



The Catalyst

connecting chemists

GREEN CHEMISTRY

Gold Mining

The process and
its implications p 23



Dr. Ahi

*Read more about
doping control* p 7

Environment

*How contact lenses
pollute* p 19

Food

*Chemistry of soil
and taste* p 33

Writers

Elena Rubini
(Writing Director)

Sofia Schönauer
(Writing Director)

Claudia Almuzara

Paul Amar

Matt Dagwell

Milan Singh

Louis Weiss

Proofreaders

Reza Ahmad

Nadim Ahmed

Seema Bosor

Janifa Jahir

Neev Lawton

Alia Nathoo

**Graphic Editorial
Team**

Milan Singh
(Graphic Editorial
Director)

Rohima Akhtar

Anastasia Tchoumakova

**Marketing
team**

Claudia Almuzara
(Marketing Director)

Tania Jassal

Alicia Marin

Jasmine Ng

Note from the Co-Founders

Our third issue of The Catalyst revolves around the theme of Green Chemistry. We wanted to kick off the new year by bringing your attention to how the field of Chemistry impacts our environment and can contribute to finding ‘greener’ solutions that can help with the pollution and plastic crises, to name a few. Indulge in an array of articles ranging from green alternatives for rocket fuel to the chemistry behind contact lenses.

For a well-balanced read, check out our assorted off-themed articles covering a COVID-19 drug, the life of world-renowned scientist Marie Curie, as well as the effects of soil composition on aroma and taste of crops.

Finally, we are excited to share with you two new interviews with Dr. Ahi and Dr. Huamán Rodriguez, experts in their respective fields of doping control and human rights, as well as a continuation of our gold nanoparticle series.

A special thank you to our writers, proofreaders, graphic editors and marketing team that helped put together this issue.

Happy reading!

The Founders



Elena Rubini
Writing Director



Milan Singh
Graphic Editorial Director



Sofia Schönauer
Writing Director

Table of Contents

1

The Plastic Revolution

Tackling one of our most prominent crises, this article explores metathesis reactions as a possibility for plastic monomer recycling without losing product quality as a green polymer alternative.

2

The Powers of Chromatography in Doping Control

This article guides you through examples of the complex procedures involved in doping control, through interviewee and expert Dr Shobha Ahi's experiences and research.

3

Recycling Our Emission

Through various approaches of catalyst design, get an overview on electrochemical CO₂ conversion as a way of cutting down our greenhouse gas emissions and slow down climate change.

4

Is Molnupiravir the Next COVID-19 Treatment?

At the frontlines of research, this article presents you with a drug in clinical trials for the ongoing pandemic, with potential to bring an earlier end to our restricted day-to-day lives.

5

Contact Lenses and Pollution Go Hand in Hand - The Reality that Has Been Lying Right Before Our Eyes

Considering a contamination rarely discussed, this article presents you with the pollution created by disposable contact lenses. Read about consequences and current research into greener alternatives.

6

Gold Fever - What We Do for a Little Luxury

Explore the dark side of gold mining through environmental and humanitarian aspects. The common processes of mining around the world are enhanced by human rights expert Dr. Gloria Huamán Rodriguez' focus on indigenous peoples and their suffering.

7

The Chemistry of Soil and Taste - Does Chemistry Have a Last Imprint on the Food We Grow?

Learn about the effect of environmental stimuli on the taste of wine crops through adjustments on a DNA level. This article explains the importance of terroir on the taste of your favourite wine.

8

How NASA is Using Green Rocket Fuel for the First Time

As a non-toxic, easier to handle alternative to hydrazine, find out about a potentially more efficient type of rocket fuel that poses lower occupational and environmental hazards.

9

Magic Bullets for Prostate Cancer: A “Golden” Treatment that Might Just Revolutionise Cancer Therapy

A continuation of our gold nanoparticle series, this article walks you through the emerging application of these “golden bullets” used to treat prostate cancer.

10

Marja Skłodowska: A Life Account

A bibliographic account of Marie Curie's contributions to the scientific community gives you an insight into success and pitfalls in her personal and academic life. Get to know one of Chemistry's most famous Nobel laureates.

p 3

p 7

p 11

p 15

p 19

p 23

p 33

p 37

p 41

p 45

The Plastic Revolution

Author: Matt Dagwell

Plastic materials have been an essential part of life ever since the first synthetic plastic was produced by Belgian chemist, Leo Baekeland, in 1907. Utilised in many aspects of life, from a box of strawberries to the pump gears of a jumbo jet, plastics have well and truly dominated the materials industry for over a hundred years. However, with the current climate crisis worsening with soaring pollution and waste levels all over the planet, chemists and the world over are tirelessly attempting to find materials able to reproduce the strength and durability of plastics without the environmental consequences. Today, over 300 million tonnes of plastic waste are produced every year, with around 10 million tonnes ending up in the oceans. This is expected to increase by 60% in the next nine years, having detrimental effects on over 800 marine and coastal species, at risk of both ingestion and entanglement. I think it is safe to say that this plastic waste problem needs to be addressed.

Olefin Metathesis

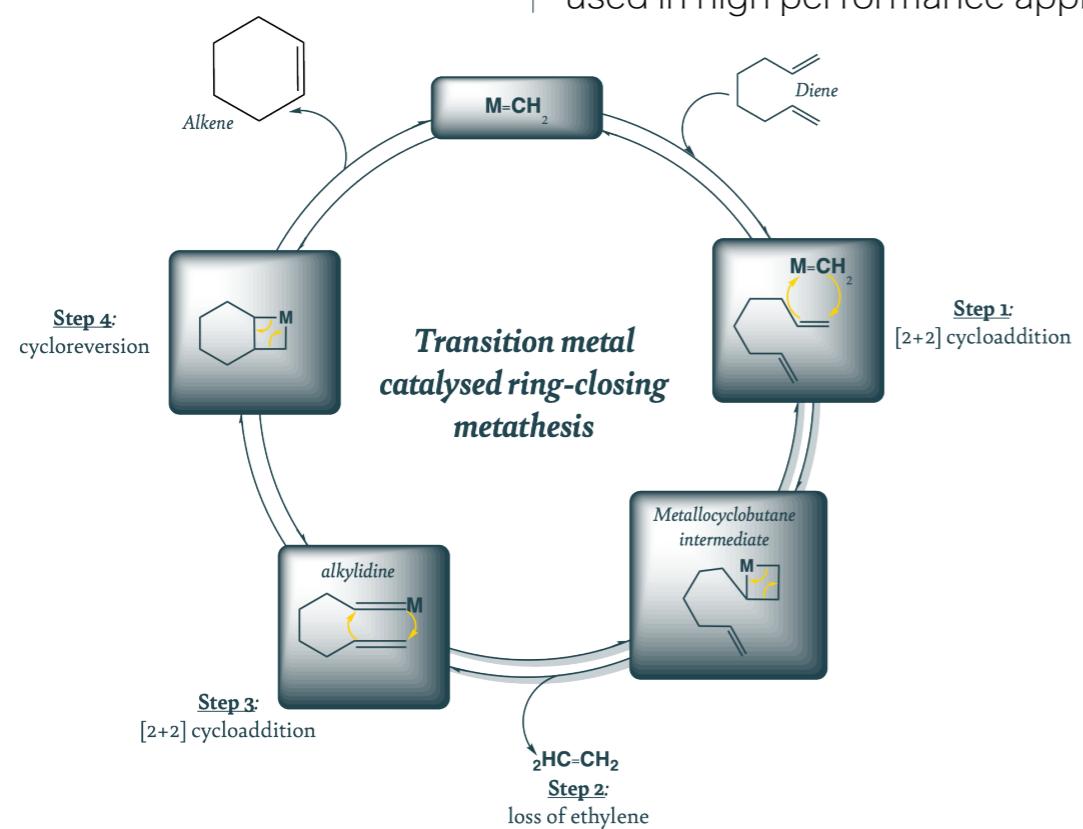
One of the main avenues by which chemists are trying to solve the plastic problem is by using specific synthetic routes that enable the reconfiguration of already-made plastics into improved, recyclable ones. One of these methods is the well understood synthetic route of olefin metathesis. A common subject taught in undergraduate chemistry degrees, olefin or alkene metathesis is a synthetic pathway developed by the Nobel laureates Grubbs, Schrock and Chauvin. The pathway utilises the chemistry of alkenes and a specific catalyst known as the 'Grubbs catalyst', which has a ruthenium metal centre and plays a vital role in the transfer of electrons during this reaction. There are many different types of olefin metathesis reaction, however the ones we will focus on in this article will be ring opening metathesis polymerization (ROMP) and ring closing metathesis (RCM).

Ring Opening Metathesis Polymerization (ROMP)

The ROMP synthetic route has three key stages: initiation, propagation, and termination. During the initiation phase, the cyclic olefin (alkene) coordinates to the metal centre through the alkene bond. At this point, a new complex is formed between the cyclic olefin and the metal centre in breaking the carbon-carbon double bond of the cyclic compound. The electrons within this new complex shift, causing the carbon-carbon bond in the original olefin to break. This generates a straight chain where the propagation step then begins. In this step of the reaction, similar pathways to the initiation phase take place with other cyclic olefins in the reaction mixture, generating a long hydrocarbon chain. To terminate this process, an additional alkene can be added that will undergo an initiation reaction, but in doing so will block any further polymerisation occurring.

Ring Closing Metathesis (RCM)

The RCM synthetic route follows a similar mechanism in that it is cyclical in nature (**Scheme 1**), enabling the reaction to proceed many times. In this mechanism the metal catalyst is complexed to only one of the alkene functional groups present on the now polymeric structure. The metal centre is then able to insert itself onto this double bond, almost forming a kind of secondary Grubbs's catalyst within the polymer itself. From here, a similar step to the initiation process found in the ROMP mechanism occurs, with the coordination of a second alkene functional group occurring, followed by electron transfer resulting in the final ring closure.



Scheme 1. General Mechanism for RCM

So How Is This Making Greener Polymers?

The synthetic strategies described previously have recently been applied to produce polymers that are able to not only polymerise into useful materials, but also able to depolymerise back into their constituent monomers to be recycled into new plastics in the future. Now you may be wondering, is that not what already happens at a recycling plant? And you would be correct, it is. However, with the current methods of recycling, the plastics produced tend to lack in quality and therefore may not be useful in the applications they once were. This method combats this problem by producing plastic that, once recycled, maintains a good thermal stability and mechanical function, thus keeping their original properties and so can continue to be used in high performance applications.

The work done by Sathe et al. (2021) showed that the use of poly(cyclooctenes) with a fused ring at the -5 and -6 positions allowed the molecules to overcome their problems of high ring strain values and gain a ring strain similar to that of the polymerizable and depolymerizable molecule cyclopentene. This allows for not only the enthalpically favourable but entropically disfavoured process of polymerization, but also the entropically favoured and enthalpically disfavoured process of depolymerization, which is normally constrained due to high ring strain values present in the constituent monomers. Both of these processes (ROMP and RCM) can also be stopped by simply adding or removing the organometallic catalyst, meaning that if we were to create a polymer and then remove the catalyst, no depolymerization would occur, placing the polymer in a so called 'kinetic trap' and thus remaining in its polymeric state with high performance properties.

So Could This Be The Future of Plastic Production?

Overall, this research is certainly a big step in the right direction for sustainable plastic production, that allows for the maintenance of high-quality materials to be used unlike in the current methods of recycling. This is an issue that desperately needs to be tackled by scientists all over the globe in order to maintain the oceanic ecosystems and even help them to prosper once more. I am excited to see what research is done off the back of this article and look forward to seeing what the future of sustainable polymer science has in store for us.



The powers of chromatography in **DOPING CONTROL**

FEATURING DR SHOBHA AHI



DR SHOBHA AHI

Senior Research Fellow and
Drug Control Center Deputy
Director.

Performance enhancement has featured in sports since ancient times. Almost yearly, doping scandals shake athletes and fans alike. From an outsider's perspective, the process of doping control, spanning everything from receiving a urine or blood sample to reporting a violation of anti-doping rules, seems relatively straightforward. Nonetheless, a lot of brainpower goes into developing the process of analysis that the athletes' samples go through.

Authors: Sofia Schönauer

Generally, urine samples are homogeneous mixtures containing many different substances, including water, urea, salt, and other electrolytes. The presence of other chemicals depends on a person's diet, medication or supplements taken. For athletes, samples are analyzed at one of 29 laboratories worldwide, accredited by the World Anti-Doping Agency (WADA). WADA has a list of over 350 prohibited substances and methods in sports – updated every year – that samples are screened for. Doping control relies on the separation and identification of all of the substances present in a sample, as per the WADA prohibited list, whether they might be metabolites of a performance-enhancing drug, or the confounding factors which can affect the results. To ensure reliability, repeatability and clean separations, different screening methods have been developed for each of the substances on the list.

Chromatography is the key component to these separations. Gas chromatography, coupled with a mass spectrometry detection, is one of the most common analysis techniques, although it includes the risk of possible decomposition at high temperatures, leading to difficulties in the detection of prohibited substances, especially at low concentrations. Liquid chromatography proves to be a promising technique for the separation of more polar, volatile and thermolabile banned substances using simple sample clean-ups. Dr Shobha Ahi, a Senior Research Fellow and Deputy Director at King's College London's Drug Control Centre, provides us with an insight into some challenges in her complex yet highly interesting and crucial line of work.



Testosterone, a hormone more prominent in male athletes after puberty, is strongly correlated to increasing muscle mass and strength if abused in sports. Synthetic testosterone is known as the most abused anabolic androgenic steroid in sports for its ergogenic (physical performance-enhancing) effect on strength. The intake of testosterone and its precursors are prohibited in and out of competition, all year round. It is crucial for anti-doping laboratories to be able to distinguish between the body's own (endogenous) and external (exogenous) testosterone. Dr. Ahi's case study demonstrated the gas chromatography/combustion/isotope ratio mass spectrometer (GC/C/IRMS) technique as a way to distinguish the synthetic anabolic agent by its $^{13}\text{C}/^{12}\text{C}$ ratio, which usually drops due to synthetic testosterone having a smaller carbon-13 content than the endogenous ones. Hence, abuse of synthetic testosterone could be determined by a deviation of the isotope ratio from the international standard for ^{13}C content.

Efficient separation and purification of the urine sample needs to be done first, through High Pressure Liquid Chromatography, to eliminate concerns regarding co-elution and low peak heights of important substances like androsterone and etiocholanolone.

Prednisolone is an immuno-suppressant, which reduces inflammations and is usually only available via prescription. It belongs to the glucocorticoids category and it is prohibited by WADA during competitions, as they only have immediate effects on the athlete, and its use during off-season doesn't impact fair play. Upon intake, prednisolone was shown to elevate blood glucose levels short-term for three hours, raise white body counts and suppress blood lactate levels right after exercise. A correlation with an ergogenic effect was also found as a result of decreased sense of pain.



Prednisolone is metabolized a lot by the body, which is why the parent drug isn't extensively present in the urine sample. The goal Dr Ahi's team set themselves was to determine as many metabolites of this drug as possible, for detection even after longer time periods. Previous issues with low volatility and thermal instability of the compounds in gas chromatography led the researcher to use a high-pressure liquid chromatography/electrospray ionization/tandem mass spectroscopy technique. Ten metabolites were detected, one of them being a long-term metabolite of prednisolone, allowing detection of usage even after a longer time-span.

Urine is the matrix of choice for the detection of prohibited substances in an athlete's sample due to its availability and non-invasive collection technique. However, complexities associated with the urine matrix and its variability based on factors like diet, for example, makes the work of anti-doping scientists especially difficult. The challenge is to keep up their methods with enhanced sensitivity and selectivity for the detection of prohibited substances.

The upcoming methodology of Dried Blood Sample (DBS) testing is based on the transfer of a limited volume of capillary blood onto a filter paper or similar matrix. This is being explored in Dr Ahi's laboratory, to unveil the potential of detecting various prohibited substances in a single drop of blood. The DBS testing in doping control offers a more convenient

and affordable alternative for the collection of samples from athletes. In addition to the benefits of simple sample collection, DBS also facilitates transport and storage conditions, at an overall reduced cost. The chromatographic and mass-spectrometric testing methods based on DBS hold a promising future in anti-doping.

As such, Dr Ahi's field of anti-doping research is ever-evolving, as new performance-enhancing drugs and derivatives keep on emerging during the process of drug discovery. Following the inclusion of a new compound/s on the WADA prohibited list annually, a screening method needs to be developed and validated alongside the over 350 other compounds while keeping up with the turn-around times for reporting samples. This can be especially tricky at huge sporting events, which leaves the Drug Control Centre with upward of 200 samples a day to analyse within a 24-hour turn-around.

Dr Ahi's take on it: "The job of an anti-doping scientist is for a lifetime; there are constantly new things to learn and explore. My quest to knowledge always finds its way because of the ever-improving scientific progress in the field of anti-doping, and that's what I love about my work!" This passion is reflected in Dr Ahi's ongoing research: investigating flagged, suspicious peaks revealing possibly new drugs, finding analysis methods with lower limits of detection and more efficient sample preparation, and giving inspiring talks to aspiring chemists.

Recycling our Emission

Author: Paul Amar

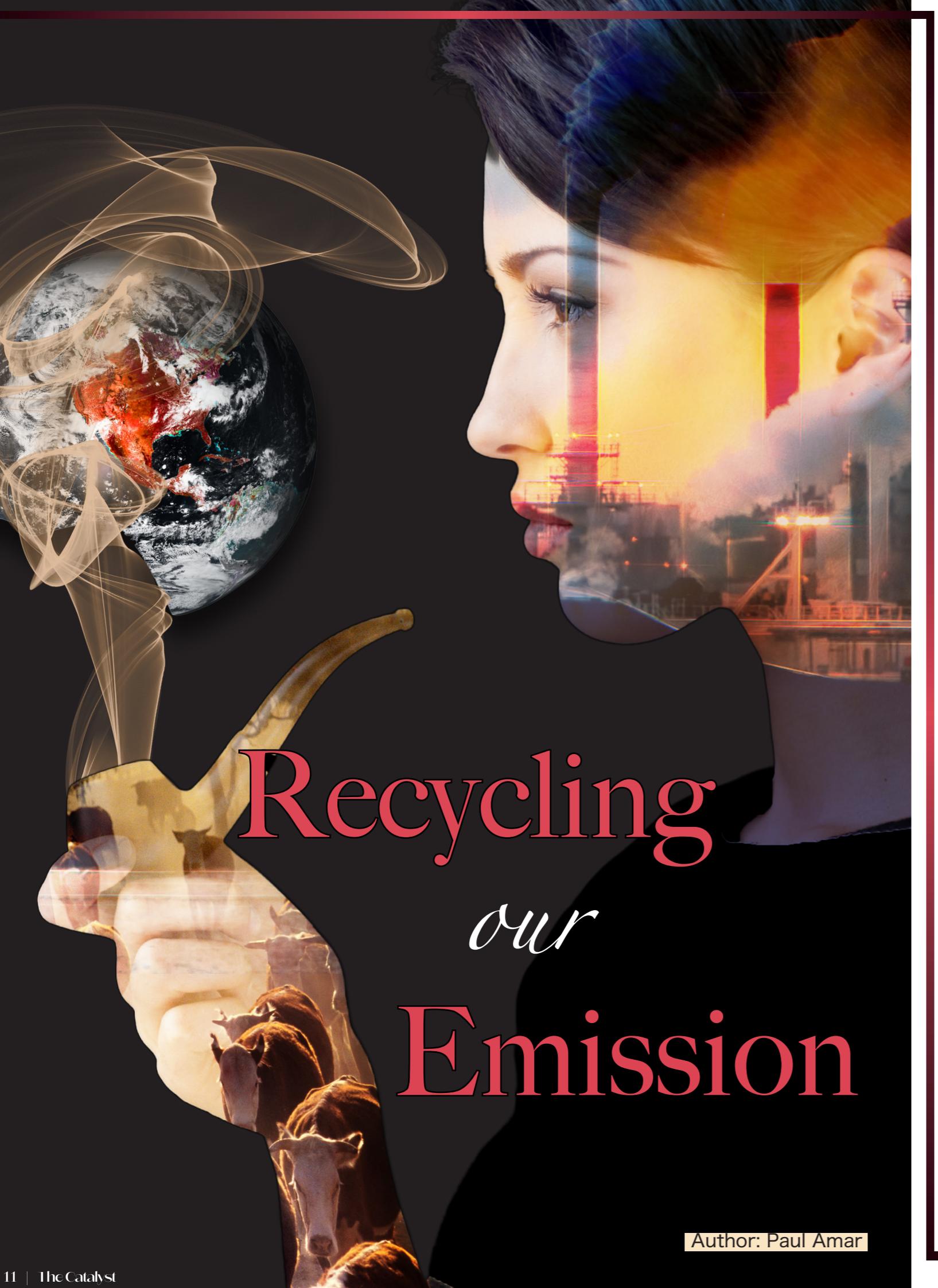


ur planet is slowly burning; and our constant fossil fuel burning society is far from sustainable. CO₂ is highly thermodynamically stable ($\Delta G = -393.5 \text{ kJ/mol}$) and our most prominent greenhouse gas, and we pump it out faster than we can breathe. Its reduction in our atmosphere has hence been a wide area of research recently. Two main methods exist for this, the first is CO₂ capture, in which CO₂ is trapped within a molecular cage which sequesters it from our environment. This method is the subject of many research groups, and a step in the right direction, however, this only removes the gas from our atmosphere. But what if it could also be converted into something more useful such as an organic fuel? This is the approach of the second method: (photo-)electrochemical CO₂ conversion. In this process, an electrochemical cell with a catalyst is used to drive the reduction of carbon dioxide into other species, such as carbon monoxide, formic acid/formate, methane, and even methanol or ethanol, which can then be used for various applications.

This is an ever-growing area of research, with over 2000 papers published a year (2020). It has attracted significant attention due to its potential to be a fully sustainable process, as electricity for the reaction can be acquired from renewable sources, and the supporting electrolytes can be completely reused.

Ideally, the catalyst should also have strong physicochemical stability, stable rate of production over many cycles, high energy efficiency, and have a current density larger than 100 mA/cm². These are the key points to developing a scalable and profitable system. However, there are many obstacles and challenges along the way to developing an ideal catalyst for this reaction.

As mentioned, CO₂ is thermodynamically stable which means a suitable electrocatalyst must be employed to initiate the reaction. Unfortunately, many problems are associated with this. Let us begin by examining the exact process at hand. It all begins in an electrochemical cell, with the adsorption of CO₂ onto the surface of the electrocatalyst coated on the cathode. The reaction then begins by surface-catalysed electro-activation, where either a nucleophilic attack on carbon, or an electrophilic activation of oxygen takes place. This results in the formation of a radical anion CO-intermediate, then continues to react via proton/electron transfer to form one or many of the possible products mentioned above, which then desorbs back into the electrolyte. Already, a problem has appeared: selectivity. As there are multiple possible products from this reaction, depending on the catalyst and electrolyte, selectively producing a single product proves to be a challenging task. This obstacle is due to the very similar potentials of the reactions, and results in poor efficiency of many systems.





If we examine the potentials at which the formation of the products may occur (-0.61 to -0.33V vs SHE pH 7), it may become apparent that within this range lies the potential for another unwanted reaction: the hydrogen evolution reaction (HER), which converts H⁺ to H₂. This leads to even greater issues as not only must the formation of carbon products compete with each other, they must also compete with a side reaction which may be more viable since the reduction of hydrogen only involves a 2 electron-transfer, while certain products require a 12 electron-transfer ((m)ethanol). This is only worsened by the poor solubility of CO₂ in H₂O. An alternative can be to use non-aqueous solutions (although this goes against the goal of sustainability), but also through organic-inorganic hybrid materials which have shown some promise.

This issue is coupled with the necessity of overpotential for the process to even begin. Overpotential is the difference between the theoretical potential needed for reduction to occur, and the experimental result. This means that a surplus of energy is required and its quantity will vary depending on pH, electrolyte composition, CO₂ concentration and the electrode itself. This is a problem, as electrocatalysts are often designed with the theoretical value in mind.

To broach the topic of catalyst design, there exist 2 types of metal catalytic compositions: **homogeneous** and **heterogeneous**. Both are largely based on transition metal complex chemistry, where it is theorised that the d-electrons and vacant orbitals create a pathway to the adsorbed compound. Homogeneous catalysts can be microcyclic organics, often complexed to a metal atom; these provide abundant active sites and greater selectivity, such as metal porphyrinoid systems which are nature mimetic. However, these catalysts have only ever been able to produce carbon monoxide and formic acid to date, which are lower value than other higher energy-storage products such as alcohols or long hydrocarbons. Heterogeneous catalysts have accomplished this, though only with copper complexes so far. This makes copper a very interesting avenue of research, and a landmark review by *Nitopi and al.*

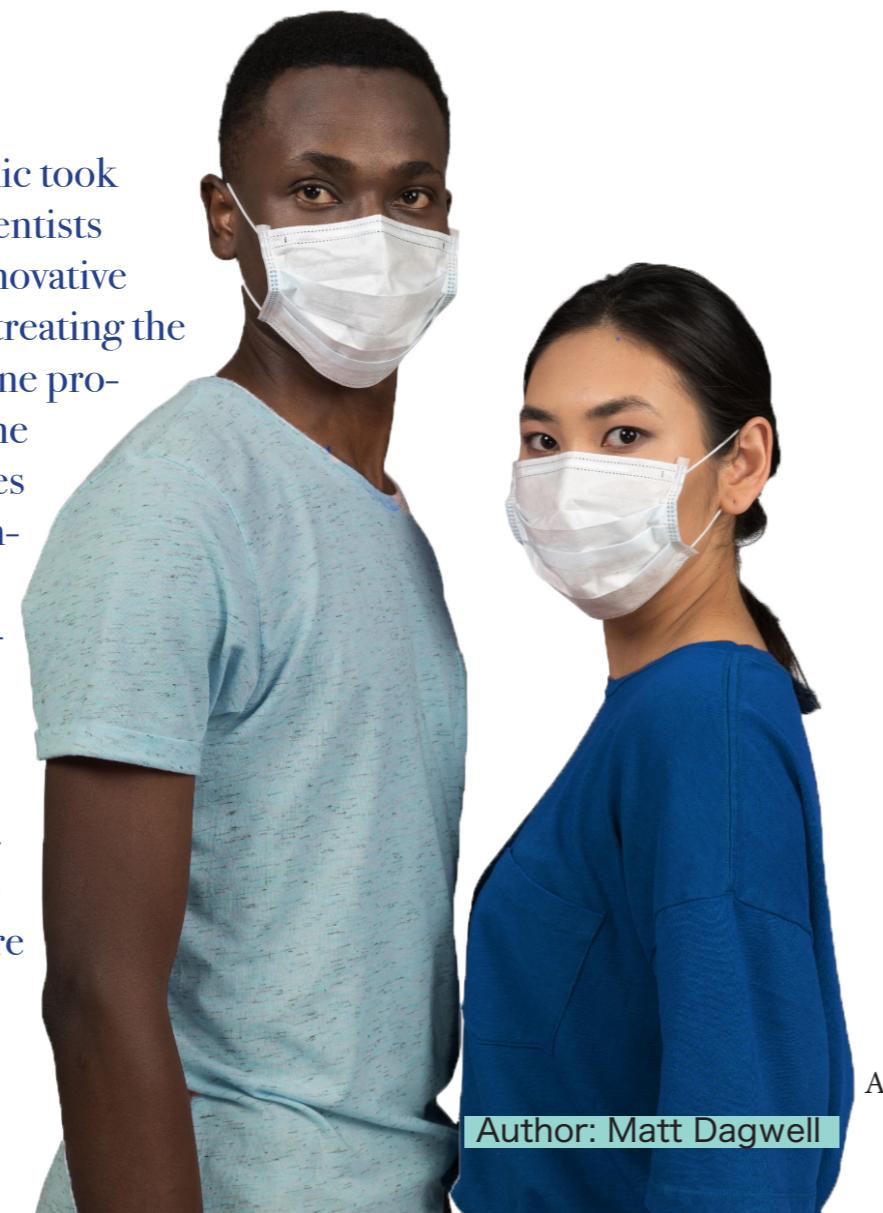
from 2019 explores Cu's fascinating properties in greater depth.

Research has also been performed for metal-free catalysts, in hopes of creating a material from earth-abundant elements. The principal avenue for this are doped, carbon-based materials, such as **N-doped graphene** or **carbon nanotubes**. These are quite promising, and potentially more interesting, providing a truly environmentally friendly solution. A mesoporous N-doped carbon material by *Song et al.* has even been successful in the production of methanol, with 100% selectivity! These also appear to exhibit lower overpotentials and affordable synthesis, making this class of materials potentially scalable once their capabilities have been fine-tuned.

It may be clear by now, that this topic is one with broad depth and potential. I have tried to provide a brief overview of the principles and difficulties associated with CO₂ conversion, but the intricate level of tunability from the composition of the catalyst, over reaction conditions, to reaction pathways could each produce a review on its own, and they have! This is a crucial area of research - one that will only become ever increasingly necessary as our planet tries to cool down. Yet researchers in this field face many challenges ahead of them to recycle our emissions.

Is MOLNUPIRAVIR the next COVID-19 treatment?

Since the coronavirus pandemic took hold of the world in 2020, scientists have been researching new innovative techniques of preventing and treating the disease. Despite current vaccine programmes being rolled out in the majority of developed countries (which has successfully prevented a big proportion of hospitalisations), the disease has inflicted over 4.5 million deaths globally. Thus, the ability to successfully treat COVID-19 patients is still particularly important; it is an ongoing battle that scientists and clinicians are still trying to fight.



Author: Matt Dagwell

Many routes of treatment have been trialled to help save patients from the respiratory disease; with antibiotics being used to prevent secondary infections, ventilators to aid breathing, and other techniques such as proning. One of the primary medicinal routes in treating COVID-19 is the use of anti-viral drugs, which directly target the virus and prevent patients from getting severely unwell. At present, one of the main antiviral drugs used for treatment is Remdesivir (see Figure 1) - originally used to treat Hepatitis C and Ebola. Remdesivir is the only antiviral drug approved by the FDA to treat severe infections caused by COVID-19. However, it is not without flaws; it is expensive to develop and can only be administered intravenously in a hospital setting, both of which make the delivery of Remdesivir difficult amidst a pandemic. Not to mention that some studies have failed to show that it offers any benefit to infected patients, thus additional antiviral drugs are needed to aid in the treatment of the pandemic-inducing virus.

One of the most promising antiviral drugs currently in phase 2 clinical trials is Molnupiravir. With a name sounding like a dragon, it may just be our best bet to help treat COVID-19 at this time.

Developed by the American pharmaceutical company Merck, it is currently showing promising results in phase 2a clinical trials. In the trials conducted, 204 participants who met the criteria of being aged 18+ and had tested positive within 96 hours of symptoms, were either given Molnupi-



ravir or a placebo within 7 days of treatment initiation. The study found that in the original nasopharyngeal swabs, 43.5% had the COVID-19 virus present. After 3 days and dosages of 800mg of Molnupiravir, this dropped to 1.9%. The decrease with participants who received the placebo only reached 16.7%. On day 5, these values dropped even further to 0% for the groups receiving 400mg and 800mg doses of the antiviral drug compared to 11.1% receiving the placebo. Administration of the 800mg dose meant that 92.3% of participants tested negative at the end of the trial, compared to 80.3% in the placebo group.

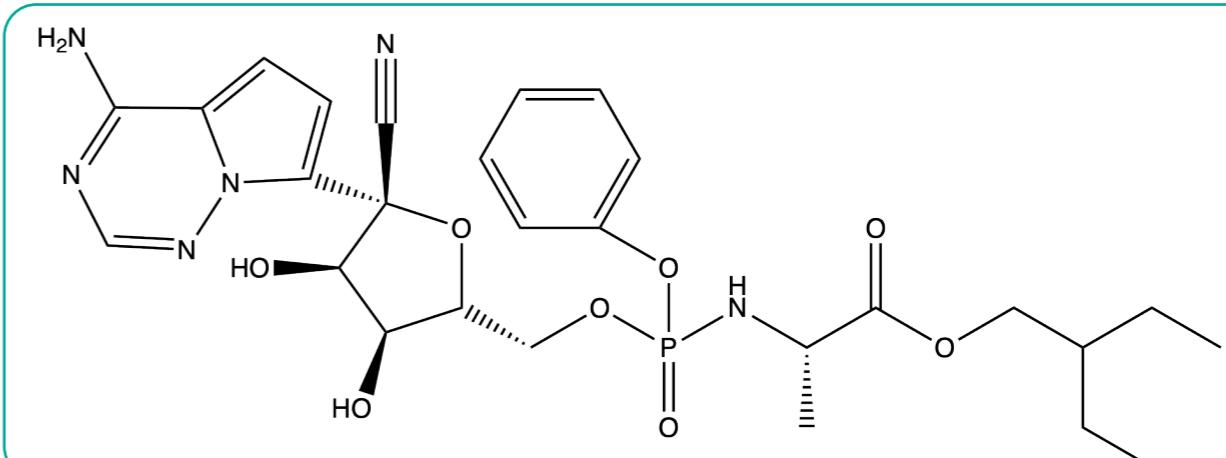


Figure 1. Structure of Remdesivir

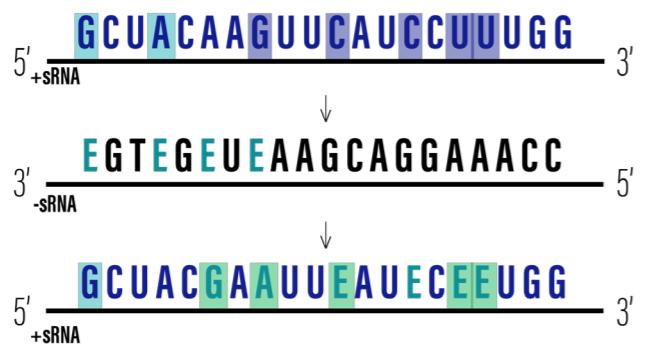


Figure 2. Mechanism of lethal mutagenesis of Molnupiravir in terms of sRNA strands.

The data seems promising for Molnupiravir, but how does it achieve such good results? The exact mechanism as to how this antiviral drug functions is debated. There are two theories currently being proposed by two research groups (Gordon et al. and Kabbinger et al.) - both are fairly similar in their approaches. Both hypotheses use the mechanism of "lethal mutagenesis" on the COVID-19 genome, which causes an error catastrophe within the virus replication cycle. During this process, Molnupiravir is derivatised from the ribonucleoside analogue β -d-N4-hydroxycytidine, which is converted into Molnupiravir Triphosphate (MTP). MTP is used to deceive the RNA-dependent RNA polymerase (RdRp), which is used by the coronavirus during viral replication by competing with Cysteine Triphosphate (CTP) nucleosides and Uracil Triphosphate (UTP) nucleosides (proposed by Kabbinger et al.). Or by competing with Guanine Triphosphate (GTP) nucleosides and Adenine Triphosphate (ATP) nucleosides (proposed by Gordon et al.). With every viral replication where a positive sense strand is converted to a negative sense strand, MTP is incorporated instead of one of these nucleosides. Therefore when the negative

sense strand is copied to generate another positive sense strand, errors are generated. The second positive strand should look like the original strand, but instead random nucleosides are placed within the strand due to the incorporated MTP, causing the virus particles to be ineffective at infecting other host cells, which ultimately decreases the viral load and helps treat a COVID-19 infection.

In conclusion, Molnupiravir seems to be a promising candidate for the treatment of COVID-19. However, further clinical trials will give us more information as to how promising or not this drug may be. But for now, current research is suggesting it could be the future for antivirals against this disease;

But for now, current research is suggesting it could be the future for antivirals against this disease

with minimal adverse effects in patients, a high efficacy and easy oral administration - it holds the potential to save numerous lives worldwide.

Have you heard of our ongoing collaboration with the *Chemistry Seminar Series* at King's College London?

Organised by Dr Reading, Dr McTernan and Dr Muller, the university hosts a broad range of chemistry talks twice a month.

Head over to our last edition featuring a cutting-edge interview with Dr Dodani!

Talk with Experts

Dr. Sheel Dodani
Assistant Professor at The University of Texas at Dallas

Author: Paul Amar

Interview
WITH DR SHEEL DODANI

OFF THE MED

The Catalyst, in association with the KCL Chemistry Department Seminar Series 2021/2 is delighted to present the first of an ongoing series of Talks with Experts. In this series we sit down with researchers working on the front lines of scientific advancement to delve deeper into their cutting-edge research and gain insight into how they have successfully attained the distinguished positions they hold today. Now, grab a chair and join us on a journey through today's technology and incredible research.

We've all once added NaCl (table salt) to our food to make it taste better, but did you know that there are approximately 115 g of chloride (Cl) in your body? Biological receptors that selectively detect and position sodium (chloride's cationic counterpart) have been extensively studied in cell biology. However, anions such as Cl⁻ are scarcely understood, despite also serving as essential nutrients for life. Dr. Dodani's interest lies in understanding "the who, what, when, where, and why of what anions are doing in living cells." This has wide therapeutic implications because dysregulation of anions is implicated in a plethora of diseases from cystic fibrosis to neurological disorders. To address this and "accelerate biological insights with molecular technologies", the work of Dr. Sheel Dodani is crucial.

Dr. Dodani is an Assistant Professor at The University of Texas at Dallas (UT Dallas), where in addition to teaching various (bio)chemistry courses, she leads the Dodani Lab. Her highly skilled research team is focused on building a chemical biology toolkit, based on engineering turn-on, fluorescent protein-based biosensors for halides (specifically chloride) and oxy-anions. These imaging tools would provide spatial and temporal resolution to help us understand the exact role, location, and mechanisms of anions within our body. On a fundamental level, her research aims to shed light on the thermodynamics and kinetics of anion-protein interactions. Crucial work which Dr. Dodani enjoys because "[...] you never know what you will learn. We do not talk about anions

CONTACT LENSES AND POLLUTION GO HAND IN HAND

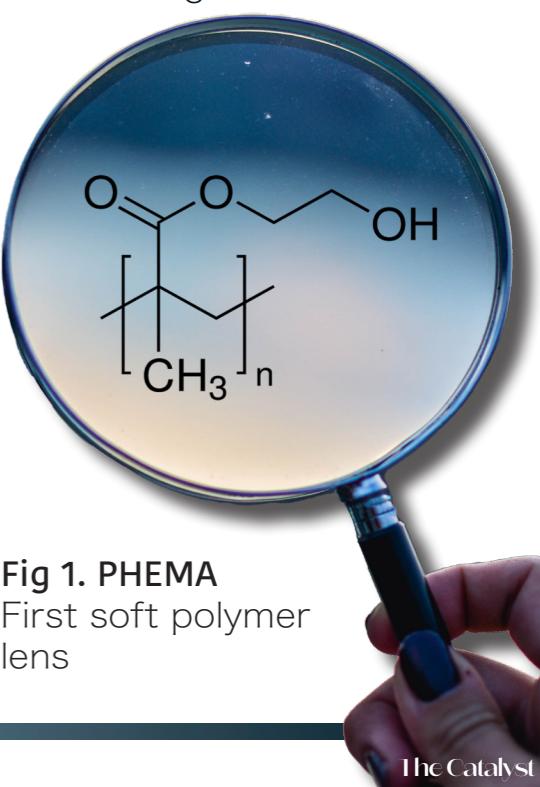
The reality that has been lying right before our eyes

Author: Elena Rubini

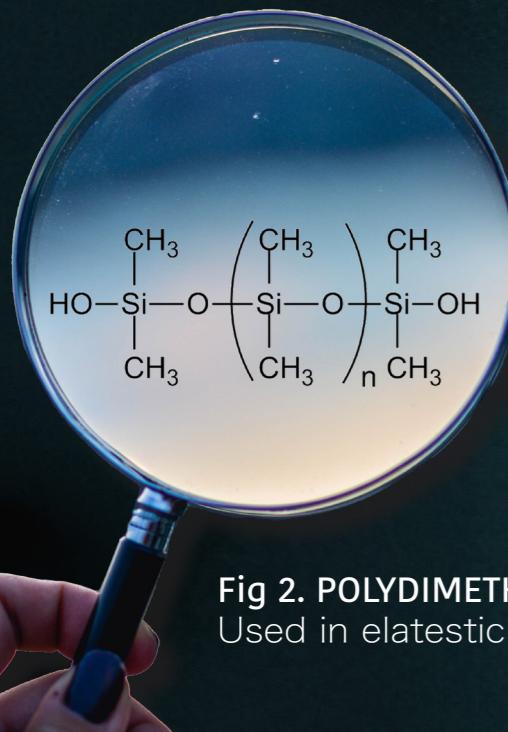
The first notions of contact lenses date back to the 1500s when Leonardo Da Vinci, the influential artist and scientist, discussed the idea of altering what we see through our cornea by submerging our head in a bowl of water or by wearing a water-dense glass surface on our eye. Five centuries later, wearing contact lenses forms part of the daily routine of over 45 million Americans alone. Unfortunately, 15-20% of these lens-wearers dispose of their lenses by simply flushing them down the drain. How this practice contributes to global plastic waste pollution is rarely discussed. A 2018 study conducted by the University of Arizona and presented to the American Chemical Society showed that between 1.8 and 3.4 billion contact lenses are flushed away annually, equivalent to roughly 25 tons of plastic waste. Correcting our habits of how to properly discard our contact lenses requires an understanding of their composition.

Contact lenses are made of gels, and the formation and synthesis of gels stem from the field of supramolecular chemistry. A gel is a solid-like network immersed in a liquid-like medium, where the solid-like network prevents liquid flow. In essence, a gel consists of gelators (molecules that make up the solid-like network), and a solvent (the liquid-like medium). Two main types of gels exist: polymer-based and low-molecular weight gels, commonly known as hydrogels. Hydrogels are highly water-absorbent and are the main components in contact lenses. The gelators are united by non-covalent interactions to form fibrils, fibres and the greater network. Hydrogel formation resembles the building of a spider web: the individual gelators and their intermolecular interactions build fibrils, the fibrils are woven to form thicker fibres and, finally, fibres entangle to form the gel network in the solvent.

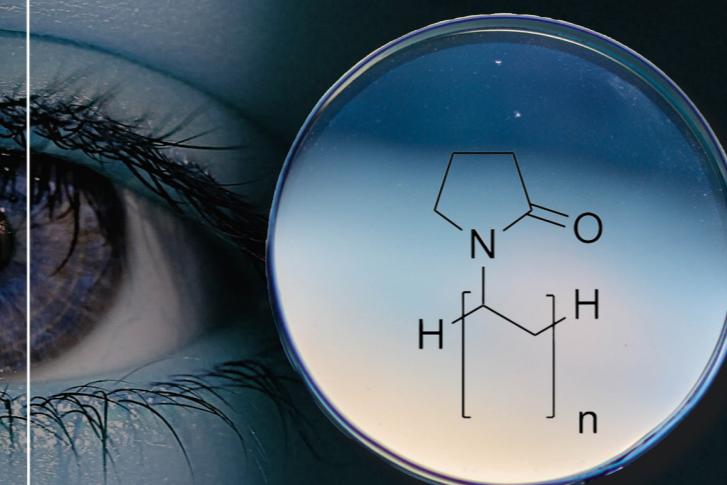
Today, the most commonly used contact lenses are soft hydrogel lenses that were first developed in 1961 by the Czech scientist Otto Wichterle. The hydrogel lenses were made from a polymer known as polyhydroxyethyl methacrylate (PHEMA), which were more comfortable to wear compared to the previously used hard contact lenses, and also had the advantage of being permeable to oxygen. The networks that make the hydrogels are hydrophilic and insoluble, thanks to the oxygen atoms present in the polymer, which form hydrogen bonds with surrounding water molecules. All hydrogels contain a minimum of 10% water by weight and can take up to 1000 times their dry weight. In fact, contact lens wearers will note that, when lenses are removed towards the end of the day and they are no longer in a moist environment, the lenses quickly dry up and become hard and frail as the water molecules evaporate. People who wear reusable weekly or monthly contact lenses will place their lenses into a cleaning solution, such as a peroxide, which allows the lenses to retain their soft, flexible gel characteristic.



Although these first soft gel lenses were substantially more comfortable than previous lenses, potential for improvement existed. New polymers were explored and included in the hydrogel blend to improve the oxygen permeability of the lens. The challenge focussed on developing a lens that could be used for extended periods of time without causing hypoxia in the eye. The cornea is one of the few parts of the body that is not directly served by blood vessels. Oxygen and other essential nutrients are transported through nerve fibres and diffusion from the tear fluid, on the outside, and the aqueous humour (a thick water-rich layer between the lens and the cornea), on the inside. Reduced oxygen supply is the main concern associated with contact lenses. Over the years, thinner and more permeable contact lenses have been developed. The pivotal turning point was the introduction of polysiloxanes (silicons) to optimise the lenses' oxygen-permeability. The polymers containing silicon and oxygen allow the hydrogel lens to have greater oxygen-permeability than water, therefore allowing a longer period of contact lens wearing, whilst keeping the cornea oxygenated.

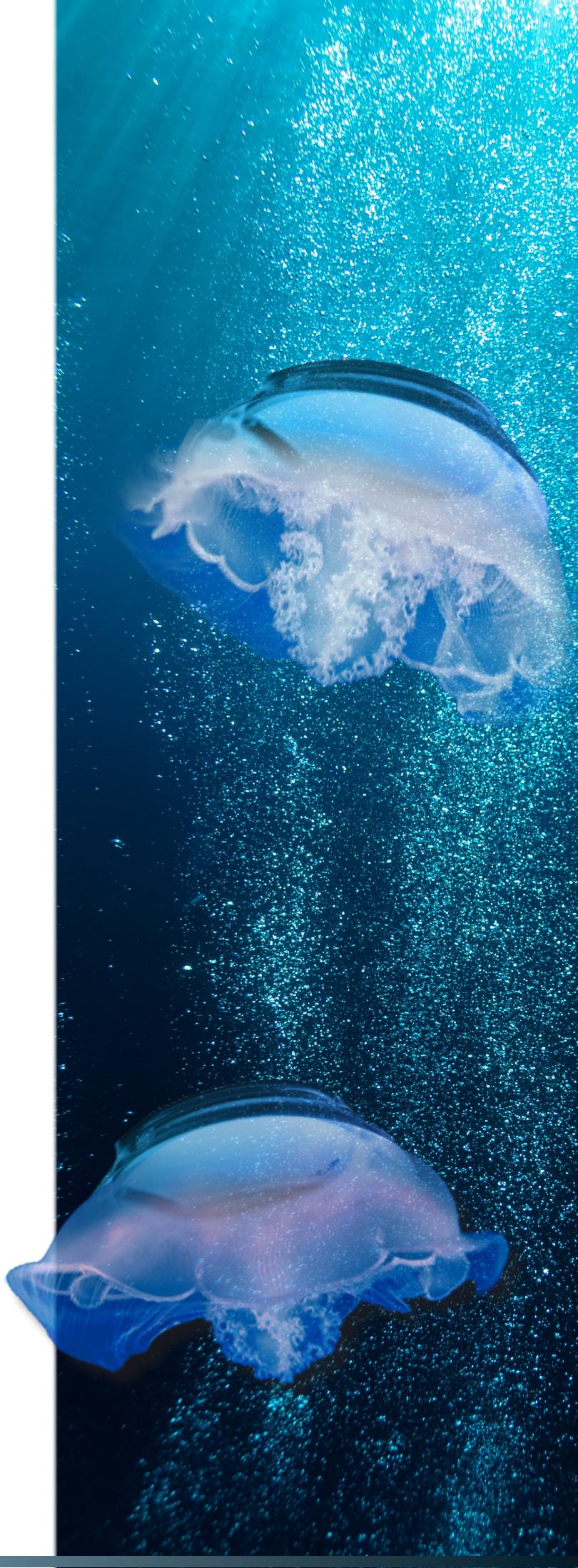


Silicone contact lenses underwent further refinement as silicone is hydrophobic if used in isolation and requires surface treatments to become hydrophilic in nature. The next generation of silicone hydrogel lenses used compounds such as polyvinylpyrrolidone (PVP) and the most recent lenses are made from a slightly modified polymer, created to be hydrophilic from the outset. Soft contact lenses are produced using a process known as injection moulding whereby the hydrogel lens material is heated, placed in a mould and, as the lens dries, it is shaped to fit the eye.



With an understanding now that contact lenses are made from polymers, essentially very strong plastics, we realise that recycling contact lenses is not so simple. Disposing of contact lenses down the drainpipes, where they are exposed to microbes at a sewage treatment plant, prevents the breakdown of the lens components. The contact lenses are only fractured into smaller pieces, which remain vastly present in a combination substance of wastewater and sludge. The sludge is later deposited on land and the fractured lenses can be washed by rain into rivers, lakes and the sea where they are consumed by fish, birds and other animals, ultimately poisoning wildlife and ecosystems. The consumption of contact lenses starts with small lantern fish, for example, and the toxins from the plastics trickle up the food chain to humans.

The lack of biodegradability is the core issue underlying the incorrect disposal of contact lenses, breaking down into smaller and smaller pieces known as microplastics without actually decomposing completely. In recent years, researchers have dedicated time to find a solution to making contact lenses more sustainable and possibly recyclable. There have been attempts to make contact lenses from biodegradable polymers and research is underway using stem cells to create contact lenses for therapeutic reasons, methods that are more eco-friendly. As we have seen, there is a surprising amount of chemistry behind these seamless and transparent lenses that have been lying in front of our eyes for decades. And the ramifications of their disposal begs more research to address the plastic waste crisis.



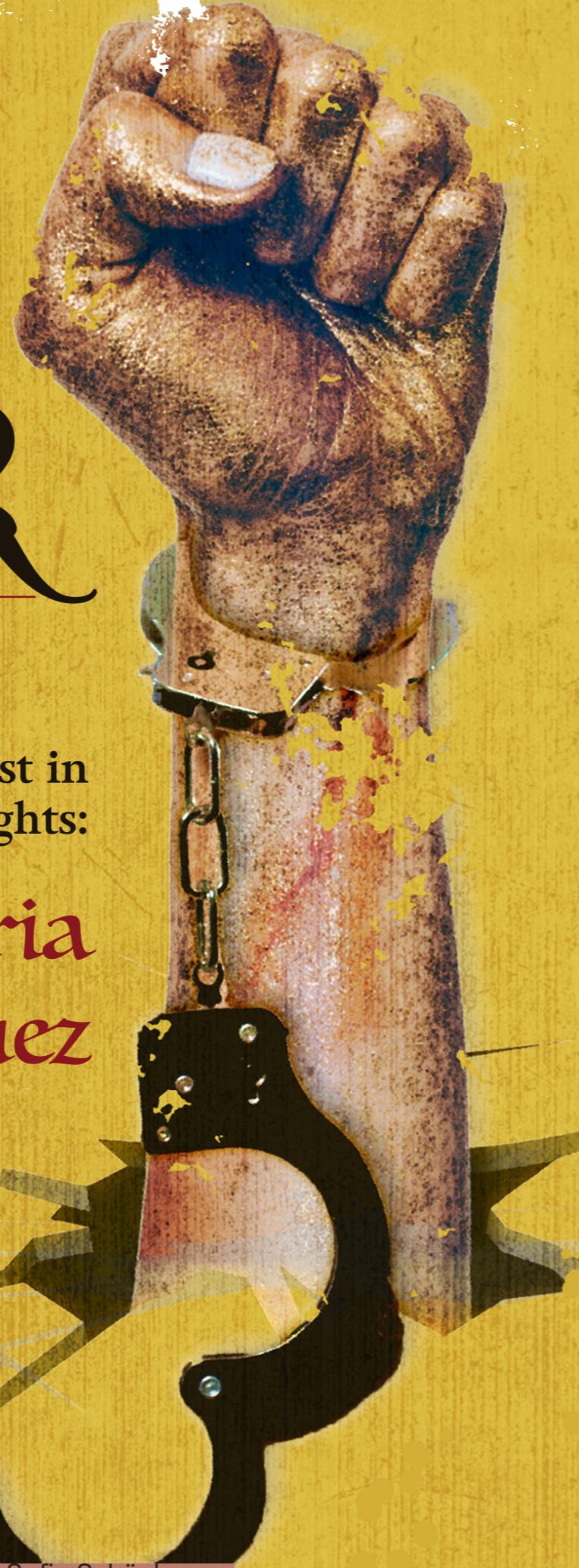
GOLD FEVER

What we do for a little luxury

Interview featuring a specialist in indigenous peoples' rights:

Dr. iur. Gloria
Huamán Rodriguez

Author: Sofia Schönauer



Gold has been an object of human fascination for centuries. Wealth, church decorations, jewelry, technology, medicine; the uses of gold evolved over time, while the exploitation of this precious metal expanded tremendously. From the search for the mystical "El Dorado" to current-day extractions; take a trip through the mining process, environmental impacts and human rights violations involved. The adverse effects presented call for research into a more sustainable mindset when it comes to gold. The process of mining for gold encompasses many steps from discovery to purification. One of the main types of retrieving it is processing ores. A range of methods for doing so were found over the years. For relatively large metallic particles, collection can be done easily through mercury whereas tiny particles, invisible to the human eye, can only be retrieved by a liquid more mobile than the viscous mercury. Other compounds such as antimony and arsenic sulfides can coat gold particles with an insoluble film, making the use of mercury inefficient. An alternative treatment with chlorine could still precipitate gold and filter it off. This treatment had high yields, but included roasting the ore which isn't easy or cheap to do. It also implied that any silver in these ores was lost. Following that, cyanide treatment was introduced to avoid both of these inconveniences.

— The Amalgamation Process



In addition to the many industrial mining companies situated there, a large part of mining in South America, Asia and Africa consists of small-scale (illegal) or artisanal (informal) workings. These rely almost exclusively on the amalgamation process to separate gold from its ore. The contamination of mercury from these types of mines is more extensive than that of industrial mining and other harmful processes combined, hence a more detailed description of everything that can go wrong, follows. Amalgamation is one of the most ancient extraction methods known. The basic principle: ores are milled with water from a nearby river, mercury is added to form amalgamate with gold, dense amalgam is separated easily from crushed rocks, and mercury is burnt off to give alluvial gold. This method of mining is widely used because of mercury's low cost and decent availability. The metal acts as solvent to other metals due to its unique properties. The full 6s, 4f and 5d orbitals result in a very stable electron configuration, meaning that ionization is disfavored. This results in weak metal-metal bonds, making mercury the only liquid metal at standard conditions, readily forming alloys –called amalgams – with other metals such as gold. After amalgamation, alluvial gold goes through purification to remove its traces of platinum, silver, copper and minerals (usually by means of electro-deposition), and lastly is refined to give 100% pure gold.

Mercury's Escape

In illegal and informal mines insufficient safety measures lead to the release of over 1000 tons of mercury every year, affecting flora, fauna and peoples around. There are two main sources: tailings and vaporization. Tailings are crushed sediments and water that are usually just released after the mercury extracts the gold from within. As this mechanical mixing is done in trommels – rotating sieves – mercury is finely dispersed as tiny droplets, called mercury flour. After separating the amalgam, some mines make an effort to recycle excess mercury for the next amalgamation process. However, not all of the mercury can be separated off due to dispersion into small entities, and is instead disposed of as part of the tailings, often back into the nearby river. The mercury flour can be carried several hundred kilometers along those rivers, reaching and contaminating areas far from the mine. More advanced processing takes the tailings and washes them in aqueous sodium cyanide to extract any unrecovered gold as aqueous dicyanoaurate(I) $\text{[Au(CN)}_2^-\text{]}$. This can then be separated from the rest of the sediments (which once again end up in surrounding water sources), and precipitated by zinc or bound to activated charcoal. Unfortunately, the addition of cyanide can also form water-soluble, extremely toxic complexes with mercury, which are released alongside the waste products, mobilized quickly and spread widely through aquatic systems. During the amalgam roasting,

mercury is usually vaporized off by means of a handheld blowtorch. The vapors are usually not recovered, or at least contained and disposed of correctly, resulting in gaseous mercury release into the surroundings.

Other techniques see mercury applied directly in mining tunnels or onto separating sediments in streams of water (called panning or sluicing for the use of sieves or platforms respectively). This even more direct exposure to nature, aquatic environments and miners alike, poses even bigger threats than the already harmful use described earlier.

And is Cyanide any Better?

Cyanide is the predominant processing method of choice for larger-scale mines nowadays, not necessarily excluding the amalgamation step before. The reaction with gold is as follows: $4 \text{ Au} + 8 \text{ KCN} + \text{O}_2 + 2 \text{ H}_2\text{O} \rightarrow 4 \text{ KAuCN}_2 + 4 \text{ KOH}$ and has the best reaction conditions when passing bromine and air through the cyanide solution. The gold can then be recovered through adsorption on activated carbon, cementation or electro-deposition by means of zinc, which replaces it as follows: $2 \text{ KAuCN}_2 + \text{Zn} \rightarrow 2\text{Au} + \text{K}_2\text{ZnCN}_4$. Cyanide-heavy tailings can also cause a lot of harm upon release, although in different proportions. Its high reactivity causes it to degrade quickly and form more or less stable salts in the environment.

How does this Affect the Environment and the People?

The large amount of illegal mining taking place across ecosystems such as the Amazon rainforest causes deforestation in huge areas as mines are very intrusive to the soil's infrastructure. Contamination of water and soil accumulates in plants, crops and fish alike. Mercury can be methylated by certain bacteria too, which can lead to bioaccumulation of even more toxic methylmercury up the food chain. The danger from this compound comes from its high volatility, alongside its ability of crossing the blood-brain and placental barriers, which isn't possible for all compounds. The biggest impact of these contaminations falls on local communities dependent on water sources and fundamental nutrients, such as the aforementioned plants, crops and fish. The unregulated release of waste mercury into the environment affects every aspect of these peoples' life, from their drinking water over food safety, to a general loss of biodiversity and destruction of territory. Mercury can cause all kinds of damage in our systems, ranging from physical health issues to impaired cognitive function. Many of the informal mines employ native people under inhumane working conditions and less than living wage pay grade. Much of the processing is done by hand: isolating amalgam from the tailings, joining amalgam extractions to a ball containing up to 80% of mercury, and distilling amalgam. The lack of protective equipment or recovery strategies from the mining company causes workers

to directly breathe in these vapors, which harms lungs, nervous system, kidneys and liver alike. Even in the rare case of appropriate safety measures being in place, miners still have a hundred-fold higher exposure than what the World Health Organization deems a dangerous amount. The high contamination levels of foods and water also have a strong impact on early development stages of children, starting in the womb. This early-onset exposure is seen to cause neurological damages, physical deformations and a decreased IQ in kids growing up in areas plagued by the gold fever.

Cyanide is not much better with regards to its effect on aquatic and human life. It's toxic to many fish species at low concentrations, with a lower limit of 20 micrograms per liter of water that will kill most of them at increasing speed as concentration rises. To humans, the direct inhalation but also ingestion of cyanide salts formed upon its degradation, can become lethal at 270 ppm or 200 milligram respectively. Acute poisoning affects miners and non-miners alike, with breathing difficulties, seizures and cardiac arrest being possible within minutes of exposure. This has led to major shut-downs



of potable water sources in huge spillages, affecting several countries along the same contaminated river. Nonetheless, chronic cyanide exposure of much smaller levels also causes some nondescript symptoms such as headaches, vertigo, irregular heart rate, and finally coma and death. Populations living around mines and along their water sources are more likely affected by these symptoms, which are no less dangerous than those caused by major spills with more media attention.

A Humanitarian Crisis

In an interview with human rights expert Dr. iur. Gloria Huamán Rodríguez, specialized in indigenous peoples' rights, we get an insight on the current, problematic situation of mining. Whether it comes to illegal, artisanal or legal mining, pollution stems from all of them. The biggest sector unfortunately is trans-national companies that still receive mining permission easily, by an "irresponsible government" that allows them to "exploit all the gold on indigenous peoples' territories without their consent".

In reference to her home country Peru, she states: "The gold fever hasn't changed, despite almost 500 years of Spaniard invasion." And it still happens at the expense of indigenous peoples, all across the world at that. The contamination of drinking water in communities is still one of the biggest problems, forcing natives out of their territory and into bigger cities, eradicating their culture, their language, their traditions.

Dr. Huamán further elaborates on the greater picture: "We cannot talk about climate change without talking about precious metal exploitation, especially in developing countries [...] as the state is preoccupied by getting investment from foreign capital, especially from unregulated gold mining." The destruction of territories of indigenous peoples, especially in developing countries, shouldn't be taken lightly. The lack of state-control, appropriate safety measures and responsibility affects all of humanity. Usually situated at "vulnerable locations such as river springs", the transport of heavy metals and toxic cyanide (among others) from mines down the streams inevitably leads to open sea. They can be swept anywhere, affecting sea life, and following suit human life, regardless of where the chemicals originated from.

This is partially due to the increase in small-scale mines that have been opening due to a gold rush comparable to the search for El Dorado. This has especially boomed during the COVID-19 pandemic, as drug cartels throughout the Americas have changed business due to higher profits available from illegal gold mining. "One way of raising awareness", suggests Dr. Huamán, "is through fame and youth, appealing to the conscience of celebrities, to get them thinking about where their sports medals, awards, clothes and jewelry come from, and what suffering happens as a consequence." Following the likes of Emma Watson and Meghan Markle when it comes to sustainable, ethical jewelry and clothing, future generations can develop a "greener" mindset, questioning some of our consumerist behaviors. The lawyer sees this change in consciousness, especially regarding our behavior as irresponsible consumers, as the key to improving everyone's quality of living. The excessive demand for gold from industrial countries for food decorations, solid gold toilets, etc. needs to stop.

A more sustainable, recycling-based precious metal market should also be established, and legislations need to be passed to eliminate this type of pollution alongside illegal mining. A framework designed by the EU exists, calling for recycling rather than extracting more gold, and that tailings mustn't have more than 10 ppm of cyanide, and aren't allowed to be disposed of in ground water. There are calls for a complete cyanide leaching ban, but to no avail yet. Nonetheless a similar legislative, ensued by an international treaty, could be the starting point for a global initiative.



Other known methods can still be used too, including panning, sluicing, gravity separation or similar mechanical separation techniques, which can then be combined with direct smelting to give gold without the use of mercury or cyanide. This has less potential for mass production, although that is not necessarily bad in this case. There are many other techniques that can and have been considered as non-toxic alternatives for gold mining, such as thiosulphate or the Haber Gold process, but these haven't reached the large scale and cost-efficiency to be able to replace either of the two main toxic methods applied nowadays. Some of the reasons behind this are thiosulphate's limited recyclability and high cost of detoxifying it.

What can be said without question, is that centuries of exploitation and human rights violations deserve attention and dedication from everyone, for the sake of humanity and our planet.

N.B. : The interviewee is an author and researcher; she has published several books about indigenous peoples' rights, and the exploitation of natural resources in ancestral territories. Her next book is "Pueblos Indígenas de Perú: Los Invisibles de la República" (Indigenous Peoples of Peru: The Republic's Invisibles). She is also the writer's relative.



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The Chemistry of Soil and Taste

Does chemistry have a last imprint on the food we grow?

Terroir is a term commonly used to describe the unique character of where a crop, particularly wine, is grown. Terroir is not limited to the soil and its chemistry, but also includes the location, the climate, and the way a crop is maintained such as pruning and soil maintenance. These factors influence the ripening of the crop and consequently affect its aroma. This means grapes grown in vineyards cannot be copied at another location. It is however difficult to identify single contributions of an individual aspect of terroir, in this case the soil, to the taste of the final product. Nevertheless, there are several clear characteristics of the soil that influence the quality of a crop.

Author: Louis Weiss

To what extent does the terroir affect the taste of crops?

The extent to which a grape vine can grow and absorb nutrients depends on the pH of the soil and the amount of organic material present. The pH determines how easily **minerals** are absorbed, the minerals being the essential elements organisms cannot live without, including phosphates, nitrates, calcium, magnesium, potassium, sodium, and other trace elements. A neutral or slightly basic soil allows for easy absorption of these nutrients. Clay and organic matter in a richer soil determine the concentration of dissolved cations such as Ca^{2+} , Mg^{2+} , K^+ , and Na^+ in the soil moisture. Poor sand and rock soils do not have this **cation exchange** between soil and soil moisture; plants in these environments almost entirely depend on humus, a soil component formed by the decomposition of animal or vegetable matter. Microorganisms break down humus into inorganic minerals in a process called **mineralisation**.

Any external influence on a plant (in this case grape vines), both biotic (fauna, bacteria, fungi, etc) and abiotic (differences in temperature, drought, sunlight, soil composition, etc) ones cause stress. Vines will adapt in response to these **stressors**. The adjustments in the vine, as a result of these various influences of the terroir, take place at the level of the DNA.

Genes are strands of DNA that code for a particular protein and can be activated or deactivated under the influence of a stressor. This is achieved by

removing or attaching **methyl groups** on the DNA through a methylation process. Methyl groups can block access to a specific gene so that it cannot be used and therefore cannot be translated into an active protein, as illustrated in Figure 1. About **5%** of all genes in grapevine DNA are altered by the influence of the terroir. Most of these genes code for transcription factors, meaning they facilitate the production of other proteins, and it can have a huge effect on the molecular processes in the grapevine. In the Barossa Valley, South Australia, the methyl groups on the DNA of Shiraz vines in 22 different vineyards were studied. Grouping the vineyards based on their location was possible by using their DNA methylation and it was found that approximately **24%** of the variation in methylation was dependent on the latitude of the vineyard. Furthermore, the height of the vineyard influenced the placement of the methyl groups on the DNA of the vines.



Figure 1. Methylation of DNA. The methyl groups, represented by the red pentagons, prevent the genes coloured in red from being translated.

So the terroir affects the DNA of the vines, but does this then affect the aromas of the wine? Yes, a gene must be accessible to be read by the mechanisms that produce proteins. The gene expression (the extent to which the codes are read to produce proteins) has a direct link with terroir-specific aromas in the wine. The genes that regulate the production of abscisic acid are very sensitive to the influences of the terroir. Abscisic acid is a hormone that regulates the growth and development of vines, as well as the response of the vine to stressors including physical damage, bacteria, and changes in temperature. By doing so, abscisic acid affects the abundance of flavonoids (a class of aromatic ketones that are associated with bitter tasting vegetation) that exist in the grape. The effects of the terroir on the regulation of abscisic acid therefore have a direct effect on the aromas of the wine.

How can crops be traced back to their origins from this?

Plants passively take up trace elements present in the soil which do not decay and so become characteristic of a soil type. Therefore, the abundance of trace elements allows a crop to be traced to its original source; this was studied by Ecologist Jim Ehleringer of the University of Utah in Salt Lake City. Ehleringer measured the concentration ratios of 40 trace elements in 50 samples of roasted arabica coffee beans from 21 countries; roasted because different temperatures can affect the concentrations of individual elements and the ratio of trace elements remains constant after roasting. It was reported that coffee beans from different regions can have distinct chemical fingerprints, determined by geology. For example, three samples of coffee beans from Yemen had a ratio of boron to manganese that

This pattern can also be seen in grape vines and peanuts. Elemental analysis techniques have even been used by coffee farmers to support a class action lawsuit against retailers who falsely market their coffee when the beans were grown elsewhere. However, these techniques do not suggest that geology shapes flavour. Terroir expression can be demonstrated scientifically in wine, indicating that factors including, but not limited to latitude, soil, orientation, pruning me-

thods, and water management have a measurable influence on the aroma profile and the terroir expression of the wine. The terroir is a sum of all these factors, and it is extremely difficult to distinguish a single variable by the taste of wine or aroma of a coffee bean. We can see that the terroir certainly influences the ripening and taste of grapes and coffee beans, but what a scientist can measure is not necessarily something that the average wine drinker can taste.

Analysis of organic compounds in cocoa liquor by country

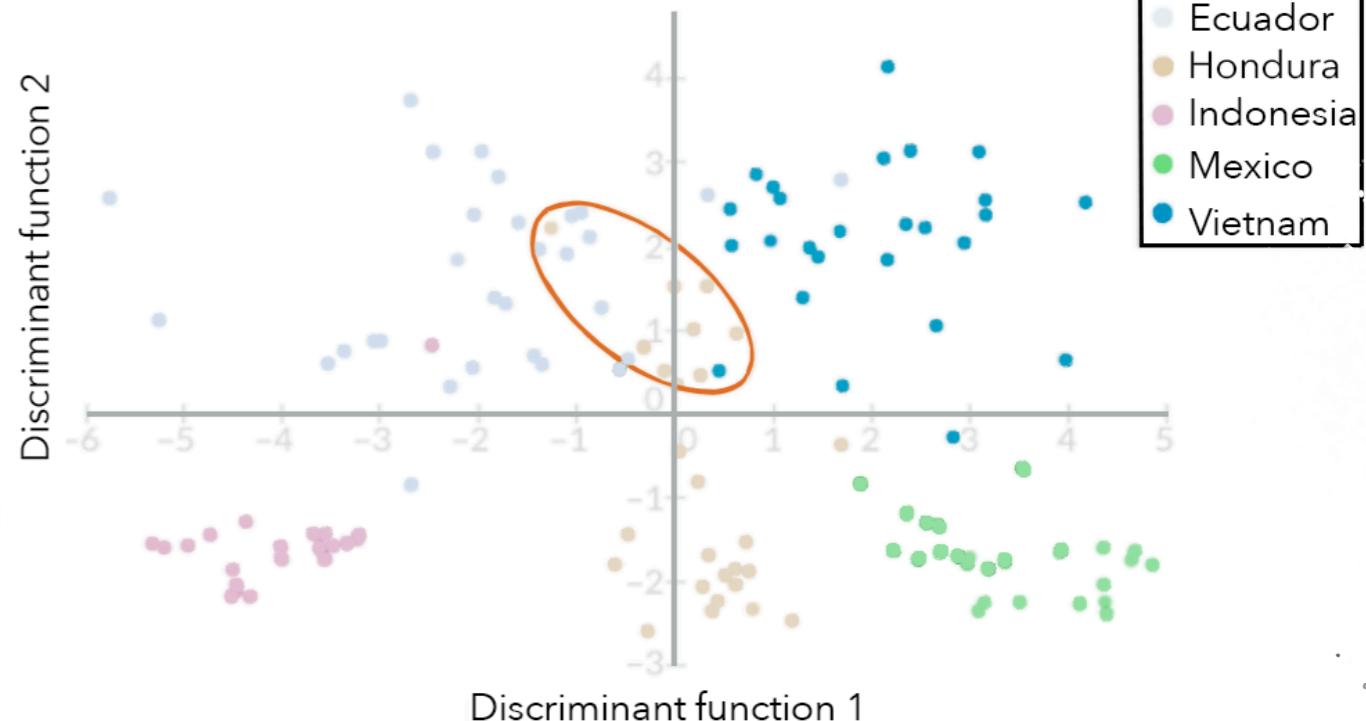


Figure 2. Graph showing the analysis of organic compounds in cocoa liquor by country. Taken from <https://www.sciencenews.org/article/terroir-food-crops-environment-smell-taste>



How is using *green rocket fuel* for the first time

Author: Louis Weiss

The chemistry of rocket fuel can be a very complex field. There are many different formulas: some secret, some privately-owned and all for a wide range of uses. However, the process by which they work on a molecular level is always the same with the objective of producing thrust. This requires the rapid production of a large quantity of gas which expels violently from a rocket nozzle, propelling it along its trajectory. This large quantity of gas must come from a small amount of fuel as the amount of mass that a rocket can usefully carry is limited.

A rocket creates thrust when liquid propellant mass is converted, during combustion, into a huge volume of gas at high temperature and pressure. This is then expelled out of its combustion chamber at high velocity, causing it to accelerate as it obeys Newton's third law of motion (that action and reaction are equal and opposite). Most chemical propellants release energy through redox chemistry, more specifically combustion. As such, both an oxidizing agent and a reducing So how are leading Space Programmes introducing greener fuels into their developments?

Decomposition can also be the source of energy with the presence of a catalyst. In the case of bipropellant liquid rockets, a mixture of a reducing fuel and an oxidizer is introduced into a combustion chamber.

With the rapid development of aerospace technologies, various chemically propelled rockets have been invented and applied for space exploration over the past decades. In some liquid rocket engines that are still in use today, hydrazine (N_2H_4) and its derivatives are widely used as the chemical propulsion fuel. With its long-term stability and high specific impulse, hydrazine is an ideal storable rocket fuel for propulsion and manoeuvre applications, such as attitude control systems for satellites.

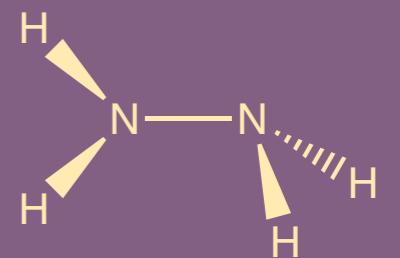


Figure 1. Molecular structure of hydrazine





However, these compounds are extremely toxic, highly volatile, carcinogenic substances and consequently have high handling and maintenance costs. Because of this, there is increasing demand in developing greener and safer rocket fuels as replacements for hydrazine and its derivatives. Thus, exploring safer hypergolic fuels has become an area of intense research.

Hydrazine was first used as a component in German rocket engines during World War II. A 30% mix (by weight) with 57% methanol and 13% water known as 'C-Stoff'. The mixture was used to power the first (and last) rocket-powered fighter plane, in which peroxide was used as an oxidizer. Today, it is mostly employed in extra-terrestrial exploration due to its high handling costs. The Curiosity Rover, which arrived on Mars in 2012, used hydrazine propellant during its landing. Furthermore, in July this year the NASA New Frontiers mission 'Juno' entered the orbit of Jupiter, powered by a hydrazine and dinitrogen tetroxide combination. Hydrazine is also used as a low-power monopropellant for the manoeuvring thrusters of spacecraft.

In all hydrazine mono-propellant engines, N_2H_4 is passed over a catalyst such as iridium metal supported by high-surface-area alumina, which causes it to decompose into ammonia, nitrogen and hydrogen:

1. $\text{N}_2\text{H}_4 \rightarrow \text{N}_2 + 2\text{H}_2$
2. $3\text{N}_2\text{H}_4 \rightarrow 4\text{NH}_3 + \text{N}_2$
3. $4\text{NH}_3 + \text{N}_2\text{H}_2 \rightarrow 3\text{N}_2 + 7\text{H}_2$

In 2011, hydrazine was included in the list of "substances of very high concern" by the European Commission for the Registration, Evaluation, Authorization and Restriction of Chemicals. Due to possible restrictions, the use of hydrazine will likely become expensive and impractical on short to medium notice. The DLR Future Fuels initiative is thus investigating so-called green propellants as hydrazine alternatives.

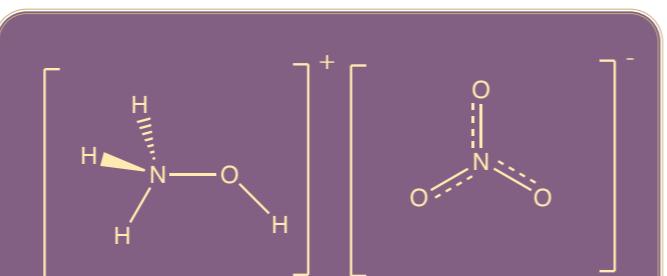


Figure 2. Molecular structure of hydroxylammonium nitrate

So how are leading Space Programmes introducing greener fuels into to their developments?

Green propellants are defined as low-hazard, low-toxicity, environmentally friendly propellants during spacecraft development, launch and operations. They provide safe handling and storability when compared to conventional toxic propellants such as hydrazine. A useful monopropellant replacement for hydrazine must be chemically and thermally stable for long-term storage, but must easily decompose and have good combustion properties. It must have a high volume-specific impulse for storage purposes, but most importantly, the propellant must be sufficiently stable to allow technicians and engineers to work safely. The Green Propellant Infusion Mission (GPIM) was a NASA technology demonstrator project that tested a more efficient chemical propellant for future generation launch vehicles and satellites: hydroxylammonium nitrate (HAN). When compared to the current industry standards for orbital manoeuvring systems, which for decades have exclusively been reliant upon hydrazine based formulations, the HAN monopropellant offers many advantages. These include longer mission durations, additional manoeuvrability, increased payload space and simplified launch processing. Preliminary studies into HAN indicated that it offers nearly 50% higher performance for a given propellant tank volume compared to a conventional hydrazine system.

HAN is an energetic ionic liquid. The charged molecules interact together more tightly and make the liquid more stable. The new propellant burns much higher temperatures than a typical hydrazine system, and there are still requirements for commercial engines to be developed that can withhold them from being damaged.

So, what does the future hold for green rocket propellants?

The eventual commercialisation will enable technology for commercial spaceports operating across the United States to permit safer, faster and much less costly launch-vehicle and spacecraft fuel loading operations. The combined benefits of low toxicity and easy open-container handling can shorten ground processing time significantly, simplifying the launching of satellites. The new fuel is 50% denser than hydrazine, meaning more of it can be stored in containers of the same volume. It also has a lower freezing point so requires less spacecraft power to maintain its temperature. All this research is helping space exploration to not just develop greener technologies as we find ourselves in a world where global warming is an issue that needs to seriously be addressed, but also to use the knowledge we have as chemists to make our research as safe and efficient as possible.



Magic bullets for prostate cancer:

a “golden” treatment that might just revolutionise

CANCER THERAPY

According to the American Cancer Society, cancer is the second leading cause of death in the world, taking some 10 million lives in 2020 alone. Prostate cancer, the most common form of cancer among men, affects one in eight males. Although steady progress in the field has been achieved over the past thirty years, the causes of prostate cancer continue to remain a mystery.

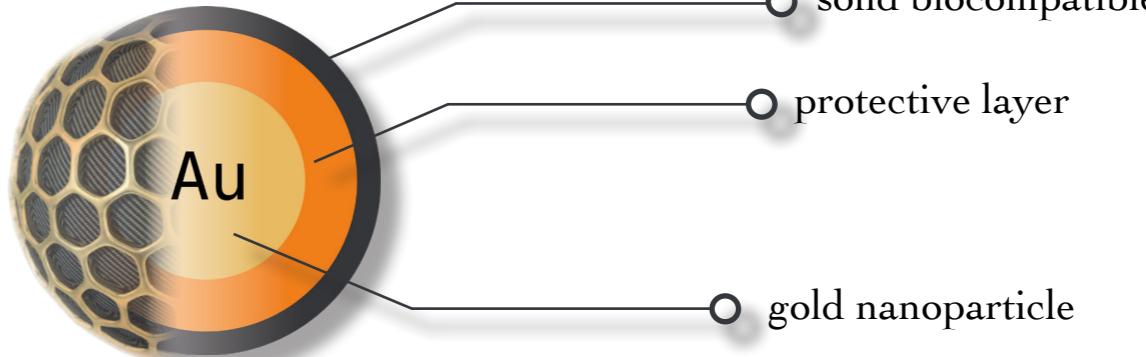
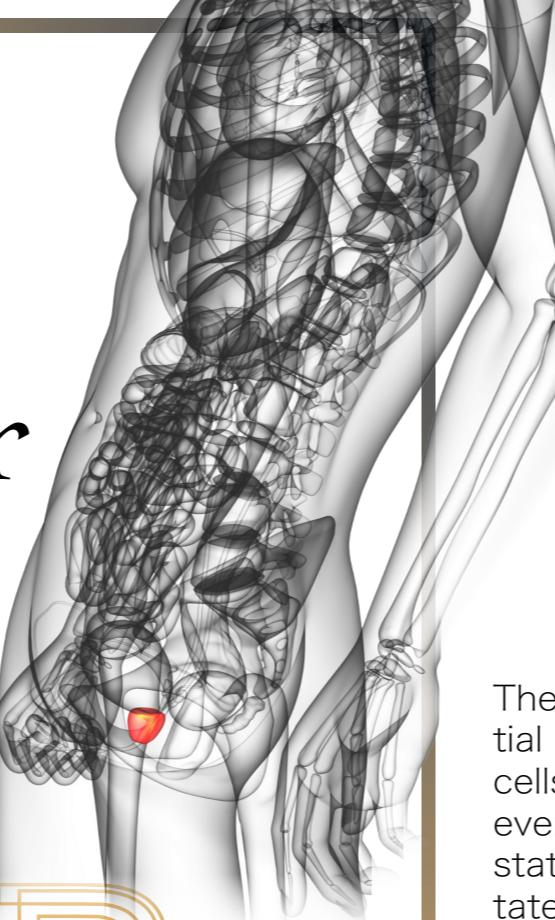
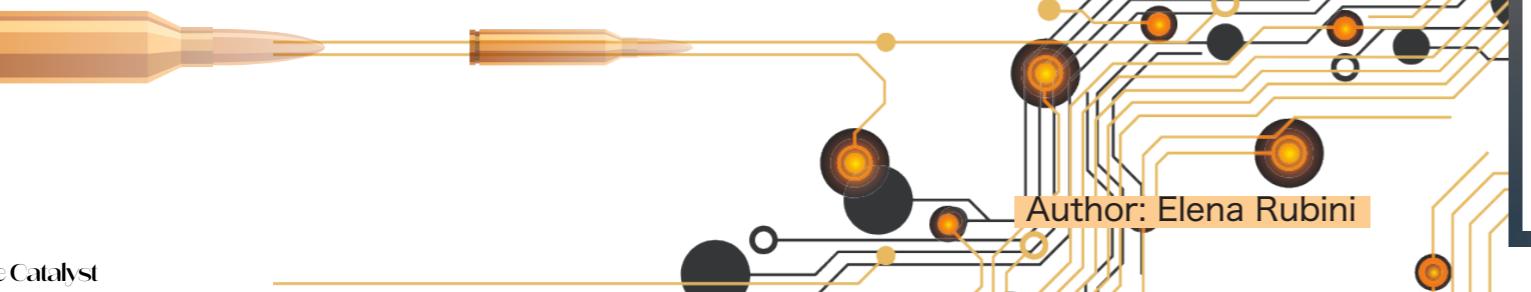


Figure 1. General structure of a gold nanoparticle

The cells in our body have the potential to become **cancerous**, but these cells are not necessarily ‘activated’ in every person. When men develop prostate cancer, their cells start to mutate into cancerous cells and grow at an uncontrollable rate. The insufficient blood flow and supply to bones cause cytokines (small proteins) to promote tumour growth through error replication in the DNA transcription. As the cancer develops, the **cytokines** facilitate the invasion and metastasise to organs or nearby bones such as the pelvic bone, and spread to the prostate itself, resulting in prostate cancer. While the causes of **prostate cancer** are still unknown, the risk factors and symptoms are clear. An unhealthy diet and higher levels of free circulating testosterone and somatotropin (the human growth hormone) in the blood substantially increase the risk of developing prostate cancer. Studies have shown that African-American men have a higher chance of contracting this type of cancer and often a hereditary factor comes into play. The main and most common risk factor for prostate cancer however is age, with 60% of patients diagnosed aged **65** and above. A small percentage of men live and die without even knowing they had prostate cancer.

Different courses of action are available when a patient is diagnosed with the disease, depending on the severity and stage of the cancer. The ‘traditional’ methods used for treating prostate cancer, including surgery, chemotherapy, hormone therapy and freezing prostate tissue, are associated with undesirable side effects such as loss of bone mass and painful urination. More recently, much research has been conducted to explore the use of nanoparticles to treat cancer. **Gold nanoparticles** (AuNPs) in particular, have proven to have unique physical and chemical properties that make them a preferred candidate for **drug delivery**. AuNPs can be used as a means of transport within our body to carry small molecules/complexes (for instance drugs) or larger structures (such as proteins or DNA strands). One of the main aims in the exploration of this new technique is how to improve the nanoparticles’ targeting and adhesive efficiency by adjusting their shape, size and material composition. Currently the most commonly used NPs are spherical in shape. New studies have shown that non-spherical NPs may be more effective than spherical NPs, however the responses that non-spherical NPs have on cancerous cells remain unclear. Having a diameter of less than 170 nm

allows the NPs to easily fit through and diffuse inside cells and capillaries. In addition, the NPs are charged creating a repulsive effect, which prevents them from aggregating and stimulates their interaction with cells.

Innovative research is underway using AuNPs as an effective delivery means for treating prostate cancer. Let us take a closer look at how AuNPs can be used in drug delivery systems from a perspective that I liken to the 'peeling of an onion'. The outer layer of the AuNP is quite versatile as it can be altered and coated in polymers or therapeutic agents, such as anti-cancer drugs. The patient's DNA can be transcribed onto this surface layer to ensure that the body does not treat it as an external threat and reject it. The removal of this outer surface reveals a monolayer that serves as a protective layer. This component of the AuNP is crucial because it contains the drug or molecules necessary for the treatment. When this final layer is peeled off, we arrive at the core of the particle: a non-toxic gold core which is relatively inert and therefore safe to enter and navigate throughout the body.

Now that we know the structure of the AuNPs, how are the attached drugs delivered? The AuNPs act as vectors and target the cancerous cells while carrying with them, for example, chemotherapeutic drugs. Noteworthy are docetaxel and doxorubicin, which represent two of the main drugs used for cancer treatment in collaboration with NPs. Let us consider doxorubicin conjugated with AuNPs. The drug will act as the taxoid, and together with the AuNP, will create the vector drug complex. A taxoid is a class of drugs derived from paclitaxel which is a chemotherapeutic drug developed for its anticancer properties. Once injected into the body, each AuNP will act as a 'magic bullet' and infiltrate the tumour location, transporting the taxoid to the desired target. At this point, all of the AuNP vectors concentrate within the tumour site, leaving the vector-drug ensemble to dissociate and release the taxoid. The drug will then cause apoptosis, destroying the cancer cells. This form of treatment has not yet been approved for use with humans and is still in the animal testing stage of its clinical trials, although FDA approval has been obtained for docetaxel as a cancer treatment. Notwithstanding that this therapeutic treatment uses

chemotherapeutic drugs, the side effects are substantially less severe than those associated with the traditional chemo and radio therapy treatments commonly used today. As a result, scientists continue to research this technique with the goal that it may be applied to prostate tumours as well as other types of cancer.

Medicinal advancements rely on efficiency of the drug delivery process. This is imperative in the treatment of many cancers as the common objective is to determine which cells need to be targeted and eliminated. AuNPs allow chemotherapeutic drugs to more effectively treat prostate cancer by accurately identifying and targeting the desired cells. The characteristic versatility of AuNPs offers the potential to replace current drug delivery methods with targeted therapy, as AuNPs work with existing drugs in a safer manner. "Magic golden bullets" may be on the horizon as a new form of cancer treatment.

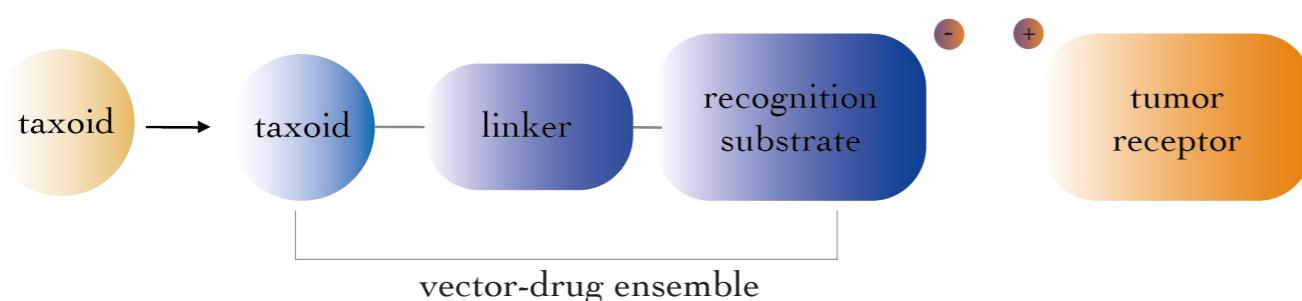
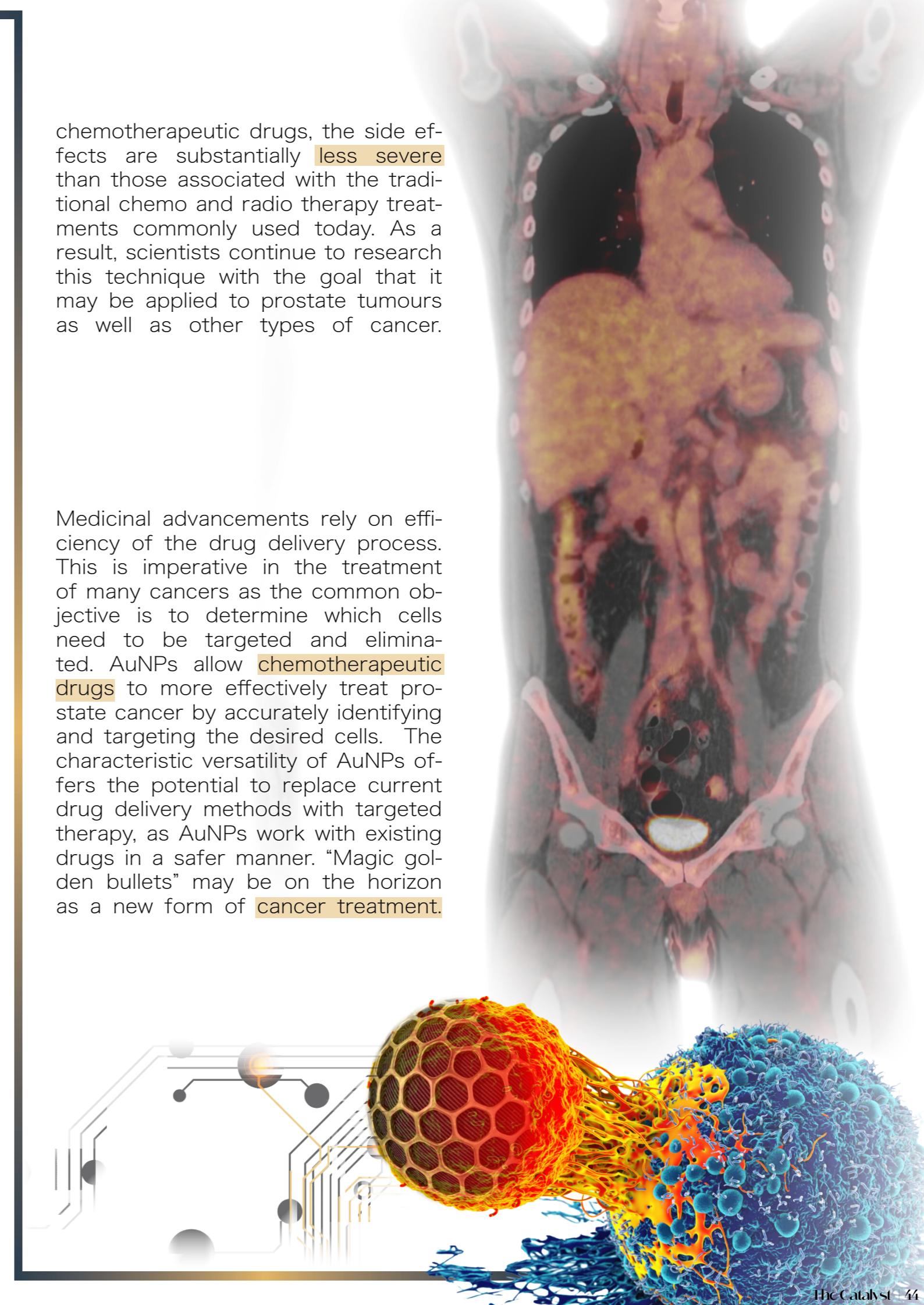
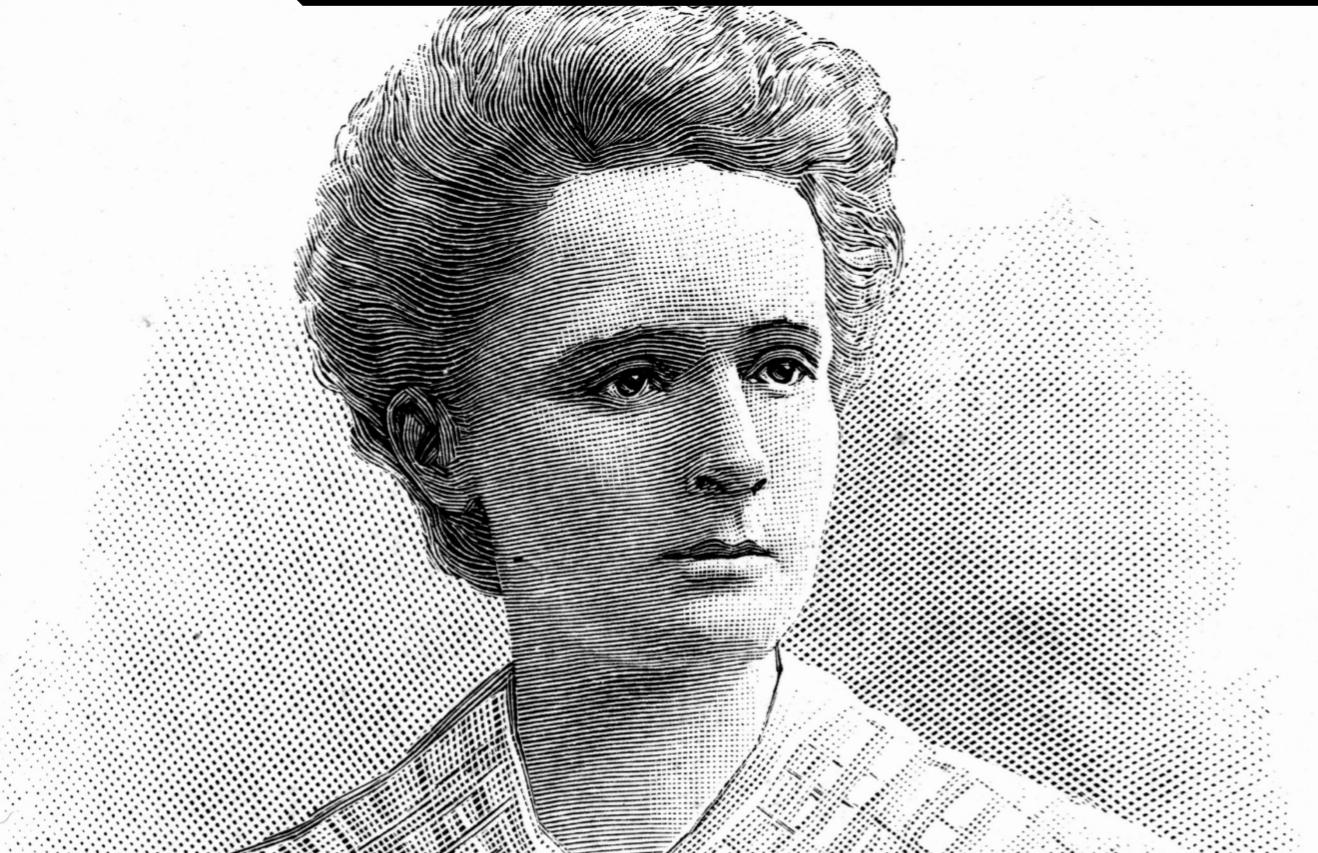


Figure 2. Mechanism of action of doxorubicin conjugated with AuNPs



MARJA SKŁODOWSKA: a life account



We've all heard about the discovery of radium and its terrible consequences on the woman who first purified it. However what you probably don't know is that Madame Curie had Polish origins. In fact, she had strong patriotic feelings towards her homeland to such a great extent that she named one of the other elements she identified, as a tribute to her country - polonium. So, let us take you through a journey, highlighting events in her life that led her to marry a Frenchman, win two Nobel Prizes and more.

Marie Curie was born in Warsaw on November 7th 1867, as Marja Skłodowska. At the time, Poland was subjugated by Russians, who controlled both the culture and the educational system of the country. This political influence gave rise to resistance movements, in which both sides of her family participated heavily. A considerable contribution to her scientific curiosity can be accredited to the *Flying University*, the secret school where academics used to teach 'illegal' subjects in an attempt to avoid *Russification*. It started there, in those secret halls and with the guidance of her father, that Marja Skłodowska became Madame Curie.

Fast forward to 1891. Aged 24, she moved to Paris, where she registered under the name of "Marie Skłodowska", and began studying Physics and Mathematics at Sorbonne University. These two subjects, in which she obtained master's degrees, would then set the foundation of her future research. Soon after, Marie was motivated to conduct a study on the magnetic properties of steel by the Society for the Encouragement of National Industry. It was during the search for a lab space for this research that she met Pierre Curie, a pioneer researcher on magnetism, who was also laboratory chief at a municipal school.

Pierre Curie was considered a man of genius, who collaborated with eminent scientists of the time including Lord Kelvin, and who conquered Marie's heart. Their bond, a mixture of love and

science, was stronger than ever and they decided to tie the knot in July 1895 in a simple civil ceremony, followed by a honeymoon trip within the country, riding bicycles. Still holding dear the memories they made together that summer, soon came the time to choose a subject for Marie's doctoral degree. After weeks of contemplation, her interest was caught by Henri Becquerel's reported discoveries. The latter revealed the puzzling existence of unknown rays emitted by uranium salts, with no pre-treatment or exposure to light. So where did the energy come from? What was its nature? These were the questions filling Marie's head and one answer shortly followed: it was radiation.

Both Curies were extremely fascinated by this phenomenon and their first experiment was to set up an ionisation chamber with equipment constructed by Pierre himself. They proceeded to measure the ionisation energy of uranium and found that the intensity of the radiation detected was directly proportional to the amount of salts present. Even for the late 1890s, their findings were merely considered characterisation data. Nonetheless, they triggered Marie's curiosity, to the point where she made a bold conclusion: the unknown rays (or radioactivity) must be an atomic property.

Marie Curie now had a theory and she immediately started following it. First, she abandoned uranium and began testing all sorts of matter, from simple pebbles in her garden to the

rare metals conserved at her university. She discovered that thorium too was emitting these rays and decided to divide the elements she was testing into 'inactive' and 'active'. So far, only two of them fell into the latter category. Then one day, while she was experimenting on certain minerals, she detected a far stronger radiation emitted by the sample, much more energetic than any of the rays encountered when analysing thorium or uranium. But how was this possible? She had investigated all the known elements, so it must be a mistake, she concluded. Like any good scientist, she reproduced the experiment several times and at every repeat, would face the same astounding results. At that point, Marie Curie knew that she was holding a sample containing at least one new element.

1898-1906. These were the crucial years in Marie Curie's life - the most intense and satisfying ones. Pierre abandoned his study of crystals to join efforts with his wife, and together they announced the existence of two new elements: radium and polonium. As it often happened at the time, the scientific community was not delighted by this discovery. Radioactivity upset some fundamental laws that were held in great respect, raising speculation of the couple. After all, the two new elements had only been indirectly detected and nobody had really seen them. The Curies welcomed the challenge and began their work. They obtained residues of pitchblende, the ore containing radium, and started purifying them; a process that would last for four long and arduous years. The conditions this was carried out in were not ideal either: they did not have enough funding to obtain a lab, forcing them to install their apparatus in a shed,

vulnerable to weather and other external factors. Finally, their labour turned into success. The couple managed to isolate one gram of radium, an element that would change the course of science irreversibly.

They decided to share this discovery with the rest of the world, including the purification technique. Recognition came in 1903, when Marie and Pierre shared the Nobel Prize in Physics with Becquerel for the study of spontaneous radioactivity. The Curies were now accomplished scientists and happy individuals. In fact, during this time period two beautiful and talented daughters were born: Irene and Eve. However, soon after tragedy knocked at their door, announcing the accidental death of Pierre Curie.

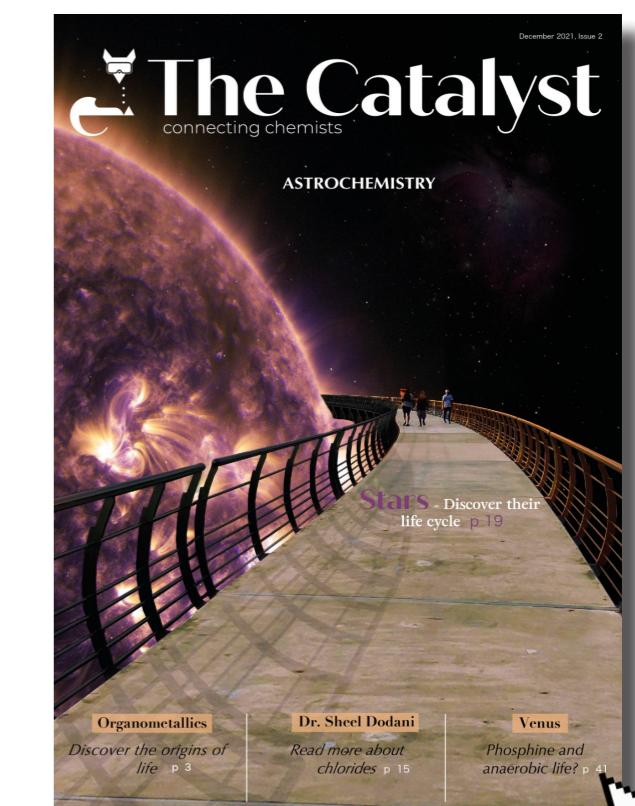
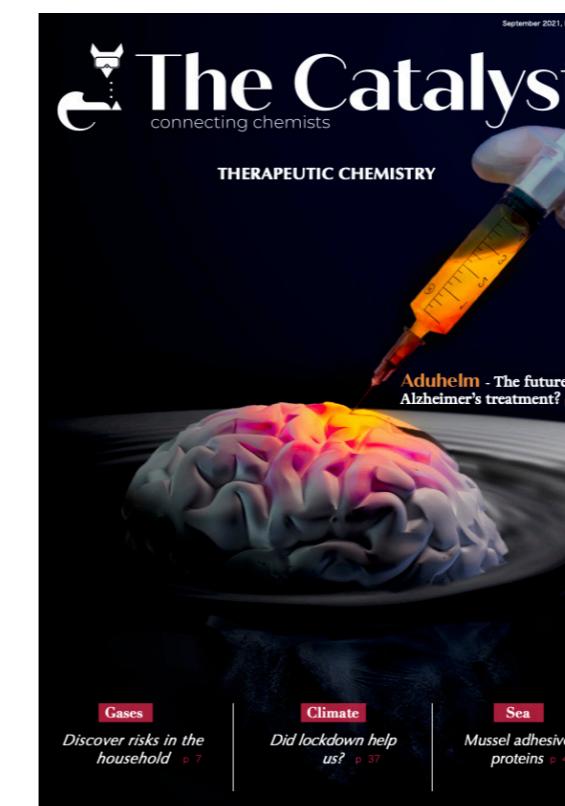
After a period of grief, life resumed. One of their dreams came true in 1909, when The Institut du Radium was founded, which included the Curies' own laboratory. Madame Curie won a second Nobel Prize in Chemistry in 1911, making her not only the first woman to win the Nobel Prize, but also the first individual holding two of them.

Unfortunately, Marie died of a blood disease - most likely caused by the radiation which she was constantly exposed to. However, the Curies' legacy survived through Irene, their eldest daughter. She would grow up to be a well-established scientist, winning the Nobel Prize in Chemistry in 1935 alongside her husband for the synthesis of new radioactive elements. And this is the story of Marja Skłodowska (1867-1934), from Warsaw to Paris.

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