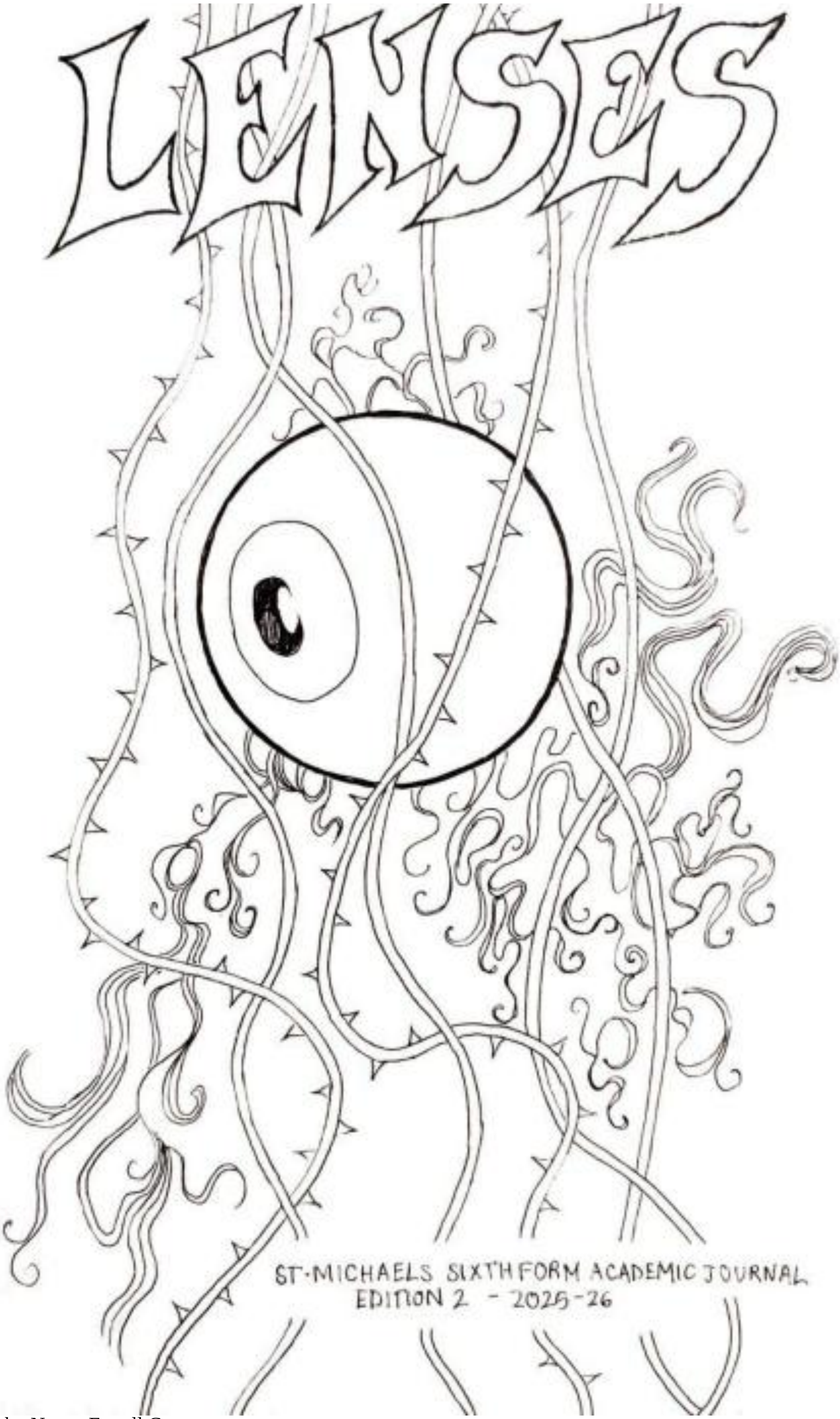


Cover by Nancy Farrell Carr

"Dearest Gentle Reader",

We are delighted to present this edition of our school's academic journal, a collection that celebrates intellectual curiosity, thoughtful research, and the confidence to explore ideas beyond the boundaries of the classroom. This volume brings together a selection of carefully chosen articles written by passionate and dedicated students, each reflecting a genuine commitment to academic excellence and independent inquiry.

What defines this edition most strongly is its diversity of thought. The articles span a wide range of disciplines, demonstrating that learning flourishes not in isolation, but at the intersection of subjects. From scientific investigation to humanities-based analysis, these works show how knowledge connects, overlaps, and deepens when approached from multiple perspectives.

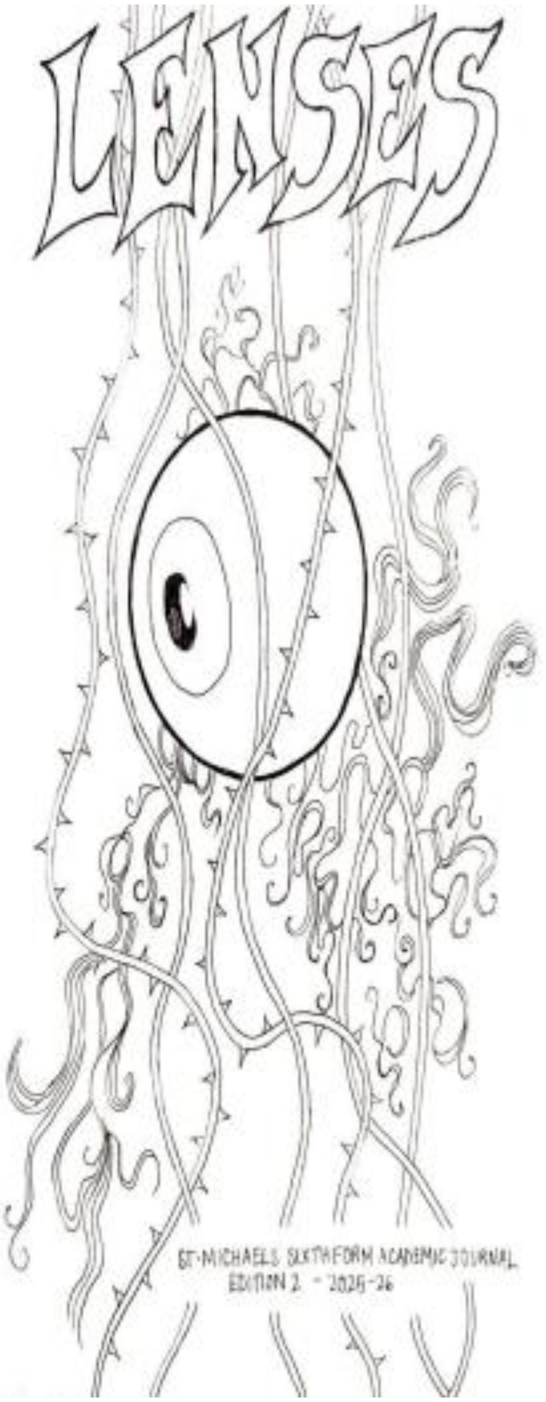
Beyond showcasing individual achievement, this journal serves as a connection within our school community. By sharing research and ideas across year groups, it allows students to learn from one another and recognise shared interests, regardless of age or academic pathway. Younger students are offered insight into what lies ahead, while older students contribute work that informs, inspires, and challenges those who follow. In doing so, the journal fosters a culture of mentorship, aspiration, and mutual respect.

At its core, this publication exists to strengthen our academic community. It reminds us that learning is a collective endeavour - one that is enriched through discussion, reflection, and the exchange of ideas. Each article contributes to a broader conversation that extends beyond these pages, encouraging readers to question, analyse, and think more deeply about the world around them.

We extend our sincere gratitude to the writers whose dedication, effort, and intellectual curiosity have made this edition possible. Your willingness to engage with complex ideas and share your insights has set a strong foundation for the future of this journal. We also thank our readers—your engagement completes the purpose of this publication. Through your curiosity and reflection, the ideas presented here are given life beyond print.

We hope you enjoy reading this edition as much as we have enjoyed bringing it together.

From Studs to Shuttles: How Materials and Design Make



From Studs to Shuttles: How Materials and Design Make or Break the Game

Teni Akinosho

At the highest level of sports, the level of performance is not simply dictated by the performer, and their physical ability. It is increasingly becoming an engineered decision, made long before an athlete steps onto the pitch, court or track. From the materials used in a football boot, to the shape of a shuttlecock, to the composite structures of an F1 car, all designs are selected for a specific reason. Components are designed to balance demands such as stability, grip, durability, comfort, and most importantly, safety. Materials play a decisive role in performance and safety in sport, and ultimately make or break the game.

Football boots are crucial to a player’s performance, and have undergone many changes in terms of the materials used, and the design of the boots, used to enhance performance. The original football boots were designed well enough just to serve their function. Leather, to protect the feet from rough and uneven surfaces, and metal studs or nails, to provide traction and prevent slipping. Despite them meeting their function, they were heavy and clunky. In the 1960s and 70s, new materials such as synthetic leather (specifically polyurethane) were introduced, making the boot lighter, and much more comfortable.

Synthetic leather is made by coating a fabric base, such as nylon or cotton, with polyurethane or polyvinyl chloride solutions, mimicking the appearance and texture of real leather. After being coated, the fabric will undergo a curing process [1]. The most common industrial method of curing is heat curing, where the fabric is passed through long ovens (typically 60°C to 100°C), solidifying the solution, and becoming “trapped” in the individual threads of the fabric being coated. This curing process enhances its durability, and water resistance.

Polyurethane (PU), is an exceptionally versatile material, and can be tailored to be rigid or flexible, making up the majority of the upper part of a boot. It is becoming more frequently used, as manufacturers can fine-tune thickness, softness, and colour, very specifically. PU is very useful in football boot uppers for multiple reasons: it’s durable, and will not crack like your average plastics, it has good shape retention, so will keep its shape and structure for longer, and it has less water absorption than real leather, so it’s much more useful for playing in wet conditions. PU is a particularly great material, as it has predictable behaviour in production, has stable performance, and has a good balance of comfort, touch, and durability - everything you would desire in a boot. However, there is a variety of the type of PU used, so high-level boots are typically made of higher-resin, and micro-fibre. This is because it’s much
lighter, and resists the tearing and stretching that would occur in the boot from the multiple sprints, jumps, and pivots a footballer would perform during a game. Microfibre PU can undergo over 200,000 bends without cracking, whereas standard PU could peel, or delaminate sooner. A bend refers to the flex of the boot at the natural break point of the foot - the ball of the foot. When being tested, a positive result is where the boot only bends at the forefoot (your big toe joint), whereas a failure result is where the boot does not bend at all, or if the boot bends in the arch of the foot. Both of these issues could cause ligament damage, strain, or arch damage. This demonstrates how materials in sports are not only used for enhanced performance, but also ensuring athlete injury prevention. While the upper protects and fits the foot, it is the sole that dictates traction and stability.

The soleplate provides structural stability, while creating a flexible platform for movement, and protecting the foot from stud pressure. The average professional level soleplate is made of lightweight engineered polymers, such as carbon fibre composite, Pebax, and thermoplastic polyurethane.

Pebax polymers are copolymers (polymers made of two or more different monomers), made of rigid polyamide blocks, and soft polyether blocks. By changing the ratio of the blocks, a wide range of flexibility can be produced. Pebax polymers have low energy loss, meaning that when the polymer is stretched, the polymer is extremely efficient at storing energy, and returning that same energy when the stress (essentially a measure of how “hard” material is being pushed or pulled) is relaxed, which results in explosive energy being felt in the foot [3]. This low energy loss provides exceptional “snap-back” acceleration, allowing players to reach their top speeds faster during explosive bursts, key for wingers and strikers. Furthermore, the use of Pebax polymers in soleplates, will result in reduced muscle fatigue. As the soleplate is doing more mechanical work by springing back, the foot and calf muscles do not have to work as hard to maintain performance, resulting in delayed muscle fatigue over the average 90 minutes, and reducing the chance of injury.

Pebax provides that crucial energy return, while thermoplastic polyurethane (TPU) is important for its resistance to abrasions and tearing, allowing the sole to undergo high-

intensity use without damage.
The material of the studs of a football boot will vary, depending on the surface you are playing on, whether that be firm ground, soft ground, or turf, but all materials share the ultimate goal of producing traction, stability, facilitating agility, and preventing injuries.

For firm ground, TPU and nylon are used in the studs due to their toughness, but still offer a slight flex. Aluminium alloy studs tend to be used upon a soft ground, due to their lightness, and resistance to rusting.
The shape of the studs is important too, as they work by controlling traction on whatever surface a footballer plays on, pressure distribution, and rotational ability. Conical (round) studs are the typical all-rounders, due to their ability to rotate 360 degrees with little resistance, which is ideal for midfielders needing to pivot quickly. They also allow even distribution of pressure around the foot, which massively improves comfort on harder surfaces. Bladed studs are long and fin-shaped, designed to slice through the ground, providing higher maximum linear traction. Maximum linear traction is the maximum "straight line" grip generated between the studs, and the playing surface. The higher this is, the more force a player can apply on the ground without slipping, allowing for a more explosive acceleration from a standing start. However, researchers have discovered that there is an optimal zone of friction. If it is too small, there is too little traction, which leads to slipping, and reduced speed. On the other hand, if it is too high, it can lead to foot fixation, which is when the boot gets stuck, increasing the risk of ACL injuries, and ankle injuries. High-level boots tend to have chevron "v" studded boots - a hybrid of blade and conical studs. This combines the rotational ease of the conical studs, and the directional grip of the bladed studs, allowing players to sprint, pivot, and change direction, while maintaining optimal traction, along with minimizing the risk of strains and injuries [4]. From the materials of the upper, to the composition of the studs, every component of the boot is engineered to optimise performance, enhance comfort, and prevent injuries - a prime example of how materials can decide an entire football game.

Just as football boots are designed for performance and injury prevention, every component of a badminton player's kit, from the racket to the shuttle, is engineered for speed, control, and precision. The most important equipment of badminton is, of course, the racket. An ideal high-level badminton racket should have a superior strength to weight ratio, withstand high string tension, and be durable.

The frame of high-level badminton rackets are made of carbon fibre, graphite and composite materials. Carbon fibre is both lightweight and stiff, which offers quick swing speed and increased power. Carbon fibre is not a single material, but instead is composites of fibres embedded in a resin matrix. This design reduces vibrations in the racket, produced by the interaction of the shuttlecock on the string bed, and the following lingering vibration of the frame, as it tries to return to its original shape. Vibration of the racket needs to be reduced, as excessive vibration is a primary cause of injury in the hand or arm, including inflammation or discomfort. In addition, reduced vibration of the racket means that more energy is transferred to the shuttle, as opposed to the surroundings, which increases the power, particularly of smashes. Carbon fibre reduces vibrations by the vibrational energy travelling through the countless fibres, and resins creating frictions - allowing the kinetic energy of the vibration to be transferred to heat, dampening the vibrations. A racket should not have zero vibration, as it lacks that “feel” as to whether or not a player has hit the sweet spot of a smash or drop shot.

The strings of the racket also play a key part of performance. High level strings are designed to withstand high tensions, while producing a “ping” sound, and having a crisp feel. Tensions in high-level strings are about 28-30+ lbs for optimum control and increased accuracy. Professional players play with multifilament strings, made of thousands of tiny high-polymer nylon fibres woven together with string, using manufactured fibres such as Vectran. Vectran is a high performance polymer, with extra strength and high elasticity, and it quickly absorbs vibrations [5].

The thickness of the strings can also be tailored to the player's preferred playing style. Thinner strings (22 gauge which is roughly 0.644 mm) are less durable, but stretch back further after impact with the shuttle, creating a trampoline effect, and generating more repulsion power on the shuttle. Thicker strings are more durable, holding tension longer. They have greater control, but tend to be stiffer.

The racket design is important, but the same is true for the shuttlecock’s. They are designed to have a stable flight path, and withstand impact speeds that can go up to 217 mph. Shuttles used in professional matches are made of goose feathers. They are preferred over duck feathers, due to higher durability, and better flight stability. To ensure the shuttle has stable aerodynamics, shuttles will only use feathers from the left wing only (or right, but never mixed). If the feathers were mixed, it would disrupt rotational balance as they curve in opposite directions. By using feathers from only one side of the wing, the shuttle will have stable clockwise rotational movement. The cork base of the shuttle is made of natural cork, as opposed to synthetic or compressed foam which is used in lower levels. The natural cork produces better elasticity, and weight balance, producing a consistent bounce of the strings, resulting in the desired stable flight path. The shuttle is designed in a conical shape, so that the shuttle will always fly cork first, regardless of its orientation, immediately after striking. Furthermore, its unstreamlined shape means that the air will separate from the surface early, causing a significant pressure difference between the front and back of the shuttle, also known as base drag. As a result, the shuttle has a very high in flight deceleration, only retaining 20% of its initial speed. This is crucial to a match, because it means that the shuttle will not constantly fly out of the court, therefore allowing for steep downward drops [6].

Just like with football boots, or badminton rackets, every material chosen in Formula 1 Racing is selected specifically to ensure maximum performances, while also ensuring the protection and injury prevention of the drivers. Within the car, every component used is designed to be lightweight but strong. All elements are aerodynamic and heat resistant, from the monocoque, to the tyres, and even to the protective gear the drivers wear. Contrary to sports like football or badminton, the materials that Formula 1 uses must have the capability of withstanding forces beyond human tolerance.

The monocoque simply refers to the central part of the car's body, a component that is critical for the performance, and safety, of the driver. It is a lightweight, ultra-strong single piece structure, and is made from carbon fibre reinforced polymer (CRFP), with a honeycomb core of aluminium or Nomex. CRFP's backbone consists of high-strength, thin strands of carbon fibres, which are then embedded in a polymer matrix, binding the fibres together and helping distribute stresses evenly throughout the CRFP [7]. It has a high strength to weight ratio, which is crucial to the car's performance. Reduced weight allows for better, more agile handling of higher cornering speeds, and its high rigidity means that the structure will not bend or twist under high loads. It provides immense impact protection, due to impact energy being spread over a much larger area, minimising damage at the point of impact. The aluminium, or Nomex, is sandwiched between the CRFP layers to increase structural integrity, impact resistance, and prevent buckling for precise handling. At high speed impacts, the honeycomb layer crushes progressively, dissipating the kinetic energy from the crash, and ensuring that it does not reach the driver. Furthermore, Nomex is used for its heat resistant properties, due to the fact that it will not melt in, or support, combustion in the air, providing increased safety should a fire incident occur [8]. Nomex is not only used in the monocoque, it is also used in the racesuits, and can withstand temperatures at 200°C. The racesuits are therefore able to protect the driver through the nomex fibres expanding and carbonizing, forming a protective, insulating layer between the heat and skin.

Formula 1 tyres are composed of a specific tightly controlled mixture of natural rubbers, synthetic material and carbon black and strengthening materials like Kevlar. This mixture balances the need for extreme grip, heat management and structural integrity, operating optimally from 100-110°C. The softer compounds provide better maximum grip via heat generation, while the harder compounds provide for durability. Carbon black is pure elemental carbon produced by incomplete combustion or thermal decomposition of hydrocarbons under specific conditions, and provides for abrasion resistance and improved heat conduction [9]. Heat conduction being controlled in F1 cars, allows for optimal heat management- the right components like the brakes, electronics and driver are kept cooler and the tires and engineer fluids are kept hot for maximum speed and durability.

From football boots, to badminton rackets and shuttle to F1 cars, materials are not simply chosen, they are engineered to enhance performance and precision, and prevent injuries. Sports produces a special lens to observe how materials influence the sports we all love to watch. As material and technology continues to develop, athletic and mechanical ability will continue to push through the limits proving that materials do not just support the game- they change it.

Footnotes

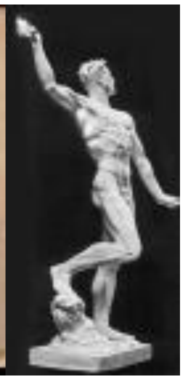
1. **China TPU Film Manufacturer.** *Understanding the Benefits of PU Fabric* Available at: https://www.tpu8.com/pu-fabric/ [Accessed 07 Feb. 2026]
2. **ResearchGate.** *A Study of Football Footwear Bending Stif ness* Available from: https://www.researchgate.net/publication/273823600_A_Study_of_Football_Footwear_Bending_Stiffness [Accessed 07 Feb. 2026]
3. **Pebax Powered.** *A Very Special Kind of Polymer Chemistry* Available from: https://pebaxpowered.arkema.com/en/peba x-technology/# [Accessed 07 Feb. 2026] 4. Castillo-Domínguez, A., Torrontegui-Duarte, M., Páez-Moguer, J., Gómez-del-Pino, Á., Cervera-Garvi, P., Mainer-Pardos, E., Lozano, D. and García-Romero, J. (2022). *The Influence of Stud Characteristics of Football Boots Regarding Player Injuries.* **International Journal of Environmental Research and Public Health**, 20(1), p.720. doi:https://doi.org/10.3390/ijerph20010720. [Accessed 08 Feb. 2026]
5. **Kuraran.** *Vectran* Available from: https://www.kuraray.com/global-en/products/vectran/#accordion-c05af972b9-item-441491200f [Accessed 07 Feb. 2026] 6. Alam, F., Nutakom, C. and Chowdhury, H. (2015). *Effect of Porosity of Badminton Shuttlecock on Aerodynamic Drag.* ***Procedia Engineering***, 112, pp.430–435. doi:https://doi.org/10.1016/j.proeng.2015.07.220. [Accessed 08 Feb. 2026]
7. **CCUK.** *What is Carbon Fibre-Reinforced Polymer (CFRP)? A Guide to Structural Strengthening and Repairs* Available from: https://www.fibrwrap-ccuk.com/blog/what-is-carbon-fibre-reinforced-polymer-cfrp-a-guide-to-structural-strengthening-and-repairs/ [Accessed 08 Feb. 2026]
8. **PMW magazine.** *Materials development in F1* Available from: https://www.pmw-magazine.com/features/materials-development-in-f1.html [Accessed 08 Feb. 2026]
9. **ICBA.** *What is Carbon Black?* Available from: https://www.carbonMaterials development in F1 | Professional Motorsport World-black.org/new-page-2 [Accessed 08 Feb. 202

Is ‘bad’ art *that* bad?

Una Soguilon

You walk into an art gallery, and you see an unmade bed at the centre of the room: duvets wrinkled; bedsheets stained; dirty clothes; and other pieces of rubbish scattered on and around it. It looks bad, ugly – unashamedly so, but that’s just what contemporary art is, right? If urinals and a plank of blue wood get more attention than a painting by an Italian artist during the Renaissance, then what is the state of art today? Why is all the art today so *‘bad’*, and why do so many people like it?

To understand ‘bad’ art, one should travel to wartime Germany, specifically to Munich during the late 30s and the early 40s. The Nazis opened the *Große Deutsche Kunstausstellung* (*Great German Art Exhibition)* in July 1937, showcasing realistic paintings



of nature and families, as well as sculptures of people which echoed the same ones the Ancient Greeks made well over two thousand years ago. Seems tame. Great, even. However these pieces came with a purpose, all of them having been picked out by Hitler himself, chosen to stylistically and ideologically represent what, in his eyes, German art was and wasn’t. To the Nazis, art was a tool used to define the values of a society in addition to influencing a nation’s development; therefore, through this exhibition, Hitler’s take on the Second Reich’s traditional values of ‘Kinder, Küche, Kirche’ (translated to: children, kitchen and church) could be promoted to those in the Third Reich [1] – the same ones drilled into children’s heads during school, only illustrated as happy families and landscapes in oil paints and watercolour, its conventionality reminiscent of Hitler’s own artworks. Furthermore, the sculptures made by Josef Thorak and Arno Breker appear heavily influenced by classical sculptures of the Ancient Roman and Greek varieties, the idealised figures created by them reinforcing the Nazi belief in a ‘superior’ race – devoid of any Jewish influence. [2] In short, the Great German Art Exhibition was used to further push Nazi values onto the public, aesthetically prioritising realism and simplicity, in addition to pushing Nationalism, racial purity and traditional values. All hallmarks of what the Nazis deemed as ‘good’ art.

Concurrently, the *Entartete Kunst (Degenerate art)* exhibition attempted to make a mockery out of anything other than what the Nazis deemed as ‘great’ or ‘German’. Unlike the latter, some of the artists included are still talked about today, surprisingly (considering the name of the exhibition) in high regards. About 650 pieces by names such as Otto Dix, Wassily Kandinsky and Piet Mondrian were seized by the Nazis in order to be displayed and ridiculed at this exhibition [3] [4]. Although what would be now associated with ‘great German’ art was far from anything displayed at the Degenerate Art Exhibition, some avant-garde pieces were initially chosen for the Great German Art Exhibition by Joseph Goebbels (the minister of propaganda), however they were swiftly removed from the exhibition a month before it opened by Hitler, whose more realistic and classical tastes were clashed with. Thus, the idea for a separate exhibition which focused on ‘degenerate’ (for example, anything Modernist or racially impure) art was born; an event in which everything Hitler stood against being put in the spotlight. Despite the intention for this exhibition being one of mockery and ridicule, and the attempts of discouragement of appreciation made by those who organised the exhibition, it is estimated that the Degenerate Art Exhibition had more than 2 million visitors in 1937 – more than 4 times the amount of the Great German Art Exhibition. [5] This statistic provokes the question: why do people want to see 'bad' art?

Bad is a strong word; in this context, it refers to anything seen as not conforming to traditions, or society's preconceived notions about fine art (i.e. realism or proportionality). However, these standards change, an example being the artists featured in both of the previously mentioned exhibitions. Although Classical art is still venerated due to its undeniable influence over Western art (including those who were Nazi-adjacent), the interest (whether coming from a place of positivity or negativity) in modern art has only grown over time. Perhaps fine art has shifted from a focus of capturing the physical to depicting concepts, after all, the popularity of camera photography has rapidly increased since the 20th Century [6]. Furthermore, there is also no set definition of what modern art is – only a rough estimate of when it started (the late 19th Century), however not even that pins down exactly what modern art encapsulates. But if one was to take from experts, and to put it as simply as can be, modern art is the rejection of the traditions of fine art (particularly those of Institutions from the West) – whether it's genre or techniques. Additionally, artists within this movement are more likely to use their art as expressions of themselves and concepts, as well as avenues to pursue experimentation and widening our expectations of what art could be [7]. Obviously, as all art is subjective, modern art is no stranger to controversy: phrases like "My child could do that" are familiar when talking about modern and contemporary art.

Despite being grouped as one in conversations about art, there is a distinction between modern and contemporary art, with the latter, whilst being even more difficult to define, can be singled out due to its use of an even wider and newer selection of mediums since the accessibility of technology and other resources has grown so much within the past 50 years. A main problem that contemporary art inherits from modern art is its unpopularity, the only difference being that the distaste of contemporary art is a more commonly shared sentiment. Much like modern art, the actual meaning of the piece may not be clear at the first glance, but as forms of expression start varying even more, a sense of unfamiliarity can take over the viewer, potentially leading to a misunderstanding (or lack of understanding) of the piece and thus resulting in them disliking the piece. As much as art can be about appreciating the artwork (in an aesthetic sense), I believe it can also be about the interpretations made of the work by the artist themself or the lack thereof, which can further guide opinions about it, rather than just leaving an opinion at "I don't like how it looks". [8]

As hinted at before, not all art (bad or good) is meant to aesthetically please. Beauty in art can be used as a tool, whether its association with tradition and conservatism can lead it to be used to uphold tyrannical regimes, or the complete rejection of it being used to comment on the ugliness of the current world [9]. Another interpretation of 'bad' art that doesn't seem to look particularly 'good' is that it evokes a feeling of vulnerability. Unlike ancient deities and the poised position of a 17th Century noble, 'ugly' art does not need to perform, instead it just has to exist. Take Tracey Emin's *My Bed* (1998) as a prime example of 'bad' art, initially denounced by critics as 'exhibitionist' and 'self-degrading'. Much like a lot of art, past and present, there is symbolism, but rather than being an animal or a colour, Emin's symbol is her bed. Being an object that remains a constant in the lives of those fortunate enough, bed have seen everything: from birth, sickness, intimacy and death. Therefore, through this symbolism, *My Bed* is an act of confession, one made after days spent in bed during the aftermath of a break up. The pure filth depicted putting the view face-to-face with the ugly truth of human experiences, similar to the diary of a young woman, available to the public. It is a portrait of neither paint nor pencil, but of fragments of her own life – a concept that was not grasped by others, leading to its dismissal as 'bad' art. [10]

Overall, what can be considered 'bad' is not always necessarily so, most of the time it is only considered as that at a first glance. Hence, knowing the context in which a piece was conceived is important to understanding it from a deeper level than superficiality. Liking 'bad' art is an act of rebellion in itself, the rejection of tradition *is* a tradition in art spanning over many years: from Dada to punk to the Theatre of Cruelty – all of which hang onto the idea of provocation. If these movements are all still widely celebrated, then can 'bad' art actually be *good?*

Footnotes

1. **Tate Gallery.** *Degenerate art.* Available at: https://www.tate.org.uk/art/art-terms/d/degenerate-art [Accessed: 08 Feb. 2026]. 2. **German Art Gallery.** *Great German Art Exhibitions* & *Totalitarian Art.* Available at: https://germanartgallery.eu/great-german-art-exhibitions/ https://germanartgallery.eu/totalitarian-art/ [Accessed 08 Feb. 2026]
3. **National Galleries Scotland.** *Degenerate Art.* Available at: https://www.nationalgalleries.org/art-and artists/glossary-terms/degenerate-art 4. **Almeroth-Williams, T.** *Exposing a Nazi: The exhibition destroying a myth.* Available at: https://www.cam.ac.uk/stories/exposing-a nazi [Accessed 08 Feb. 2026]
5. **United States Holocaust Memorial Museum.** *"Degenerate" Art - Holocaust Encyclopedia.* Available at: https://encyclopedia.ushmm.org/content/en/article/degenerate-art-1 [Accessed 08 Feb. 2026]
6. **St Neots Museum.** *A brief history of photography.* Available at: https://www.stneotsmuseum.org.uk/articles/a-brief-history-of-photography/#:~:text=

In%20the%20late%20Victorian%20period,wages%20rose%20in%20the%201950s [Accessed 10 Feb. 2026]

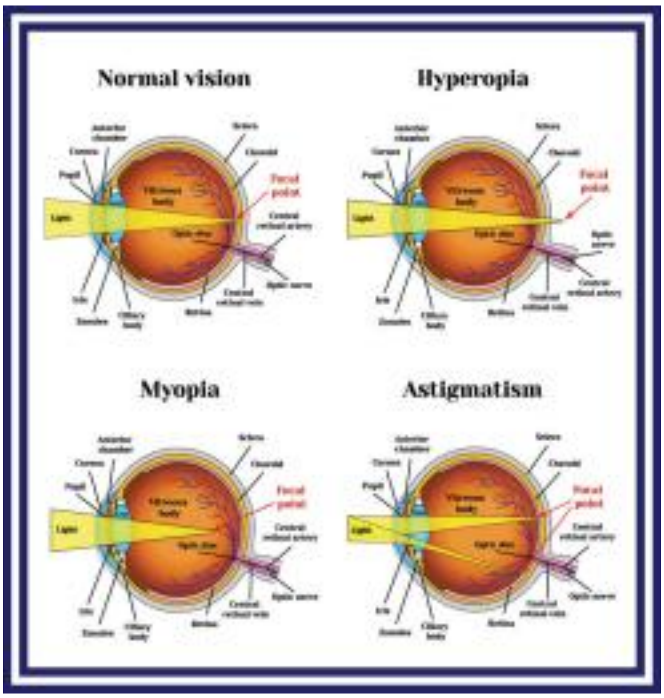
7. **The Museum of Modern Art.** *What is modern art?* Available at: https://www.moma.org/collection/terms/modern-art/what-is-modern-art [Accessed 10 Feb. 2026]
8. **Johnson, J. (2015)** *Contemporary Art vs. Modern Art: Defining now from then.* Available at: https://blogs.chapman.edu/collections/2015/11/30/contemporary-art-vs-modern-art/ [Accessed 10 Feb. 2026]
9. **Dozier, A. (2023)** *Why "ugly" paintings are so popular.* Available at: https://www.artsy.net/article/artsy-editorial -ugly-paintings-popular [Accessed 10 Feb. 2026]
10. **Hubbard, S. (2024)** *Tracey Emin: My Bed (1998) - Significant Works.* Available at: https://artlyst.com/tracey-emin-my-bed-19 98-significant-works-sue-hubbard/ [Accessed 10 Feb. 2026]

A Day In the Life

Méabh Tierney

Back in November 2025, I attended a lecture at the Institute of Physics titled Adventures in the Physics of Everyday Living. We always think of physics as the science that explains how the universe works. The grand scale of physics encompasses launching rockets to space, building nuclear reactors, the Big Bang Theory, and countless other examples. However, sometimes it is the myriad of infinitesimal ways concepts of physics can be applied in our lives, that should give us leave to pause and ponder these marvels of existence. Both within natural phenomena, to devices and objects that humans have created, physics is at the heart of everything. In this article, I wish to explore a few examples of this so-called 'everyday' physics and to illustrate the wonders of our ordinary days.

In the morning, after waking up and washing my face, I reach for the plastic blue pots containing a pair of contact lenses. Suddenly the world sharpens, I can make out the words on a poster on the other side of my room, and the light is no longer a fuzzy blur. One would assume that contact lenses are a relatively modern invention, however the idea was first proposed by Leonardo da Vinci (he really did think of everything) in 1508, who gave birth to the concept of neutralization of the cornea by a new refracting surface [1]. The purpose of contact lenses is to correct refractive errors such as myopia (near-sightedness), hyperopia (far-sightedness), presbyopia (age-related farsightedness) and astigmatism (when your cornea is curved irregularly) [2]. I have astigmatism and myopia, which means that without wearing corrective glasses or contact lenses, light is focused in front of the retina - this is



often due to the eyeball being too long. Having a parent who is myopic means that you are more likely to also have myopia. Since both my parents are myopic (thanks mum and dad), it seemed to be only a matter of time before I too joined the 2.64 billion people (as recorded in 2020) who have myopia [3].

Figure 1 : Where light is focused due to different eye problems [4].

Contact lenses are meant to capture and refract light in a way that corrects how eyes with one of the above conditions process light. Contact lenses ensure that the focal point will be on the retina. For someone with myopia, concave lenses are used to focus light onto the retina. Concave lenses are thicker on the outside and thinner in the centre which refract the light slightly outwards to correct the over-focusing tendency (the fact that light is focused before the retina). Convex lenses are used to treat hyperopia as they refract light slightly inwards which increases the focusing power of the eye, ensuring light is focused on the retina. Once my contacts are in, and I can see clearly, I begin to make my way to school …

On to the first lesson of my day, where I pick up my ballpoint pen and begin to write. The point of a ballpoint pen is (like the name suggests) a lubricated ball bearing (usually made of sturdy metals like brass, steel or tungsten carbide) which is driven by friction between the ball bearing and the surface it is writing on. The material the ball bearing is made from is important. Tungsten carbide in particular has exceptional durability preventing deformation under high pressures and maintaining a smooth ink flow. Additionally, tungsten carbide is corrosion and abrasion resistant, provides high hardness and has low surface roughness. Its surfaces are uniformly filled with tiny pores which reduces wear between the ball bearing and the ball seat (the socket into which the ball bearing fits). It has low surface roughness with uniform fine pores which ensures the capillary action as ink is slowly taken out continuously, whilst surplus ink returns to the body of the ball seat [4]. The way the humble ball point pen works is thanks to several mechanical functions including gravity and rotational forces like centripetal forces. Gravity - that ‘pulling’ force ever dragging us down- works its magic on the ink in the ink reservoir, forcing it down onto the ball bearing. I put pen to paper and lo and behold, the ink coats the ball bearing and my pen begins to write. The rotation of the ball bearing causes its surface to be coated in a thin layer of ink. Most of the work done to put the ink onto the paper is due to the initial touch of pen to paper, however if more ink is needed to flow onto the ball bearing, work is done by the centripetal force [5]. The role of gravity in ball point pens illustrates why when you hold the pen upside down and then try to write again, it takes a few seconds for the ink to flow as the ink has been pulled away from the ball bearing by gravity, creating an air gap that must be overcome [6]. The ball point pen is a mess free alternative to preceding pens like fountain pens (my preferred writing instrument) and quills, both of which relied upon capillary action. From the 19th century, inventors (such as John Jacob Parker and Poenaru) began to embark on a quest to create a self -feeding, mess-free ink pen. However it wasn't until 1938 that brothers László and Georg Bíró developed the modern day ballpoint pen. The ball bearing is calculated to be the exact size and shape to fit tightly into the socket of the pen to allow for smooth rotation without excess ink flow [7]. However if it is too tight, friction will cause a scratchy writing experience. The ball bearing and socket provide a continuous cap to prevent air from reaching the ink as this would cause the ink to dry up and it prevents the evaporation of any volatile components of the ink thus maintaining a constant ink viscosity.

Ballpoint pens function primarily due to gravity - but what about when there is no gravity, how do astronauts in outer space write ? (a quick segue into the not so everyday physics !) In the 1960s, NASA sought to solve this problem by using the AG-7 Anti Gravity Pen from 1967 which was developed by Paul. C Fisher an American inventor in 1965 who was trying to improve the modern ball point pen. This pen could write upside down, work without gravity, function at extreme temperatures (-34 to 121 °C), write underwater and on greasy surfaces [8].

This pen used a sealed, gas pressurised ink cartridge at about two atmospheres by compressed nitrogen gas which continuously forced ink against the ball bearing [9], thus resulting in the smooth flow of ink in any orientation. The ink used by the pen was thixotropic, meaning that it remained a solid inside the cartridge but liquefied when the ball bearing moved, as the movement sheared the chemical polymer bonds in the ink turning it to liquid. This was to prevent any leakages. The fisher space pen is now an iconic reimagination of the ballpoint pen - however I think I will stick to my Biro for my maths homework.

Finally, as I'm walking home from school and the sun is setting, lights are turning on everywhere, some of these flash vibrant rainbow hues into the fading natural light of day. These neon signs declaring that this restaurant is 'open' or displaying the name of the shop are actually due to a striking physics phenomenon. Neon lights are made up of gas discharge tubes which emit different colours depending on the element they contain. Atoms of inert gases like neon, helium or argon will almost always be found in monoatomic form. This is because they are incredibly chemically unreactive and as such they won't bond with any other atoms. However, when a voltage is applied across a gas vapour tube containing one of these gases, the tube begins to glow. This is because the electrons in the gas become excited and are promoted to a higher energy state. When the electron returns to its original orbital, photons carry away the energy difference between orbitals. This causes the discharge tube to glow [10]. The energy of the emitted photon is equal to the frequency of the photon multiplied by Plank's constant, as such it can be seen that energy and frequency are proportional (and energy and wavelength are inversely proportional). However when the electron de-excites, it may not move directly back to its original position, as such there are multiple possible ways it could emit radiation.

The allowed transitions for an electron in an element are those for which the angular momentum quantum number (l) changes by 1 unit [11]. The position of an electron (its orbital) can be described by quantum numbers. 'N' is the principle quantum number which describes the energy of the electron. The angular momentum quantum number (l) describes the general shape of the orbital which the electron is in. The magnetic quantum number (ml) describes the orientation of the orbital in space. The final quantum number describes the spin of the electron (ms). As the angular momentum number can only change by 1, an example of an allowed transition would be an electron in an s orbital moving to a p orbital. Depending on where the electron de-excites to, the energy emitted would be different and as much the wavelength of the emitted photon would be different. The photons emitted by the atom form the emission spectrum of that atom. Every atom has its own unique electronic configuration and as such will produce a different emission spectrum. As each photon wavelength corresponds to a different colour of light, different elements produce different colours. Despite the name 'neon lights,' it is only the red-range coloured lights that are produced by neon, helium produces an orange colour when subject to an electric current. Argon produces a lilac colour, however when placed into tubes with a green fluorescent coating, it gives off a green glow. A gray or green light can be due to krypton and a blue light due to mercury vapour [12].

Finally I am home and although my day is over, the way physics impacts my day never is. From running water in a tap to watching television, or simply switching on a lightbulb, there are so many things in our daily lives that are down to physics and maybe tomorrow I will explore some more.

Footnotes

1. **Bharat Gurnani and Kaur, K. Nih.gov (2023)**. *Contact Lenses. [online]* Available at: https://www.ncbi.nlm.nih.gov/books/NBK580554/?scrlybrkr=9eb7ed1a [Accessed 2 Feb. 2026].
2. **Specsavers.co.uk. (2024)**. *Contact Lenses at Specsavers | Specsavers UK. [online]* Available at:

https://www.specsavers.co.uk/contact-lenses/home?srsltid=AfmBOopK5N9N-_B70GwVg7i3m7qhO-ekg1_7gwnxw1Z8VTooIFOaYhc1 [Accessed 2 Feb. 2026].

3. **www.myopiaprofile.com. (n.d.).** *Myopia is responsible for around one-third of global uncorrectable visual impairment | Myopia Profile. [online]* Available at: https://www.myopiaprofile.com/articles/myopia-is-responsible-for-around-one-third of-global-uncorrectable-visual-impairment [Accessed 8 Feb. 2026].
4. **www.lenspure.com. (n.d.).** *How Do Contact Lenses Work? The Science Behind Them - LensPure. [online]* Available at: https://www.lenspure.com/articles/how-do-contact-lenses-work [Accessed 14 Feb. 2026]
5. **Zamorano, R. Linkedin.com (2026).** *You've probably written thousands of words with a ballpoint pen without thinking twice about the precision engineering in your hand. That simple writing tool can produce 45,000 words from just 1. [online]* Available at: https://www.linkedin.com/pulse/deceptively-clever-engineering-inside-ballpoint-pen why-raul-zamorano-exz8e [Accessed 8 Feb. 2026].
6. **APlusPhysics Community. (n.d.).** *Physics of a Ballpoint Pen. [online]* Available at: https://aplusphysics.com/community/index.php?/blogs/entry/969-physics-of-a-ballpoint-pen/ [Accessed 8 Feb. 2026]
7. **Delve. (n.d.).** *Ingenious Engineering: Ballpoint Pens. [online]* Available at: https://www.delve.com/insights/from-quills-to-precision-the-ingenious-engineering-behind-ballpoint-pens [Accessed 8 Feb. 2026]
8. **Fisher Space Pen (2025).** *5 Reasons the Fisher Space Pen Bullet Space Pen is the Ultimate Everyday Carry Pen. [online]* Available at: https://fisherspacepen.co.uk/fisher-space-p en-company/ [Accessed 8 Feb. 2026].
9. **The University of Sydney. (2021).** *Fisher space pen. [online]* Available at: https://www.sydney.edu.au/science/news-and-events/news/2021/01/22/fisher-space-pen.html [Accessed 14 Feb. 2026]
10. **Scientific American (2006).** *How do neon lights work? [online]* Available at: https://www.scientificamerican.com/article/how-do-neon-lights-work/ [Accessed 8 Feb. 2026]
11. **Upenn.edu. (2024).** *Atomic Excitation and SL Production Index. [online]* Available at: https://www.sas.upenn.edu/~seanjw/Atomic%20Excitation%20and%20SL%20Production%20Index.html [Accessed 8 Feb. 2026].
12. **Creations, N. (2014).** *Neon Creations: The Science Behind The Signs. [online]* Available at: https://www.neoncreations.co.uk/blogs/blog/neon-creations-science-behind-signs [Accessed 14 Feb. 2026]

Hydrogen: The Ideal Fuel of the Future

Sophie Wong

Rapid global population growth and the modernisation of society have led to a substantial rise in global energy demand [1]. Currently, most of this demand is met through fossil fuels - a finite non-renewable energy resource. However, the continued reliance of non-renewable fuels has been proven unsustainable, due to their inevitable depletion, and the fact that burning these fossil fuels results in an increase in greenhouse gas emissions.

The greater quantities of greenhouse gases released into the Earth's atmosphere, contribute to the enhanced greenhouse effect [2]. More infrared radiation from the Sun is being absorbed and reradiated at the surface, warming the Earth's atmosphere, thus causing global warming. Additionally, the burning of fossil fuels has given rise to environmental problems such as air pollution, rising sea levels and loss of biodiversity. As these threats to the environment mount, so do concerns towards fossil fuels' sustainability for the future and has fostered the need of

more eco-friendly and cleaner alternatives.
Among other renewable resources, hydrogen has emerged as a promising renewable energy carrier [3]. This is primarily because, unlike fossil fuels, the combustion of hydrogen produces water as a byproduct, instead of pollutants and greenhouse gases [4]. Hydrogen is also an advantageous energy carrier due to its high energy yield, high storage capacity and because it can be derived from plentiful sustainable sources such as biomass and water.

An increased use of hydrogen as an energy carrier enables the transition to a ‘hydrogen economy’ [3], a term coined by electrochemist John O’M. Bockris. It refers to a socio-economic system where hydrogen is used as the main energy resource, replacing traditional fossil fuels, thus reducing the emissions of greenhouse gases and mitigating climate change.

Despite its potential, there are a few obstacles which need to be tackled before hydrogen can be used as an alternative to fossil fuels. At standard temperature and pressure, hydrogen has a very low volumetric energy density, meaning that it must be compressed or liquified for efficient storage and transportation. This requires a considerable amount of energy and investment. Transporting hydrogen through pipelines can also result in energy losses and demand major infrastructure development. Furthermore, many current hydrogen production methods still rely on fossil fuels, undermining its environmental benefits [4][5]. Therefore, to truly carry out a sustainable hydrogen economy, hydrogen must be produced using renewable energy sources. This means that exploration into hydrogen production from renewable energy resources is necessary.

Photocatalytic water splitting technology can be seen as a notable method of hydrogen production. It, as well as other research and studies, has been developed following the discovery of the photocatalysis reaction by Japanese Chemists Honda Kenichi and Dr Fujishima Akira in 1967 [6]. They found out that titanium dioxide could split water into hydrogen and oxygen when exposed to light.

Similarly, photocatalytic water splitting is a process that uses solar energy to split water into hydrogen and oxygen. This technology appears promisingly sustainable as it utilises the fact that solar energy is a free and abundant energy resource that is available around the world [7]. This method of hydrogen production also produces ‘green hydrogen’, as it can provide a high energy yield without producing pollutants and greenhouse gases.

The rate of this reaction is accelerated using a photocatalyst. When the photocatalyst absorbs photons with energy equal to or greater than its band gap, electrons will jump from the valence band (lower energy level) to the conduction band (higher energy level), forming a hole in the valence band. The excited electrons reduce water to form hydrogen, while the holes oxidise water molecules to form oxygen. [1][4]

Evidently, photocatalysts are crucial to photocatalytic water splitting reactions. It is important for photocatalysts to meet certain criteria, to ensure that they are efficient and stable enough to enhance the reaction performance and support large-scale production of hydrogen. Their requirements include having a narrow energy bandgap which allows for efficient absorption of solar energy. Most catalysts only operate under ultraviolet light, which only accounts for 4% of solar energy. It is therefore desirable for photocatalysts to work under visible light, as this is nearly half of the incoming solar radiation. In addition, the photocatalyst should have minimal photo corrosion. This occurs when the anion from the catalyst is oxidised by the photogenerated holes instead of water, resulting in oxygen not being produced. This property also reduced the long-term stability of the catalyst. [4][8][9].

Thus, photocatalysts include transition metal oxides, especially TiO2, metal nitride, metal sulphides, [4] as they hold most of these characteristics. Without these properties, catalytic performance is hindered, and therefore finding and developing photocatalysts remains a significant challenge. Nevertheless, countries such as China, Japan and South Korea are heavily investing in photocatalyst research and development, hoping to increase hydrogen production and tackle environmental issues [10].

To conclude, hydrogen is regarded as the ideal sustainable fuel, due to its renewability and environmental friendliness. Sustainable hydrogen production technology is possible through photocatalytic water splitting, using sunlight. This reaction can provide high energy yield without pollutant byproducts. Nonetheless, various requirements for photocatalysts need to be addressed for this reaction to occur efficiently. Overall, the development and advancement of technology and methods such as these will enable a global ‘hydrogen economy’, where hydrogen acts alternatively to fossil fuels as a primary, sustainable energy carrier. Ideally, this reduces greenhouse gas emissions, thus reducing global environmental issues and the depletion of non-renewable energy resources.

Footnotes

1. **Manoj Kumar, Neeraj Kumar Singh, Ruplappara Sharath Kumar, Rajesh Singh (2024).** *Towards Sustainable and Green Hydrogen Production by Photocatalysis: Insights into Design and Development of Ef icient Materials (Volume 2).* Available at: https://pubs.acs.org/doi/10.1021/bk-2024-1468.ch001 [Accessed 16 Feb. 2026]
2. **Cullers, Robert L. (2023)** *Enhanced greenhouse ef ect.* Available at: https://www.ebsco.com/research-starters/earth-and-atmospheric-sciences/enhanced-greenhouse-effect [Accessed 16 Feb. 2026]
3. **Science Direct (2023).** *Hydrogen production, transportation, utilization, and*

storage: Recent advances towards sustainable energy. Available at: https://www.sciencedirect.com/science/article/abs/pii/S2352152X23026051 [Accessed 16 Feb. 2026]

4. **National Library of Medicine (2016).** *Photocatalytic Water Splitting—The Untamed Dream: A Review of Recent Advances.* Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC6274578/ [Accessed 16 Feb. 2026]
5. **The Sustainability Directory (2025).** *What Are the Drawbacks of Hydrogen Energy?* Available at: https://energy.sustainability-directory.com/question/what-are-the-drawbacks-of-hydrogen-energy/#fundamentals [Accessed 16 Feb. 2026]
6. **Kizuna (n.d.)**. *Artificial Photosynthesis Changes CO2 into Energy.* Available at: https://www.japan.go.jp/tomodachi/2020/earlysummer2020/photosynthesis.html [Accessed 16 Feb. 2026]
7. **Mohammad Jafar Molaei (2024).** *Recent advances in hydrogen production through photocatalytic water splitting: A review.* Available at: https://www.sciencedirect.com/science/article/abs/pii/S0016236124003053 [Accessed 16 Feb. 2026]
8. **Royal Society of Chemistry (2023).** *A perspective on two pathways of photocatalytic water splitting and their practical application systems.* Available at: https://pubs.rsc.org/en/content/articlelanding/2023/cp/d2cp05427b?utm_source [Accessed 16/02/26]
9. **Katherine Villa, José Ramón Galán-Mascarósa, Núria Lópeza, Emilio Palomares (2021).** *Photocatalytic water splitting: advantages and challenges.* Available at: https://recercat.cat/bitstream/handle/2072/529936/Sust%20Energ%20Fuels_2021_5_4560.pdf?sequence=1 [Accessed 16 Feb. 2026]
10. **Chemicals and Materials (2026*).*** *Photocatalysts Market Size, Share, and Industry Analysis, By Material Type.* Available at: https://www.fortunebusinessinsights.com/photocatalysts-market-114185 [Accessed 16 Feb. 2026]

Caffeine: Society's Stimulant Olivia Adamczyk

So, what exactly *is* caffeine? Caffeine is a stimulant which blocks adenosine receptors, therefore increasing the activity of dopamine and norepinephrine, two types of neurotransmitters, improving mood and energy in tandem.[1] Though one may associate caffeine with coffee and tea, the methylxanthine alkaloid is also present in cocoa beans and yerba mate, among other sources (it can be naturally extracted from some 63 plant species). It is a natural pesticide, as are tannins (a polyphenolic compound also present in certain plants, such as tea). Where they differ, however, is that instead of deterring herbivores with a strong unpleasant taste, caffeine in high concentrations can paralyse and kill insects. Naturally, it is found in the highest amounts in buds and younger segments of plants. Caffeine also functions as an allelopathic agent, inhibiting the growth of competing plants. When caffeine-producing plant leaves fall to the ground, they release caffeine into the soil, inhibiting the germination of seeds from competing species. This reduces competition over resources and increases chances of survival for the specific caffeine-producing plants. Additionally, the stimulant properties of caffeine can enhance pollination, as pollinators are more able to memorise the location of the plant for future nectar collection (and repeated reproductive assistance).[2] The compound was first identified and isolated in 1819 by German chemist Friedlieb Ferdinand Runge, though long before that point it was a commonly consumed and socially acceptable drug. Caffeine is generally extracted by steeping plant products (be it coffee or tea) in a process called infusion, though fizzy and energy drinks have garnered increasing popularity since their initial formulation, particularly among the youth.

1. BENEFITS

1.1 Stimulant:

The most widely consumed psychotropic drug, caffeine is most commonly ingested in its various forms as a source of energy. Caffeine performs this function through inhibiting the ability of adenosine binding with receptors in nerve cells. Adenosine automatically builds up over the course of the day in the brain, resulting in drowsiness and decreased alertness, which caffeine effectively disrupts by non-selectively binding to adenosine receptors in place of the neurotransmitter due to its similar structure.[3] For this reason, it is not only imbibed as coffee and tea, but also one of the main selling points of energy drinks, preworkout powder (caffeine has been proven to positively impact athletic performance) and caffeine tablets. Unfortunately, with consistent caffeine intake, the brain compensates for the regular adenosine inhibition by producing more receptors, which can result in unpleasant withdrawal symptoms such as tiredness and headaches. (more on this in risks- withdrawal symptoms) [4]

1.2 Thermogenesis:

Caffeine is an alkaloid, or a chemical compound containing mostly basic nitrogen atoms, which has the unique capability of being able to act as both a hydrogen-acceptor or hydrogen-donor in hydrogen bonding, depending on amine functionality (caffeine is a hydrogen acceptor).[5] Thermogenesis is the production of heat and a by-product of metabolic processes- through the inhibition of phosphodiesterases and consequent increased efficacy of noradrenaline, caffeine increases the rate of thermogenesis. In adaptive thermogenesis, the mitochondria produces heat instead of ATP as an end product of oxidative phosphorylation. This is due to fatty acids activating uncoupling protein-1 when norepinephrine binds to β-adrenergic receptors coupled to an adenylyl cyclase system as a response to lower environmental temperatures.[6]

This is a particularly useful benefit during weight loss, most importantly in those suffering from obesity-related health complications, as the process of adaptive thermogenesis stimulated by caffeine contributes a non-negligible amount to calories burned when in motion. Citing a study by AG. Dulloo[7], V A. Gramza-Michałowska concluded that:

"It was found that individuals, consuming the tea extract containing 90 mg EGCG, three times daily, burned 266 kcal per day more than the group without addition of catechins. However caffeine ingested in equivalent amount that is found in green tea did not show significantly higher energy expenditure, suggesting that thermogenic properties of tea may be due to interactions between caffeine and polyphenols"[8]

The conclusion of this study determined that pure caffeine did not have a significant impact on caloric cost, but that it does so only alongside other substances found specifically within tea, notably polyphenols, or more specifically, catechin which is found in high quantities in green tea. Several studies show that caffeine ingested this way increases the caloric cost of physical activity, compared to the caloric cost of that same physical activity without caffeine.[9] A proposed reason is decreased muscle efficiency, as caffeine is widely known to increase locomotor activity. A more accurate explanation is that catechin is known to inhibit catechol-O-methyl-transferase (the enzyme that degrades noradrenaline), therefore inhibiting transcellular phosphodiesterases- enzymes that break down norepinephrine-induced cAMP (the messenger that stimulates the release of protein-1).[10] This consequently enhances the thermogenic response.

1.3 Analgesic:

It is common to find caffeine used in combination with stronger analgesics such as acetaminophen and aspirin in medications marketed towards managing headaches as an adjuvant. Caffeine is proven to strengthen drug efficacy by increasing the Cmax and plasma area under the curve (the value of AUC versus time after dosage indicates the extent of exposure of a drug and the rate of its clearance from the body), lowering the required dose and consequently minimising side effects.[11] Analgesics are a classification of medications which provide pain relief when ingested or otherwise injected, the main groups of which being NSAIDs (also anti-inflammatory and antipyretic), acetaminophen (also antipyretic) and opioids.[12] In Caffeine and Heachaches, Dr Robert E. Shapiro states that:

“A meta-analysis of 30 clinical trials indicates that adding caffeine to an analgesic agent reduces the dosage needed of that analgesic agent to achieve equivalent analgesia by 40%”[13]

Further randomised control trials determine that the specific rate ratio of headache relief is 1.36, a value which is significant and applicable to the relief of tension and/or migraine pain.[14] Caffeine functions by accelerating acetaminophen absorption and enhancing the antinociceptive (inhibiting of pain stimuli detection)[15] properties.
This is done through the adjuvant analgesic function of caffeine, which is theorised to be because of the significant inhibition of COX-2 (cyclooxygenase-2) protein synthesis, therefore inhibition of total COX in microglial cells (primary immune defence cells of the CNS).[16] A different study found that the activation of adenosine receptors induces COX-2 synthesis, so the blocking of them by caffeine prevents this from occurring.[17, 18] COX-2 is an enzyme which produces prostaglandins, resulting in inflammation and the proliferation of pain sensations throughout the body NSAIDs inhibit these.[19]
In addition to this, caffeine also is able to act independently as a moderate analgesic, though higher doses are required (>200mg), with 300mg being the minimum statistically significant doses. The analgesic effects of caffeine when applied to headaches and migraines likely stem from the potent vasoconstrictive behaviour of the compound, and it has been found that plasma adenosine (the metabolite of ATP, which is released from neurons and astrocytes[23]) and cerebral vasodilation increases in the brain during the pain phase of migraines.[24, 25]

2. RISKS

2.1 Hypertension:

Caffeine in the body promotes the production of catecholamines (neurohormones involved in the fight-or-flight response) like adrenaline (hormone) and noradrenaline (neurotransmitter).[3] Together, they ensure that the body is receiving adequate levels of oxygen for the regular performance of organs and muscles in situations of stress. Adrenaline functions by increasing heart rate, cardiac output, and blood glucose levels through the stimulation of glycogenolysis and lipolysis (through thermogenesis). Noradrenaline comparatively increases blood pressure through vasoconstriction, or the narrowing blood vessels.[20] This increases the risk of hypertension, defined by WHO as:

“Hypertension (high blood pressure) is when the pressure in your blood vessels is too high (140/90 mmHg or higher). It is common but can be serious if not treated.(...)Hypertension is a major cause of premature death worldwide.”[21]

Hypertension can cause many severe health complications, affecting not only the cardiovascular system, but also resulting in kidney damage (and resultant failure). Elevated pressure can reduce blood flow by hardening arteries, blocking adequate blood supply to the heart (heart attack), brain (stroke) and various other organs (heart failure).[22]

2.2 Reproductive issues:

It has been determined that the negative repercussions of caffeine intake on reproductive health are the most striking in relation to pregnancy and foetal development. According to the World Health Organisation, the maximum permitted dose of caffeine per day for a pregnant individual is 300mg, as higher quantities pose a risk of malformation and even miscarriage.[26, 27] Caffeine ingested maternally crosses the placental barrier, reaching equilibrium, though due to the absence of CYP1A2 isozymes, it is unable to be metabolised and accumulates in the placenta and foetus.[28] The decrease in CYP1A2 activity in those who are pregnant naturally slows the clearance rate of caffeine from the body, further contributing to accumulation.[29] Increased catecholamines, specifically epinephrine, in the mother and fetus is considered as a potential gestational risk, though more research is needed to confirm this.[30] This can cause catecholamine-mediated uteroplacental vasoconstriction and the subsequent reduction in uteroplacental blood circulation which poses the risk of foetal asphyxia and nutrient deficiency.[3] Additionally, cellular cAMP levels increase via the inhibition of phosphodiesterase, interfering with cellular development. Both of these disruptions are strongly linked with a decline in foetal growth, largely affecting heart development.[31] Due to its structural similarity to the nitrogenous bases of deoxyribonucleotides guanine and adenine, caffeine can become incorporated into foetal DNA during mitotic synthesis, resulting in chromosomal anomalies.[32]

In relation to fertility, there is evidence to suggest that excess consumption disrupts reproductive hormone levels, interfering with ovulation and sperm quality, though evidence in relation to females is conflicting and requires further documentation.[33] Nonetheless, doctors recommend limiting caffeine intake when attempting to conceive, with a daily maximum of 200mg.[34]

2.3 Withdrawal symptoms:

Habitual caffeine use can result in two prominent withdrawal symptoms, that being fatigue (plus irritability) and headaches, which are a major factor in dependence on the drug.[13] However, it has been suggested that the common promotion of energy drinks to adolescents increases the prevalence of caffeine dependence. Concerning the negative physical and neurological effects of withdrawal, a study by Danielle Wikoff found that:

"Excessive use, especially in amounts beyond 400 mg/day for adults or 2.5 mg/kg/day for adolescents, has been linked to negative effects such as anxiety, sleeplessness, tachycardia, gastrointestinal issues, and, in rare instances, toxicity necessitating medical treatment"[35]

Though short-term headaches can result from caffeine intake cessation (very high caffeine doses may too induce headache), complete abstinence from caffeine is likely to be beneficial for regular migraine sufferers, as overuse of the compound has been shown to affect regional brain glucose metabolism.[36] Susceptibility to withdrawal symptoms varies from person to person, and the likelihood of analgesic-overuse headache is not guaranteed for all individuals, though it is considered to be at least partially heritable. The non-selective blocking of adenosine receptors over time leads to their upregulation, and noticeable elevations in adenosine plasma concentrations, exacerbating symptoms of tiredness and mood disturbances.[13]

3. CONCLUSION

Caffeine is a wonderfully fascinating compound, with various medical and recreational applications that are yet to be fully researched or applied to real-life. I am writing this article as a method of objective analysis pertaining to the benefits and risks of caffeine consumption, which are varied and, at times, misrepresented or ignored. All in all, the drug is versatile and useful, as long as it is consumed responsibly and within limits (for those wondering, the maximum for adolescents is 100-175mg for a body weight of 40-70kg[37], or in the upper limits, as much as there is in a can of monster!!). So; drink responsibly and remember to stay hydrated, especially if you're drinking coffee!

Footnotes

1. **Cleveland Clinic.** *Caf eine: What It Is and What It Does*. [online] Available at: https://health.clevelandclinic.org/caffeine [Accessed 23 Dec. 2025].
2. **Biology Insights. (2025)**. *What Plants Contain Caf eine and Why Do They Make It?* [online] Available at: https://biologyinsights.com/what-plants-contain-caffeine-and-why-do-they-make-it/ [Accessed 29 Dec. 2025].
3. Reddy, V.S., Shiva, S., Manikantan, S. and Ramakrishna, S. (2024). Pharmacology of Caffeine and Its Effects on the Human Body. doi:https://doi.org/10.1016/j.ejmcr.2024.100138.
4. www.sciencefocus.com. (n.d.). *How the right amount of caf eine unlocks lifelong benefits for your body and mind*. [online] Available at: https://www.sciencefocus.com/the-human body/benefits-of-caffeine. Clinic, C. (2025).
5. **ResearchGate.** (n.d.). (PDF) *An Interdisciplinary Investigation Into Alcohol, Caf eine, and Prozac.* [online] Available at: https://www.researchgate.net/publication/313430611_An_Interdisciplinary_Investigation_Into_Alcohol_Caffeine_and_Prozac
6. Souza, S.C., Christoffolete, M.A., Ribeiro, M.O., Miyoshi, H., Strissel, K.J., Stancheva, Z.S., Rogers, N.H., D'Eon, T.M., Perfield, J.W., Imachi, H., Obin, M.S., Bianco, A.C. and Greenberg, A.S. (2007). *Perilipin regulates the thermogenic actions of norepinephrine in brown adipose tissue.* **Journal of Lipid Research**, [online] 48(6), pp.1273–1279. doi:https://doi.org/10.1194/jlr.m700047-jlr 200.
7. Dulloo, A.G., Seydoux, J., Girardier, L., Chantre, P. and Vandermander, J. (2000). *Green tea and thermogenesis: interactions between catechin-polyphenols, caf eine and sympathetic activity.* **International Journal of Obesity and Related Metabolic Disorders**: Journal of the International Association for the Study of Obesity, [online] 24(2), pp.252–258. doi:https://doi.org/10.1038/sj.ijo.0801101 .
8. Gramza-Michałowska, A. (2013). *Caf eine in tea Camellia sinensis — Content, absorption, benefits and risks of consumption.* **The journal of nutrition, health & aging**, 18(2), pp.143–149. doi:https://doi.org/10.1007/s12603-013-0404-1.
9. Clark, K.S., Coleman, C., Shelton, R., Heemstra, L.A. and Novak, C.M. (2019). *Caf eine enhances activity thermogenesis and energy expenditure in rats.* **Clinical and Experimental Pharmacology and Physiology**, 46(5), pp.475–482. doi:https://doi.org/10.1111/1440-1681.13065.

10. Young Sil Yoon, Tsai, W.-W., Van, S., Chen, Z., Lee, K.-F., Morgan, D.A., Kamal Rahmouni, Matsumura, S., Wiater, E., Song, Y. and Montminy, M. (2018). *cAMP-inducible coactivator CRTC3 attenuates brown adipose tissue thermogenesis.* **Proceedings of the National Academy of Sciences of the United States of America**, 115(23). doi:https://doi.org/10.1073/pnas.1805257115.
11. Scheff, J.D., Almon, R.R., DuBois, D.C., Jusko, W.J. and Androulakis, I.P. (2011). *Assessment of Pharmacologic Area Under the Curve When Baselines are Variable.* **Pharmaceutical research**, [online] 28(5), pp.1081–1089. doi:https://doi.org/10.1007/s11095-010-0363-8.
12. **Cleveland Clinic (2021).** *Analgesics: Uses, Treatment, Risks*. [online] Available at: https://my.clevelandclinic.org/health/drugs/21483-analgesics.
13. Shapiro, R.E. (2008). *Caf eine and headaches*. **Current Pain and Headache Reports**, 12(4), pp.311–315. doi:https://doi.org/10.1007/s11916-008-0052-z.
14. Zhang, W.-Y. (2001). A Benefit-Risk *Assessment of Caf eine as an Analgesic Adjuvant.* **Drug Safety**, 24(15), pp.1127–1142. doi:https://doi.org/10.2165/00002018-200124150-00004.
15. Neis, V.B., Rosa, P., Gislaine Olescowicz and Lúcia, A. (2017). Therapeutic potential of agmatine for CNS disorders. *Neurochemistry International*, 108, pp.318–331. doi:https://doi.org/10.1016/j.neuint.2017.05.006.
16. Fiebich, B.L., Lieb, K., Hüll, M., Aicher, B., van Ryn, J., Pairet, M. and Engelhardt, G. (2000). *Ef ects of caf eine and paracetamol alone or in combination with acetylsalicylic acid on prostaglandin E2 synthesis in rat microglial cells.* **Neuropharmacology**, 39(11), pp.2205–2213. doi:https://doi.org/10.1016/s0028-3908(00)00045-9.
17. Fiebich, B.L., Biber, K., Lieb, K., Van Calker, D., Berger, M., Bauer, J. and Gebicke-Haerter, P.J. (1996). *Cyclooxygenase-2 expression in rat microglia is induced by adenosine A2a-receptors.* **Glia**, [online] 18(2), pp.152–180. doi:https://doi.org/10.1002/(sici)1098-1136(199610)18:2%3C152::aid-glia7%3E3.0.co;2-2.
18. Lanteri-Minet, M. and Pegahi, R. (2025). *Paracetamol and Caf eine Combination in Pain Management: A Narrative Review.* **Pain Research and Management**, 2025(1). doi:https://doi.org/10.1155/prm/9166828.
19. NICE (2024). *CKS is only available in the UK*. [online] NICE. Available at: https://cks.nice.org.uk/topics/nsaids-prescribing-issues/background-information/mode-of-action/.
20. Khalil, B., Warrington, S.J. and Rosani, A. (2024). *Physiology, Catecholamines*. [online] **Nih.gov.** Available at: https://www.ncbi.nlm.nih.gov/books/NBK507716/.
21. World Health Organization (2023). Hypertension. [online] World Health Organization. Available at: https://www.who.int/news-room/fact-sheets/detail/hypertension.
22. **CDC (2024).** *About high blood pressure.* [online] Available at: https://www.cdc.gov/high-blood-pressure/about/index.html.
23. Dunwiddie, T.V. and Masino, S.A. (2001). The Role and Regulation of Adenosine in the Central Nervous System. *Annual Review of Neuroscience*, 24(1), pp.31–55. doi:https://doi.org/10.1146/annurev.neuro.24.1.31.
24. Mathew, R.J. and Wilson, W.H. (1985). Caffeine induced changes in cerebral circulation. *Stroke*, 16(5), pp.814–817. doi:https://doi.org/10.1161/01.str.16.5.814
25. Wolff, H.G. (1980). *Wolf 's Headache and Other Head Pain*. **Oxford University Press, USA.**
26. World Health Organization (2002). *The world health report 2002 : reducing risks, promoting healthy life.* **Geneva: World Health Organization.**
27. Stawińska-Dudek, J., Brzoza, M., Bielecka, A., Aboud, A. and Stawińska, K. (2025). *The impact of caf eine consumption on reproductive health. A literature review.* **Polski merkuriusz lekarski : organ Polskiego Towarzystwa Lekarskiego**, [online] 53(3), pp.423–427. doi:https://doi.org/10.36740/Merkur202503119.
28. Hinds, T.S., West, W.L., Knight, E.M. and Harland, B.F. (2009). *The Ef ect of Caf eine on Pregnancy Outcome Variables.* **Nutrition Reviews**, 54(7), pp.203–207. doi:https://doi.org/10.1111/j.1753-4887.1996.tb03933.x.

29. Doepker, C., Lieberman, H.R., Smith, A.P., Peck, J.D., El-Sohemy, A. and Welsh, B.T. (2016). *Caf eine: Friend or Foe?* **Annual Review of Food Science and Technology**, 7(1), pp.117–137. doi:https://doi.org/10.1146/annurev-food-041715-033243.
30. Kirkinen, P., Jouppila, P., Koivula, A., Vuori, J. and Puukka, M. (1983). *The ef ect of caf eine on placental and fetal blood flow in human pregnancy.* **American Journal of Obstetrics and Gynecology**, 147(8), pp.939–942. doi:https://doi.org/10.1016/0002-9378(83)90250-8.
31. Fenster, L., Eskenazi, B., Windham, G.C. and Swan, S.H. (1991). *Caf eine Consumption during Pregnancy and Spontaneous Abortion.* **Epidemiology**, 2(3), pp.168–174. doi:https://doi.org/10.1097/00001648-199105000-00002.
32. Weng, X., Odouli, R. and Li, D.K. (2008). *Maternal Caf eine Consumption During Pregnancy and the Risk of Miscarriage: A Prospective Cohort Study.* **Obstetric Anesthesia Digest**, 28(4), pp.229–230. doi:https://doi.org/10.1097/01.aoa.0000337929.31867.c3.
33. Schliep, K.C., Schisterman, E.F., Mumford, S.L., Pollack, A.Z., Zhang, C., Ye, A., Stanford, J.B., Hammoud, A.O., Porucznik, C.A. and Wactawski-Wende, J. (2012). *Caf einated beverage intake and reproductive hormones among premenopausal women in the BioCycle Study.* **The American Journal of Clinical Nutrition**, 95(2), pp.488–497. doi:https://doi.org/10.3945/ajcn.111.021287.
34. Krotz, S. (2025). *Caf eine and Fertility: Exploring the Latest Research Findings.* [online] **Inovi Fertility and Genetics Institute**. Available at: https://www.inovifertility.com/blog/caffeine-and-fertility-exploring-the-latest-research-findings/.
35. Doepker, C., Franke, K., Myers, E., Goldberger, J.J., Lieberman, H.R., O'Brien, C., Peck, J., Tenenbein, M., Weaver, C. and Wikoff, D. (2018). *Key Findings and Implications of a Recent Systematic Review of the Potential Adverse Ef ects of Caf eine Consumption in Healthy Adults, Pregnant Women, Adolescents, and Children.* **Nutrients**, [online] 10(10). doi:https://doi.org/10.3390/nu10101536.
36. Di, W., Shi, X., Zhu, Y., Tao, Y., Qi, W., Luo, N., Xiao, Z., Chen, Y., Jia yin. Miao, Zhang, A., Zhang, X. and Yu, F. (2012). *Overuse of paracetamol caf eine aspirin powders af ects cerebral glucose metabolism in chronic migraine patients*. **European Journal of Neurology**, 20(4), pp.655–662. doi:https://doi.org/10.1111/ene.12018. 37. Cho, H.-W. (2018). *How Much Caf eine is Too Much for Young Adolescents?* **Osong Public Health and Research Perspectives**, [online] 9(6), pp.287–288. doi:https://doi.org/10.24171/j.phrp.2018.9.6.01.