIOLOGY: SHOULD WE BRING BACK EXTINCT ANIMALS?

Sophie Spray – Biology

Introduction

We live in a time of mass extinction. Every day between 30 and 150 species disappear from the face of our planet, and studies reveal that extinction rates today are one thousand times higher than they were in pre-human times.

De-extinction, also known as resurrection biology, refers to a blend of high-tech methods that enable scientists to bring back species from the brink of extinction and beyond. Should this be used to undo some of the harm from mass extinction?

Thylacines: The Tasmanian Tiger

Human activity can be held accountable for countless extinctions, such as that of Thylacines, also known as Tasmanian Tigers. They roamed the earth until they were slaughtered to extinction in the 1920s by European colonists, as they were seen as a threat to livestock. Geneticist Andrew Pask refers to this as a "human-driven extinction".

Over several years, Pask and a group of scientists have been aiming to bring these striped tigers back to life. But how can this be done?

The first step is to sequence the extinct animal's DNA and create a genetic blueprint of every single cell in the body. Pask and his team successfully did this in 2017, with a baby preserved in alcohol taken from a mother's uterus. Although the DNA was in good condition, it wasn't entirely intact - UV light and bacteria had broken it down into fragments. As a result, the task of working out how various bits of DNA would fit together was deemed impossible.

Luckily, a small mouse-sized marsupial called a Dunnart was able to complete the blueprints. The Dunnart shares 95 per cent of DNA with the Thylacines, and thanks to the Nobel Prize-winning genome editing method Crispr-Cas9, scientists were able to tweak the genes of a Dunnart to match the Thylacines. This method allows scientists to alter the DNA of living things by removing, replacing or adding core DNA components with pinpoint accuracy. The scientists can now work towards making a Thylacine cell that can then be developed into an embryo and implanted into a close-lying relative's uterus.



A 1980s stamp showing the Thylacine, or Tasmanian Tiger (Source: Canva)

The Woolly Mammoth

Another example of extinction is the famous Woolly Mammoth. Over 20,000 years ago, the Woolly Mammoth roamed the cold tundra of Europe, Asia and North America. Their disappearance is unclear - whether it was also a human-driven extinction due to hunting, or if they simply couldn't adapt quickly enough to the Earth's warming climate. Nevertheless, the Woolly Mammoth now solely exists as frozen DNA in the Arctic Tundra. But how could this be the case forever?

Over the years, scientists have been studying bringing back the mammoth by inserting its DNA into the genome of an Asian Elephant, its closest relative. This idea of 'editing' genes was made by Professor George Church at Harvard Medical School, and aims to create a hybrid 'mammoelephant' which is adapted to withstand the cold in the Siberian Tundra.

Through these processes, there is the potential that the Woolly Mammoth and the Thylacine may be seen on the Earth's face once again. But is reintroducing mammoths and Thylacines into existing ecosystems ethically right?



Illustration of a woolly mammoth (Source: Canva)

The Pros

Many experts believe bringing back animals like the mammoth would be one of the greatest conservation victories of all time. The process of de-extinction could produce healthy, genetically vibrant animals which can breed naturally and contribute positively to the environment. Woolly Mammoths, for example, can help boost biodiversity. Their natural behaviour consists of knocking down vegetation, which clears land and maintains landscapes. In addition, their dung is full of nutrients that fertilise the ground and prevent the habitat becoming barren. With arguments like this, scientists point out that reintroducing animals such as the mammoth could help restore the health of ailing ecosystems.

Furthermore, de-extinction could bear positive benefits not only for the environment, but also for people and modern healthcare. In the mid-1980s, a special animal called the Gastric-Brooding Frog became extinct. This animal had a unique feature of being able to convert its stomach into a makeshift uterus. It could stop producing stomach acid so that it did not digest its young. If scientists could figure out the changes and steps involved in this, treatments for stomach ulcers could potentially be developed, helping people recover from stomach surgery.

Therefore, it is undeniable that de-extinction could provide potentially significantly beneficial environmental and social benefits if the process is deemed successful. However, de-extinction is not entirely beneficial.

The Cons

A lot of scientists argue that this process is unnatural and since these animals have become extinct, others have evolved and adapted to fill their niche. Reintroducing extinct animals back into the environment might upset existing ecosystems, potentially triggering a threat to other organisms, and on a more drastic scale could even push other species into extinction.

Scientists also point out that de-extinction will never actually be able to produce animals in the form they were in before extinction. For example, the Woolly Mammoth won't actually be the Woolly Mammoth, but instead a mixture of elephant and mammoth. This brings a whole new ethical argument to the table, that creating a hybrid like this is a cruel experiment and the new animals may suffer serious health problems. They will be subject to constant testing, and their survival is not guaranteed

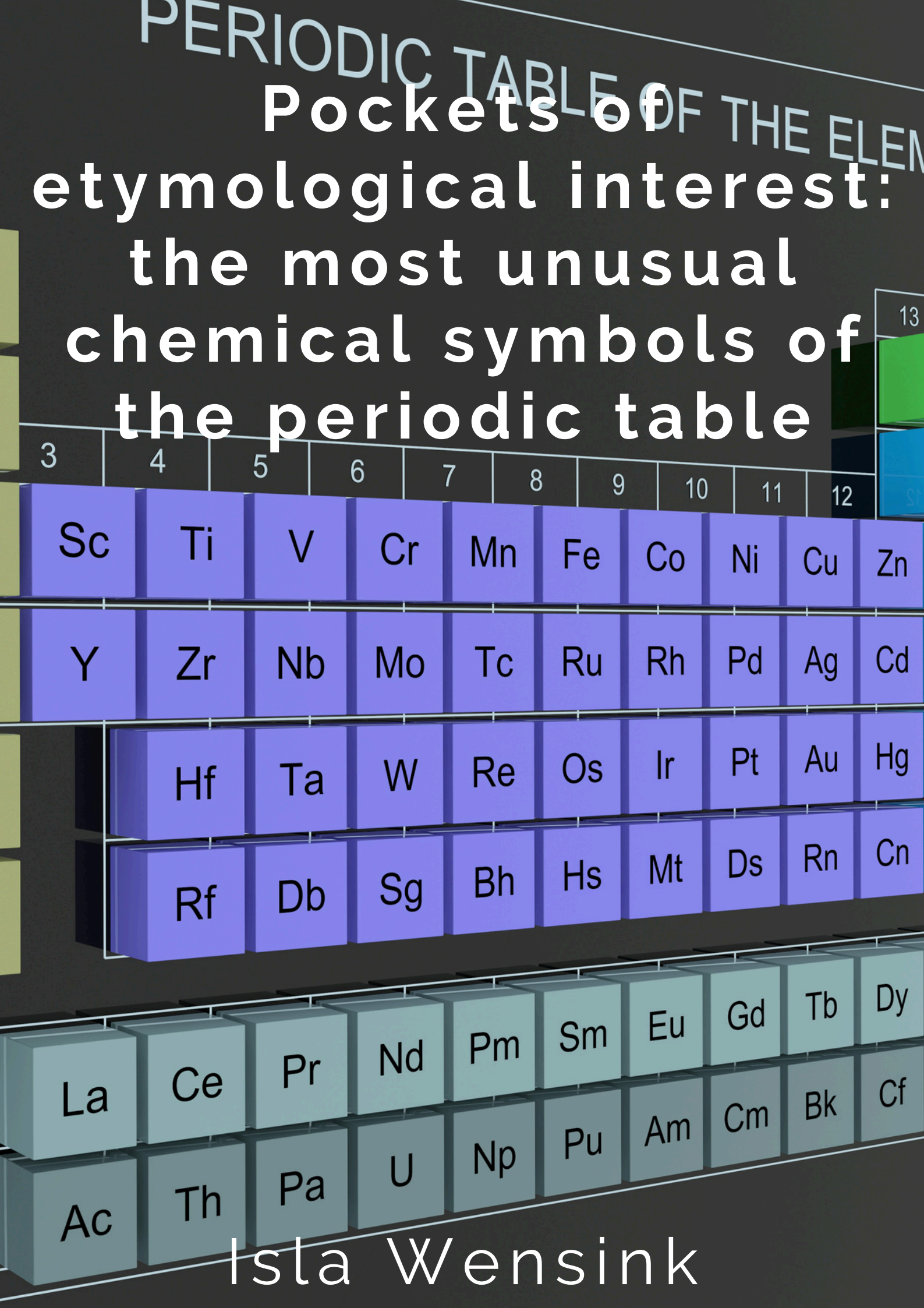
Furthermore, resurrection biology is an extremely costly process which will require tens of millions of pounds in funding. Opponents of this process argue that the money is better spent on trying to save currently endangered species before they go extinct.

Conclusion

The idea of being able to bring back species from the dead can seem very exciting, but in reality, the new creatures will never be the same as they once were. De-extinction has the potential to bring beneficial advancements in medicine, research and for ecosystems. However, the process could also lead to great harm environmentally and financially.

"DE-EXTINCTION WILL NEVER ACTUALLY BE ABLE TO PRODUCE ANIMALS IN THE FORM THEY WERE IN BEFORE EXTINCTION. THE WOOLLY MAMMOTH WON'T ACTUALLY BE THE WOOLLY MAMMOTH"

Sophie Spray



Pockets of etymological interest: the most unusual chemical symbols of the periodic table

Isla Wensink

POCKETS OF ETYMOLOGICAL INTEREST: THE MOST UNUSUAL CHEMICAL SYMBOLS OF THE PERIODIC TABLE

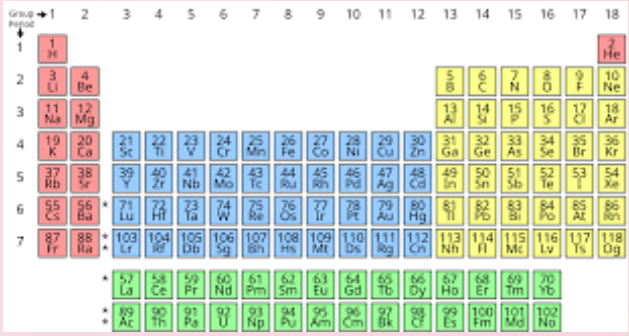
Isla Wensink: Chemistry

Introduction

An iconic image of science and a chemical dictionary, the modern Periodic Table organises the elements in trends of vertical, horizontal and diagonal direction by assigning each increasing proton number a chemical symbol. A scientific **lingua franca** (universal language) transcending any traditional translation which can be made of the table, each element can be universally represented in any reaction equation, mechanism or formula.

The study of etymology is a subfield of linguistic science, concerned with the evolution of a word and its constituent semantic meaning. The study of chemistry as a science could be considered in a similar vein: as change, the transformation of matter between ever-altering starting and ending points. It is fitting, then, that the very method of communication between chemists, the elemental symbols of the periodic table (which itself is constantly changing with discovery), is rich with individual cases of historical alteration, each element derived from different terms over centuries.

Most elements are associated with a symbol which is usually a contraction of its name, fairly consistent across translations of the table as cognates. So what about the eleven which do not share the same trend? As with any facet of Chemistry, there are exceptions to the rule: however, this is an opportunity for curiosity. A trend shared between them is in their significant history as recognised elements, easily mined or derived from oxides, used by alchemists and pioneers and astrologists from ancient times. This gives greater character to their more extensive linguistic histories (with more modern element labelling more rigid under CNIC laws), dictating little variation between the process of naming elements.



The Periodic Table of Elements (Source: Creative Commons)

GEORGE SPENCER ACADEMY

Sodium [Na] Z=11

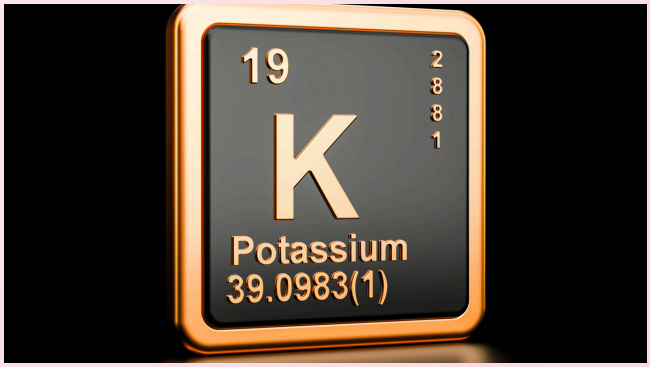
"Sodium" was extracted via electrolysis from caustic soda (NaOH) and soda ash (Na2CO3), lending its name to the compounds from which it was isolated.

The chemical symbol [Na] is a derivation of **natron**, an Arabic word for the salt used by Egyptians to mummify people.

Potassium [K] Z=19

"Potassium" was named by the first chemist to isolate pure elements, Humphrey Davy, after **potash**. Via electrolysis, in 1807 **potash** (KOH) was separated to yield pure [K], however there was debate as to whether **potash** and soda ash were the same substance. German chemist Martin Klaproth reasoned that despite similar properties, they contained different elements: **kali** [K] (from alkali), and **natron** [NA].

The chemical symbol [K] therefore comes from the full Latin **kalium** via the Arabic **gali**, for alkali.



Source: Canva

Iron [Fe] Z=26

Originating from the Anglo-Saxon **iren**, possibly further from the Greek **ieros** (for strong), and used as a recurring motif throughout initial biblical texts, "Iron" contends itself as a historically familiar element in terms of human use, additionally associated with Mars in ancient astrology.

The chemical symbol [Fe] is derived from the Latin **ferrum**, meaning "holy metal" or "firmness". In modern chemistry, the prefix "ferro-", stemming from **ferrum**, indicates the presence of element 26, [Fe]. Further derived adjectives include "ferrous", which refers to a compound containing Iron with a valence/oxidation state of [Fe(III)], the variable states undertaken by transition metals accompanied by a notable variation in descriptive language.

Copper [Cu] Z=29

"Copper" originates from the Latin for "Cyprus", **cyprium**, where Romans first obtained the ore. However, it was initially referred to as the Latin **aes**, later extended to describe its alloy with Tin [Sn], Bronze. This is due to the far more extensive use of Bronze, highlighting that prevalent substances necessitate specific new terms, for ease of communication and exchange.

The chemical symbol [Cu] directly comes from the distinction between **cyprium** and **aes**, Late Latin **cuprum** formed as a contraction of the pair, still meaning "Cyprus", despite the superficial visual difference between name and symbol.

Silver [Ag] Z=47

"Silver" likely stems from Germanic/Balto-Slavic roots such as **serebro** or **selover**; however, it is presumably a "Wanderwort" (a loan word spread amongst several languages).

The chemical symbol [Ag] comes from the Latin **argentum** for "bright". Both Silver and Gold are renowned for their shine since prehistoric times, and they are still used in jewellery and wedding rings.

Tin [Sn] Z=50

"Tin" traces back mostly from Indo-European languages which have separate words for their metals, such as the French **étain**, or Spanish **estaño**. Tin was considered to be a form of Silver [Ag] debased by Lead [Pb], which is why an older nickname "plumbum albumn" (white lead) figuratively means "worthless". The chemical symbol [Sn] is from Late Latin stannum, meaning "alloy of silver and lead".

Antimony [Sb] Z=51

"Antimony" is a corruption of the Arabic word **stibium**, and the Greek **anti + monos** meaning "not alone", due to its abundance in ancient compounds.

The chemical symbol [Sb] more directly derives from the Arabic **stibium**, from the Greek **stibi** ("mark"), describing black cosmetic powder. This is due to the element's use in darkening eyelashes, eyebrows, and painting eyelids - often leading to unfortunate results, as antimony is characteristically a cumulative poison which can cause respiratory and cardiovascular problems.

Tungsten [W] Z=74

"Tungsten" is combined from the Swedish/Danish phrase **tung sten**, for "tough stone".

The chemical symbol [W] stands for **Wolfram**, a contraction of **wolf rahm**,

"[ANTIMONY'S] USE IN DARKENING EYELASHES, EYEBROWS AND PAINTING EYELIDS OFTEN LEADS TO UNFORTUNATE RESULTS, AS IT IS A CUMULATIVE POISON"

Isla Wensink

meaning “wolf soot/cream”. This refers to the foam produced during the extraction of [W] from the mineral **wolframite**, and could be a label of contempt due to it being considered as less valuable than Tin [Sn], significantly lost during the smelting process of the substance.

Gold [Au] Z=79

Gold can be traced back to the Teutonic word **gulth**, meaning “shining metal”.

The chemical symbol [Au] is taken from the Latin **aurum**, referring to the “splendid” metal. Alternatively, **aurum** may mean “shining dawn” due to its etymological ties to the word **aurora**, meaning “dawn”.

Mercury [Hg] Z=80

“Mercury” is taken directly from the mythological Roman messenger god, Latin **mercurius**, the name suggesting that the metal has been used since prehistoric times coupled with astrology as well as alchemy. Coined in 1828, the term “mercuric” describes the condition of mercury in the [Hg(II)] oxidation state, or bivalent.



Mercury in a thermometer (Source: Creative Commons)

The chemical symbol [Hg] originates from **hydragyrium**, the Ancient Greek for “liquid silver” - fitting for mercury, notable for being the only liquid metal at room temperature (293-298 K).

Lead [Pb] Z=82

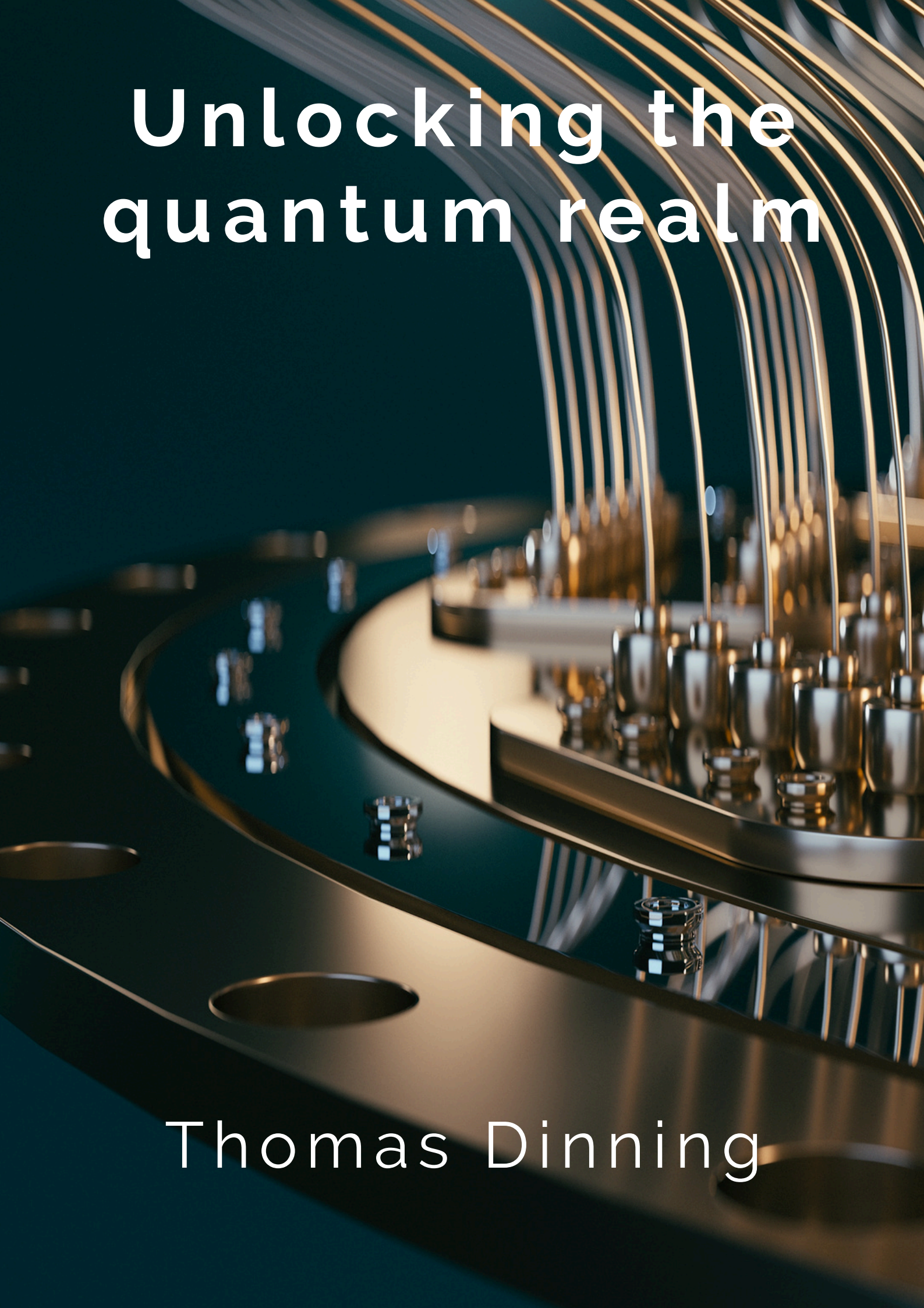
“Lead”, often speculated to be the ‘first’ metal discovered, has no known root except for possible Anglo-Saxon association. This is likely due to drastic changes in both the written and verbal communication of the word over time, so while alchemists could never transmute the substance into Gold [Au], people managed to transmute the term for it to be unrecognisable.

The chemical symbol [Pb] is taken from the Latin **plumbum**, itself derived from far more archaic languages, meaning “waterworks”. This is where the modern English terms ‘plumbing’ and ‘plumber’ come from; Lead melts at low temperatures allowing for easy handling, and it was used in Roman plumbing, which is likely how the word was spread.

Conclusion

An appreciation for subject-specific etymology, in this instance regarding the lexicon of a chemist’s most fundamental tool, may help “liberate the study of language from excessive isolation”. The insistence on polarising the Humanities and Sciences, and a more generalised separation between all disciplines of academic study, can only serve as a detriment to those truly fond of their subject.

Unlocking the quantum realm



Thomas Dinning

UNLOCKING THE QUANTUM REALM

Thomas Dinning: Physics

Introduction

The first computer was a loom, using punched cards made from wood to input instructions for complex weaves and patterns. Since then, they have progressed for over 200 years through Charles Babbage's hypothetical analytical engine to Turing's computers during the 1930s and 1940s. After the Second World War, there were more advancements, such as UNIVAC (the first commercial computer) and the invention of the transistor, which allowed for an incredible reduction in the size of computers (which had been the size of large rooms). By the 1960s, we had computers that helped navigate the Apollo 11 crew to the Moon. Ever since, computers have become more and more powerful, portable and accessible, as today we all rely on computers to perform the most basic, day-to-day tasks.

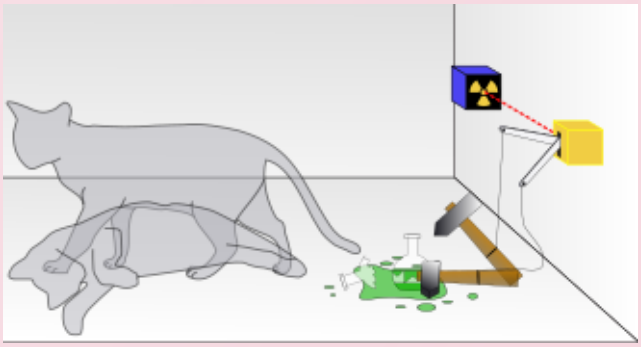
Computers are quite literally behind every aspect of modern society. From banks to hospitals, almost all our data is now handled by computers. However, since the first practical PCs in the 1990s, the fundamental way in which they work has stagnated, and we have seen very few changes in capabilities. They still use bits (1s and 0s) to store information and Boolean logic to manipulate said data. Computers in the past could perform the exact same processes (albeit often thousands of times slower). This could all be about to change with quantum computing.

Quanta

According to the Cambridge Dictionary, a quantum is defined as "the smallest amount of energy that can be measured". Quantum physics is essentially the study of the smallest particles, "quanta". These particles exhibit many properties not seen in conventional particles, such as superposition and entanglement.

Superposition

In the early 19th century, Schrödinger devised a thought experiment relating to a cat trapped inside a box with poisoned food. He observed that the cat could be considered both dead and alive. Essentially, that thought experiment related to the possibility for quanta to exist in multiple states at the same time. Quantum superposition is the theory that particles

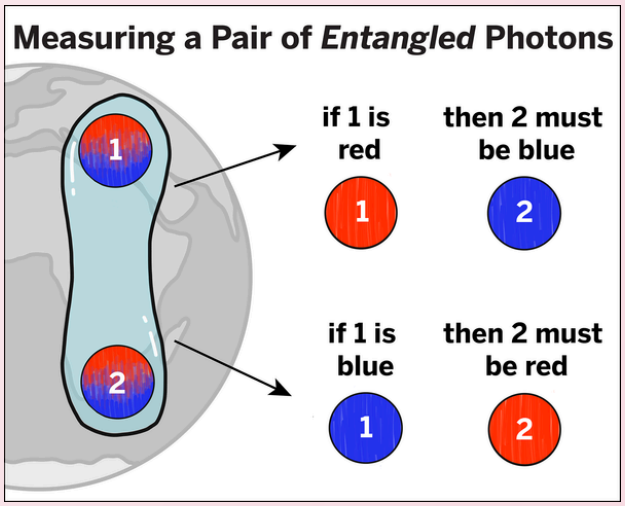


Schrödinger's cat: a cat, a flask of poison, and a radioactive source connected to a Geiger counter are placed in a sealed box. The quantum description uses a superposition of an alive cat and one that has died. (Source: Creative Commons)

don't have an assigned state to any one of their properties (spin, position, momentum) until it is measured. Measurement (or observation) here simply means any interaction with its environment. Interestingly, both Erwin Schrödinger and Albert Einstein both believed quantum mechanics to be an absurd or incomplete theory and its experiment was Schrödinger's way of showing this to the world. Today, quantum theory is generally accepted by the Physics community.

Entanglement

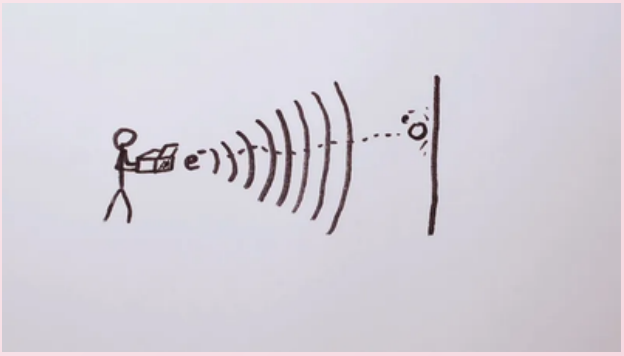
Entanglement is the process by which two quantum particles can be connected together so that they will mirror each other. This process means that they will always have correlating states no matter the distance between them, until the entanglement is broken. Entanglement has been demonstrated in many experiments of the 21st century, even showing correlations between two entangled masses of many hundreds of atoms.



Quantum Entanglement (Source: The Quantum Atlas)

Wave-particle duality

This is a property of quantum particles which means that they can be seen as particles or waves - like how energy and matter can be converted into each other as shown by Einstein's equation $E = mc^2$. This is important because it allows for interference between the waves in quantum computers.



Wave-particle duality (Source: Britannica)

So what is a quantum computer?

A quantum computer is simply a computer that uses qubits instead of bits. A qubit is a particle with quantum properties, capabilities of entanglement and superposition. Superposition is invaluable because it means that the qubits can hold infinitely many superpositions of 1 and 0, meaning that they can essentially store (and perform calculations on) multiple data at once. Entanglement is where these benefits are compounded; by entangling Qubits, we can exponentially increase the number of calculations that can be run in parallel. When entangled, qubits produce a wave output caused by the interference of each respective superposed state in the entangled system. This is how outputs can be produced by quantum computers.

Difficulties

There is an almost innumerable amount of problems that researchers run into when trying to create quantum computers. Decoherence means that quantum systems can collapse into a non-quantum state when measured. The problem arises that unintentional measurements can occur from outside factors contacting the quantum system. Decoherence is also useful as it allows outputs to be read from the quantum computer. Outside interference needs to be minimised to prevent unwanted quantum interference and decoherence. This interference often comes in the form of heat, resulting in the need for supercooled conditions in quantum computers. Errors are also mitigated by comparing the states of multiple redundant qubits. Another issue is that of creating entangled systems and providing them with data to manipulate in the first place. This is the issue currently impacting scalability. We have the ability to create and maintain only small groups of quantum particles, up to 1,000 qubits in IBM's latest computer - and even this is revolutionary with most past computers, even from Google and IBM having just 10s or 100s of qubits.

The future

Quantum computers, while not currently available in any useful form, offer huge potential for advancements in a wide range of areas.

Firstly, quantum computers would be able to create simulations of quantum interactions which could prove invaluable to research in the field of quantum mechanics.

In business and computer science, optimisation is the field which offers the most promise in terms of quantum computing. By running processes effectively in parallel, quantum computers offer to search databases, find paths and work through many possibilities to find a best fit - potentially invaluable in chemistry

"WE HAVE THE ABILITY TO CREATE AND MAINTAIN ONLY SMALL GROUPS OF QUANTUM PARTICLES, UP TO 1,000 QUBITS IN IBM'S LATEST COMPUTER"

Thomas Dinning

and medicine where large molecules needed for treatments or other processes could be discovered using quantum optimisation algorithms. Breakthroughs have been made this year by AlphaFold, with its researchers being rewarded with the Nobel Prize in Chemistry, and Google Deepmind is seeking to improve this using quantum computers.

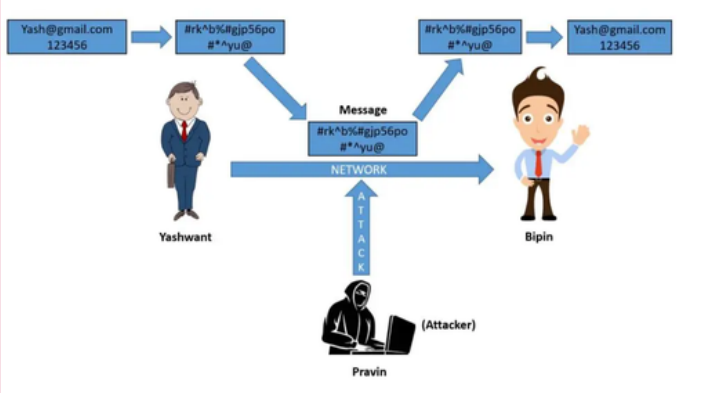
Potentially the most threatening use of quantum computing, though, is in cryptanalysis. By the same methods previously mentioned, quantum computers could potentially crack common encryption mechanisms. Public key encryption algorithms rely on the attacker being unable to factor a large number with its only factors being two primes. This works because a typical computer, even an immensely fast one, would not be able to factorise the public key to get the private key within the attacker's lifetime.

For example, RSA encryption commonly uses a key bit length of at least 4096 bits. Unfortunately, quantum computers promise to be able to break these cyphers in a useful amount of time. According to a 2021 paper by Gidney and Ekerå, a computer with 20,000,000 qubits could break 2048-bit RSA in 8 hours, meaning that it would be useful for trying to break important encryptions using a quantum computer. Fortunately, we have the potential to create new encryption algorithms that can withstand the force of qubits.

Conclusion

Quantum computing is a huge field which, although proposed over 50 years ago, is just beginning to be explored today. It poses great challenges to our manufacturing sector, great opportunities to business, physics and other fields, and great threats to security.

One thing is for sure: quantum computing is a long way from being ready just yet - despite steady and impressive progress over the past 5 years - and by the time it is, measures will be in place to prevent the loss of security to those with malicious intents: not least because only huge corporations will be able to access them even when they are available. Think back to UNIVAC - it cost around £10 million (adjusted for inflation). Overall, there is less need for worry and more need for awe at the thought of what is to come.



The process of cryptanalysis (Source: CyberHoot)

Are we safe from cosmic rays?

Cephas Yeung

ARE WE SAFE FROM COSMIC RAYS?

Cephas Yeung: Physics

Introduction

In day-to-day life, we experience a phenomenon called cosmic rays. Cosmic rays were first discovered by Victor Hess, when he conducted experiments at high altitude to test for radiation using an electrometer. (An electrometer is a tool to measure a small electric charge and voltage). At an altitude of 5,000 metres, he measured a noticeable difference in radiation - twice as intensive compared to being on the Earth's surface.

From this observation, Hess concluded that there must exist an extremely strong form of radiation from space entering the Earth's atmosphere - cosmic rays.



The electroscope used by Hess (Source: National Air and Space Museum, USA)

How do cosmic rays affect us?

Cosmic rays generally do not impact us on Earth, as most cosmic rays are deflected or neutralised by Earth's atmosphere and magnetic fields [University of Chicago].

Some cosmic rays might still get through the Earth's atmosphere, and there is a chance that cosmic rays can cause DNA to mutate. That is why pilots (and regular flyers) have an increased risk of developing cancer.

Cosmic rays and digital voting

In 2003, in a small town of around 100,000 people in Belgium, election votes were counted by a computer system where the voter used a pen to touch a screen. They also used a magnetic card voting system, which turned out to be highly significant. After voting closed and the votes were counted, there was an anomalous positive result for the candidate Maria Vindevoghel, from a little-known party with no chance of winning. Once the local authorities realised this, they decided to recount the result. As a result, Vindevoghel had lost 4,096 votes from the first count.

Scientists and mathematicians will recognise the number 4,096 as a power of 2. So why did Vindevoghel have an extra 2^{12} votes? Upon inspection, the authorities checked the magnetic card voting system to see if a software bug caused the results. But it was caused by **bit flips**, produced by cosmic rays.

Computers are made from 1s and 0s (the binary system, or base 2). A **bit flip** happens when external energy particles like cosmic rays interact with the transistor of the

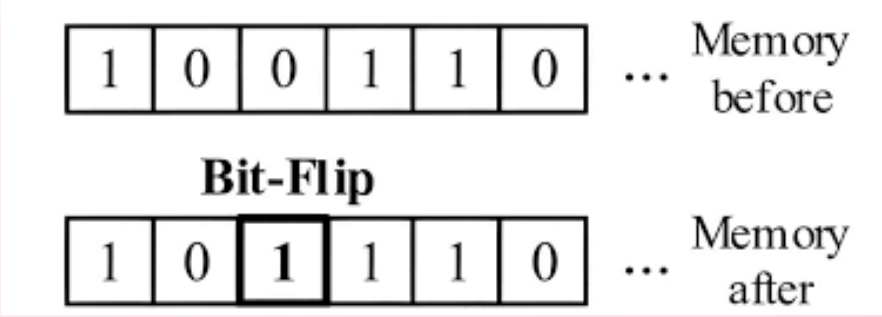


Illustration of a bit flip (Source: ScienceABC)

computer and alter the properties of the electron flowing through it and, by extension, the voltage value across the transistor terminal. This causes a '0' to become a '1', or vice versa [ScienceABC]. Research [Robert Elder] has shown that a computer with 4GB of memory has a 96 per cent chance of experiencing at least one bit flip every three days, which means it might be happening right now in any given computer.

Cosmic rays and aviation equipment

As a Qantas flight headed from Singapore to Perth, the flight conditions were perfect. The pilot operating the flight was experienced. The aeroplane ascended and entered autopilot mode. The plane flew towards Australia without major incident. But two hours into the flight, the aircraft made a sudden pitch down of 8.4 per cent and descended 200 metres rapidly, experiencing a G-force of -0.8g. The flight crew, after several attempts, managed to regain control of the aircraft, but it then experienced a second pitch down of 3.5 per cent and a G-force of 0.2g, descending another 120 metres. The plane also showed false warnings of an overspeed and stalling (impossible to happen at the same time). The passengers without seatbelts fastened were thrown out of their chairs and hit the floor, then the ceiling, of the plane.

Why did the aircraft behave so suddenly and irregularly? As it turned out, the aircraft's computer started to provide incorrect information, caused by data corruption. It mislabelled altitude and the angle of attack, causing a false correction to the latter, leading to the flight computer pitching the nose down.

The cause of the corruption was a cosmic ray leading to a bit flip. The byte in question was associated with the labelling of the plane's control system, and it switched a label from "Angle of Attack" to "Altitude".

In the end, the pilot managed to ground the plane, and while there were no fatalities, there were 119 injuries (mostly minor).

How do we prevent bit flips from happening?

In most cases, stopping bit flips is an impossible task. However, sometimes we can use error-correction codes (ECCs), which fix the error caused by the cosmic rays or high energetic particles flipping bits. Most modern computers requiring high precision to run are equipped with ECCs.

Cosmic rays and evolution

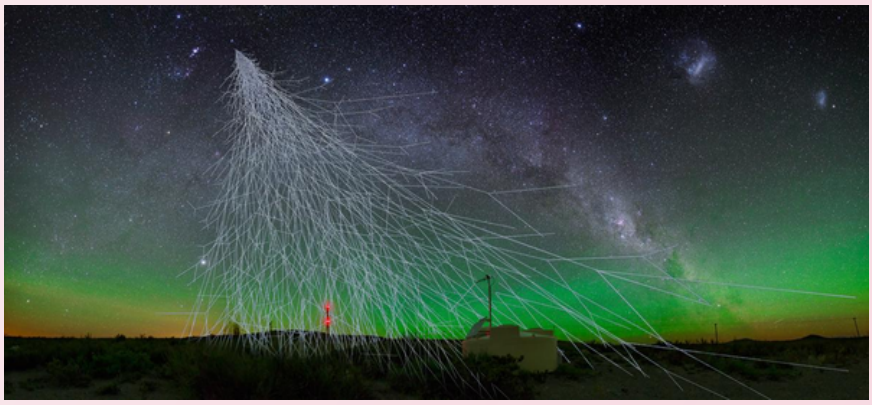
Cosmic rays arriving from outer space (mainly protons) collide with the nuclei of the upper atmosphere, in turn creating more particles called pions. The charged pions are quickly decayed, emitting a particle called **muon**. Muon is an extremely penetrating particle that can reach all sites where life could have started. This can interact directly with biological molecules, leading to mutations as a consqeuence.

Cosmic rays are important biologically as they can be responsible for inducing genetic mutations. At low levels, they are beneficial and allow evolution to occur, creating different species in nature.

Conclusion

Cosmic rays happen all around us: whether producing natural beauty in our world, or negatively disrupting our day-to-day lives, or causing harm to our digital landscape.

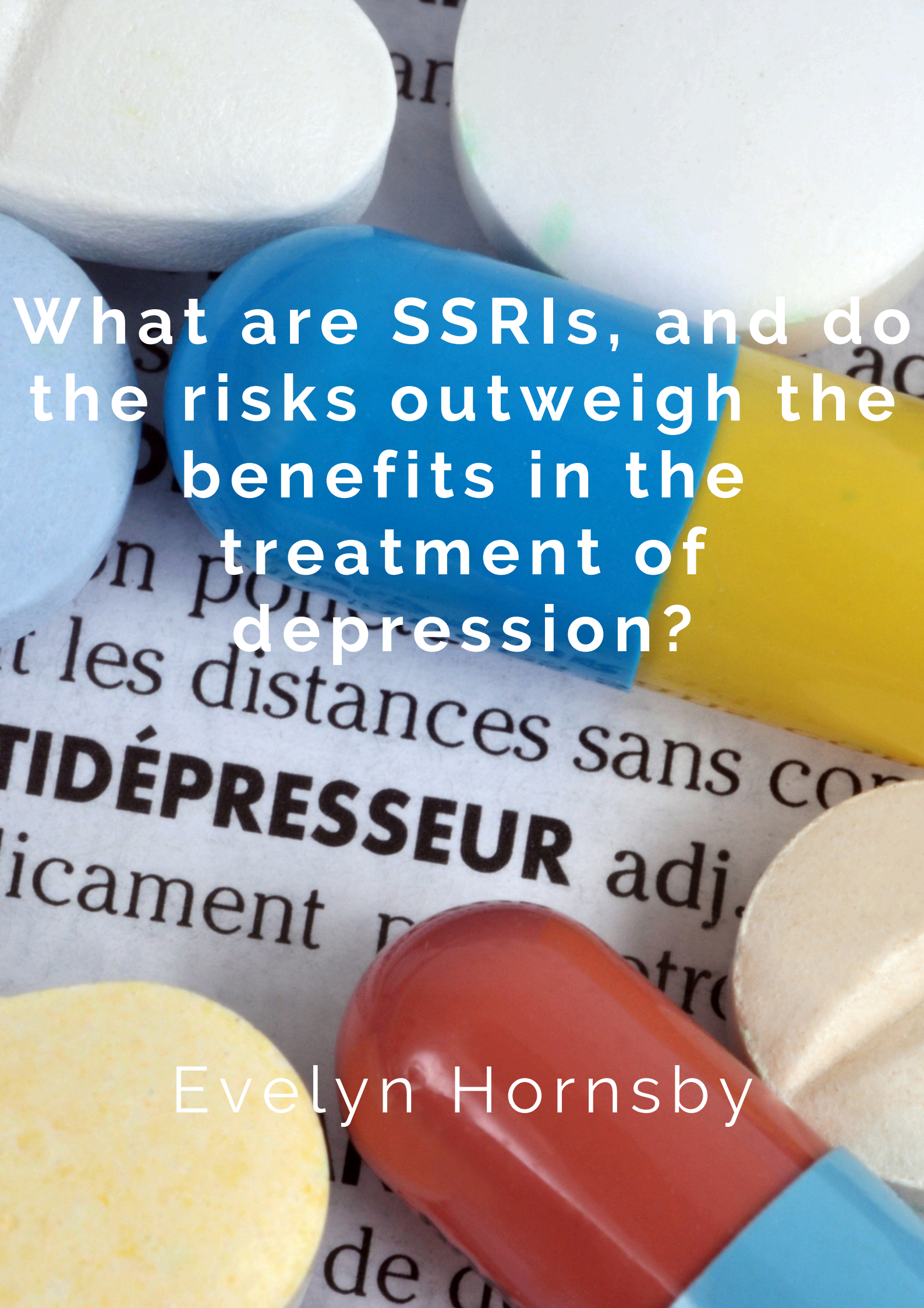
More positively, cosmic rays allow evolution and natural selection to occur, creating a wider diversity of species. As a result, our surrounding nature is more spectacular.



Cosmic rays hitting the Earth (Source: University of Chicago)

"AT LOW LEVELS, [COSMIC RAYS] ARE BENEFICIAL AND ALLOW EVOLUTION TO OCCUR, CREATING DIFFERENT SPECIES IN NATURE"

Cephas Yeung



What are SSRIs, and do the risks outweigh the benefits in the treatment of depression?

Evelyn Hornsby

WHAT ARE SSRIs, AND DO THE RISKS OUTWEIGH THE BENEFITS IN THE TREATMENT OF DEPRESSION?

Evelyn Hornsby: Biology

Introduction

Selective serotonin reuptake inhibitors (SSRIs) are a widely used type of antidepressant. They are mainly prescribed to treat depression, particularly in persistent or severe cases, and are often used in combination with a talking therapy such as cognitive behavioural therapy (CBT). They are provided by the NHS.

The concept of SSRIs is based on the serotonin hypothesis. However, other explanations of depression (from a 2015 study by Marta Bembnowska) include:

- A mother's anxiety while pregnant;
- The influence of family and conflicts;
- Sociocultural factors, such as education, religion, value systems, social conditions, social factors and lifestyle.

The introduction of antidepressants was a breakthrough in the treatment of depression, alleviating severe symptoms and increasing mood, allowing those suffering from depression to gain a higher quality of life. However, antidepressants do not come without risks. There can be side effects that come from taking these medications.

Breaking down SSRIs

Serotonin is a chemical messenger, known as a neurotransmitter, that is made by the body's nerve cells from a protein called **tryptophan**.

In connection with depression, serotonin is one of the chemicals in your body that helps to control mood. The neurotransmitter has many other roles, such as influencing appetite and bowel movements.

Re-uptake in this context means that serotonin is taken back into the pre-synaptic neuron by transporter proteins, and then are either recycled or broken down by enzymes.

As they are 'inhibitors', and to inhibit means to hinder, restrain or prevent, SSRIs are inhibiting the reuptake and breakdown of serotonin. This means that SSRIs influence the levels of serotonin, so they are used mainly to treat depression.

According to the NHS, SSRIs are the first-choice medicine for depression, because they have fewer side effects in general than other antidepressants such as tricyclic antidepressants. As well as depression, SSRIs can be used to treat a number of different health conditions, such as generalised anxiety disorder, obsessive compulsive disorder, bulimia and post-traumatic stress disorder.

How do they work?

To understand the workings of SSRIs, we have to look further into the process of synaptic transmission. Synaptic transmission is the process by which neurons in the brain communicate and pass information. Information is passed down the axon of the neuron as an electrical impulse, known as action potential.

Once the action potential reaches the end of the axon, it needs to be transferred to another neuron or tissue. It must cross the synaptic gap between the presynaptic and postsynaptic neuron.

In the axon terminal at the end of the neuron there are synaptic vesicles. These contain neurotransmitters, the chemical messengers (for example, serotonin). When the electrical impulse or action potential reaches these synaptic vesicles, they release their contents of neurotransmitters into the synapse (the gap between the presynaptic and postsynaptic neuron).

These neurotransmitters then carry the signal across the synaptic cleft. They then bind to receptor sites on the postsynaptic cell and complete the process of synaptic transmission.

The process of the reuptake of neurotransmitters is when the chemical messengers are reabsorbed back into the presynaptic cell it was released from. This is essential for synaptic functioning. Reuptake also allows neurotransmitters to be reused and helps to regulate neurotransmitter levels. In short, the reuptake of serotonin decreases the levels of the synapse.

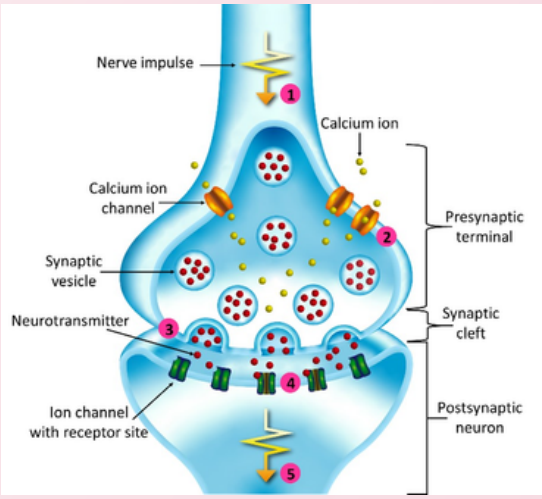


Diagram of synaptic transmission (Source: Okinawa Institute of Science and Technology)

Furthermore, this introduces the 'serotonin hypothesis' of clinical depression that proposes that diminished activity of serotonin pathways plays a causal role in the pathophysiology of depression.

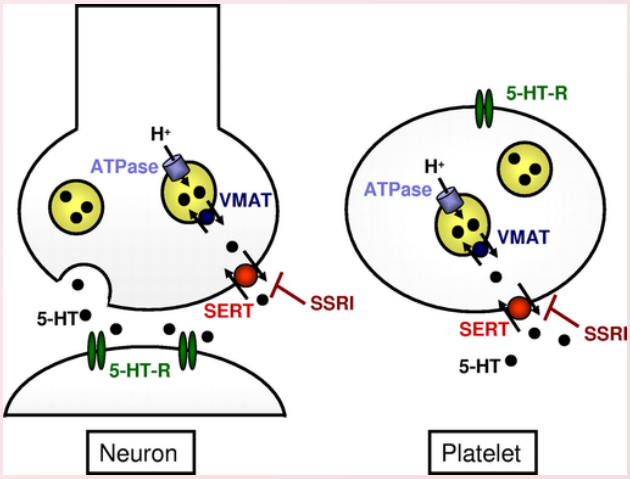
According to this model, levels of serotonergic neurotransmission in the forebrain are a key determinant of mood: high activity results in euphoria; low activity results in dysphoria. So, this hypothesis (described by William R. Schafer in 1999) states that depression is caused by chronically low levels of serotonergic transmission.

How SSRIs work is that they interfere with the activity of the serotonin transporter (5-HTT), which is a reuptake molecule that removes serotonin from the synapse. As a result, the putative low levels of synaptic serotonin in depressed patients are elevated, relieving depression (Schafer, 1999),

What are the risks of SSRIs?

With any medical treatment there are risks involved. SSRIs, unsurprisingly, do usually generate side effects. Some patients taking the antidepressants develop insomnia, skin rashes, headaches, joint and muscle pain, stomach upset, nausea or diarrhoea, according to Harvard Medical School in 2021. These problems, however, are generally temporary or mild.

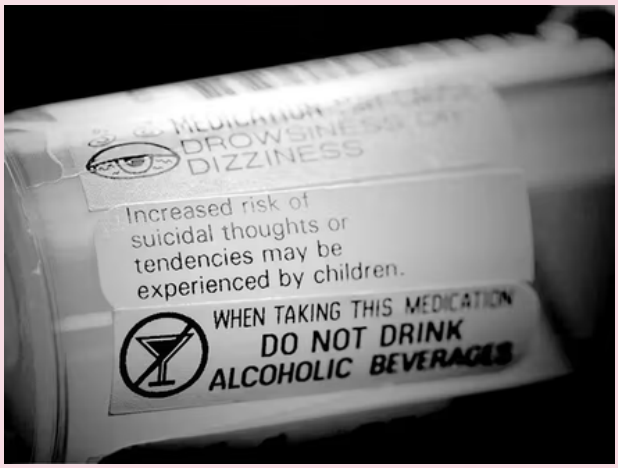
A more serious problem that can occur is internal bleeding. A 2021 study by Rene Zeiss et al. demonstrated an increased risk of brain haemorrhages, peri- and post-operative bleeding, and gastrointestinal haemorrhages, especially of the gastrointestinal tract. This is due to the fact that the inhibition of serotonin reuptake can affect platelet aggregation, since platelets also express the serotonin transporter (shown by Edinoff et al., 2022).



SSRIs deplete platelet serotonin, leading to a reduced ability to form clots (Source: Anglin et al., 2014)

Additionally, there can be issues with drug interactions. SSRIs are broken down in the liver by a group of enzymes and many other drugs are metabolised by the same system. If a SSRI is taken along with another drug that enhances serotonin activity, a condition called the **serotonin syndrome** may develop. This includes symptoms such as racing heart, sweating, high fever, high blood pressure, and sometimes delirium.

A final risk for SSRIs that must be considered is suicide. The risk that antidepressants will incite violent or self-destructive actions is the subject of continuing controversy and research from Harvard Medical School. There is thought to be a particular risk for young people under the age of 25. A warning is placed on all package inserts for antidepressants in common use for suicidal thought, hostility and agitation in children, teenagers and young adults.



A warning label on an antidepressant (Source: Medical News Today)

What are the benefits of SSRIs?

The first use of antidepressants took place in the 1950s with two tricyclic antidepressants (which also inhibit neurotransmitters), iproniazid and a monoamine-oxidase inhibitor. However,

SSRIs were not introduced until the late 1980s with the introduction of fluoxetine. There is evidence that SSRIs are more effective than tricyclic antidepressants. SSRIs have been shown to be more effective in the treatment of depression with anxiety, obsessive compulsive disorder, panic disorder and social phobia.

Furthermore, in four observational cohort studies of four common SSRIs reported by physicians as part of the prescription-event monitoring programme in the UK, with more than 10,000 patients in each drug group, 36 per cent of physicians reported fluvoxamine as effective and 60 per cent for fluoxetine, sertraline and paroxetine (Kauffman, 2009).

Although there is an argument to say that SSRIs increase the risk of self-destructive behaviour, the lifetime suicide rate of people with major depression is 15 per cent, and depression can be lethal in other ways. For example, a history of major depression doubles the risk of heart disease.

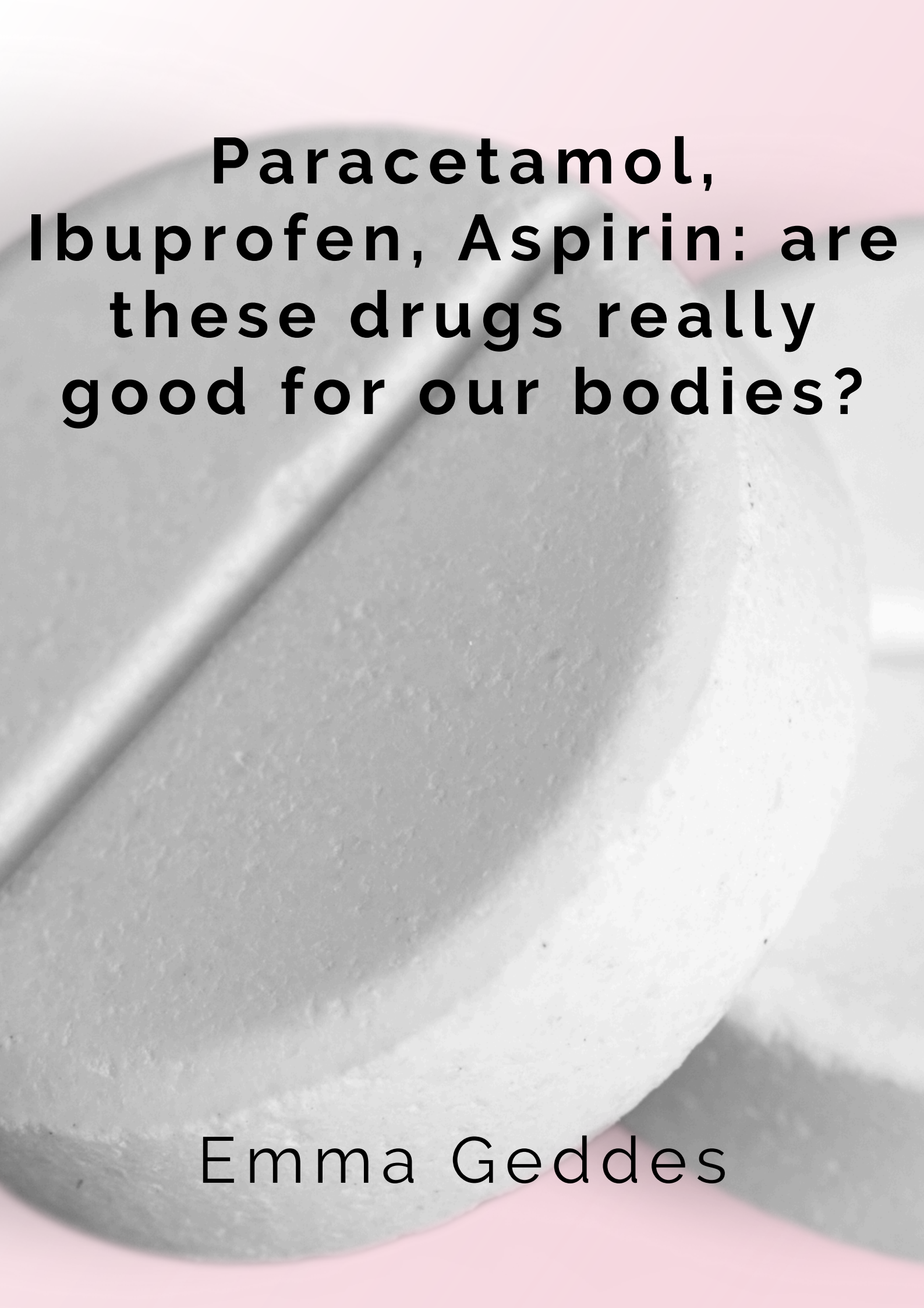
The balance of the risk of suicide varies depending on an individual's underlying risk for self-destructive behaviour. For patients with severe depression that have a high risk of this, the risk-benefit balance may be more favourable than for patients with conditions such as anxiety and mild depression. A solution for this problem suggested by the NHS is telling a close friend or relative that you have started taking antidepressants. Ask them to read the leaflet that comes with your medicine and confirm if they can observe if your symptoms are getting worse, or if they are worried about changes in your behaviour.

Conclusion

SSRIs are a type of drug most widely used as antidepressants due to their role in interfering with 5-HTT, the serotonin transporter and thus increasing the levels of serotonin in the synapse, alleviating depression. Although there are risks with antidepressants and SSRIs, they do not outweigh treating severe symptoms of depression and increasing the quality of life for the patient.

"ASK [A FRIEND OR FAMILY MEMBER] TO READ THE LEAFLET... AND CONFIRM IF THEY CAN OBSERVE IF YOUR SYMPTOMS ARE GETTING WORSE"

Evelyn Hornsby



Paracetamol, Ibuprofen, Aspirin: are these drugs really good for our bodies?

Emma Geddes

PARACETAMOL, IBUPROFEN, ASPIRIN: ARE THESE DRUGS REALLY GOOD FOR OUR BODIES?

Emma Geddes: Chemistry

Introduction

So many of us are quick to trust the medicines we find on the supermarket shelves. It is true that extensive trialling is performed on the drugs we buy; however, new findings are released every year to suggest the drugs we ingest are perhaps not as good for us as we thought. So, what exactly are we putting into our bodies, and are they harmful for us?

What actually are Paracetamol, Ibuprofen and Aspirin?

Ibuprofen works by reducing inflammation by decreasing our body's production of prostaglandin. This is done by inhibiting the activity of COX1 and COX2 enzymes. A major issue with this is the COX2 enzyme triggers pain, whereas the COX1 enzyme maintains the stomach lining. Therefore, taking Ibuprofen consistently over time can lead to stomach irritation (e.g. stomach ulcers) and, in the worst cases, can cause stomach bleeding. Ibuprofen is often used to treat period pain, toothaches and migraines.

Paracetamol is a more mysterious drug and is used to treat moderate to mild pain. We first encountered this drug over 100 years ago, but the way in which we believe Paracetamol works has changed over time. The most prevalent idea is that Paracetamol works by blocking the chemical messengers in your brain that tell your body you have pain. Paracetamol is relatively harmless when taken over long periods of time; however, it can be harmful if you exceed the daily dose. Taking more than the recommended dose can lead to damage to the liver (and, occasionally, the kidneys).



Paracetamol pills (Source: Creative Commons)

Aspirin, similarly to Ibuprofen and Paracetamol, is typically used as an everyday pain reliever. What is interesting about Aspirin is the variety of uses it has. Aspirin is useful as it irreversibly inhibits the COX1 enzyme, an enzyme essential in blood clotting. Therefore, Aspirin is used as a blood thinner (to prevent blood clotting) as well as an everyday pain reliever. Due to its irreversible properties, Aspirin is also

longer-lasting than Ibuprofen. The effects of Aspirin are more extreme than Ibuprofen as the inhibition of the COX1 and COX2 enzymes in Ibuprofen are reversible. Therefore, it is often recommended to take Ibuprofen for more moderate pain. Similarly to Ibuprofen, a side effect of Aspirin is that it causes stomach bleeding and other forms of gastrointestinal irritation (such as stomach ulcers).

Are they harmful for us?

An important thing for us to understand about Paracetamol is that studies and clinical trialling, such as the trials from the Cochrane Library, suggest Paracetamol is no better than a placebo in dealing with chronic pain (pain which lasts for over three months). In this trial, participants were given the maximum daily dose of Paracetamol, or a placebo, for three months.

Another systematic review made by the Cochrane Library suggests that Paracetamol can provide pain relief, but only for the minority. For postoperative pain (pain after surgery), only one in four people benefit; for headaches, just one in ten people benefit.

Many of us see Paracetamol as the typical form of pain relief. Feeling nauseous? Take Paracetamol. Got stomach pain? Take Paracetamol. However, many findings suggest that the use of Paracetamol may actually be ineffective.

Although Ibuprofen is effective, a large international study was funded by the Medical Research Council and the British Heart Foundation, showing that high doses of Ibuprofen increased the risk of a major vascular event (e.g. a heart attack, a stroke, or dying from a cardiovascular disease).

Aspirin too showed that there are risks to taking this drug, especially for your heart. Two large clinical trials comparing Aspirin with placebos among people without heart disease have given reason to be cautious with consuming Aspirin. Both trials showed that a low dose of Aspirin did not prevent subsequent heart attacks or strokes over a period of approximately five years. However, there were findings that Aspirin did increase the risk of major bleeding, as it has blood thinning properties.

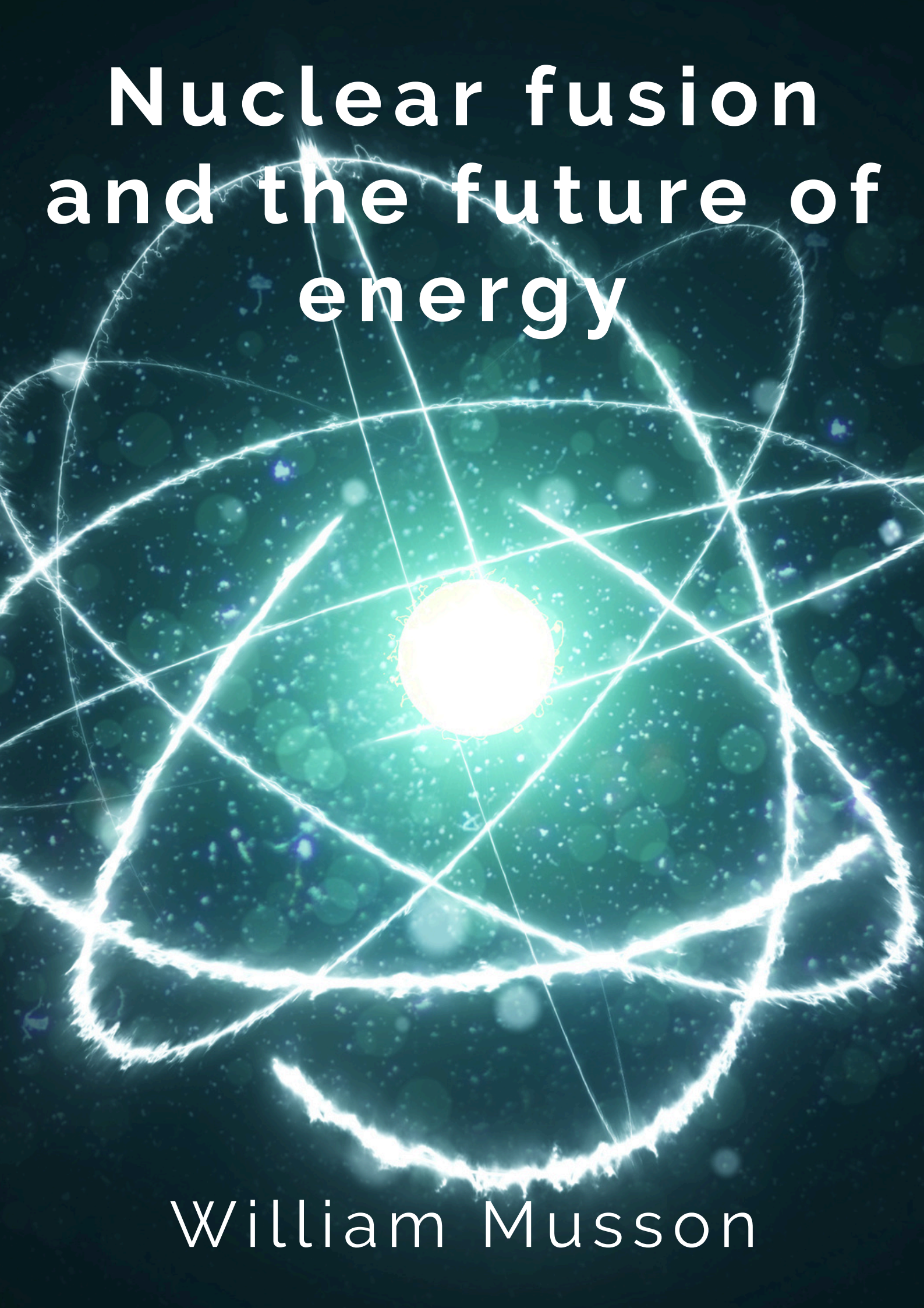
Conclusion: what are other ways we can deal with pain?

Paracetamol is often ineffective when dealing with chronic pain. Other supplements that we can use to deal with chronic pain include Omega-3 fatty acids and Vitamin D.

Furthermore, turmeric has many beneficial properties, including its anti-inflammatory effects, so it could be a good natural substitute for Ibuprofen. It is recommended to consume black pepper at the same time to allow for maximum absorption.

Paracetamol, Ibuprofen and Aspirin are all used carelessly as methods to reduce acute pain, and using more natural ingredients may be more effective at reducing the risk of cardiovascular disease and tackling chronic pain, something which many of these conventional drugs are not fully effective at achieving.

Nuclear fusion and the future of energy



William Musson

NUCLEAR FUSION AND THE FUTURE OF ENERGY

William Musson: Physics

Introduction

Energy has become a staple in our society, used every second in our lives for our own convenience, whether that be in heating and cooling, electricity, lighting, or manufacturing new products for our consumption. It is hard to imagine a world where we don't use energy, and that is not surprising when you imagine a world without something as essential as electricity. You would never be reading this article, as I would never have written it. Energy is so deeply rooted in our society that you can't help but think about it, whether in a renewable or non-renewable form. If you want to delve into the world of nuclear fusion and fission, the possibilities of energy and its implications on the earth are endless and constantly evolving.

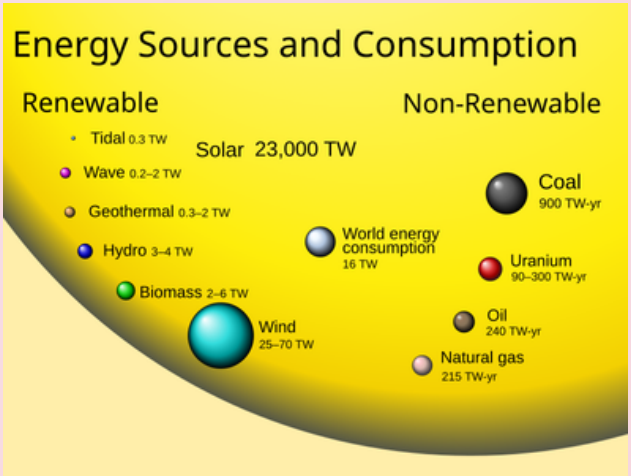
What is energy?

A world before energy isn't actually too hard to imagine. Yes, we wouldn't have things that seem so essential, mainly electricity. But, for example, we could still have heating in our homes, as our body would regulate its temperature to fit in line with external conditions. Manufacturing for consumption could still be done by humans, just not by machines.

This is because scientists define energy as the ability to do work through taking a store of energy and transferring it into a different type of energy, such as energy from lipids, carbohydrates and proteins, into thermal energy to regulate body temperature, as used in the example. If energy is transferred from its original form to be used in another, more useful form, then how do we harness this 'original' form of energy?

Sources of energy

Energy can be obtained in many different ways. These can be categorised into 'renewable' and 'non-renewable' energy. In general, as a society, we should strive to use mainly renewable sources as they have several benefits over their counterparts. This includes the fact that they have lower carbon emissions and air pollution, having a positive impact on the future of our Earth. Furthermore, the fact that they are infinite allows them to be sustainable forever, as the harnessing of energy is not dependent upon non-renewable factors but more so the natural world. Wind, solar and tidal energy will all occur without human interference; all we have to do is harness it.



Energy sources and global consumption
(Source: Creative Commons)

The same can't be said for its counterpart, which is most prominently noticed by the burning of fossil fuels. Around 34 billion tonnes of carbon dioxide are released annually into the atmosphere worldwide as a result of burning fossil fuels. Coal accounts for around 45 per cent of this, followed by oil at 35 per cent and gas at 20 per cent. The only reason fossil fuels are still used is because of how reliable they are, and how cheap and easy they are to convert to energy.

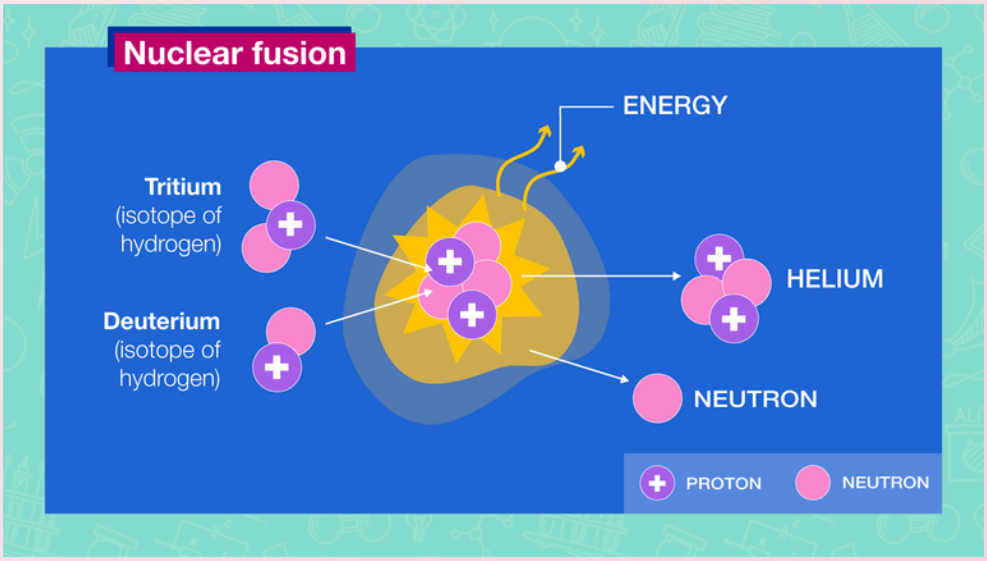
But what if our future held another reliable way to harness energy? Would dangerous and deadly fossil fuels stop being used?

Nuclear fusion

Nuclear fusion is a process that constantly occurs in the centre of our sun and every other star. When under high enough pressures and hot enough temperatures, two small atoms are able to overcome their electrostatic repulsion and form a heavier atom, such as two hydrogen atoms fusing to form a helium atom. But how is it related to energy? Well, when the two atoms fuse, the resulting mass of the heavier atom is less than the original mass of the two original atoms. To understand this further, we must reference what is the most famous equation in the world: $E=mc^2$.

Einstein's equation relates energy (E) and mass (m), showing the link between them and how they can be converted between one another. In our earlier example, the mass that was lost from the fusion was multiplied by the speed of light squared (approximately a value of $9x10^{16}$) to give us the energy stored in this mass. This allows for massively large amounts of energy to be produced by nuclear fusion.

As of 2022, the reaction most feasible for us to use on Earth is between two isotopes of hydrogen: deuterium and tritium. If one gram of these isotopes can be fused, it would provide us with approximately 340 gigajoules of energy. 340 GJ of energy is approximately 94,444.4 kilowatt-hours, which is enough to power twelve UK houses for one year. Theoretically, if



The process of nuclear fusion (Source: International Atomic Energy Agency)

nuclear fusion could be replicated on Earth at an industrial scale, it would provide us with a clean, safe and virtually limitless source of energy for us to harness.

This leads into the argument for whether nuclear fusion should be used as a sole energy source, or whether the ones we have should continue to be used. Put simply, if nuclear fusion can be safely replicated on Earth, then yes, we should only use it for energy. Nuclear fusion provides so many positives that the few negatives are negligible in the grand scheme of energy sources. It would be safe and clean for the planet, as it doesn't release carbon dioxide. It will produce no long-lived nuclear waste. Most of all, the controlled fusion of atoms can release nearly 4 million times more energy than the chemical reactions of burning fossil fuels. What would be the point of using other sources of energy when fusion releases nothing harmful, is infinitely renewable as the reactants are abundant in our Earth, and can produce more energy than all other current sources?

Conclusion

Overall, nuclear fusion is the pinnacle of what energy production should look like - the endless production of energy with no harm to the environment and the Earth that we inhabit.

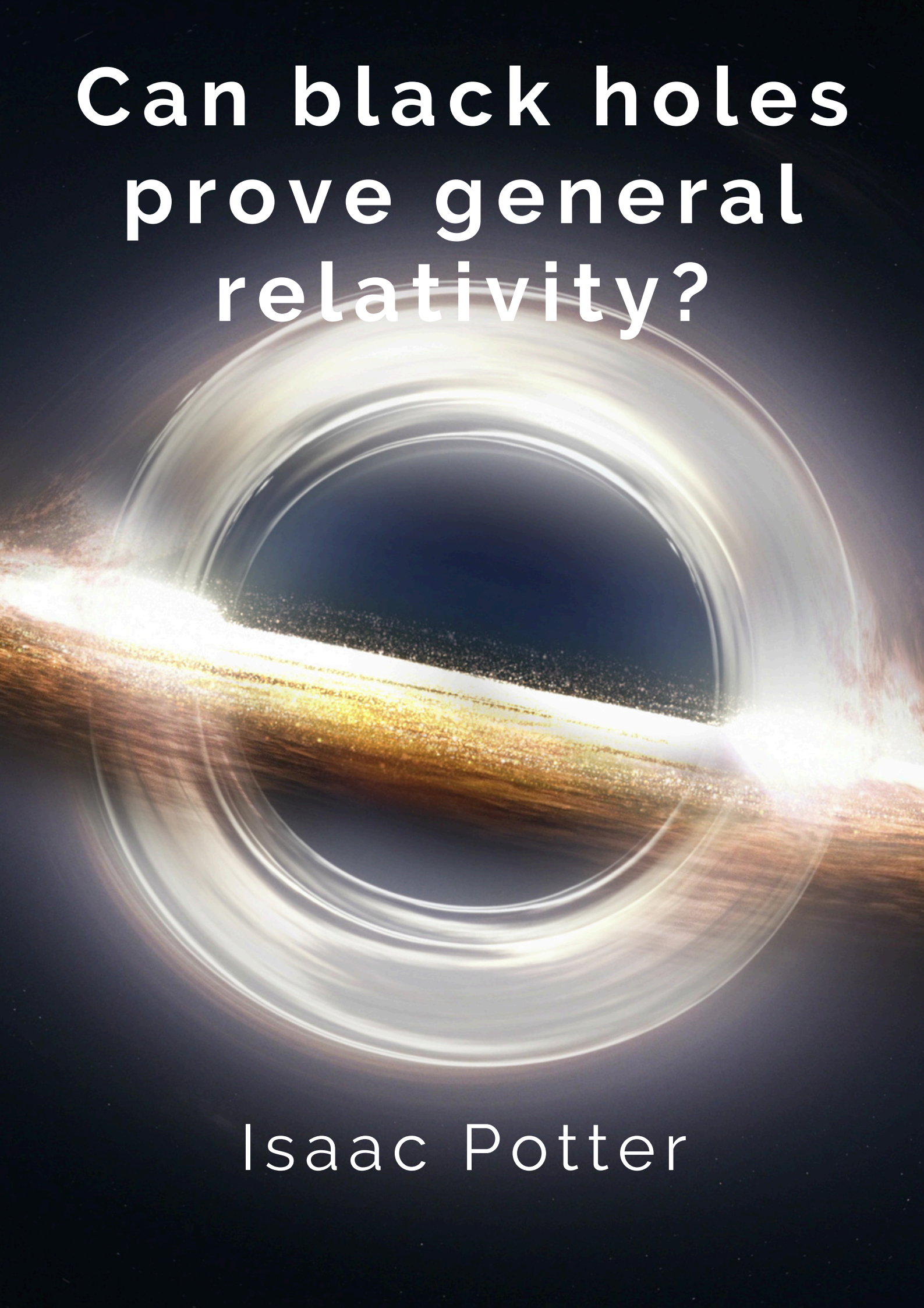
However, there are still challenges we face in recreating nuclear fusion similar to that of the Sun on Earth. It currently consumes more energy than it produces due to needing to create temperatures exceeding 100 degrees Celsius, intense pressure, and sufficient confinement to hold the plasma to maintain the fusion for long enough to yield a net power gain.

However, further advancements in nuclear fusion could allow us to meet increasing energy demands in the future while still combating rising worries about climate change. The future's bright - the future's nuclear.

"NUCLEAR FUSION PROVIDES SO MANY POSITIVES THAT THE FEW NEGATIVES ARE NEGLIGIBLE IN THE GRAND SCHEME OF ENERGY SOURCES"

William Musson

Can black holes prove general relativity?



Isaac Potter

CAN BLACK HOLES PROVE GENERAL RELATIVITY?

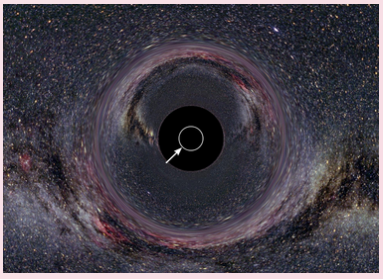
Isaac Potter: Physics

Introduction

Black holes, once considered purely theoretical, were finally confirmed to exist in 1971, and remain one of the most fascinating phenomena in modern-day Physics. The objects simply defy everything we thought we understood about the universe: the laws of gravity, space, and even the concept of time.

One of the most intriguing and perplexing properties of a black hole is something known as the **event horizon**. The event horizon is best described as a boundary beyond which nothing, neither matter nor light, can escape. This region defies our understanding and expectations of gravity as the strength of it becomes so strong that it can be called infinite, as it becomes impossible for anything to escape it.

Einstein's Theory of General Relativity is based on the idea that massive objects cause a distortion to space time due to their immense gravitational field strength. So, can Einstein's Theory of General Relativity be proven by the existence of the event horizon?



The event horizon in the Milky Way (Source: Creative Commons)

What is the event horizon and the point of singularity?

Black holes are formed when a huge star collapses in on itself after running out of fuel (which is produced by nuclear fusion). This compresses the mass of the star into one single point, known as the “point of singularity”, where it is thought to be infinitely dense. Surrounding this is the event horizon, where nothing can escape as gravity is too strong. The amount of velocity needed to escape the event horizon is faster than the speed of light; as nothing can go faster than the speed of light, matter becomes “trapped” there for the black hole’s entire lifespan.

Black holes demonstrate the nature of space-time near extremely heavy objects. Also, they curve space itself so nothing is able to escape them. Einstein's equations of General Relativity show that when enough mass is compressed into a small space, space-time curvature becomes infinite, hence creating a point of singularity displayed in the centre of black holes.

Time Dilation

One of the most compelling and unintuitive predictions of General Relativity is time dilation. Time dilation is the idea that time passes more slowly near massive objects due to gravitational field strength. This phenomenon is also sometimes referred to as gravitational time dilation. The closer to the event horizon an object is, the more

pronounced time dilation becomes. This is because gravity increases as something gets closer and closer to the event horizon. As a result, time appears to slow down relative to the object from an observer's point of view, far away from the black hole. This effect becomes more pronounced exponentially as something gets closer to the event horizon. For example, if an object is right in front of the event horizon, time would appear to come to a halt to an outside observer.

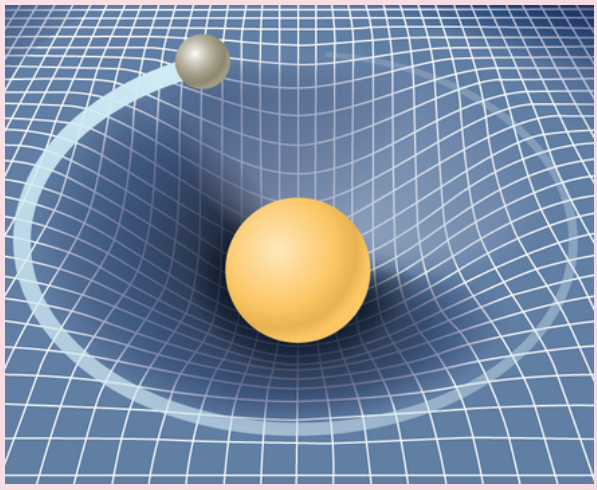
Gravitational Lensing

Another way black holes can be used to prove General Relativity is through something called **Gravitational lensing.** Gravitational lensing occurs when a large celestial object creates enough gravitational force to bend space time which bends the path of light, causing the light to be visibly bent and appear as though you are looking through a lens. In 2019, the Event Horizon Telescope (EHT) achieved a ground-breaking result by capturing the "shadow" of a black hole in the galaxy M87. This shadow arises from the bending of light near the event horizon, which essentially matches the theoretical predictions derived from Einstein's General Relativity.

Changes to Black Holes proving General Relativity

While black holes provide compelling evidence supporting General Relativity, they also pose challenges. This is due to the uncertainties that still exist when we explore the nature of black holes. Certain features, as talked about earlier, such as the point of singularity, simply do not work in our understanding of Physics. General Relativity is not fully able to explain the conditions met at the point of singularity, suggesting the need for a quantum theory of gravity.

Another source of uncertainty lies within the technology we currently use to investigate black holes. The extraordinary distance and extreme, unknown environments surrounding black holes make precise



A smaller mass orbiting in the distorted space-time of a larger mass
(Source: Creative Commons)

measuring extremely difficult. For example, the EHT's imaging of the black hole in the M87 galaxy provides unprecedented knowledge regarding black holes; however, the resolution is still constrained by the technical capabilities of radio astronomy, meaning errors could occur and 100% certainty is never guaranteed.

Conclusion

Black holes aren't just a huge, useless ball in space that destroys everything in its path. They are crucial for testing the foundations of physics and how we understand the fundamentals of how we live our daily lives. Observations such as time dilation, gravitational lensing and the existence of the event horizon all prove the predictions by General Relativity. However, these extraordinary environments test the theory's limits, pushing scientists towards a deeper understanding of gravity and space-time. In the future, the study of black holes will continue to develop and expand on our understanding of General Relativity.

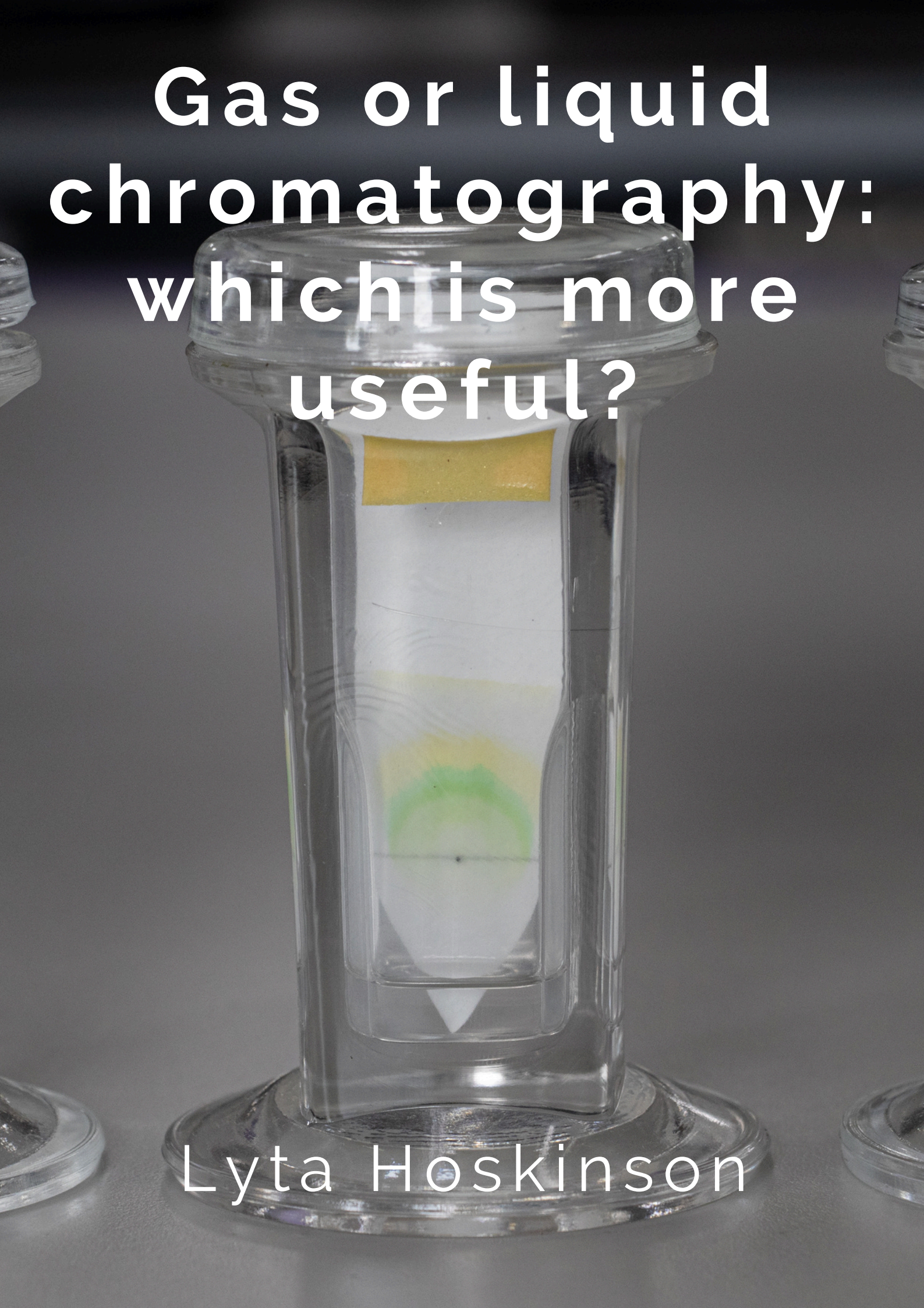


The M87 super-massive black hole (Source: Creative Commons)

"[BLACK HOLES] ARE FUNDAMENTAL FOR TESTING THE FOUNDATIONS OF PHYSICS AND HOW WE UNDERSTAND THE FUNDAMENTALS OF HOW WE LIVE OUR DAILY LIVES"

William Musson

Gas or liquid chromatography: which is more useful?



Lyta Hoskinson

GAS OR LIQUID CHROMATOGRAPHY: WHICH IS MORE USEFUL?

Lyta Hoskinson: Chemistry

Introduction

Chromatography is applied in many situations like quality control labs. In these labs, it is used to identify specific substances in a solution. There are two main types of chromatography: gas and liquid. Gas chromatography is used for the analysis of volatile, thermally stable compounds like forensic science analysing the substances in blood. Conversely, liquid chromatography is used for the analysis of non-volatile, thermally unstable organic substances which are used in 'monitoring drugs' in pharmaceuticals and quality control labs (Baranowska et al. 2013).

In addition, there are other types of chromatography like ion chromatography and thin layer chromatography: both types of liquid chromatography. This article will explain the differences between the two, how each process works, and the applications of each type of chromatography.

Gas chromatography

Gas chromatography is 'used to determine trace impurities in both organic reagents and standards' (American Chemical Society, 2016). This means that it is effective in sensing the presence of impurities in a very precisely made standard and a less precisely made reagent which is more likely to have impurities in it. Gas chromatography is divided into two types: gas-liquid chromatography (which is used more commonly to find impurities in a solution) and gas-solid chromatography.

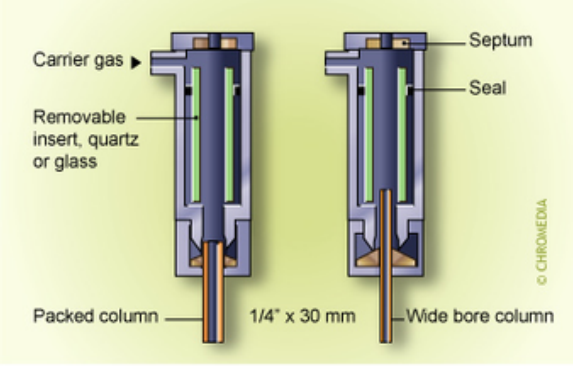
The process of gas chromatography is that the reagent/standard first passes through a column packed with a non-volatile liquid phase on a porous solid support, after being vapourised into a gaseous state. It is carried through the column by a highly unreactive gas like nitrogen, argon or helium; this is known as the mobile phase. The column has smaller capillary columns which have fused silica bonded to the liquid phase. This gives the column a strong resolving power and chemical inertness which makes it so the silica cannot react to the reagent or standard inside the column so it doesn't change the original products made and therefore gives the desired results.

The two types of capillary columns are:

- **Narrow-bore columns**, which have a diameter of 0.22-0.32mm;
- **Wide-bore columns**, which have a diameter of 0.53mm.

Narrow-bore columns bond with the thin film liquid phase, which results in a high resolution but a low sample capacity. This means that the results show less skewed peaks than wide-bore columns, making it more accurate for some substances; however, the process is longer and more time-consuming for a lab worker. The wide-

bore column bonds with a thick film of liquid phase which then results in a low resolution but a high sample capacity. This suggests that the wide-bore columns are more suited for analysing a large capacity of a solution but is less effective as it gives skewed peaks in the final result. Once the gas has passed through the column, it is put through a detector which picks up the peaks, proportional in area to the concentration of the gases of interest.



Installation of a wide-bore column (Source: Chromedia)

Gas chromatography can be used for many research and analysis purposes. The five uses I have researched are:

- **Food analysis:** chromatography is used in food analysis to find and trace elements in specific foods. These can include carbohydrate groups, protein groups, vitamins, steroids and pesticides. This is to make sure the food produced is safe to consume and is not poisonous or toxic in any way, shape or form.
- **Environmental monitoring:** the main way gas chromatography is used in environmental monitoring is 'to analyse volatile and non-polar compounds' (News-Medical, 2021). This is to ensure that the air and water consumed is safe to breathe and drink. Overall, for environmental research and monitoring, 'gas chromatography is an indispensable analytical technique in the battle against pollution. Its ability to detect, analyse and monitor various pollutants is critical for environmental protection efforts' (Zhejiang, 2024).
- **Drug testing**: used to test chemical compounds within the human body using their bodily fluids (e.g. blood samples, urine and sweat). It is most commonly used in the Olympics to test for any drugs present in the contestant's body. Gas chromatography breaks down the athlete's sample into component parts, so it's easy to tell which substances the athlete has consumed and in what quantity.
- **Forensics:** gas chromatography is used in forensics to discover a person's death by the substances in their blood, such as any poisons or toxic substances that shouldn't usually be there in the body.
- **Manufacturing drug control:** gas chromatography is used mainly to test the purity of substances in drugs in quality control. It analyses the different elements in the drug to show any impurities clearly. This allows the chemist to determine whether or not the drug is safe to use.

Additionally, gas chromatography can be used in mass spectrometry. It is used to identify standard-grade reference materials and analyse the environment and petroleum products/ biological materials. Mass spectrometers have a high vacuum system where it measures the difference in mass to charge ratio of ionised atoms or molecules to separate from each other. In

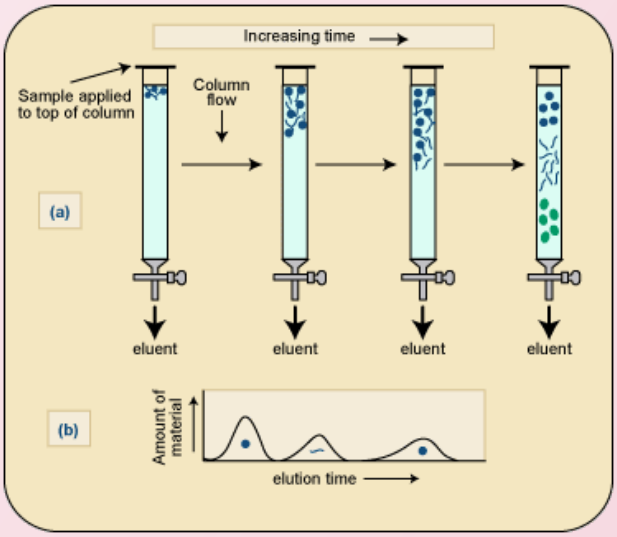
the results, the largest peak in mass spectroscopy is called the base peak which is automatically at an arbitrary height of 100. This is then used to compare the other peaks to the base peak.

Liquid chromatography

Liquid chromatography starts with a liquid sample, which is then carried by the mobile phase (an effluent). However, the effluent has to be chosen specifically with regard to its polarity compared to the stationary phase. The stationary phase is a column filled with porous spherical or irregularly shaped particles. It will use gravity or some other force at a high pressure to pull apart the different elements of the mixture. The stationary phase materials depend on activity and particle size. An anhydrous (without water) component has the highest activity grade, meaning they attract solutes quicker than the alternatives. Furthermore, the use of different solvents compared with different stationary phases means that the reactions are different. This means that the solvents will pass through the column of the stationary phase at different speeds, which is used to identify the different compounds.

Ion chromatography

Ion chromatography is a form of liquid chromatography designed to identify anions and cations using ion exchange. The liquid phase of this chromatography is the 'crude sample' with the charged particles in it. When passing through the stationary phase column, the charged particles break by binding to the walls of the column which is in an oppositely charged state. The ions which are broken apart are then eluted (removed from the column by a solvent which has varying ionic charges in it, usually containing a salt gradient) and can be detected (Cheriyedath, 2016).



The process of ion chromatography (Source: SERC)

Ion chromatography can be used for these purposes:

- The separation and purification of blood components
- Fermentation
- Biotechnology (quality control of drugs)
- Food and clinical research (analysing certain proteins and wheat variations in food)

Thin-layer/planar chromatography

Thin-layer/planar chromatography, a form of liquid chromatography, is a technique used to isolate non-volatile mixtures (BYJU'S, 2019). The experiment is carried out by the solution being placed on a piece of aluminium foil, plastic or glass which has been coated with a layer of an absorbent material (usually aluminium oxide or silica

gel). After the separation, each component shows a dot on the foil which has a different retention factor which can be calculated.

Thin-layer chromatography is one of the fastest, least expensive, simplest and easiest chromatography techniques. The separation technique depends on the affinity of the solution being tested (how well a substance reacts with another material) to the stationary phase at it moves over the stationary phase. The components with a higher affinity level over the stationary phase at a slower rate whereas other components with a lower affinity travel at a faster rate, as they don't react well with the stationary phase material. Planar chromatography has these four components:

- **Chromatography filter paper**: used inside the chamber and placed in the mobile phase where it moistens.
- **Chromatography chamber:** used to keep a controlled environment whilst the reaction is occurring.

Chromatography chamber plates: the stationary phase is applied onto the inert and stable plates in a thin layer.

Conclusion

Both gas and liquid chromatography have their uses. Both are used in many different industries, such as the pharmaceutical and food industries, where they are used to test the components of samples. While gas chromatography focuses on separating compounds with a low molecular mass with a high volatility, liquid chromatography focuses on separating more solid compounds with a larger molecular weight, like proteins. Therefore, both are necessary in the testing of substances. However, liquid chromatography is less expensive and can be used to identify certain cations and anions, something gas chromatography cannot do. Liquid chromatography is economically and environmentally better than gas chromatography.

"BOTH GAS AND LIQUID CHROMATOGRAPHY ARE USED IN THE PHARMACEUTICAL AND FOOD INDUSTRIES TO TEST THE COMPONENTS OF SAMPLES"

Lyta Hoskinson


Is anyone out there?
Luke Alexander

IS ANYONE OUT THERE?

Luke Alexander: Physics

Introduction

It was the summer of 1950, and renowned Italian physicist Enrico Fermi was having lunch when he blurted out spontaneously, "But where is everybody?", startling those with him.

Fermi had realised that, if extra-terrestrial life did exist, as contemporary UFO reports suggested, then where were the aliens? Logically, if the conditions required for life are similar to those seen on Earth, then surely, across the billions of stars in our galaxy alone, there ought to be habitable planets with intelligent life. Surely we would have observed some conclusive evidence of extra-terrestrial life: actual visitors, or at least unexplainable signals from space?

This idea forms the basis of the Fermi Paradox: the contradiction between the high likelihood of intelligent extra-terrestrial life, and the lack of conclusive evidence of advanced life.

The Drake Equation

The Fermi Paradox isn't just a logical contradiction. The Drake Equation was proposed in 1961, attempting to determine an approximate number of active, developed and communicative civilisations in the Milky Way galaxy. Although it is an approximation, it summarises the main factors that are contemplated when thinking about extra-terrestrial life. It is given by:

$$N = \mathrm{R}_* \cdot \mathrm{f}_p \cdot \mathrm{n}_e \cdot \mathrm{f}_1 \cdot \mathrm{f}_i \cdot \mathrm{f}_c \cdot \mathrm{L}$$

Where:

- R* = the average rate of star formation in our Galaxy.
- fp = the fraction of those stars that have planets.
- ne = the average number of planets that can potentially support life per star that has planets.
- f1 = the fraction of planets that could support life that actually develop life at some point.
- fi = the fraction of planets with life that go on to develop intelligent life (civilisations).
- fc = the fraction of civilisations that develop a technology that releases detectable signs of their existence into space.
- L = the length of time for which such civilisations release detectable signals into space.

While many versions of this equation have been made, it is often heavily criticised. A lot of the values used are purely speculative at this point in time, and so we cannot get an accurate picture of the number of developed civilisations which exist. This equation was intended more to create discussion about this topic, and less to provide a truly accurate estimate. But using the most up-to-date estimates, using both theoretical maximum and minimum values, calculations using this equation have given a range of:

$$9.81 \times 10^{-13} < N < 15,600,000.$$

This shows that perhaps there is a chance that we are alone in our galaxy, but also that it's likely that there is intelligent life out there. So, why haven't we found any?

GEORGE SPENCER ACADEMY

Some suggested solutions

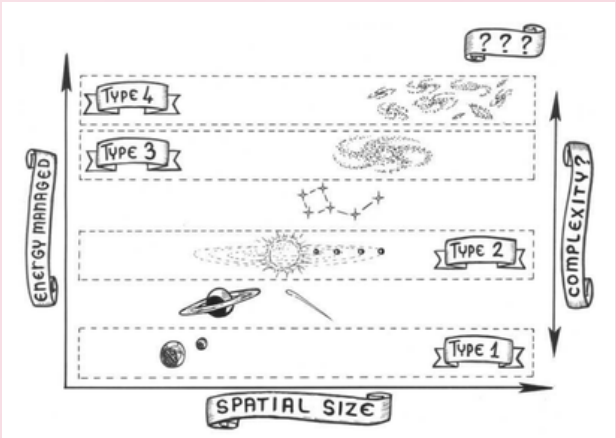
Over the years, many people have attempted to resolve the paradox, but nothing can be proven. The truth is that we have no idea who, or what, is out there, and if they are, is there a good reason we haven't found them yet?

A popular (and perhaps the most plausible) explanation for the Fermi Paradox is the Rare Earth hypothesis - the idea that the evolution of life resulting in intelligence was an improbable event, so much so that there are very few occurrences of it across the observable universe. Advocates for this solution base their reasoning from the fact that our existence is due to so many statistically unlikely events - being in the inhabitable "Goldilocks" Zone, having a stable orbit, plate tectonics, an atmosphere among many other things. This theory has been criticised however - the idea that conditions similar to those here are required for life has been said to be anthropocentric (humankind is the most important).



The Rare Earth hypothesis (Source: E. Alderson)

Another interesting resolution to the paradox is the Great Filter Theory: the idea that there is some sort of "barrier" to development which results in detectable extra-terrestrial life being extremely rare. We don't know what this "filter" is, but it would explain the huge discrepancy between the calculated statistical probability of coming into contact with extra-terrestrial life, and the fact that we have observed none. The filter suggests that there is a step of development a civilisation must complete as it proceeds to the highest levels of the Kardashev Scale. This filter could be anything from the development of single-cell life, to space colonialism. If this theory is true, we have no idea if we're before or after the filter - will we be the ones making contact, or are we all doomed?

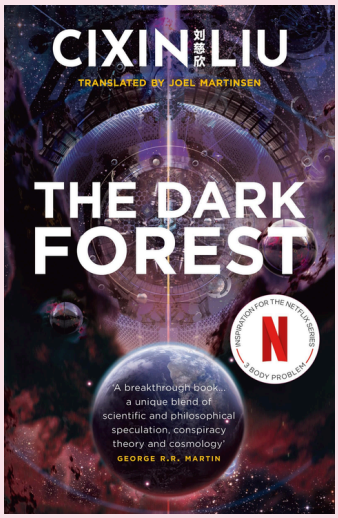


An illustration of the Kardashev Scale: a method of measuring a civilisation's advancement using the amount of energy it can harness and use (Source: Astrobites)

A suggested resolution to the paradox is simply the idea that alien life is totally and utterly incomprehensible - so much so that even if it was right in front of us, we'd have no idea it was there or how to understand its existence. Perhaps a physiological barrier may stop communication between any life - what we understand as maths and

reason could be nonsensical gibberish to another species. For how can we even know if they interact with the world in a similar way as us? Life developed in a completely different environment compared to us may be so different that we can't even imagine what existence is like for them. We can see examples of this even on this planet - for example, the mantis shrimp, an aquamarine animal, has 16 photoreceptor cells, compared to the 3 that we humans have. This means that they have access to an unimaginable spectrum of colours we can't even begin to comprehend. How would a species that developed in a completely different system to us interpret the world? It's even possible that an alien civilisation has observed us, but due to our laughably primitive level of technology, they have found no need to contact us, for what would be the point?

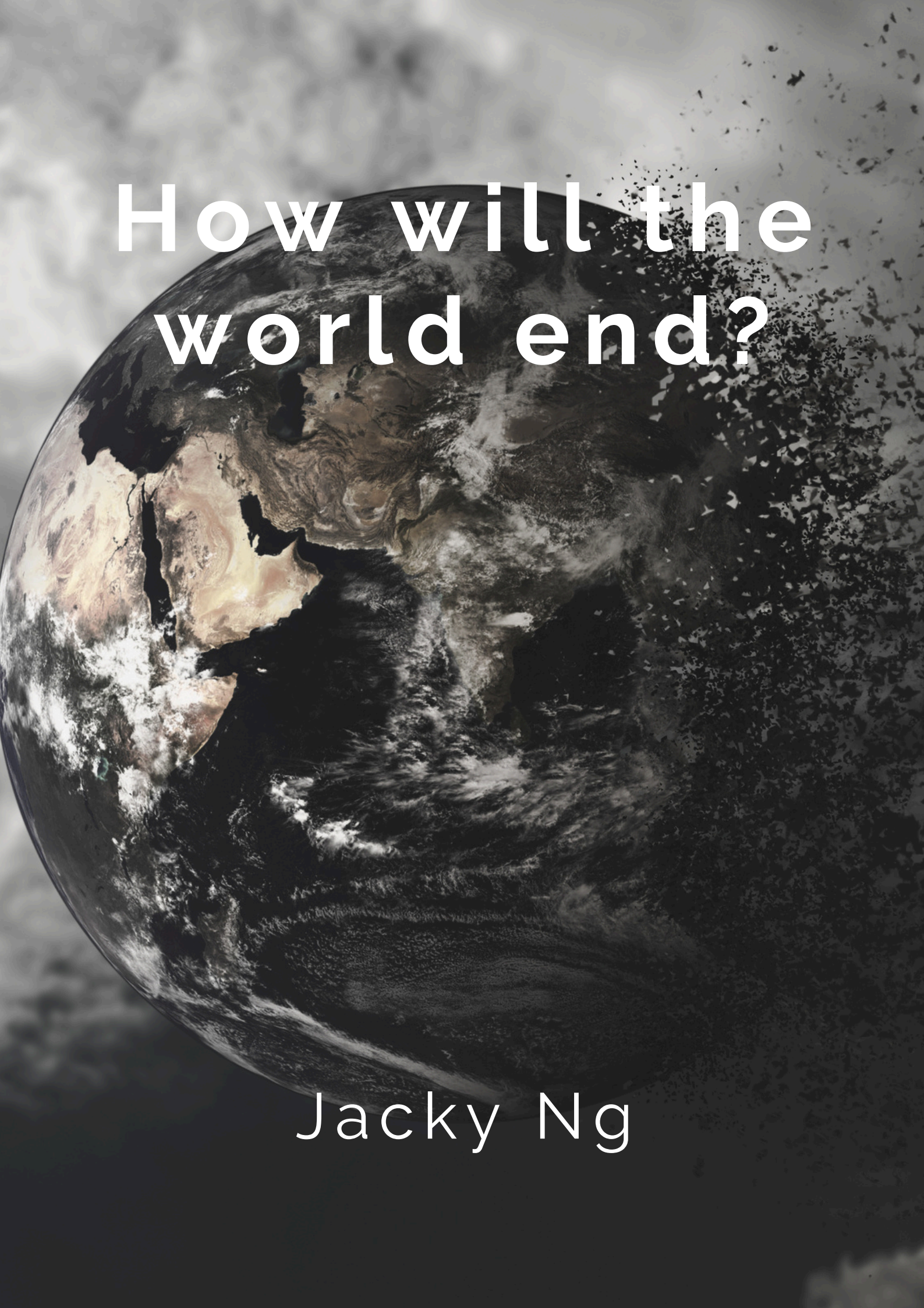
There are also other, more sinister explanations for the Fermi Paradox. A popular theory in common media is the Dark Forest hypothesis (the name of which is derived from Liu Cixin's novel, The Dark Forest). It suggests that in fact many intelligent civilisations exist throughout the universe, but they are both "silent and hostile", remaining undetected in fear of being destroyed by another civilisation. This fear comes from the idea that the intentions of a civilisation can never be known with certainty, and so self-preservation brings one to "shoot first and ask questions later" in order to ensure the survival of one's species. In addition, logically any civilisation will likely consider another civilisation a threat - if a species' primary goal is survival, and a species will generally continuously expand, whilst the matter in the universe remains constant, then it is inevitable that this species will encounter another, in which case it is likely to exterminate the other, for that other species will inevitably wish to expand and survive. We, on Earth, are fearlessly shouting into the void in our search for extra-terrestrial life - is this something we will come to regret?



The Dark Forest (Source: Amazon)

Conclusion

In the end, we don't know what's out there, and it's likely that we'll never find out. Maybe we'll make contact with extra-terrestrial life in our lifetimes or maybe we are truly alone in the universe. Perhaps we'll be the first species to make it past the Great Filter (maybe we already have!) and we'll be the ones who establish contact with others. Or maybe time will show us why advanced species choose not to contact primitive species. For all we know, extra-terrestrial life is arguably one of the biggest questions not only just in Physics, but for humanity as a whole. No matter what happens, if we ever do come into contact with another species, it will change us all, forever.



How will the world end?

Jacky Ng

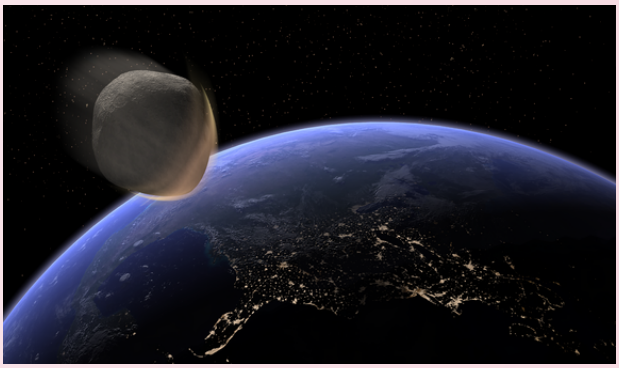
HOW WILL THE WORLD END?

Jacky Ng: Physics

Introduction

Walking and driving around through our everyday lives, we tend to think of life on Earth as a static proposal. Rarely do people look up and think of the big universe that exists around us. We do live in an expanding, evolving cosmos, and the universe is a very big place, with our planet an almost infinitesimally small part of it. Life on Earth originated around 4 billion years ago, and complex creatures like us have been around for only a few hundred thousand years. But life on Earth is a temporary activity - it will not go on forever.

Scientists think the first living things on Earth appeared as far back as 4 billion years ago, when the planet was still being hit by big space rocks. But life managed to survive anyway. Throughout Earth's history, there have been many disasters, from exploding stars and asteroid impacts to huge volcanic eruptions and sudden changes in climate. These events have wiped out many types of life: in fact, some of these mass extinctions have wiped out most species in the Earth's history.



An asteroid heading towards Earth (Source: Creative Commons)

Yet life has always rebounded. New species emerge. The cycle repeats.

What would it take to kill off life in full?

While humanity might be surprisingly fragile, it isn't easy to sterilise an entire planet. Nonetheless, there are a few possible doomsday events that could permanently extinguish all life on Earth.

Death by deoxygenation

Nearly 2.5 billion years ago, during a time known as the Great Oxidation Event, cyanobacteria (also known as blue-green algae) released a lot of oxygen into the atmosphere. This oxygen made it possible for complex life to develop, including creatures like humans that need air to breathe.

However, about 450 million years ago, during the Late Ordovician mass extinction, the opposite happened. Oxygen levels dropped suddenly and stayed low for millions of years, causing a huge die-off of life on Earth.

The extinction became worse still when oxygen levels in the oceans went down. Researchers found clues in old samples of seafloor rocks that hint at how glaciers changed the layers of the ocean, affecting how much oxygen there was. Still, people argue about the exact reason for the oxygen drop. Ironically, whereas most sea life would have struggled in these conditions, some anaerobic life forms that thrive in low-oxygen conditions might have done better. Small organisms like

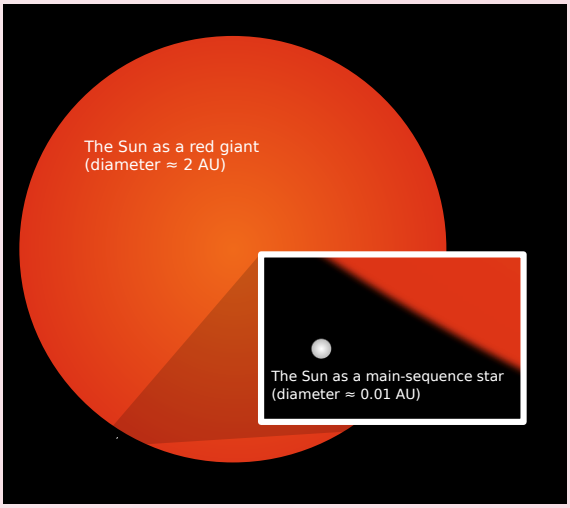
sulphate-reducing bacteria may have exploited the dearth of oxygen, perhaps altering the chemistry of the ocean further and contributing to the bleak conditions.

In all, more than 80 per cent of life on Earth died during this event. Some scientists worry that something similar could happen again, since climate change today is already lowering oxygen levels in the oceans, which could harm marine life.

The evolution of the Sun

In about a billion years, most living things on our planet will die because there won't be enough oxygen. This information comes from a study published in March in the journal Nature Geoscience.

The scientists believe that our oxygen-filled atmosphere isn't going to last forever. In about a billion years, the Sun will become a red giant due to a lack of hydrogen, causing the amount of oxygen in the atmosphere to drop back to levels seen before the Great Oxidation Event. To figure this out, the researchers used climate models and biogeochemistry models to predict what will happen to our atmosphere as the Sun ages and produces more energy.

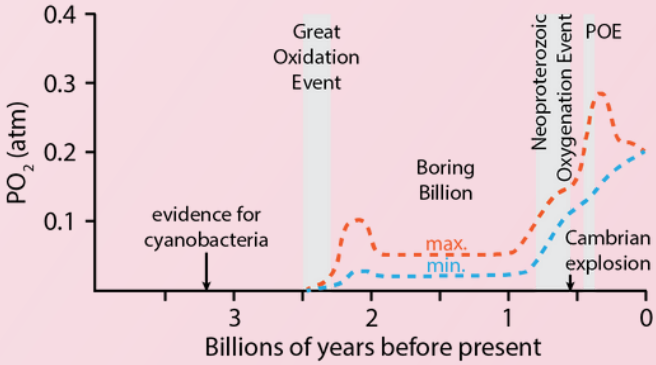


The Sun as a red giant compared to its current size as a main-sequence star (Source: Creative Commons)

They discovered that eventually, the Earth will reach a stage where carbon dioxide in the atmosphere breaks down. When that happens, plants and organisms that produce oxygen through photosynthesis will start to die off. Without enough living things, our planet will not be able to maintain the oxygen-rich atmosphere that humans and other animals need to survive.

The exact timing of when this will begin and how long it will take - this process of losing oxygen could happen in as little as 10,000 years - depends on many different factors. But in the end, the researchers say this disaster is something that will definitely happen to our planet.

Fortunately, humanity has another billion years to come up with an answer.



A graph of oxygen vs time (Source: Creative Commons)

The boiling of Earth's oceans

It is fortunate that our planet Earth happens

to be of the right size and weight, with an atmosphere, and at the right distance from a star that is exactly as big as ours. Only a precise combination of all these factors can result in a planet that supports life and has plenty of liquid water on its surface. For billions of years, Earth has been an ocean-covered world, with simple and complex life originating in the seas and only coming onto land relatively recently. Yet thanks to the future evolution of the Sun, our oceans won't be around forever.

As helium builds up in the Sun's core, the region in which nuclear fusion takes place expands, with dire consequences for humanity.

Over time, as the Sun gets hotter and larger, it shines more brightly and ejects more energy as it ages. In one to two billion years at most, the energy flux that the Sun emits would increase to a critical amount: great enough that radiation received by a single water molecule in the Earth's ocean over the course of a day would be hot enough to boil it. If the oceans heat up and the air fills with water vapour, the effects of greenhouse gases will increase, forcing the Earth's temperature to rise very quickly. Our planet will start to look a lot more like Venus instead of how Earth is now, consequently becoming entirely unsuitable at supporting life on its surface. Perhaps only a few simple organisms might live high in the clouds, but life as we understand it will end on our planet. The experiment of complex living things will have reached its natural conclusion.

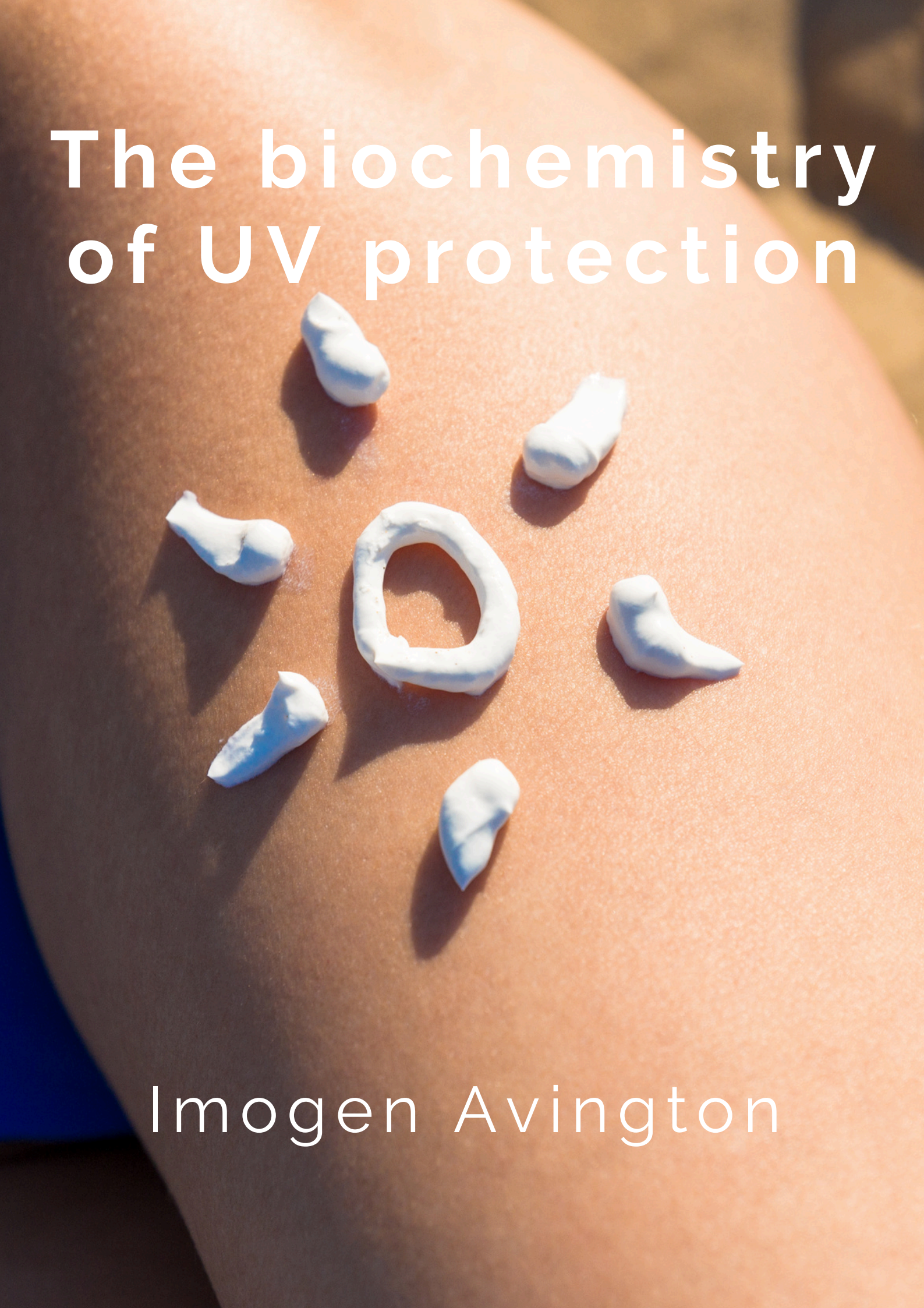
Conclusion: the end of the world

In summary, deoxygenation and the eventual loss of oxygen in the atmosphere pose serious risks to mankind, but the boiling of the Earth's oceans is the most likely cause of human extinction. This is tied to the life cycle of the Sun: something we cannot stop. Over the next one to two billion years, as the Sun gets hotter, rising temperatures will eventually cause the oceans to evaporate. Without water or a stable atmosphere, our planet Earth will no longer be able to support life, leading to the end of the human race on Earth and most other living things.

"THANKS TO THE FUTURE EVOLUTION OF THE SUN, OUR OCEANS WON'T BE AROUND FOREVER"

Jacky Ng

The biochemistry of UV protection



Imogen Avington

THE BIOCHEMISTRY OF UV PROTECTION

Imogen Avington: Chemistry

Introduction

Ultraviolet (UV) radiation is a form of energy produced by the Sun. UV has shorter wavelengths than visible light, making it invisible to the human eye. However, it was only after the 1930s that scientists started to become aware of the harmful nature of UV radiation. Their previous focus on the importance of Vitamin D clouded the recognition of the health hazards created by UV exposure.

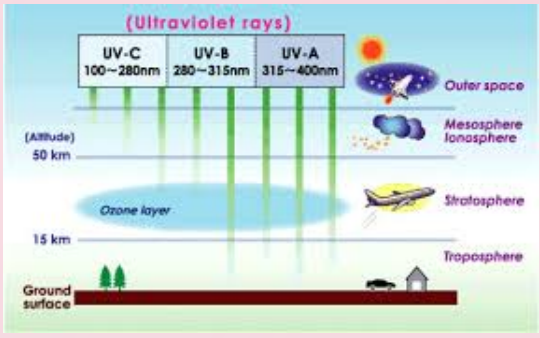
As technology has evolved, it has been proven that too much exposure to UV from sunlight can cause detrimental effects to your health in both the long term and short term. As well as sunburn, premature aging and eye damage, UV radiation can be classed as a **carcinogen.** This means it can damage the DNA in skin cells, leading to mutations resulting in skin cancer. In order to prevent skin cancer, the application of sun cream is strongly encouraged, especially in sunnier climates. This is because sun cream lowers your overall UV exposure by blocking the penetration of UV rays.

Are UV rays all the same?

Not all UV rays are the same. While the Sun emits UV radiation, the UV spectrum is divided into UV-A, UV-B and UV-C rays (based on the size of wavelength). UV-C rays are the most harmful; however, they are not a concern to people's health, given that almost all of these are absorbed by the atmosphere and ozone layer.

UV-B forms between 5 and 10 per cent of all UV rays that reach the Earth's surface. UV-B does not penetrate past the skin's epidermis, meaning it is associated with causing sunburn. However, its high energy means it can be absorbed by DNA. Damage to the DNA in skin cells can cause mutations or genetic defects that lead to skin cancer. Additionally, it is important to recognise that it is not just the skin that can be damaged from UV exposure. UV-B can also cause cataracts, worsening your vision.

Contrastingly, UV-A forms between 90 and 95 per cent of UV rays that reach the Earth's surface. Whilst UV-A cannot be absorbed by DNA, it can penetrate further. Its rays reach the dermis (the inner layer of the two main layers of the skin), contributing to tanning and triggering damage to DNA. UV-A also damages fibres in your skin called collagen, which breaks down elastin, leading to premature aging if exposure is too high.



Different types of UV rays (Source: earthlydelights)

The risk of cancer from exposure to UV radiation is arguably the most concerning consequence; today, excessive UV light exposure is recognised as a major cause of skin cancer, with the USA having approximately 1.3 million cases of skin cancer each year. The three main types of skin cancer are:

- Basal cell carcinoma
- Squamous cell carcinoma
- Melanoma

Cumulative sun exposure causes basal cell and squamous cell skin cancer, while episodes of severe blistering sunburns, usually before the age of 18, can cause melanoma later in life. Scientists for cancer research found that nine in ten cases of melanoma could be prevented by staying safe in the outdoors and avoiding sunbeds.

Protection against UV

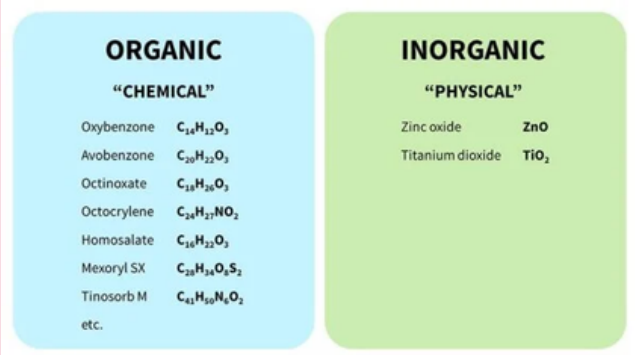
The information, data and stories surrounding the consequences of exposure to UV radiation make it clear that a certain degree of protection is required. Whilst this is simple in the context of tanning beds, the overwhelming source of energy provided by the Sun cannot be avoided. This is where sun cream comes in.

Sun cream is a photoprotective topical product that protects against harmful UV rays, therefore decreasing the chance of someone burning and preventing noticeable aging. But how does this work?

Crucial to its function, sun cream contains chemicals that are classed as **active ingredients.** Active ingredients are compounds that filter the Sun. In this case, they are commonly referred to as UV filters. UV filters can be organic or inorganic.

Organic sun cream contains chemicals that absorb the UV rays and convert the energy into thermal energy (heat), in order to prevent UV rays from penetrating the skin. Organic UV filters are aromatic compounds that can protect against UV-A or UV-B. For this reason, sun cream usually contains multiple organic filters in order to provide broad spectrum UV protection.

On the other hand, inorganic UV filters contain metallic compounds (either titanium dioxide or zinc oxide), acting as a physical barrier to reflect and scatter the UV rays. Physical UV filters protect against both UV-A and UV-B. They also have fewer irritants than chemical filters and are therefore ideal for sensitive skin. However, physical filters have less water resistance and tend to leave a more noticeable white cast than chemical filters. As a result, broad spectrum sun cream is recommended. This contains a mixture of organic and inorganic UV filters to provide optimum protection against the harmful rays alongside being a practical topical product.



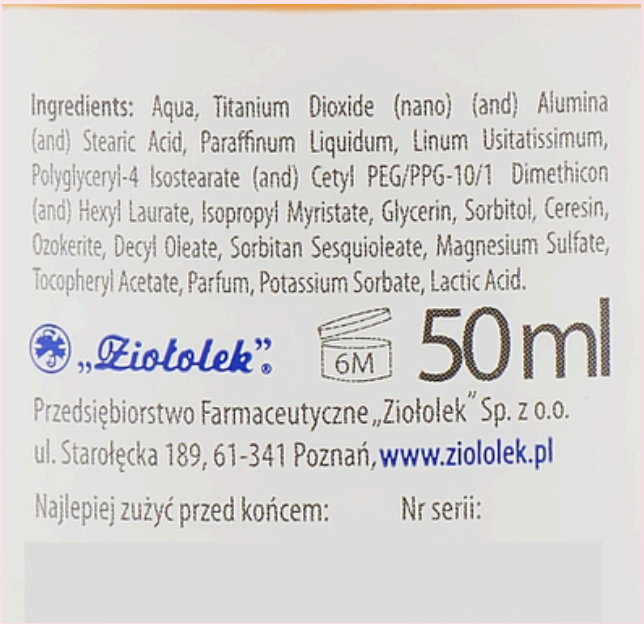
Active ingredients in organic and inorganic sun cream (Source: Lab Muffin)

Alongside active ingredients, sun cream contains formulation stabilisers, sensory enhancers and additional ingredients (which do not impact how the product works). For example, antioxidants are present to neutralise the free-radical-damage caused by exposure to UV.

Another improvement to UV protection is the introduction of nanoparticles. Nanoparticles of titanium dioxide and zinc oxide are used as they do not leave as much of a residue on the skin. Their small size also provides a large surface area-to-volume ratio for improved efficacy.

Conclusion

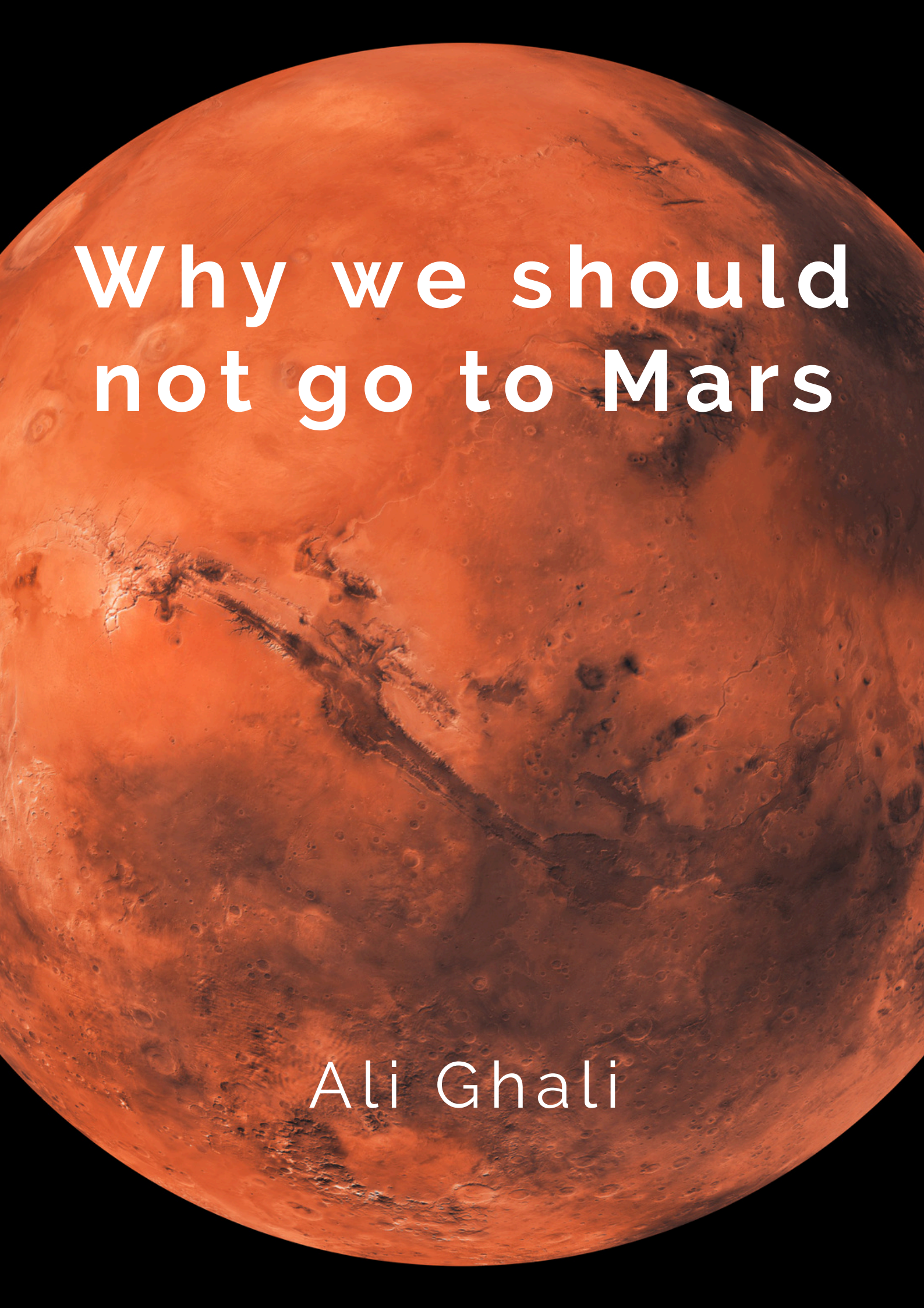
Overall, the significant harms caused by exposure to UV radiation from the Sun highlights the importance of UV protection. It is important to encourage safety in sunny weather, especially in hotter and sunnier climates, and this can be done by considering the effects of UV-A and UV-B rays.



Ingredients for Factor 30 sun cream for children (Source: makeup.uk)

"A MIXTURE OF ORGANIC AND INORGANIC UV FILTERS PROVIDE[S] OPTIMUM PROTECTION AGAINST HARMFUL RAYS"

Imogen Avington



Why we should not go to Mars

Ali Ghali

WHY WE SHOULD NOT GO TO MARS

Ali Ghali: Physics

Introduction: what is space migration?

Space migration, or colonisation, is the process of organising human settlements beyond Earth. Although it sounds incredibly interesting, some argue it to be a complete waste of time. Others argue that space migration could lead to incredible advancements in our resources and economy. For example, there is a planet called "**55 Cancri e**" which is made of diamonds. Logically, if someone could bring back the diamonds from **55 Cancri e** to Earth, they could make a fortune.

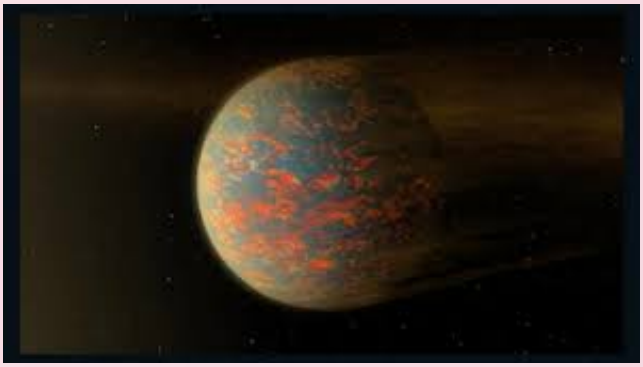
However, **55 Cancri e** is forty light-years away. Therefore, if someone were to travel at the speed of light, it would take them 40 years to reach the planet. According to our current laws of Physics, no-one can travel at the speed of light.

Furthermore, once said person arrived on the planet of diamonds, they would not be able to survive its atmosphere. This is why Earth is so special: other planets lack the basic resources we need to survive, such as oxygen.

What is the point?

Space migration is considered by others due to its ability to provide rare resources, prevent possible human extinction and solve the issue of climate change on Earth. However, these are unrealistic goals. Since 1964, NASA has invested 21 billion dollars in Mars-related adventures. Although this does not compare to the investments required to tackle other issues that space migration would tackle, we are not on Mars (or anywhere other than Earth) yet. Therefore, NASA is likely to continue investing in Mars for many years to come.

Instead of wastefully aiming to abandon our beloved home Earth and embark on a risky adventure to Mars, I argue that humanity should shift its goals toward tackling our issues here on Earth.



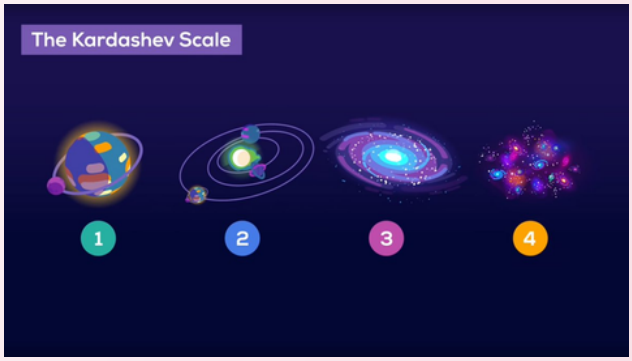
An artist's impression of 55 Cancri e (Source: Cambridge University)

What's after Mars?

If we cannot solve the issues of global warming and resource depletion on Earth, what makes us think we would be able to solve that problem on Mars?

There is a concept called the **Kardashev scale** which shows the advancement of humanity, with different technologies equipped on each scale. Type I civilisations

can harness all the energy that reaches its home planet from its parent star (in our case, the Sun). Although the concept is quite futuristic and we have not even reached the level of a Type 1 civilisation, there is a consistent pattern throughout Kardashev's work.



The Kardashev scale (Source: The Harriton Banner)

Humanity cannot skip stages in advancements. This is the way I see space migration. Before we can live on different, strange and quite literally out-of-this-world planets, we must learn to collaborate as humans in a functional society that can maintain the planet we live on. Wars still happen, crime is still common and climate change is still sky-rocketing. So I ask: while we have all these problems to work on, why do we pump billions of dollars into Mars?

But don't forget Mars

If humanity were to direct its trajectory to ending global warming among other dangerous changes in the world, science, Physics and all things Space are destined to still have discoveries. By the time climate change has been solved, we will be even more ready to continue space exploration, paving the way for other things such as intergalactic travel. We would have no time limit as Earth and its resources would be almost everlasting. Humanity would not be fighting for our survival.

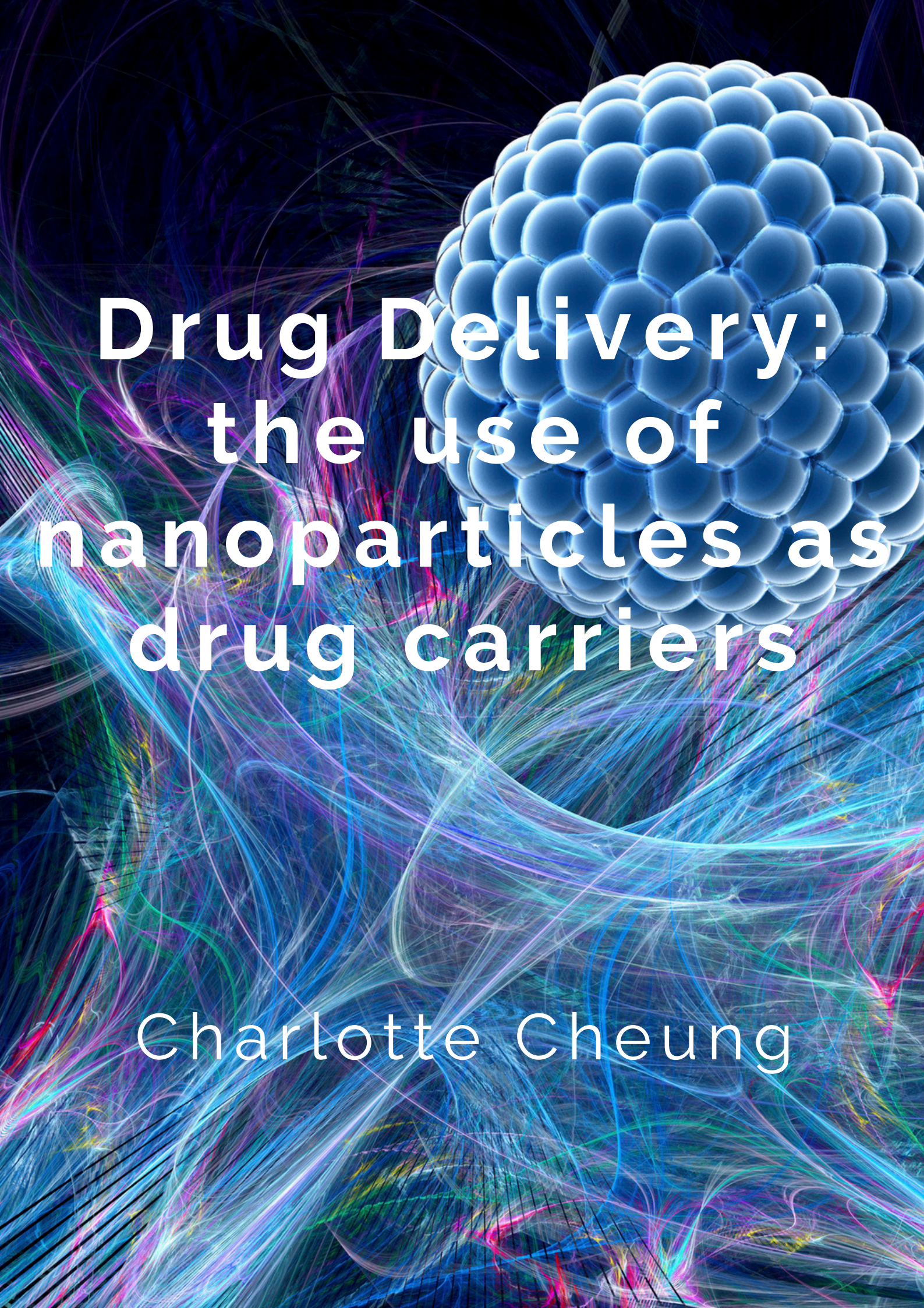
Is all space exploration useless?

Space migration and colonisation is purely for the advance of humanity, while space exploration is for the development of science and Physics. When we see more and more strange, diverse planets and stars, we learn much more about the universe and improve our comprehension of it. This is beneficial in numerous ways.

For example, we can use our understanding of the universe to help solve Earth's problems, explore other planets and other stars, all of which could lead to greater opportunities for scientific discovery and achievements. For instance, the same technologies developed to capture clear images of space have been used to improve medical scans that save lives, such as MRI or CT scans. Also, the same research into preventing the build-up of ice on spacecraft has been adapted to provide safe commercial aeroplanes in similar ways.

So now what?

While space migration concepts are enticing and exciting, from a scientific standpoint it is necessary to form priorities. We must focus on developing technology that will enable us to explore our Earth successfully and safely, then the solar system. Only after that can we look to more distant objects in space. Humanity and all living things have a special connection with the Earth.



Drug Delivery: the use of nanoparticles as drug carriers

Charlotte Cheung

DRUG DELIVERY: THE USE OF NANOPARTICLES AS DRUG CARRIERS

Charlotte Cheung: Chemistry

Introduction

Drug delivery can be defined simply as a pharmaceutical technique, based on the use of formulation and drug carriers to transport chemicals to a targeted organ. In modern medicine, scientists have a Drug Delivery System (DDS) that specialises in introducing drugs in a cost-effective, safe way and controlling the drug release within the body.

A DDS system typically involves a formulation or a device, such as different types of nanomaterials with stable chemical structure and a small size of molecule. This increases the solubility of the drug and even prevents drug interactions, which helps significantly with extending medicinal efficacy while reducing unwanted side effects or rejection by the immune system, such as a severe allergic response.

This article will explore further the properties of nanoparticles, their application in drug delivery systems and their potential. Meanwhile, the article will further discuss the possible concerns and challenges about research on nanoparticles and new DDS systems.

Properties of nanoparticles

Nanoparticles are tiny, with a size between 1 and 100 nanometres, and can only be observed using specialised equipment such as electron microscopes.

Examples of nanoparticles include fullerenes, graphite, graphene and carbon nanotubes. Fullerenes are unique as they are completely built up of carbon atoms joined by strong covalent bonds between molecules. It is also arranged in a three-dimensional structure of pentagons and hexagons which forms a cage-like structure.

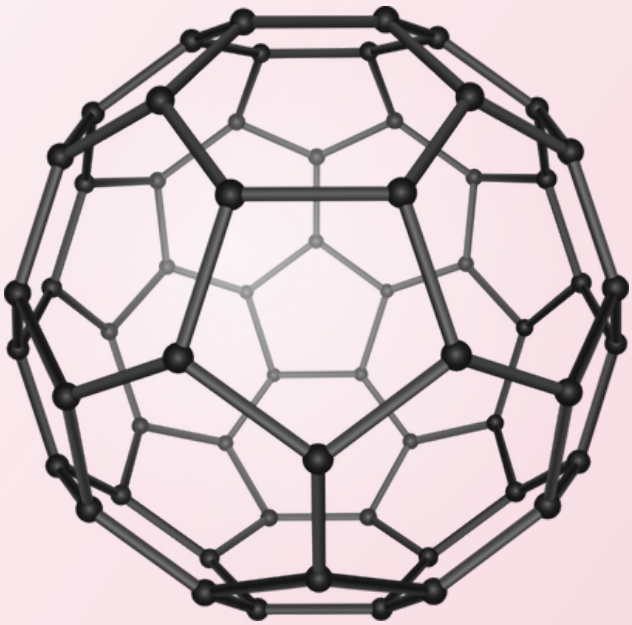
A well-known example of fullerene is C60 (buckminsterfullerene) with a size of 1 nm. C60 is often used as a drug carrier because the carbon structure allows it to have the capability to bind with both organic and inorganic molecules. This makes fullerene useful as it enhances the precision of drug delivery.

Fullerenes possess three main properties that make them particularly useful for drug delivery:

- **High surface-area-to-volume ratio:** this enables fullerene to attach various drugs, and enter or exit through cell membranes efficiently. This characteristic makes it beneficial to apply on situations that require high reactivity, or a fast drug delivery to a specific part of the organ.
- **Stability:** very stable on both chemical and thermal aspects. This means that

fullerenes are reliable and would not react with other chemical substances or release toxicity that causes harm to the human body.

- **Antioxidant:** fullerene, as an artificial product, has the ability to delay or prevent cell damages. This makes them useful not only for transferring medicine to the body, but also for preventing diseases caused by oxidation, such as heart diseases, and prohibiting the growth of malignant tumours.



A C60 molecule (Source: Creative Commons)

Application in a Drug Delivery System

A Drug Delivery System involves a variety of methods to deliver medication, including swallowing, inhalation, absorption through skin or injection. Determining the appropriate method is crucial as it can affect how a medicine targets specific parts of the body, minimises pain for patients, and reduces the risk of unexpected side effects. For instance, microneedle patches are designed for painless vaccinations, allowing for a direct penetration of the skin without reaching the nerves. These patches also have less strict storage requirements, meaning that they do not have to be stored in low temperatures and can be used more easily.

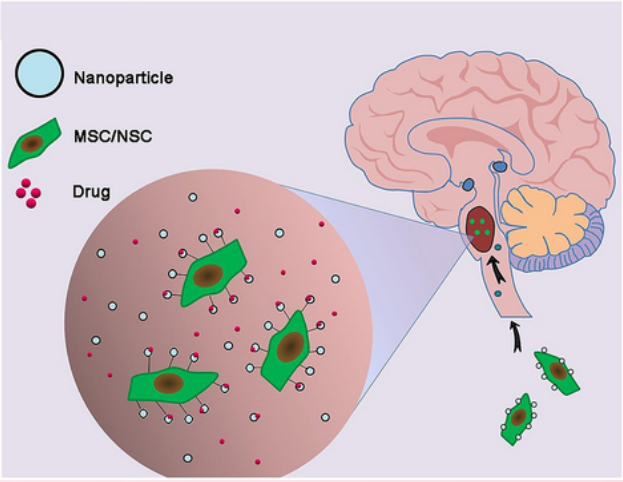
In a nanoparticle-based DDS, medications are packaged in nanoparticles to ensure a safe delivery in the human body. Nanoparticles can be targeted to specific cells, such as carrying anti-cancer drugs to tumour cells, which increases the concentration of the drug at the tumour site, enhancing the therapeutic outcome. In addition, nanoparticles' capability in carrying a large drug load presents the potential to adapt in drug delivery, including modifications to mimic the immune system, and reduces the chances of rejection and inflammatory response.

Ethical considerations of nanoparticles

Nanoparticles could cause chain reactions in both the environment and human bodies. Although modern science has proven the benefits of nanoparticles on drug delivery, many also argue that they can have a negative effect on health. Major concerns include that nanoparticles could lead to long-term effects on metabolism and the removal of substances within the human body. These claims still require more scientific evidence.

Furthermore, the patenting of nanoparticle drugs creates confusion between scientists and the public. In response to public concerns, proper rules about drug delivery

systems must be established to ensure the safety and rights of patients. As a result, Europe set up a nanoscience and nanotechnology patent-monitoring system under the European Patent Office. However, public concerns surrounding the safety of nanoparticles mean further medical research and trials will be required.



An example of how nanoparticles could be used in drug delivery systems (Source: Journal of Young Investigators)

Safety concerns and challenges of nanoparticles

Due to their small particle size, nanoparticles can be easily inhaled or absorbed by skin. As they may enter the bloodstream and travel throughout the body, it can be difficult to remove them through metabolism.

Furthermore, the production of nanoparticles remains limited due to its high cost and length of time required for manufacturing. The public might also be fearful of these drug carriers as they could cause respiratory problems.

Challenges in researching a new DDS

Research on a new DDS faces the barrier of the difficulty of controlling drug releases. This is due to materials with large particle sizes having poor water solubility and absorption within the human body.

On the other hand, the use of small particles could be a good replacement for traditional drug carriers. However, its acceptability to the human body could not be fully guaranteed, as well as the fluctuation of drug concentration over time as a main issue that affects therapeutic outcomes. This means that a new DDS must make a balance between the particle size and drug solubility, which must be well-considered.

Conclusion

The application of nanoparticles does show the potential to be adapted into a new drug delivery system. Fullerenes, based on their unique, cage-like structure formed of carbon atoms, also have a high drug load capacity that makes them an ideal drug carrier. Other methods of drug delivery, such as microneedle patches, help to deliver medication painlessly and efficiently, with a less rigid storage requirement. They can also be used to target specific organs.

Alongside the potential of nanoparticles, their ethical and safety concerns must also be considered. Nanoparticles are a double-edged sword; their production, usage and disposal strongly rely on cooperation between scientists and the public, to ensure that drug delivery is as safe as possible.



Fly on the wall: more important than you might think

Maggie Dalby

FLY ON THE WALL: MORE IMPORTANT THAN YOU MIGHT THINK

Maggie Dalby: Biology

Introduction

When investigating a crime scene, one might think that insects and bugs would be detrimental to the process. After all, they would eat and use the body, making it harder to complete the investigation.

But how can insects help the investigation process? The answer lies in **forensic entomology**. This is the study of insects and other bugs and their use in criminal investigations. Insects are key in working out important details in crime scenes, such as estimating the date of death, identifying the presence of drugs, and analysing DNA.

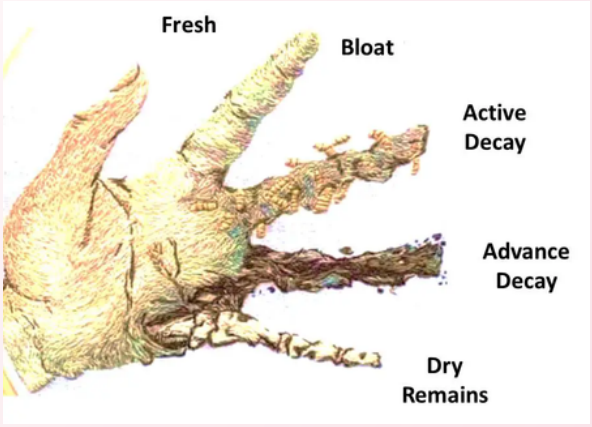
Timeline of decomposition

When a body is left to decompose in the ground in a temperate environment, it lets out an odour produced by the bacteria in the decay process. This attracts insects such as blue and green bottle blowflies and other carrion insects. After a few hours, insects have already laid eggs on the body and the larvae hatched can start to eat the body [Paola Magni, 2022].

In the first stage of decomposition (the 'fresh stage', between the moment of death and the first signs of bloating), the carcass has no outward changes in appearance, but the bacteria have started the decomposition process. The insects attracted to the body at this stage are mostly flies. Some examples include flies from the calliphoridae, muscidae and sarcophagidae families.

Once the bloating comes in (the second stage), the lack of oxygen in the body allows anaerobic respiration to occur, and the bacteria starts to release gases like methane and hydrogen sulphide. This smell is what attracts more insects to come in. Insects are able to sense these odours from kilometres away. This stage is when the initial insects' eggs start to hatch and where a feeding frenzy starts, where not only the freshly hatched maggots start eating, but beetles such as the carrion beetles come in to gain the nutrients from the body. Predaceous beetles (for example, rove and clown beetles) come in to feed on the maggots themselves.

The third stage is active decay. Larval insects chew through the bodies and allow the gas to escape. This causes the tissue to liquify. By the end of this stage, the maggots are concentrated in the chest area, allowing the beetles to eat more maggots. Once most flesh is eaten, the maggots leave to pupate in the soil. This allows Dermestid beetles to lay their own eggs on the body. They are scavengers that eat dry materials (fur, feathers and dead plants).



Stages of decomposition (Source: Forensic's blog)

These dermestid beetles are what essentially finish the decay, starting what is known as the dry stage (the final stage of decomposition), eating the remaining flesh of the body, leaving only bones, dry skin, cartilage and hair. These beetles are used in museums regularly for displays, so if you have seen an animal's skeleton, this is the reason why it can be displayed [Dalhouse University, 2020]. Each insect and their stage of life is in a different stage of decomposition. This is what allows the accurate dating of the body in criminal investigation.

How are insects useful?

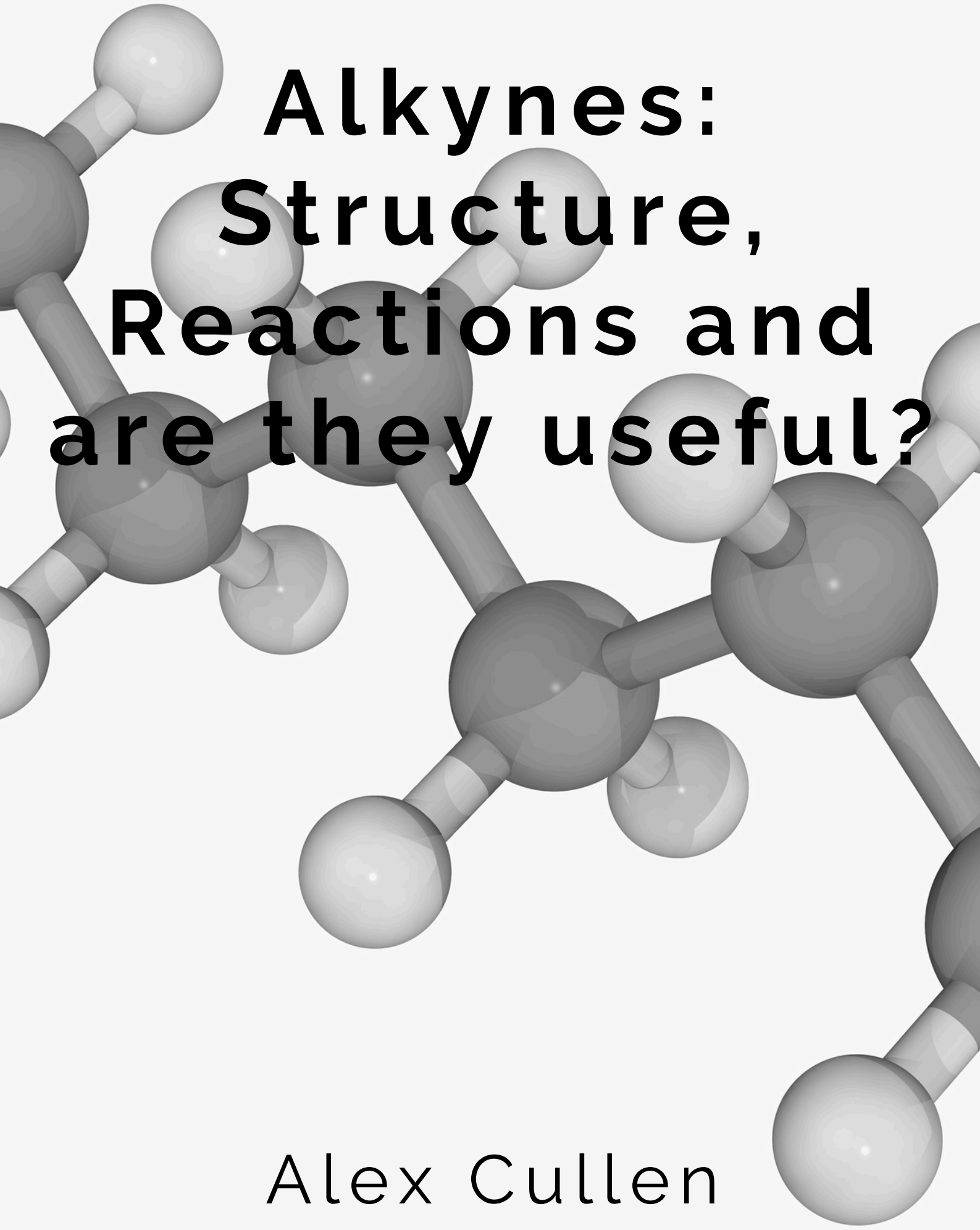
In some cases, insects have been used to solve the crime, such as the murder of two women in 1935, where bluebottle fly larvae (calliphora vicina) were found in their bodies. They were between 12 and 14 days old, which allowed the police to work out a timeframe of the disposal of the bodies. The murderer killed his wife and their housemaid in Ruxton and had dumped them at the Scottish borders. This was the first case in the UK that had used maggots in a forensic entomology case and allowed the police to identify where in the UK they were originally killed [Natural History Museum].

Insects are also useful in cases with drugs and poisons, since they can affect the rate of maggot growth on the body and how attractive the flies find it. Many cases will use blood, urine, soft tissue or hair analysing, but what can forensic scientists do when there are few of these remains left (such as when the carcass is mostly bone)? They turn to the insects which consumed the carcass. The substances from the body are also stored in theirs.

Insects are known for their hard exoskeleton, made from chitin (a substance similar to the protein keratin, found in our hair and nails). Chitin, like keratin, can hold substances like drugs for a long time after they have been consumed. So, when these insects are collected from the body, their chitin can be analysed in a similar fashion to our Keratin, to detect the presence of drugs or poison. Insects are more reliable for their purpose than hair, and even more helpful as they are available for a much longer time period. Empty fly cocoons left in the environment by the body and skin or carrion beetles have been used for the toxicological studies for mummified bodies all from weeks to even years after death [Paola Magni, 2022].

Conclusion

Insects are used for many different things in investigations, from tracking poison and drugs to dating bodies. Without them, many cases would be left unsolved. Insects are not just important in our environment, but in our court of law too.



Alkynes: Structure, Reactions and are they useful?

Alex Cullen

ALKYNES: STRUCTURE, REACTIONS AND ARE THEY USEFUL?

Alex Cullen: Chemistry

Introduction

Alkynes are a type of hydrocarbon that contain at least one carbon-carbon triple bond (C≡C). This distinguishes them from other hydrocarbons such as alkanes and alkenes which contain only single carbon-carbon bonds and at least one double carbon-carbon bond respectively. Alkynes are an important compound in organic chemistry due to their triple bond which results in a unique set of chemical and physical properties. Alkynes can be a part of several useful reactions with the result of important products.

The chemical structure of alkynes

The general formula for alkynes is C_nH_{2n-2}. This means that for every carbon atom, the number of hydrogen atoms is 2 less than double the number of carbon atoms. For example, the shortest alkyne is ethyne (C_2H_2), where there are 2 carbon atoms and one hydrogen atom for each carbon atom. For propyne, there would be 3 carbon atoms, so there would be 2(3)-2 = 4 hydrogen atoms. Therefore, its formula would be C_3H_4..

The triple bond in alkynes arises as a result of one sigma (σ) bond and two pi (π) bonds. The sigma bond is created via the head-on overlap of sp hybridised orbitals from each carbon atom. In sp hybridisation, one s orbital and one p orbital mix to form two sp hybrid orbitals. This happens for each carbon atom. The sp hybrid orbitals are aligned linearly with a bond angle of approximately 180 degrees to allow the formation of a sigma bond. This is a single strong bond and is the primary connection between the two carbon atoms in the triple bond. The electrons form a bond that lies directly between the two carbon nuclei, providing stability to the molecule. After sp hybridisation, each carbon atom has two unhybridised p orbitals left. The two pi bonds arise from the sideways overlap of these unhybridised p orbitals. The pi bonds are weaker than the sigma bond as their electrons are not directly between the nuclei.

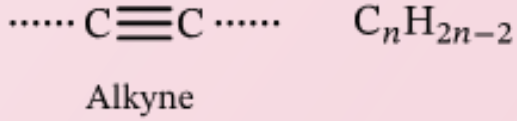


Illustration of the alkyne triple bond and the general formula (Source: Nagwa)

The physical structure of alkynes

Like other hydrocarbons, the physical properties of alkynes occasionally depend on the size of the molecule. However, also similarly to other hydrocarbons, there are some general characteristics shared by nearly all alkynes.

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Firstly, alkynes generally have higher boiling points than alkanes and alkenes of similar molecular weight due to the presence of the triple bond, which leads to stronger intermolecular forces (van der Waals forces). Additionally, as the carbon chain length increases, the boiling points of alkynes also increases. This is as a result of there being more van der Waals forces due to the increased number of atoms in the molecule. For example, ethyne has a boiling point of -84˚C, whereas octyne has a boiling point of 125˚C. This can be explained by ethyne having only 4 atoms, compared to octyne's 22 atoms. This trend is similar to that of alkanes and alkenes.

	CH_3CH_3 alkane	$H_2C = CH_2$ alkene	$HC \equiv CH$ alkyne
Melting point ^0C	-181.5	-169.4	-18.8
Boiling point ^0C	-161.7	-103.8	86.3

Melting and boiling points of alkanes, alkenes and alkynes (Source: Creative Commons)

Secondly, due to the bond angle of 180 degrees, alkynes are typically symmetrical molecules and so the dipole that forms between a hydrogen atom and a carbon atom is cancelled out. As a result, alkynes are non-polar molecules. This means that they are insoluble in water. Despite this, they are soluble in organic solvents such as ether, acetone and benzene. Like their boiling points, their solubility in organic solvents increases as carbon chain length increases. Due to their light molecular structure, alkynes tend to be less dense in water.

Finally, alkynes have a distinct odour. Their characteristic smell is often associated with industrial processes like welding and cutting.

The reactions of alkynes: addition reactions

Alkynes are best known for their addition reactions, where the triple bond in the alkyne is broken and single bonds are formed with other atoms or groups. Four common addition reactions that alkynes undergo are hydrogeneration, halogeneration, hydrohalogenation and hydration.

During hydrogeneration, two hydrogen molecules are added across the triple bond, causing the conversion of an alkyne into an alkane. This can be done with the presence of a catalyst such as palladium. For example, ethyne can be hydrogenated into ethane. The equation for this reaction would be:

$C_2H_2 + 2H_2 \rightarrow C_2H_6$

Alkynes also react with halogens. Halogens are the elements in the 7th group of the periodic table. They include elements such as fluorine, chlorine, bromine and iodine. The halogens, like hydrogen, are added across the triple bond. For example, ethyne reacts with chlorine to form 1,2-dichloroethene. The equation for this reaction would be:

$C_2H_2 + Cl_2 \rightarrow C_2H_2Cl_2$

A third reaction that alkynes can undergo is hydrohalogenation. This occurs when

alkynes react with hydrogen halides like hydrogen chloride (HCl) or hydrogen bromide (HBr). During the reaction, the halide ion adds to one carbon whilst the hydrogen atom adds to the other carbon atom. The equation for the reaction between ethyne and hydrogen chloride with the production of vinyl chloride is:

$C_2H_2 + HCl \rightarrow C_2H_3Cl$

The final addition reaction that alkynes can undergo is hydration. In the presence of an acid catalyst, which is typically H_2SO_4, and a mercuric salt, Hg^{2+}, water adds across the triple bond of an alkyne to form an aldehyde or a ketone. An aldehyde contains a double bond between a carbon atom and an oxygen atom at the end of an organic compound and a ketone contains a double bond between a carbon atom and an oxygen atom in the middle of an organic compound. An example of this reaction is ethyne reacting with water to form ethanal. The equation for this reaction is:

$C_2H_2 + H_2O \rightarrow CH_3CHO$

Ozonolysis

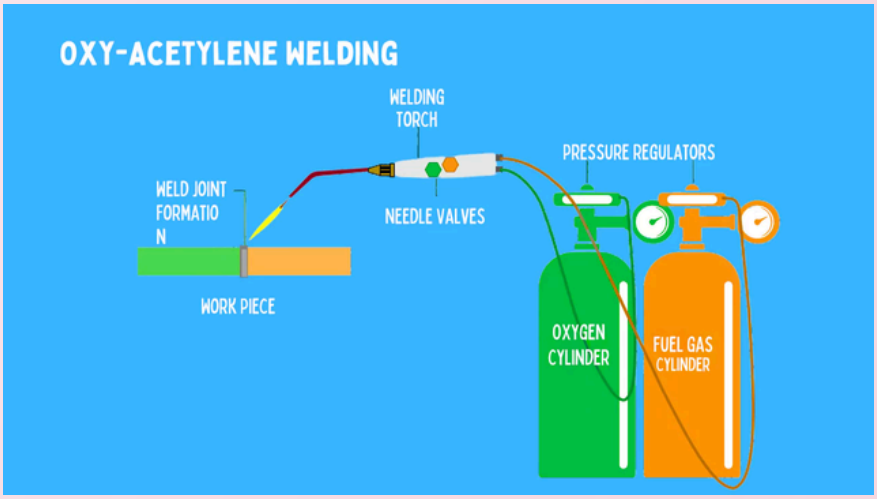
Ozonolysis is a reaction where alkynes are split apart by molecules of ozone. Ozone (O_3) is a highly reactive gas composed of three oxygen atoms. It is both naturally occurring and man-made. When it reacts with alkynes, it forms aldehydes and ketones. This reaction breaks the triple bond in alkynes to form smaller, functionalised compounds. An example of this reaction is the ozonolysis of ethyne to form two molecules of methanal (previously known as formaldehyde). The equation for this reaction is as follows:

$C_2H_2 + O_3 \rightarrow 2CH_2O$

The uses of alkynes

The reactivity and the versatility of alkynes make them a useful substance for a wide range of processes in various industries.

First, they can be used in welding and cutting. Ethyne, also known as acetylene, is used in oxy-acetylene welding and cutting



The process of oxy-acetylene welding (Source: The Engineering Choice)

due to the high temperature that forms when it is burned in oxygen. This makes it ideal for metal cutting and welding.

Secondly, the reactivity of the triple bond allows chemists to perform a wide variety of reactions to build complex molecules.This means that alkynes are also used in the synthesis of other organic compounds. This includes pharmaceuticals. For example, alkynes can be used in the synthesis of certain anticancer drugs and antibiotics.

Finally, the ability of an alkyne to form reactive intermediates makes them useful for the production of pesticides, herbicides and insecticides.

Conclusion

Alkynes are hydrocarbons with at least one carbon-carbon triple bond. This triple bond allows alkynes to have some unique properties and reactions and therefore indicates their usefulness. Their linear structure allows them to undergo many different reactions including multiple addition reactions and ozonolysis. They are valuable compounds in industrial processes, including the production of certain pharmaceuticals and compounds for agriculture. Their unique triple bond allows them to play an important role in organic chemistry, indicating their usefulness and importance in future chemical applications and advancements.

"THE ABILITY OF AN ALKYNE TO FORM REACTIVE INTERMEDIARIES MAKES THEM USEFUL FOR THE PRODUCTION OF PESTICIDES, HERBICIDES AND INSECTICIDES"

Alex Cullen

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