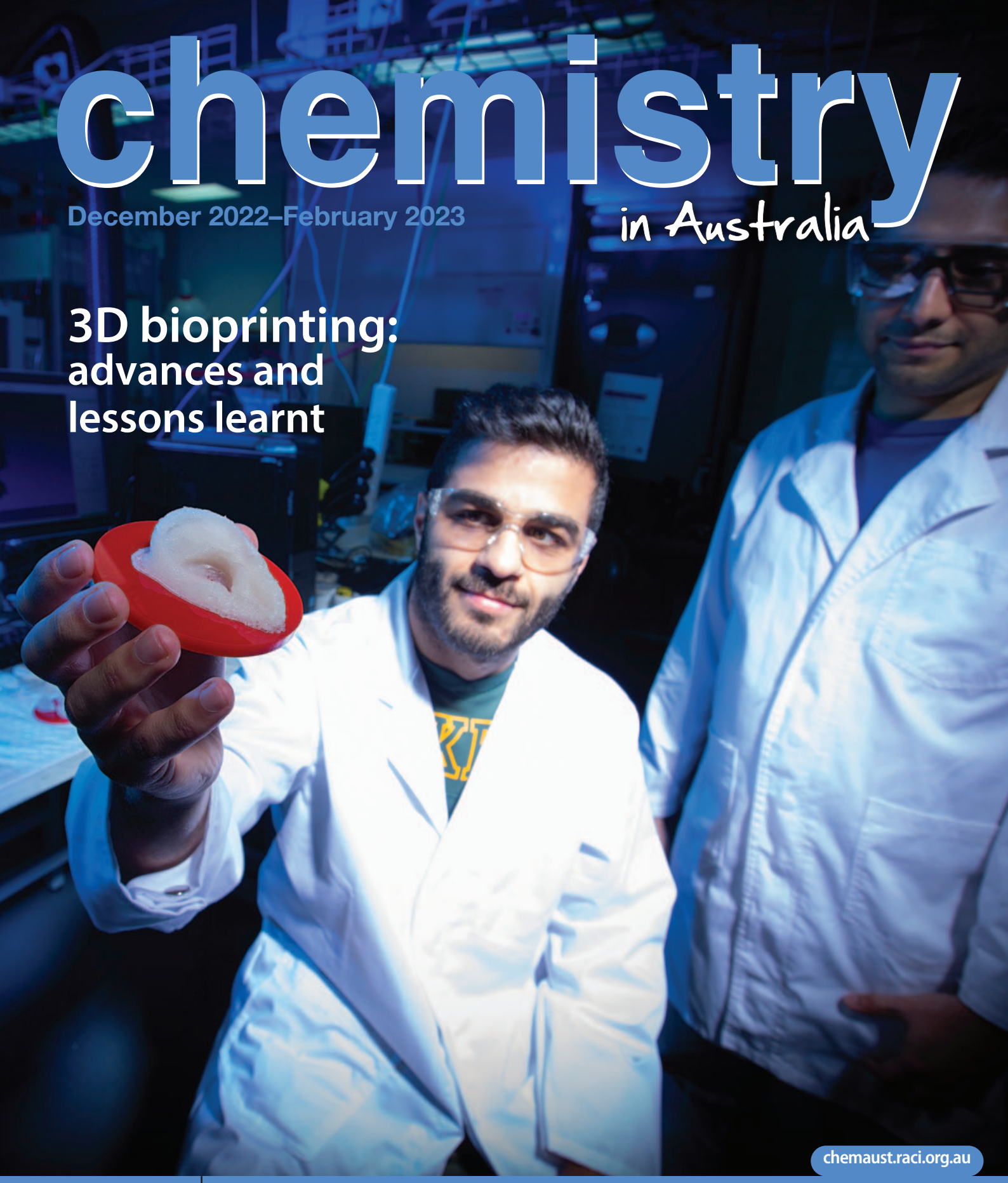
chemistry in Australia

December 2022–February 2023

3D bioprinting: advances and lessons learnt



chemaust.raci.org.au

raci
ROYAL AUSTRALIAN CHEMICAL INSTITUTE

- 2022 Science Nobel Prizes
- Recognising and supporting diversity
- RACI's University Ambassadors Program

www.rowe.com.au

Online 24 hours 7 days a week, by phone or face to face, we give you the choice.

INSTRUMENTS - CONSUMABLES - CHEMICALS - SERVICE & REPAIRS

ROWE SCIENTIFIC PTY. LTD. www.rowe.com.au

Ajax Finechem · Bel-Art Products · chem-supply · cowie · CHROMACOL · Gilian · KartellLABWARE · SIGMA-ALDRICH · MN · MERCK · METTLER TOLEDO · OHAUS · SIMAX · Tarsons · TPS · Techno Plas · VELP SCIENTIFICA · witeg

A 100% Australian owned company, supplying scientific laboratories since 1987.

South Australia & NT
Ph: (08) 8186 0523
rowesa@rowe.com.au

Queensland
Ph: (07) 3376 9411
roweqld@rowe.com.au

Victoria & Tasmania
Ph: (03) 9701 7077
rowevic@rowe.com.au

New South Wales
Ph: (02) 9603 1205
rowensw@rowe.com.au

Western Australia
Ph: (08) 9302 1911
rowewa@rowe.com.au

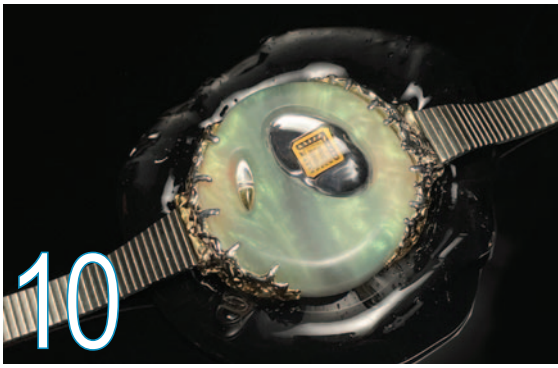
Quality System
Quality Endorsed Company
ISO 9001:2015
LIC 10372
SAI Global

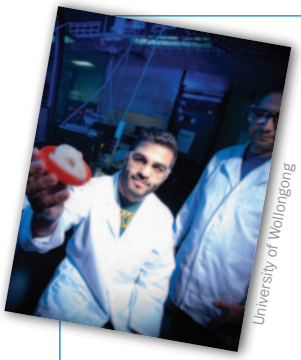
REF535

X:\MARKETING\ADVERTISING\CHEMISTRY IN AUSTRALIA

chemistry in Australia

December 2022–February 2023



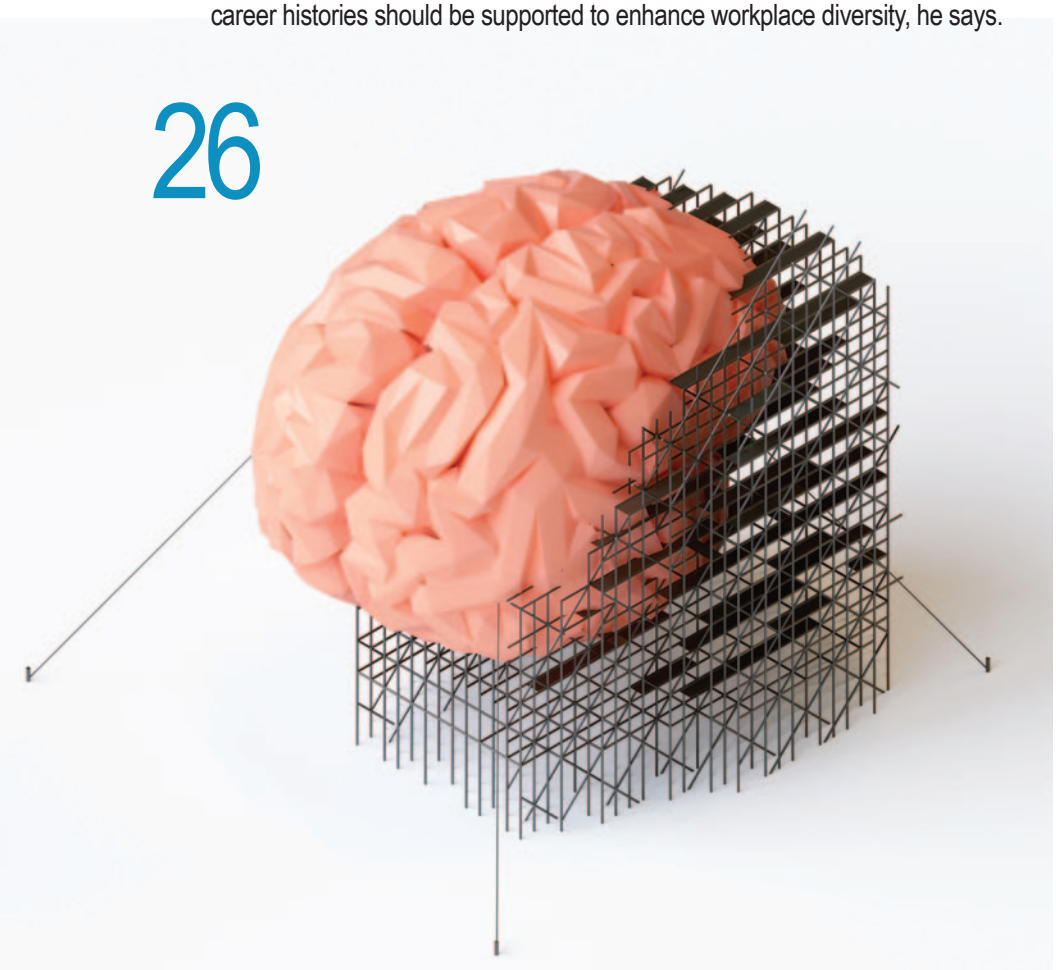

University of Wollongong

cover story

20

3D bioprinting: tracking to translation

Accrued knowledge from a convergence of biomaterials, tissue engineering, stem cell biology and 3D biofabrication advances is providing unprecedented insights into and controls over cellular systems on the bench.



chemaust.raci.org.au

Navigating new waters

I would like to start my first column for *Chemistry in Australia* by thanking all those who encouraged and supported me to join the RACI Board as President-Elect back in 2020. It feels like yesterday, but in those two years I have learnt so much more about RACI – an organisation that is the living proof that strength comes from diversity. I feel both proud and humble for the opportunity I have been given to lead the RACI over the next two years. I joined RACI shortly after I came to Australia, and some of my proudest professional moments include becoming a Fellow of RACI in 2017 and then, earlier this year, receiving recognition for being a RACI member for 25 years – time does indeed fly when you are having fun!

In the past two years, RACI has shown its resilience in the face of unprecedented global turmoil. I am certain that when the now outgoing President Professor Steve Bottle was elected to the RACI Board in 2018, he would not have expected that he would have to steer the RACI ship through the choppy waters of the pandemic, state border closures and the world of virtual meetings. But steer the ship he did, firmly and calmly. Being a cadet on Steve's ship in the last two years as he sailed the RACI through this storm has given me confidence for the upcoming journey through new but hopefully calmer waters in the next couple of years. I want to use this opportunity – and I think I can speak for both the RACI Board and the entire RACI community – to thank you, Steve, for your leadership and your contributions to RACI during your service on the RACI Board over the past four years and as RACI President for the past two years.

Another person who I feel deeply indebted to is our recently retired CEO, Roger Stapleford. Roger was the longest serving CEO in RACI history. He took on managing the RACI in 2010, and in the next 12 years he strengthened the organisation considerably with his superb administration and management skills. This put the organisation in a good shape for the unprecedented challenges that we faced over the last couple of years – he built a strong ship and when the pandemic storm hit us, Roger kept all the engines going, ensuring we stayed afloat through the rough seas. Another highlight of Roger's career with the RACI was the centenary celebrations in 2017, with the publication of *A century of bonds* and the RACI Congress in Melbourne, which was the biggest gathering of chemistry professionals the country has ever seen. I ask you to join me in thanking Roger for everything he has done for RACI.

The world has changed after the recent turmoil, be it in academia, government or industry. This will be a period of uncertainty but also opportunity for our profession and RACI.

Finally, I want to use this opportunity to welcome our new CEO, Shenal Basnayake. The world has changed after the recent turmoil, be it in academia, government or industry. This will be a period of uncertainty but also opportunity for our profession and RACI. We are very fortunate to have Shenal joining the RACI crew to help us navigate those new waters. We have a big job ahead in ensuring that RACI continues to advocate for the interest and activities of the chemical sciences and the RACI membership community in a rapidly changing environment. I therefore encourage you all to reach out to me, Shenal or other board members with your thoughts and suggestions on what you think RACI is doing well, where we could improve, where our focus should be, and any new ideas you might have in terms of how RACI can better support you and the chemistry profession.

Looking forward to working with you all on growing RACI from strength to strength.

Pall Thordarson FRACI CChem (president@raci.org.au) is RACI President.

chemistry in Australia
chemaust.raci.org.au

EDITOR
Sally Woollett
Ph 0406 321 312
wools@westnet.com.au

PRODUCTION EDITOR
Catherine Greenwood
catherine.greenwood@bigpond.com

ADVERTISING SALES
Mary Pappa
Ph/fax (03) 9328 2033/2670
mary.pappa@raci.org.au

PRODUCTION
Control Publishing
publishing@control.com.au
www.control.com.au

BOOK REVIEWS
Damien Blackwell
damo34@internode.on.net

RESEARCH HIGHLIGHTS
David Huang
david.huang@adelaide.edu.au

EDUCATION RESEARCH HIGHLIGHTS
Reyne Pullen
reyne.pullen@sydney.edu.au

GENERAL ENQUIRIES
Ph/fax (03) 9328 2033/2670
chemaust@raci.org.au

PRESIDENT
Pall Thordarson

MANAGEMENT COMMITTEE
Antigone Christou-Rappos, Helmut Hügel, Melanie MacGregor, Nigel Simpson, Richard Thwaites

CONTRIBUTIONS
Contributors' views are not necessarily endorsed by the RACI, and no responsibility is accepted for accuracy of contributions. Visit the website's resource centre at chemaust.raci.org.au for information about submissions.

ISSN 0314-4240 e-ISSN 1839-2539

raci ROYAL AUSTRALIAN CHEMICAL INSTITUTE

Hubris and opportunities

Thank you so much for your service over many years, Roger (R. Stapleford, 'Diamonds, gold and gems of chemistry', September–November 2022, p. 6). And thank you for highlighting one of RACI's greatest opportunities – providing a reason for non-academic chemists, chemical engineers, metallurgists etc. to join (like they used to do many decades ago).

Our Australian industries are awash with people working in fields such as mining, mineral processing, energy, environment and chemical manufacturing. It would be interesting to see what percentage of chemistry/chemical engineering/metallurgy graduates takes up RACI membership. We can't afford to continue the trend towards becoming the RAUCI (Royal Australian University Chemical Institute). We can't afford to ignore the 'forgotten children' that Roger referred to.

I also really enjoyed Rob Capon's article (September–November 2022, p. 36). It was not only well written but also interesting and useful. It also highlighted the hubris that scientists (not Professor Capon) are sometimes guilty of. Rob alluded to the co-joined outrageous assumptions we were fed as undergraduates that 'like non-protein-coding DNA, natural products were nuisance chemistry with no particular purpose'. And we're still being fed that pap.

That is not science in the tried and tested Baconian mode. Instead, it is hubris par excellence. It is now known that the non-coding-DNA contains the 'switches' that regulate up to 80% of the genome. It is now becoming evident that many illnesses are linked to mutations in the non-protein-coding DNA, since only a few rare illnesses can be attributed directly to genes alone. There's compelling evidence that the evolutionary concept of junk DNA has held back medical science for decades.

Perhaps the utility of ongoing natural product chemistry, too, might be further enhanced if we could answer the question 'Why is it there?' and 'What is its design purpose?', rather than assuming there is little or no utility. One final quote – this time from the engineer, statistician and quality guru W. Edwards Deming, 'In God we trust. All others must bring data'.

And surely, such detective work would be much more fun and intellectually satisfying too.

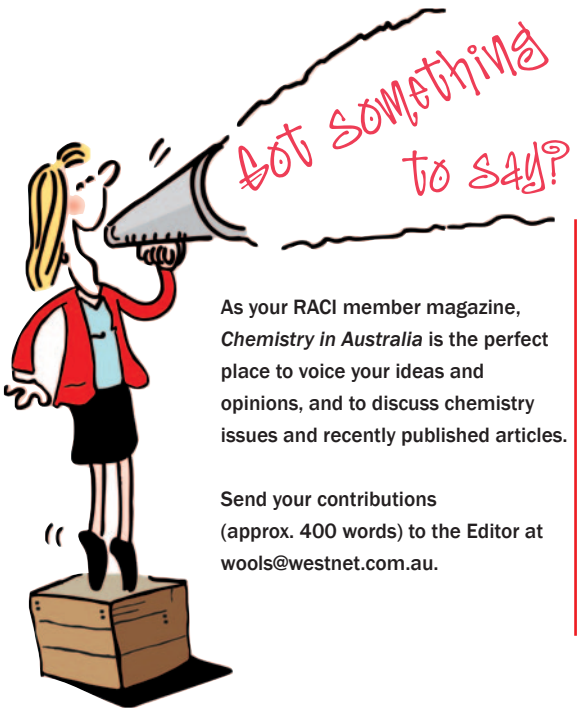
Stephen Grocott FRACI CChem

'Your say' guidelines

We will consider letters of up to 400 words in response to material published in *Chemistry in Australia* or about novel or topical issues relevant to chemistry. Letters accepted for publication will be edited (no proof supplied) for clarity, space or legal reasons and published in print and online. Full name and RACI membership type will be published. Please supply a daytime contact telephone number (not for publication).

Publication does not constitute an endorsement of any opinions expressed by contributors. All letters become copyright of the Royal Australian Chemical Institute and must not be reproduced without written permission.

Send letters to wools@westnet.com.au.



As your RACI member magazine, *Chemistry in Australia* is the perfect place to voice your ideas and opinions, and to discuss chemistry issues and recently published articles.

Send your contributions (approx. 400 words) to the Editor at wools@westnet.com.au.

Correction

In Peter G. Lehman's article 'Knowing your onions' (September–November 2022, p. 39) the 'no tears' onions developed by Bayer (now BASF) are Sunions®, rather than Sonions.

The click reaction that changed chemistry

The Royal Swedish Academy of Sciences has awarded the Nobel Prize in Chemistry 2022 to Carolyn R. Bertozzi (Stanford University, USA), Morten Meldal (University of Copenhagen, Denmark) and K. Barry Sharpless (Scripps Research, La Jolla, USA) 'for the development of click chemistry and bioorthogonal chemistry'.

The Nobel Prize in Chemistry 2022 is about making difficult processes easier. Sharpless and Meldal have laid the foundation for a functional form of chemistry – click chemistry – in which molecular building blocks snap together quickly and efficiently. Bertozzi has taken click chemistry to a new dimension and started using it in living organisms.

Chemists have long been driven by the desire to build increasingly complicated molecules. In pharmaceutical research, this has often involved artificially recreating natural molecules with medicinal properties. This has led to many admirable molecular constructions, but these are generally time consuming and very expensive to produce.

'This year's Prize in Chemistry deals with not overcomplicating matters, instead working with what is easy and simple. Functional molecules can be built even by taking a straightforward route,' said Johan Åqvist, Chair of the Nobel Committee for Chemistry.

Sharpless – who is now being awarded his second Nobel Prize in Chemistry – started the ball rolling. Around the year 2000, he coined the concept of click chemistry, which is a form of simple and reliable chemistry, where reactions occur quickly and unwanted by-products are avoided.

Shortly afterwards, Meldal and Sharpless – independently of each other – presented what is now the crown jewel of click chemistry: the copper-catalysed azide–alkyne cycloaddition. This is an elegant and efficient chemical reaction that is now in widespread use. Among many other uses, it is utilised in the development of pharmaceuticals, for mapping DNA and creating materials that are more fit for purpose.

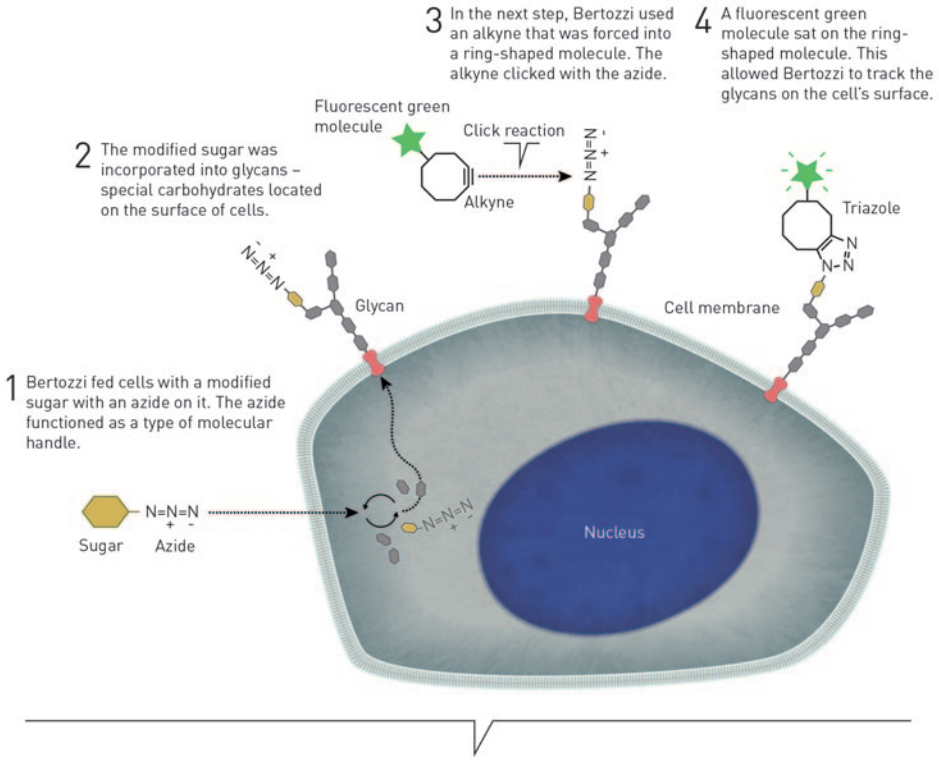
Bertozzi took click chemistry to a new level. To map important but elusive biomolecules on the surface of cells – glycans – she developed click reactions that work inside living organisms. Her bioorthogonal reactions take place without disrupting the normal chemistry of the cell.

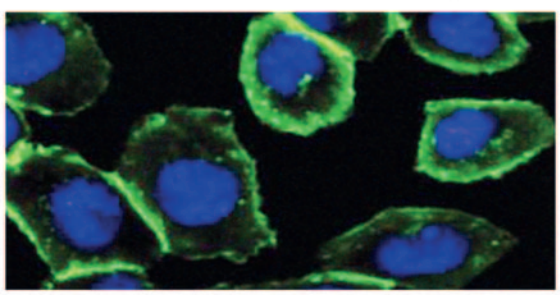
These reactions are now used globally to explore cells and track biological processes. Using bioorthogonal reactions, researchers have improved the targeting of cancer pharmaceuticals, which are now being tested in clinical trials.

Click chemistry and bioorthogonal reactions have taken chemistry into the era of functionalism. This is bringing the greatest benefit to humankind.

Nobel Prize Outreach

Bioorthogonal chemistry illuminates the cell

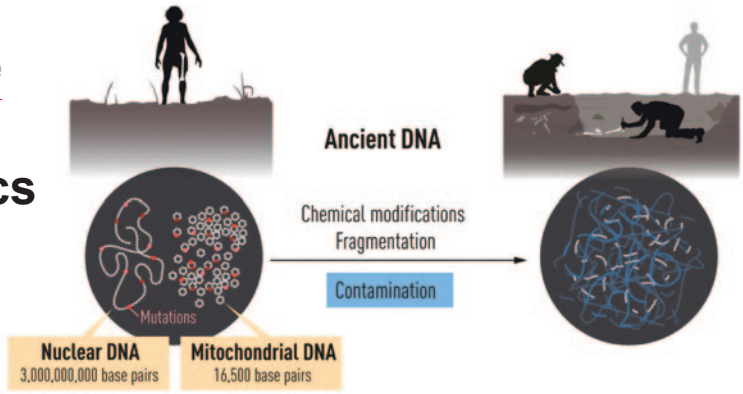




Bertozzi used the strain-promoted click reaction to track glycans. They have a green glow in the picture. The cell nucleus is coloured blue. Thanks to the glycans' green glow, Bertozzi was able to follow them in the cell.

Image from *Proc Natl Acad Sci USA* (2007) 104:16793–16797

The pioneer of paleogenomics



The Nobel Assembly at Karolinska Institutet has awarded the 2022 Nobel Prize in Physiology or Medicine to Svante Pääbo (Max Planck Institute for Evolutionary Anthropology, Germany, and Okinawa Institute of Science and Technology, Japan) 'for his discoveries concerning the genomes of extinct hominins and human evolution'.

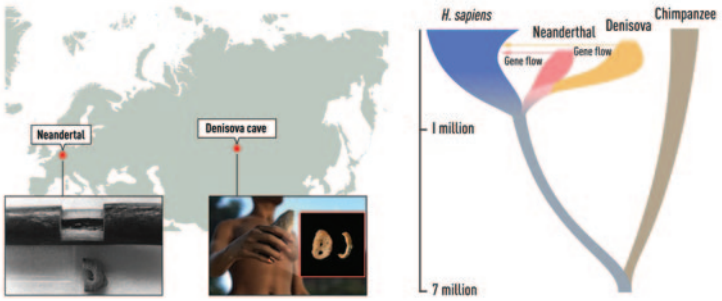
Through his pioneering research, Svante Pääbo sequenced the genome of the Neanderthal (*Homo neanderthalensis*), an extinct relative of present-day humans, and discovered a previously unknown hominin, Denisova.

Homo sapiens first appeared in Africa approximately 300 000 years ago, whereas our closest known relatives, Neanderthals, developed outside Africa and populated Europe and Western Asia from about 400 000 years until 30 000 years ago, when they went extinct. About 70 000 years ago, groups of *Homo sapiens* migrated from Africa to the Middle East and, from there to the rest of the world. *H. sapiens* and Neanderthals thus coexisted in large parts of Eurasia for tens of thousands of years. But what do we know about our relationship with the extinct Neanderthals?

Early in his career, Pääbo became fascinated by the possibility of usng modern genetic methods to study the DNA of Neanderthals. However, DNA becomes chemically modified over time and degrades into short fragments. After thousands of years, only trace amounts of DNA are left, and what remains is massively contaminated with DNA from bacteria and contemporary humans. As a postdoctoral student, Pääbo started to develop methods to study DNA from Neanderthals, an endeavour that lasted several decades.

In 1990, Pääbo was recruited to University of Munich, where he continued his work on archaic DNA. He decided to analyse DNA from Neanderthal mitochondria. The mitochondrial genome is small and contains only a fraction of the genetic information in the cell, but it is present in thousands of copies, increasing the chance of success. With his refined methods, Pääbo managed to sequence a region of mitochondrial DNA from a 40 000-year-old piece of bone. Thus, for the first time, we had access to a sequence from an extinct relative. Comparisons with contemporary humans and chimpanzees demonstrated that Neanderthals were genetically distinct.

As analyses of the small mitochondrial genome gave only limited information, Pääbo now took on the enormous challenge of sequencing the Neanderthal nuclear genome. At this time, he was offered the chance to establish a Max Planck Institute in Leipzig, Germany. At the new Institute, Pääbo and his team steadily improved the methods to isolate and analyse DNA from archaic bone remains. With the help of collaborators and new technical developments, Pääbo published the first Neanderthal genome sequence in 2010. Comparative analyses demonstrated that the most recent common ancestor of Neanderthals and *H. sapiens* lived around 800 000 years ago.



Comparative analyses by Pääbo and his co-workers showed that DNA sequences from Neanderthals were more similar to sequences from contemporary humans originating from Europe or Asia than to contemporary humans originating from Africa. This means that Neanderthals and *H. sapiens* interbred during their millennia of coexistence. In present-day humans with European or Asian descent, 1–4% of the genome originates from the Neanderthals.

In 2008, a 40 000-year-old fragment from a finger bone was discovered in the Denisova cave in the southern part of Siberia. The bone contained exceptionally well-preserved DNA, which Pääbo's team sequenced. The DNA sequence was unique when compared to all known sequences from Neanderthals and present-day humans. Pääbo had discovered a previously unknown hominin, named Denisova. Comparisons with sequences from contemporary humans from different parts of the world showed that gene flow had also occurred between Denisova and *H. sapiens*. This relationship was first seen in populations in Melanesia and other parts of South East Asia, where individuals carry up to 6% Denisova DNA.

Pääbo's discoveries have generated new understanding of our evolutionary history. At the time when *H. sapiens* migrated out of Africa, at least two extinct hominin populations inhabited Eurasia. Neanderthals lived in western Eurasia, whereas Denisovans populated the eastern parts of the continent. During the expansion of *Homo sapiens* outside Africa and their migration east, they encountered and interbred not only with Neanderthals, but also with Denisovans.

Through his groundbreaking research, Pääbo established an entirely new scientific discipline, paleogenomics, and scientists can access a unique resource to better understand human evolution and migration. We now understand that archaic gene sequences from our extinct relatives influence the physiology of present-day humans.

Nobel Prize Outreach

Entangled states – from theory to technology

The Royal Swedish Academy of Sciences has awarded the Nobel Prize in Physics 2022 to Alain Aspect (Université Paris-Saclay and École Polytechnique, Palaiseau, France), John F. Clauser (J.F. Clauser & Assoc., USA) and Anton Zeilinger (University of Vienna, Austria) 'for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science'.

Aspect, Clauser and Zeilinger have each conducted groundbreaking experiments using entangled quantum states, where two particles behave like a single unit even when they are separated. Their results have cleared the way for new technology based upon quantum information.

The ineffable effects of quantum mechanics are starting to find applications. There is now a large field of research that includes quantum computers, quantum networks and secure quantum-encrypted communication.

One key factor in this development is how quantum mechanics allows two or more particles to exist in an 'entangled state'. What happens to one of the particles in an entangled pair determines what happens to the other particle, even if they are far apart.

For a long time, the question was whether the correlation was because the particles in an entangled pair contained hidden variables, instructions that tell them which result they should give in an experiment. In the 1960s, John Stewart Bell developed the mathematical inequality that is named after him. This states that if there are hidden variables, the correlation between the results of a large number of measurements will never exceed a certain value. However, quantum mechanics predicts that a certain type of experiment will violate Bell's inequality, thus resulting in a stronger correlation than would otherwise be possible.

Clauser developed Bell's ideas, leading to a practical experiment. When he took the measurements, they supported quantum mechanics by clearly violating a Bell inequality. This means that quantum mechanics cannot be replaced by a theory that uses hidden variables.

Some loopholes remained after Clauser's experiment. Aspect developed the set-up, using it in a way that closed an important loophole. He was able to switch the measurement settings after an entangled pair had left its source, so the setting that existed when they were emitted could not affect the result.

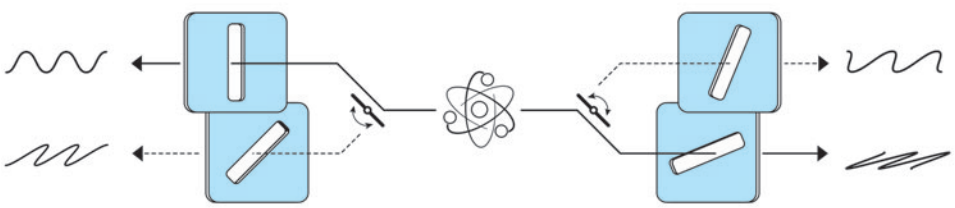
Using refined tools and a long series of experiments, Zeilinger started to use entangled quantum states. Among other things, his research group has demonstrated a phenomenon called quantum teleportation, which makes it possible to move a quantum state from one particle to one at a distance.

'It has become increasingly clear that a new kind of quantum technology is emerging. We can see that the laureates' work with entangled states is of great importance, even beyond the fundamental questions about the interpretation of quantum mechanics,' said Anders Irbäck, Chair of the Nobel Committee for Physics.

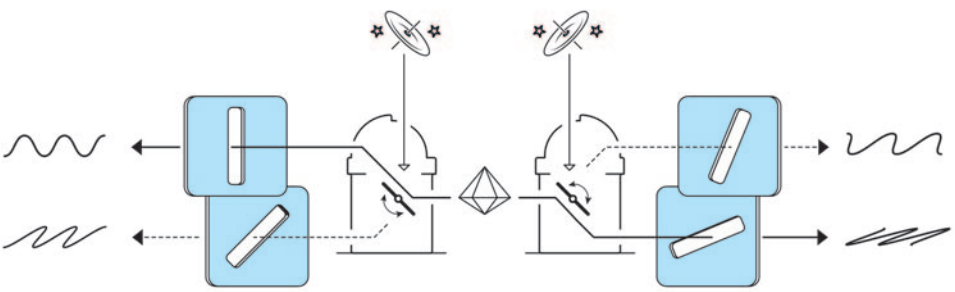
Nobel Prize Outreach

Experimenting with Bell inequalities

John Clauser used calcium atoms that could emit entangled photons after he had illuminated them with a special light. He set up a filter on either side to measure the photons' polarisation. After a series of measurements, he was able to show they violated a Bell inequality.



Alain Aspect developed this experiment, using a new way of exciting the atoms so they emitted entangled photons at a higher rate. He could also switch between different settings, so the system would not contain any advance information that could affect the results.



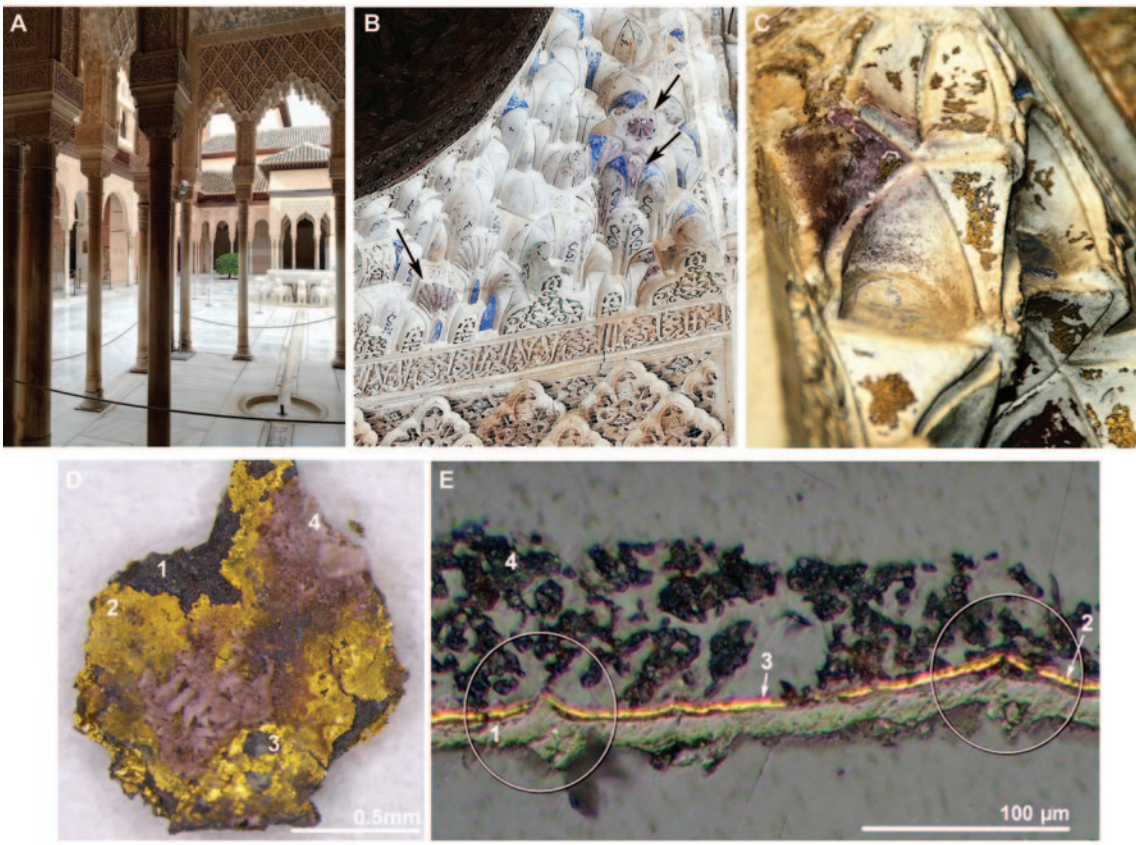
Anton Zeilinger later conducted more tests of Bell inequalities. He created entangled pairs of photons by shining a laser on a special crystal, and used random numbers to shift between measurement settings. One experiment used signals from distant galaxies to control the filters and ensure the signals could not affect each other.

Corrosion has turned Alhambra gold leaf purple

Spain-based researchers have finally solved the mystery of why purple stains have appeared on the intricate gilded tin plasterwork of the historic Alhambra palace in Andalusia, Spain. Using electron microscopy, Isabel Guerra and Carolina Cardell from the nearby University of Granada discovered how an unusual corrosion process has spontaneously converted the gold leaf into pure gold nanospheres that were just the right size to appear as a purple hue.

As they write in *Science Advances*: 'We've demonstrated direct evidence of an unusual electrochemical corrosion-based pathway for gilded tin that has produced gold nanospheres of different sizes, though mostly of [around] 70 nanometres, to impart purple colour.'

Guerra and Cardell hope their latest results will help historians and conservationists to prevent further corrosion in ancient gilded objects.



Gilded tin on plasterwork at the Alhambra palaces. (A) General view. (B) Purple colour. (C) Damaged gilded tin with areas tinted purple in the Alhambra Muqarnas hall. (D) Image of the gilded tin structure showing from inside to outside: corroded grey-black metallic foil (layer 1); damaged metallic golden leaf (layer 2); fragments of iridescent purple-greyish covering (layer 3); and purple-tinted whitish coat at surface (layer 4). (E) Polarisation light microscopy image of the gilding cross-section.
C. Cardell and I. Guerra, University of Granada, Spain, *Science Advances* (2022)

Built during the High Medieval Ages, the gold–tin alloy used to gild the magnificent Alhambra has become mottled with a purple colour over the last 800 years. While this process has been well documented over time, no-one has pinned down the actual mottling process – until now.

Using high-resolution TEM and a combined field emission SEM-EDX and Raman spectrometer system, Guerra and Cardell characterised the gilding and purple patches from plasterwork samples at the micro- and nano-scales.

As the researchers highlight, the SEM-EDX is armed with diverse detectors to deliver different images while the Raman spectrometer is fitted with a near-IR diode laser and green laser, and allows simultaneous secondary electron imaging and Raman analyses on the same sample and area.

The Alhambra gold leaf contains many fissures and voids, and analyses revealed how complex galvanic and chemical aeration-based corrosion processes had de-alloyed the imperfectly bonded gold–tin metals over time – this damage had also been enhanced by the palace's chloride-rich environment.

The unstable alloy surfaces then formed gold nanospheres, which at around 70 nanometres in diameter, were the optimal size to impart the purple hue. What's more, the plasterwork had been also been coated with white gypsum back in the 19th century, which exaggerated the purple effect.

'Our work demonstrates gold dissolution, millimetric migration, physical translocation, and deposition [of] secondary pure gold nanospheres over a centurial time scale', says Guerra.

'Our research is done on a real case study of more than five centuries of weathering under natural conditions, limiting our ability to elucidate the exact corrosion model', she adds. 'However, the results shown here will hopefully help experts of ancient gilded objects with the information relevant to corrosion methods and materials of intervention, as well as corrosion prevention.'

by Rebecca Pool; first published at analyticalscience.wiley.com

Brilliant alternative uses for diamond

A semiconductor in the Time is Forever watch.

A Queensland University of Technology researcher has joined forces with an Australian jewellery designer to showcase the brilliance of diamond in medical, scientific and other applications.

Diamond does not naturally conduct electricity, but Associate Professor Dongchen Qi from the QUT Centre of Material Science led research to make it both conductive and controllable as a high-capacity semiconductor.

In a collaborative research project including RMIT, Qi's team advanced their work to build a diamond-based transistor using a low-cost process to print a liquid gallium metal oxide layer onto the diamond surface.

'The oxide layer is indispensable in transistors, which are fundamental building blocks that allow computers and other logic devices to function', said Qi.

'Normally you need very fancy equipment and high temperatures to form an oxide layer on diamond, but gallium is liquid at room temperature, which made it suitable to print.'

Qi said diamond semiconductor technology was not ready yet but eventually researchers aimed to push it from the lab into everyday use in watches, computers, electric cars and smart chargers.

'Diamond is one of the most energy-efficient third-generation semiconductors and is suited to very high-power, high-frequency signal amplification and energy conversion unattainable by other semiconductor materials like silicon.

'It probably won't replace silicon but could potentially work in harsh environments like space, for example, where the extreme temperatures and radiation are normally detrimental to silicon devices.

'We can potentially grow diamond from carbon waste using less energy and resources than needed for silicon production but growing it in large wafers is still an unsolved challenge.'

Qi said communicating research beyond the scientific community was important and a key factor in his decision to lend independent Australian jewellery designer Danielle Karlikoff two diamond semiconductor devices from his earlier research.

Karlikoff wanted to subvert the importance of diamond cut, colour and clarity in her concept collection and showcased the semiconductor in the Time is Forever watch as part of her Second Life Diamonds collection, recently exhibited at Het Nieuwe Instituut (The New Institute) in Rotterdam, The Netherlands.

'Concept jewellery is not designed to be wearable, but has a role in communicating possibilities through ideas, education, and the expansion of perceptions', Karlikoff said.

The Second Life Diamonds collection included diamond and carbon-based research products from QUT, Australian National University, the University of New South Wales and the University of Melbourne.

Queensland University of Technology

Viruses can 'hitchhike' on microplastics

Microplastics are not just tiny particles that can be ingested; they can also carry viruses, a University of Queensland study has revealed.

The study, led by Associate Professor Jianhua Guo and Dr Ji Lu from the university's Australian Centre for Water and Environmental Biotechnology and published in *Water Research* (doi.org/10.1016/j.watres.2022.119115), investigated if microplastics have the ability to harbour viruses, including the one found inside *E. coli* bacteria.

'We often hear about the human and environmental harm caused by microplastics in water, but there is little known about whether the tiny microplastic particles can carry viruses', Guo said.

'What we found is that viruses can hitchhike on microplastics and prolong their infectivity, which means there could be an increased risk of virus transmission throughout waterways and the environment.'

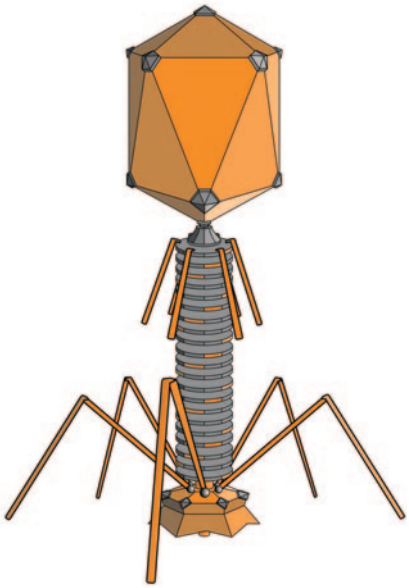
Lu said they used the *E. coli* bacteriophage in the study, which is a virus that infects and replicates within the bacteria itself and is not harmful to humans.

'By testing polystyrene particles of varying sizes, we found that more than 98% of the virus we used was found on the microplastic, and over half of the viruses could still be detected 10 days later – much longer than if the virus particles were free-floating in the water', Lu said.

The team also tested how sun exposure and the size of microplastics helped prolong the virus's survival and found the more environmental damage on the microplastic, the more likely it was to carry viruses.

'The virus-carrying microplastics could be a big issue', Lu said.

'The required dosage to be infectious to humans varies between different types of viruses, but there could be instances where the dosage is enough on a microplastic to cause potential infection.



A representation of the structure of a typical myovirus bacteriophage.
Adenosine

'Because microplastics can potentially accumulate deadly viruses and travel through waterways, it might be risky to eat seafoods harvested from areas where they are frequently contaminated by microplastics.'

Lu said the study started when wastewater was being tested to detect COVID-19 cases in the community, which spurred the team's investigation into what could mediate virus transmission in water environments.

'Our findings also indicated that microplastics could affect how viruses are distributed in water, which could be of interest in future studies', Lu said.

'Our findings have opened the door to further research that is needed in this area, including to test if other pathogens can hitchhike on more types of microplastics', he said.

'The fact that viruses and microplastics can interact with each other could be problematic for human health, but more research needs to be conducted to investigate these impacts further.'

University of Queensland

How old is that fingerprint?

TV forensic dramas make it seem easy to determine when fingerprints were left at the scene of a crime. In reality, the oils in fingerprints degrade over time, and it's difficult to work out their age. Now, researchers reporting in *ACS Central Science* (doi.org/10.1021/acscentsci.2c00408) have discovered molecular markers for changes to these oils over a seven-day period – information that could be used to estimate fingerprint ages more accurately.

Identifying the age of fingerprints at a crime scene is extremely important for trying to work out who was present at the time of the crime. Previously, Young Jin Lee and colleagues showed that triacylglycerols in fingerprint oils react with ozone in the air, forming oxidation products whose presence could be used to estimate when prints were deposited. But ozone reacts with other oils, such as squalene, wax esters, fatty acids and diacylglycerols, generating a complex mixture of oxidation compounds. So, Lee and Andrew Paulson wanted to develop a method to decipher that mixture of compounds and find molecular markers that could more precisely estimate the age of a fingerprint.

Fingerprint oils were analysed by high-resolution mass spectrometry and two new unique molecular trends were identified – the presence of epoxides and an increase in medium-length fatty acids. Although their use for estimating fingerprint age is still to be determined, epoxides were observed in the fingerprints, formed from triacylglycerols, wax esters, fatty acids and diacylglycerols. Interestingly, there was a large increase in the amount of 10-carbon-long saturated fatty acids – capric acid or decanoic acid – which the researchers suggest come from ozone reacting with certain C–C double bonds unique to human fingerprints.

American Chemical Society

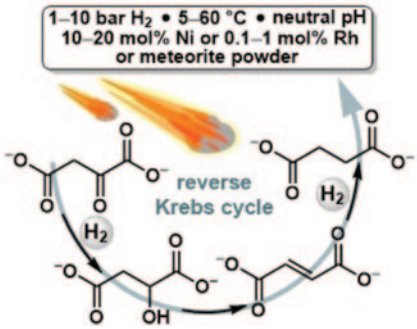
Probing primeval reaction pathways

Naturally occurring chemical reactions may have evolved into the biochemical processes we know today. A team of researchers has now discovered that a reaction sequence from the so-called reverse Krebs cycle – a fundamental biochemical process – can also take place without enzymes. The team writes in *Angewandte Chemie* (doi.org/10.1002/anie.202212932) that metals and even powdered meteorite material can catalyse the hydrogenation reactions.

Cells obtain energy and molecular building blocks through metabolic processes. Compounds are synthesised and broken down again in universal biochemical processes with the help of enzymes. However, simple organic molecules such as organic acids, amino acids and peptides have been found in extraterrestrial objects, suggesting that organic molecules might have existed on early Earth, even before life as we know it developed.

Taking the theory of a self-organising chemical network, some fundamental biochemical reaction sequences derived from naturally occurring chemical reactions may have evolved into the biochemical processes we know today. Sophia Rauscher and Joseph Moran of the University of Strasbourg, France, have now investigated a sequence of the reverse Krebs cycle, a biochemical process used by some microorganisms for fixing carbon dioxide. In this portion of the process, the small organic molecule oxaloacetate is hydrogenated and dehydrated to give succinate in three chemical steps.

In the cellular reverse Krebs cycle, hydrogenation takes place using enzymes that transfer organically bound hydrogen. In order to simulate hydrogenation as it might have occurred on the primordial Earth three to four billion years ago, Rauscher and Moran used elemental hydrogen and metal catalysts. They justified these choices since hydrogen is formed in natural geological processes and can accumulate in reservoirs in the ground or in hydrothermal vents. In addition, meteorites that fell to Earth during this period brought metals with them.



In the experiment, malate was initially formed from oxaloacetate in a hydrogenation reaction, even under mild reaction conditions, mimicking the first hydrogenation step in the pathway. Following the dehydration of malate to fumarate, succinate was formed from fumarate in a further hydrogenation step, following the same sequence of molecules and reactions as in the biological reverse Krebs cycle. Metals such as nickel and even pure powdered meteorite sample were able to catalyse the reactions. These findings could prove relevant for our understanding of the origins of some fundamental metabolic pathways, the authors argue.

Angewandte Chemie

RSC commits to 100% open access

The Royal Society of Chemistry (RSC) aims to make all its fully owned journals open access within five years, making it the first chemistry publisher and one of the first society publishers to commit to a fully open access future.

Free, unrestricted global access aligns with RSC's organisational strategy, which highlights the crucial role of collaboration and the open sharing of scientific knowledge in addressing global challenges, from disease to climate change. Nations in the 'Global South', which will be the worst affected by these issues, are often those with the least access to such crucial information; open access ensures that everyone, everywhere has the same potential to access and contribute to the latest discoveries, leading to a better future for all of us.

RSC is partnering with institutions around the world to develop new open access models that work for them, and that do not rely solely on authors paying processing or publication charges. These can present a barrier to researchers, especially in the least developed countries where funds, even to conduct research, are limited.

RSC aims for most of its global author community to be covered by institutional or funder level deals. This will only be possible with the involvement and collaboration of its international partners, including institutions, corporations and funders.

As an important first step towards a fully open access future, RSC will shortly submit its portfolio of hybrid journals to the Transformative Journal Programme of cOAlitionS, a global grouping of research funders.

Dr Emma Wilson, RSC Director of Publishing said: 'RSC authors come from all over the world, so it's essential that, in our transition to open access, all authors retain the same ability to publish in our journals.

'We are aiming for a future in which open access publication makes authors' work accessible on a global scale. As we saw with COVID research, enabling that level of openness and international collaboration can be a catalyst for accelerating innovation and discovery, creating a better, more sustainable, future for all.'

Assuming sufficient support and participation from partners, RSC aims to publish all of its current portfolio of 44 fully-RSC-owned journals open access within five years.

Royal Society of Chemistry

Plans for world's largest citizen science groundwater study

Resource limitations for research into northern Australia's groundwater has meant not a lot is known about systems, but a new study will take a giant leap in our understanding through citizen science.

The study plans to use a small army of citizen scientists to collect, analyse and record samples of water taken from bores from across the Northern Territory, the Pilbara and the Kimberley.

Charles Darwin University freshwater ecologist and research leader Professor Jenny Davis said the aim was to recruit several hundred volunteers collecting water from more than 500 groundwater bores.

The citizen scientists will input data collected straight into an app designed and built specifically for the project.

'We will be providing easy-to-use and simple field kits, so citizen scientists can collect samples for testing', Davis said.

'We will be testing things such as salinity levels, isotopes of oxygen and hydrogen in the water to determine its age, and even test for microplastics.

'There is a limit to what can be done, but it will give us more information than we have now and if there are unusual results then we can do further investigation.'

Davis said groundwater is vital for communities, farmers and industry across the Northern Territory.

She said despite it being such a vital resource for so many people in the Northern Territory, there is very little known about the water or its interaction with surface water.

'The community's concern about water overuse and pollution is rising', she said.

'The remoteness and vastness of the tropical and arid regions of northern Australia mean that community engagement is the only way that information can be collected effectively across such a large spatial scale.'

Davis said she is confident she will get the volunteers as there has been a lot of community interest in the safety of their water supply and care for groundwater.

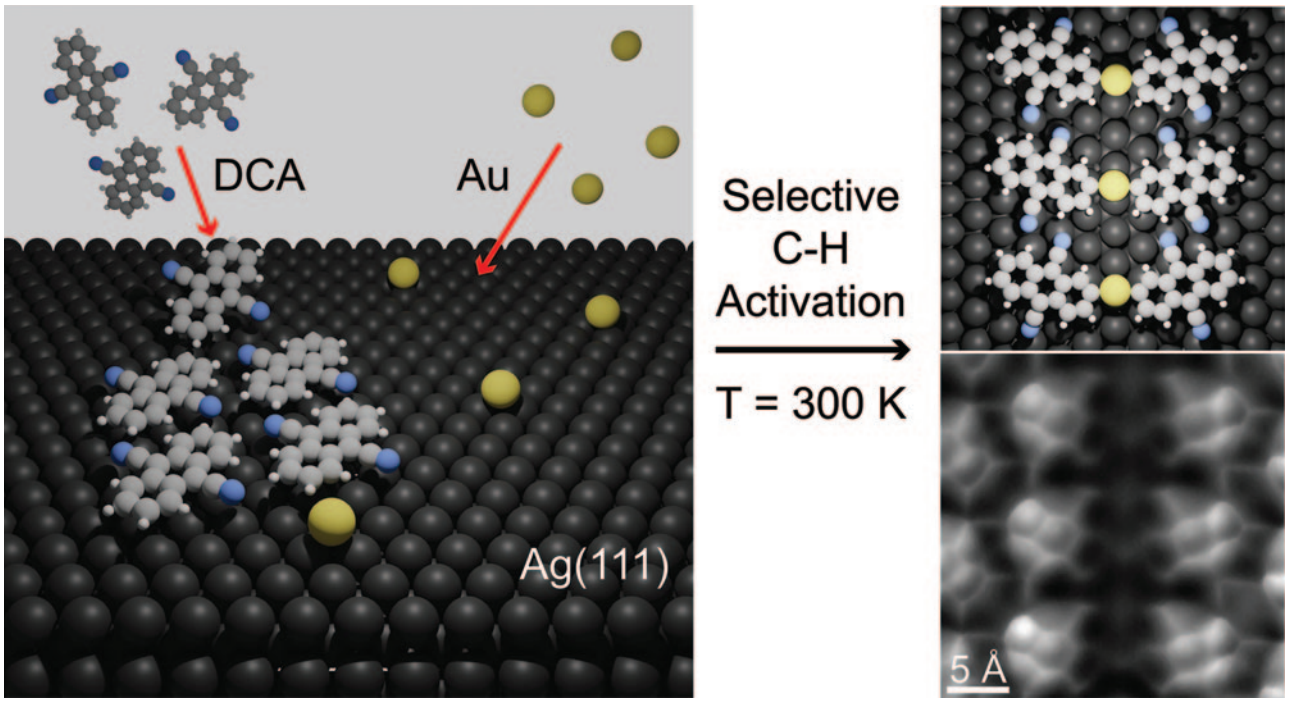
'I ran a citizen scientist project in central Australia where tourists and rangers collected waterhole water for testing and that was very successful', she said.

'This is a project that will help to empower people to make decisions about water management and water use in the Northern Territory.'

The researchers will conduct a pilot project and develop the app before rolling it out across the Northern Territory and northern Western Australia.

Charles Darwin University

A chemical reaction as good as gold



Gold atoms provide a low-energy reaction route, allowing breaking of C–H bonds at room temperature, and formation of covalently bonded DCA-Au-DCA structures. Grey: C, white: H, blue: N, black: Ag (surface), yellow: Au.

Reactions targeting carbon–hydrogen bonds have long been of scientific interest, given that almost all organic molecules contain these bonds. Led by FLEET (ARC Centre of Excellence in Future Low-Energy Electronics Technologies) at Monash University, a new study published in the *Journal of the American Chemical Society* (doi.org/10.1021/jacs.2c10154) finds that individual gold atoms may provide a low-energy route for reactions that can target specific C–H bonds.

'One of FLEET's goals is the development of materials whose electronic properties may be exploited in low-energy technologies', said corresponding author Associate Professor Agustin Schiffrin.

Organic molecules may serve as useful building blocks for tuneable construction of these materials, provided reactions between molecules can be controlled at the atomic scale.

Two big challenges stand in the way of C–H activation reactions: it's difficult to target one specific bond for reaction (poor selectivity), and a lot of energy is required to break these bonds (high activation energy). The researchers have found that single gold atoms may provide a route to C–H activation.

The researchers combined small numbers of individual gold atoms with organic 9,10-dicyanoanthracene (DCA) molecules on an atomically flat surface of silver, Ag(111).

'We used atomic-scale experimental techniques – scanning tunnelling microscopy and atomic force microscopy – to image and characterise the samples', explained lead author and PhD student Benjamin Lowe. 'These techniques revealed unusual covalent bonds between the carbon atoms of the DCA molecules and the gold atoms.'

The formation of such covalent bonds suggested that specific C–H bonds had to have first been broken. Working with theoretical collaborators at the Czech Academy of Sciences, the researchers uncovered a reaction pathway that suggested that a metal–organic intermediate state formed by single gold atoms with pairs of DCA molecules could help such a reaction proceed.

Significantly, the reaction pathway uncovered can only explain C–H breaking of one specific C–H bond. The researchers found a dramatic decrease in the energy required to break this specific C–H bond (activation barrier), enabling the reaction to occur at room temperature.

'This study directly addresses the two biggest challenges – namely poor selectivity and high activation barrier – that limit specific dissociation of C–H bonds in organic molecules', explained chief investigator Agustin Schiffrin. 'Our approach can potentially open the door to the synthesis of novel organic and metal–organic nanomaterials, with properties useful for electronics, optoelectronics, sensing, catalysis etc.'

Given the broad interest in reactions of organic molecules across a range of fields, this promising reaction has many potential applications such as polymer fabrication and modification of pharmaceutical products.

At FLEET, the researchers hope to exploit this selective and efficient reaction to produce atomically thin materials with desirable electronic properties.

ARC Centre of Excellence in Future Low-Energy Electronics Technologies

Raising the profile of women in STEM

Women working in STEM fields around the world will be able to raise their profile and discover opportunities to progress their careers following the launch of STEM Women Global.

The existing STEM Women platform, a free online directory of women working in science, technology, engineering and mathematics in Australia and Asia, has been expanded to include women scientists from across the globe, taking this Australian innovation to the world stage.

'We are very proud to bring STEM Women Global, an Australian innovation, to the international STEM sector', Australian Academy of Science President Professor Chennupati Jagadish said.

STEM Women Global, which any woman working in STEM can apply to join, allows users to search for members by their expertise, country and areas of professional interest, connecting women in STEM with individuals and organisations looking for diverse STEM experts.

STEM Women Global is an initiative of the Australian Academy of Science with the support of the InterAcademy Partnership, the Association of Academies and Societies of Sciences in Asia, the Network of African Science Academies and the Inter-American Network of Academies of Sciences.

The launch included remarks from the InterAcademy Partnership and other project partners. Speakers addressed the importance of raising the visibility of women in STEM in their regions and the significance of mechanisms such as this new directory to establish international collaborations.

As well as expanding the platform for global reach, the project will explore tools and mechanisms to support scientists in exile and will introduce multilingual options for equity of access across locations and cultures.

'The STEM Women initiative unlocks an enormous talent pool of women in STEM, increases their visibility, and directly connects them with career opportunities including international collaborations', Academy Foreign Secretary Professor Frances Separovic FRACI CChem said.

The project highlights the Academy's ongoing commitment to advancing gender equity in STEM by showcasing the breadth of scientific talent both in Australia and across the world, so that women researchers and professionals working in STEM across all countries can be recognised and offered career-advancing opportunities.

Australian Academy of Science

First Nations women take a step into STEM

First Nations students from across the Northern Territory have had a taste of STEM subjects and career pathways as part of a pre-STEM program held at Charles Darwin University (CDU). Twelve female students aged 17–40 travelled to the university's Casuarina campus for the First Nations Pre-STEM program held from 31 October to 6 November.

In partnership with Power and Water, the program provided participants with an opportunity to visit the university and get involved in workshops and activities across all areas of science, technology, engineering and maths.

CDU College of Engineering, IT and Environment STEM Pathways lecturer Dr Carla Eisemberg said the program supports education opportunities at both VET and higher education levels.

'Some of these students have little experience of STEM in VET or higher education, while others are completing a Certificate III in Conservation and Land Management', Eisemberg said.

CDU was 'really looking forward to welcoming these women to CDU and providing a wide variety of activities to meet and expand their skill sets. Their perspectives and knowledge offer a new level of insight and innovation.'

Over a week, participants visited local industries that employ STEM professionals in the Northern Territory and attended interactive workshops and social activities to connect with STEM mentors in their area of interest.

Students took part in activities related to wildlife conservation, robotics and aviation, and visited the Power and Water Corporation to learn about wastewater.

Charles Darwin University

Artificial intelligence powers record-breaking all-in-one miniature spectrometers

We see light and colours around us every day. However, to analyse the information it carries, we must analyse light using spectrometers, in the lab. These devices detect sparkles and substances that our eyes would otherwise not notice.

Now, an international team of researchers, including the University of Cambridge, have designed a miniaturised spectrometer that breaks all current resolution records, and does so in a much smaller package, thanks to computational programs and artificial intelligence.

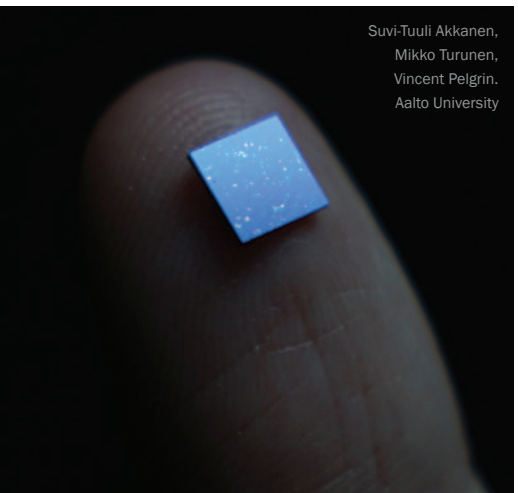
The new miniaturised devices could be used in a broad range of sectors, from checking the quality of food to analysing starlight or detecting faint clues of life in outer space. The results are reported in the journal *Science*.

Traditionally, spectrometers rely on bulky components to filter and disperse light. Modern approaches simplify these components to shrink footprints, but still suffer from limited resolution and bandwidth. Additionally, traditional spectrometers are heavy and take up extraordinary amounts of space, which limits their applications in portable and mobile devices.

To tackle these problems, and shrink the size of the system, researchers have coupled layered materials with artificial intelligence algorithms. The result is an all-in-one spectrometer thousands of times smaller than current commercial systems. At the same time, it offers performance comparable to benchtop systems. In other words, these new spectrometers will provide portable alternatives to uncover otherwise invisible information, without even going into the lab.

'We eliminate the need for detector arrays, dispersive components, and filters. It's an all-in-one, miniaturised device that could revolutionise this field', said Dr Hoon Hahn Yoon, from Aalto University in Finland, first author of the paper (doi.org/10.1126/science.add8544). This spectrometer-on-chip technology is expected to offer high performance and new usability across science and industry.

The detector uses van der Waals heterostructures – a 'sandwich' of different ingredients, including graphene, molybdenum disulfide and tungsten diselenide. Different combinations of material components enable light detection beyond the visible spectrum, as far as the near-infrared region. This means the spectrometer detects more than just colour, enabling applications such as chemical analysis and night vision.



Suvi-Tuuli Akkanen, Mikko Turunen, Vincent Pelgrin. Aalto University

'We detect a continuum spectrum of light, opening a world of possibilities in a myriad of markets', said Yoon. 'Exploring other material combinations could uncover further functionalities, including even broader hyperspectral detection and improved resolution.'

Artificial intelligence is a key aspect of these devices, commonly called 'computational' spectrometers. This technology compensates for the inherent noise increase that inevitably occurs when the optical component is wholly removed.

'We were able to use mathematical algorithms to successfully reconstruct the signals and spectra; it's a profound and transformative technological leap', said lead author Professor Zhipei Sun, also from Aalto University, and a former member of Cambridge's Department of Engineering. 'The current design is just a proof-of-concept. More advanced algorithms, as well as different combinations of materials, could soon provide even better miniaturised spectrometers.'

Spectrometers are used for toxin detection in food and cosmetics, in cancer imaging and in spacecraft – including the James Webb Space Telescope. And they will soon become more common thanks to the development and advancement of technologies such as the Internet of Things and Industry 4.0.

The detection of light – and the full analysis of spectroscopic information – has applications in sensing, surveillance, smart agriculture and more. Among the most promising applications for miniaturised spectrometers are chemical and biochemical analysis, thanks to the capabilities of the devices to detect light in the infrared wavelength range.

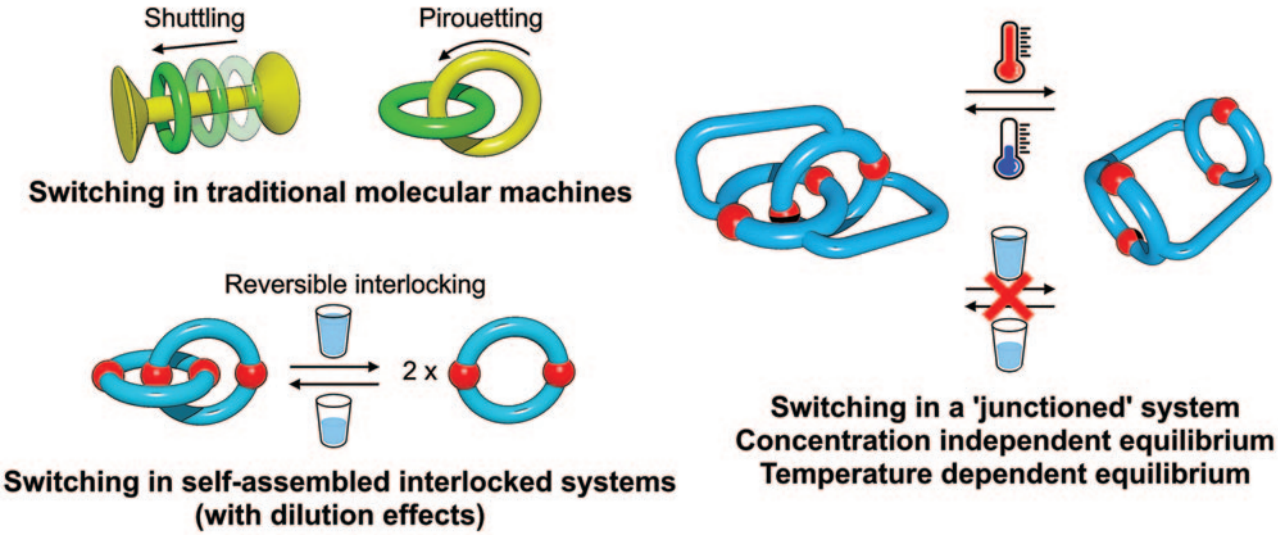
The new devices could be incorporated into instruments like drones, mobile phones and lab-on-a-chip platforms, which can carry out several experiments in a single integrated circuit. The latter also opens up opportunities in health care. In this field, spectrometers and light detectors are already key components of imaging and diagnostic systems – the new miniaturised devices could enable the simultaneous visualisation and detection of 'chemical fingerprints', leading to possibilities in the biomedical area.

'Our miniaturised spectrometers offer high spatial and spectral resolution at the micrometre and nanometre scales, which is particularly exciting for responsive bio-implants and innovative imaging techniques', said co-author Professor Tawfique Hasan, from the Cambridge Graphene Centre.

This technology has huge potential for scalability and integration, thanks to its compatibility with well-established industrial processes. It could open up the future for the next generation of smartphone cameras that evolve into hyperspectral cameras that conventional colour cameras cannot do. Researchers hope their contribution is a stepping stone towards the development of more advanced computational spectrometers, with record-breaking accuracy and resolution. This example, they say, is just the first of many.

University of Cambridge

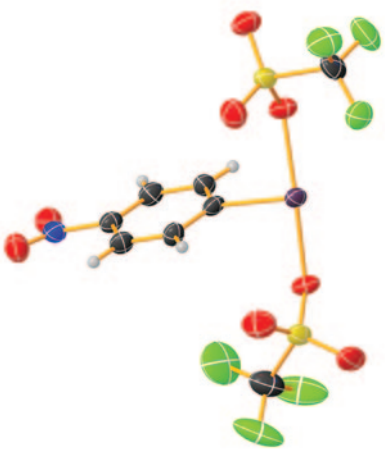
Reversibly interlocking molecules without dilution effects



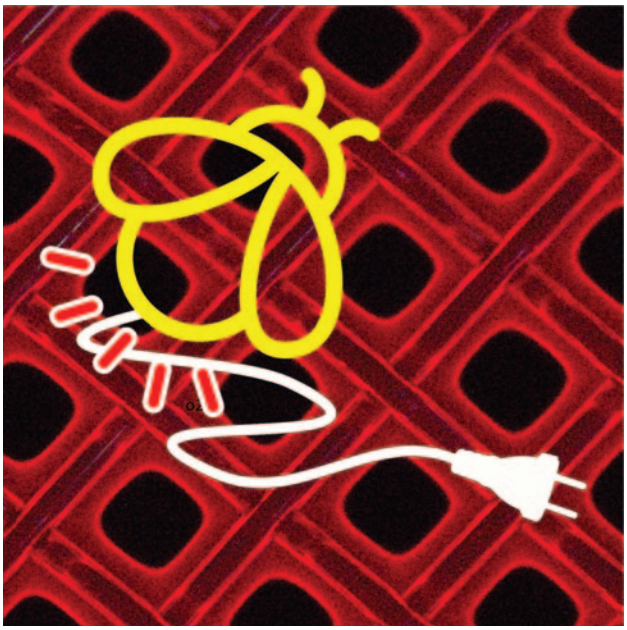
Synthetic molecular machines enable the generation of complex interlocked molecular topologies with the capacity for stimuli-responsive conformational changes that mirror nature's machinery such as proteins. However, they are often difficult to make, are produced in low yield, and require extensive purification. Instead, using high-yielding self-assembly is an attractive strategy, and can give switching between interlocked and non-interlocked states. Generally, these non-interlocked molecules combine through reversible bond breaking and re-formation to form the larger interlocked state. But thermodynamic control is not without its problems, and one of these is the effect of dilution. A consequence of the different number of components in the interlocked and non-interlocked states is that as dilution occurs, the position of the equilibrium shifts to favour the non-interlocked species. Recently, Dan Preston, of the Australian National University, and co-workers developed a strategy using junctions to attach components together to ensure that both non-interlocked species (a double macrocycle) and interlocked species (a trefoil entangled tetrahedron) consisted of the same number of components (Algar J.L., Findlay J.A., Evans J.D., Preston D. *Angew. Chem. Int. Ed.* 2022, **61**, e202210476). The system's equilibrium was independent of concentration over a 400-fold dilution range. Switching between forms was still achievable using temperature, exploiting the favourable enthalpic interactions present in the interlocked species, and the higher entropic favourability through freedom of movement in the non-interlocked species.

Isolating elusive iodine(III) oxidising agents

Iodine(III) reagents with the general formula $PhIL_2$, where L is a neutral or an anionic ligand, are widely used as oxidising agents in both inorganic and organic chemistry. The most oxidising derivative was purported to be $PhI(OTf)_2$. The Dutton group at La Trobe University has previously shown that a reaction thought to give $PhI(OTf)_2$ produces PhI(OTf)(OAc) instead, and that any attempts to make a genuine $PhI(OTf)_2$ result in decomposition to diaryl iodonium species via electrophilic aromatic substitution (EAS) (*Chem. Eur. J.* 2020, **26**, 15 863–6). More recently, the group devised a way to stabilise a genuine $ArI(OTf)_2$ species, NO_2–$PhI(OTf)_2$, by incorporating a nitro group, which shuts down decomposition by EAS while simultaneously rendering the iodine(III) more oxidising (Sharp-Bucknall L., Tania, Dutton J.L. *Angew. Chem. Int. Ed.* 2022, **61**, e202212380). The species was crystallographically characterised and isolated in a straightforward manner. Preliminary reactivity studies indicated that NO_2–$PhI(OTf)_2$ reacts in targeted EAS reactions with deactivated substrates with which the previously misidentified PhI(OTf)(OAc) does not react. Furthermore, the NO_2PhIF_2 precursor was found to be vastly easier to handle than $PhIF_2$, which might indicate that incorporating a nitro group is, counterintuitively, a good method of stabilising already electron-poor iodine(III) species.

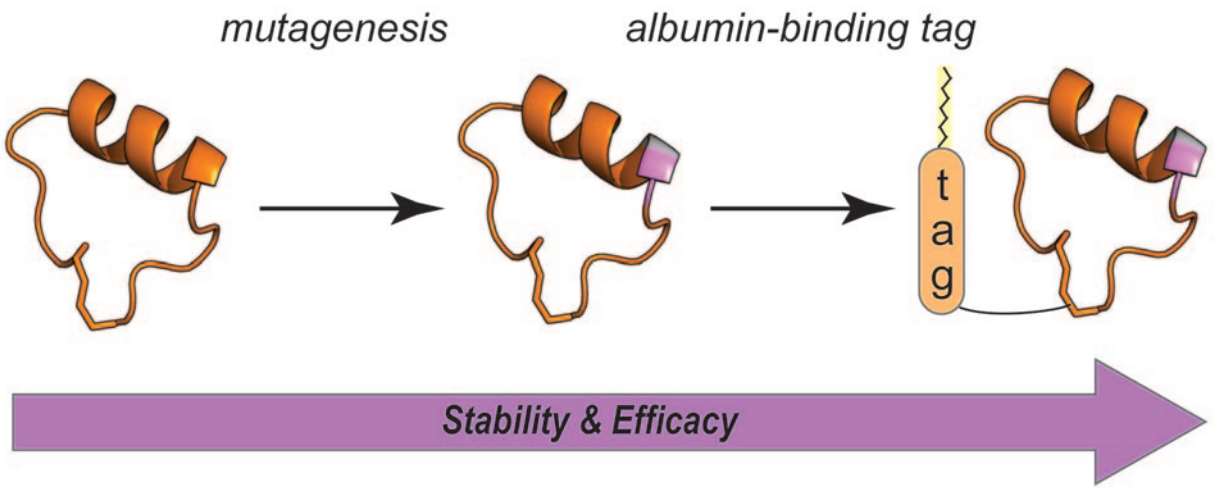


Luciferase-free firefly glow



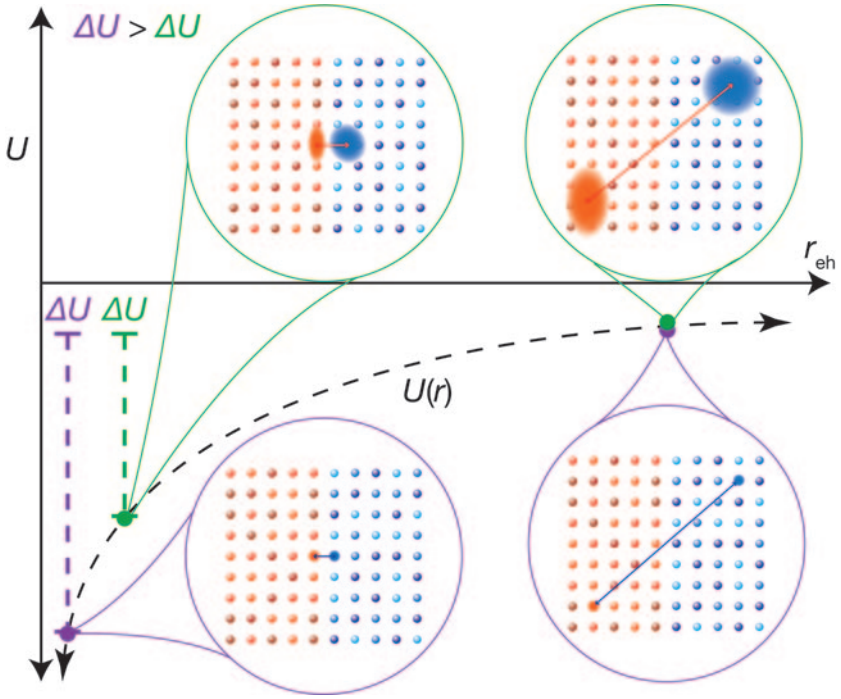
Many of us cherish summer memories of firefly light shows – one of nature's wonders. Electrochemical research has succeeded in capturing some of this eternal beauty 'in a flask'. Light emission accompanying the enzymatic oxidation of luciferin – the firefly's luminophore – by luciferase covers most of the visible spectrum, and is the basis of successful commercial assays for metabolic ATP production. But the chemical details of this light-emitting reaction and the mechanism of natural spectral tuning of luciferin are poorly understood. Addressing this knowledge gap has been hindered by a lack of laboratory model systems able to trigger luciferin luminescence in a simple reaction environment without the complexity of the enzyme active site. Recently, a team of researchers from Curtin University, Flinders University and the University of Bologna (Italy) reported luciferin electrochemiluminescence without the natural catalyst (Belotti M., El-Tahawy M.M.T., Yu L.-J., Russell I.C., Darwish N., Coote M.L., Garavelli M., Ciampi S. *Angew. Chem. Int. Ed.* 2022, **61**, e202209670). This work settles a longstanding debate, proving that natural spectral tuning of luciferin from red to green does not require keto–enol tautomerism of the light emitter. The research also provides evidence of electrostatic stabilisation of the excited state by double-layer electric fields near an electrified surface.

Stabilising peptide drugs



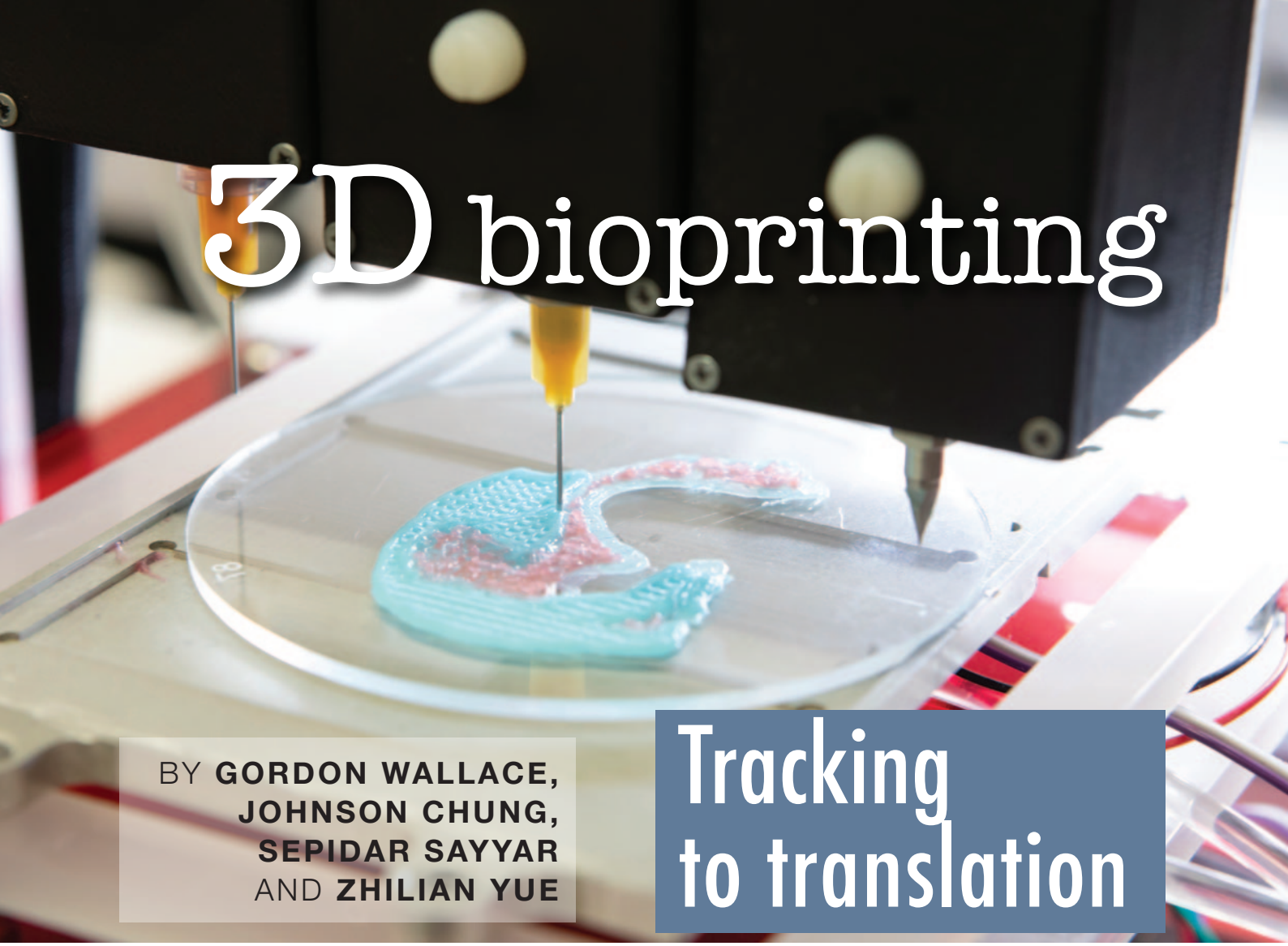
Peptides are promising drugs because of their potential for high target specificity and selectivity. But a major barrier to using peptides as drugs is their short half-lives (2–30 min) in vivo due to enzymatic degradation and renal clearance. The cyclic peptide P9-38 has previously been reported to be a potent nanomolar inhibitor of PCSK9, a validated drug target for lowering cholesterol levels. But P9-38 has a low serum half-life (0.7 h), suggesting that it could have poor in vivo activity. Now, a research team from the University of Queensland's Institute for Molecular Bioscience, collaborating with researchers from the Peking Union Medical College (China) and Università degli Studi di Milan (Italy), has successfully improved the in vivo stability and efficacy of P9-38 by applying mutagenesis and a lipidated albumin-binding tag to the peptide (Zhang Y., Wang L., Tombling B.J., Lammi C., Huang Y.H., Li Y., Bartolomei M., Hong B., Craik D.J., Wang C.K. *J. Am. Chem. Soc.* 2022, **144**, 19 485–98). The study demonstrates that, besides enhancing binding affinity, optimising stability is an effective strategy for improving the in vivo function of a peptide therapeutic.

Delocalisation kinetically enhances charge-separation efficiency in organic photovoltaics



Organic photovoltaics are next-generation devices that promise truly green energy. Compared with common silicon photovoltaics, they are cheap, lightweight, flexible and printable. In organic photovoltaics, light creates excitons, electron–hole pairs, which must separate into free charges to generate electricity. However, it remains unclear how charges with a large Coulomb attraction (more than 10 times larger than the available thermal energy) separate with near perfect efficiency. A common hypothesis is that delocalisation reduces the energetic barrier, by increasing the initial separation (and reducing the Coulomb attraction) of charges in a charge-transfer state. Confirming this hypothesis, however, has proven difficult due to the complexity of tracking the correlated motion of two quantum-mechanically delocalised charges through the large volumes required to simulate disordered materials. Daniel Balzer and Ivan Kassal from the University of Sydney have developed the first three-dimensional simulations of quantum-mechanical charge separation, including disorder, delocalisation and polaron formation (Balzer D., Kassal I. *Sci. Adv.* 2022, **8**, eabl9692). The approach, delocalised kinetic Monte Carlo, reveals that even a little delocalisation dramatically increases charge-separation efficiency. Importantly, this enhancement is not produced by the common hypothesis, but by purely kinetic (not energetic) reasons due to boosted overlaps of partially delocalised electronic states.

Compiled by **David Huang** MRACI CChem (david.huang@adelaide.edu.au). This section showcases the very best research carried out primarily in Australia. RACI members whose recent work has been published in high-impact journals (e.g. *Nature*, *J. Am. Chem. Soc.*, *Angew. Chem. Int. Ed.*, *Chem. Sci.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to David.



3D bioprinting

Tracking to translation

BY **GORDON WALLACE, JOHNSON CHUNG, SEPIDAR SAYYAR** AND **ZHILIAN YUE**

Accrued knowledge from a convergence of biomaterials, tissue engineering, stem cell biology and 3D biofabrication advances is providing unprecedented insights into and controls over cellular systems on the bench.

In many ways the most significant bioscience advances rely not only on the design and discovery of new materials chemistries but on how these are arranged in 3D space to interact with a 3D cellular system. Less obvious than the science but equally critical to creating new medical solutions is the ability to work with and listen to others who understand the biological and medical challenges at hand. These others have the ability to identify the most useful bits of this tsunami of knowledge that can be diverted into selected medical challenges.

As we work together to find the technical solution, it must be something that is scalable and deployable, something that meets all of the commercial and economic requirements to be sustainable. This translation to scaling, manufacture and deployment will depend on the availability of records maintained under an appropriate quality management system. These are processes alien to the ingrained thinking of most traditional researchers. This progress requires a change in environment and culture, and is evoking a change in mindset.

We can explore this translational journey through the lens of some of our recent projects.

Axcelda pen

The Axcelda system was developed to regenerate cartilage in defects in the knee. This collaboration was initiated through interactions with Professor Peter Choong, an orthopaedic surgeon at St Vincent's Hospital in Melbourne. The team has now grown to include Associate Professor Claudia Di Bella (surgeon) and an amazing research team drawn from researchers at the universities of Wollongong and Melbourne, Swinburne University of Technology and RMIT University.

The need

Hyaline cartilage is characterised by low cell numbers and consists of an avascular, non-neural aliphatic environment. The distinct collagen fibre structure confers appropriate mechanical properties. The regeneration of cartilage remains a challenge. The use of an approved clinical product failed in more than 60% of patients. This inability to effectively repair cartilage leads to the development of osteoarthritis, a condition that contributes greatly to healthcare expenditure.

Advances

We have developed optimal ink formulations to protect adipose stem cells during 3D printing and to ensure differentiation into cartilage. As this project progressed, the delivery (printing system) evolved to meet the needs of the bioink properties and the structural requirements of the print. Innovative approaches to stem cell isolation from the fat pad below the kneecap have been developed, enabling a rapid turnaround time relevant to clinical deployment. Being a trailblazer, to deploy a 3D bioprinting strategy in clinic for cartilage regeneration, this project extends back over an extended time period during which we have learnt a lot.

Orthopaedic surgeon Professor Peter Choong with the Axcelda biopen.

Lessons learnt

In retrospect, a blueprint for the clinical deployment plan, developed in the early stages of our collaborative work would have accelerated translation. It would have helped forge the most appropriate research/experimental pathway.

Adhering to an appropriate quality management system to document progress and changes in that pathway (as we now have) would also have facilitated translation and strengthened our IP position and strategy at an earlier stage.

In terms of bioink formulations, simplest is best to enable effective scale-up. In choosing the biomaterial components for bioinks, consideration of issues such as storage conditions required, sterilisation and packaging for deployment need to be considered. Of course, the use of biomaterials already approved for implantation will help in navigating the regulatory pathway.

We also did some things right! Building an interdisciplinary research team that brought together the right mix of skills and personalities has been critical to our success to date. In interdisciplinary research with a view to translation, the composition of the team needs to be dynamic and has a critical temporal dimension. In this case, perhaps injection of regulatory and commercial expertise earlier in the journey would have positioned the project a bit better for translation – you live, you experiment, you adjust, you learn.

3D printing of prosthetic ears.

3D printed ears

We are endeavouring to 3D print prosthetic and living ears to treat patients with microtia. This collaborative project has clinical input from Professor Payal Mukherjee, an ENT surgeon at the Royal Prince Alfred Hospital in Sydney and a prosthetist, Sophie Fleming. The research team comprises researchers with expertise in imaging, mechatronic engineers to design and build printers, materials scientists and biologists.

Bioprinting is an emerging technology that integrates cellular delivery while ensuring structural support is pre-ordained through 3D-printed scaffolds that are personalised to the patient's needs. The final outcome is to have a specialised 3D-printed bioactive implant customised to a patient's biology and anatomy, so that the scaffold material in the implant will eventually be absorbed within the body, leaving behind the patient's own tissue-engineered cartilage in the shape of their own anatomy.

The need for prosthetic ears

Worldwide, about one in 5000 babies are born with microtia/anotia, a congenital birth defect in which the external ear framework is poorly developed or completely missing. This condition is mainly treated by reconstructive surgery or external prostheses, with the latter being favoured significantly. Prosthetic reconstruction is less intensive and expensive, and provides a more aesthetic shape of the natural ear than surgery. Currently, most prosthetics are manufactured by a method that requires a highly trained prosthetist and large time investments in addition to high processing cost. 3D printing has been extensively used in various fields, most notably the biomedical domain to overcome the limitations of conventional manufacturing techniques. With this technique, complex structures can be produced more quickly and the production technology is deployable, enabling service in remote areas.

Advances

We have demonstrated for the first time the development of a portable and low-cost 3D printing system for the manufacturing of complex structures from different grades of silicone materials.

Bioprinting is an emerging technology that integrates cellular delivery while ensuring structural support is pre-ordained through 3D-printed scaffolds that are personalised to the patient's needs.

This approach allows an ear to be scanned by a handheld scanner, mirrored in virtual space and reproduced symmetrically in polydimethylsiloxane (PDMS). The rheological properties of PDMS were modified without damaging the inherent properties to make a suitable ink for 3D printing complex structures.

This system can be adapted to 3D print many types of body shapes besides facial prosthetics through minor hardware modifications.

Lessons learnt

Our system was demonstrated to be suitable for fabricating facial prostheses. However, improvements in both hardware and software in order to 3D print prosthetics in larger dimensions and higher resolution are required. Broader conversing with the prosthetic community earlier in the project would have resulted in very useful inputs towards the functional requirements and printer design.

Scanning ears to obtain 3D images using mobile phones or handheld scanners is a procedure that has a high error rate with limited resolution. Developing an efficient mobile application and computer software, as well as creating a standard protocol for ear scanning that clinicians, and preferably the patients, can perform with high accuracy and repeatability is a must. Using machine-learning techniques in this field can be very helpful. However, many 3D scans are required to be taken from different participants for this purpose. Building links with machine-learning experts earlier would have meant many images in the correct format could have been obtained.

The need for bioactive implants

In the head and neck region, elastic cartilage is key to the skeletal support of the ear, nose and throat, which are also complex 3D shapes. Elastic cartilage has limited self-regenerative capacity. Repair and reconstruction is therefore challenged by limited donor sites in the body and donor site morbidity. Alloplastic implants (which use synthetic material) can avoid donor site morbidity, shorten surgery time and improve size and contour matching, but reported rates of fracture and exposure are high. Autologous tissue reconstruction is therefore considered superior. Tissue engineering on its own has had little clinical impact in the head and neck, as solutions do not address the anatomical 3D complexity of the face.

Advances

Using 3D printing techniques, we have solved the engineering complexities needed to address the 3D shape demands and mechanical properties of the cartilage implants, using polycaprolactone-hydrogel scaffolds. We have overcome several translational milestones. We have:

- created a customised bioprinter (3D Alek)
- validated a novel technique in bioprinting that allows the scaffolds and desired cells to be co-printed without compromising cell viability
- confirmed through in vitro studies that cell survival and differentiation are maintained when both cells and scaffold are printed in this manner
- delivered 3D Alek into a clinical environment at the Royal Prince Alfred Hospital
- performed the first sheep trial for scaffold assessment in microtia, using polycaprolactone-hydrogel scaffolds printed through 3D Alek
- studied the impact of mesenchymal stem cells (the precursors of structural cell types) by co-culturing them with donor cells able to make cartilage.

Our collaborative efforts to date have enabled progress from discovery to animal trials in four years.

Lessons learnt

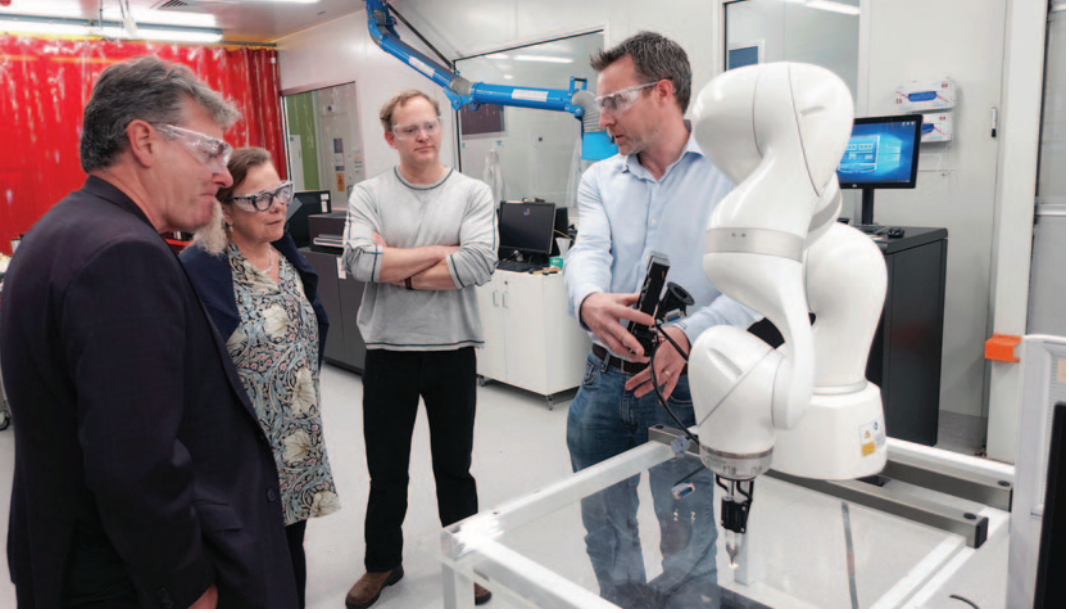
Effective communication between engineers designing the prototype printer and biologists printing the scaffold cannot be underestimated. Throughout the project, several modifications of the bioprinting process were required to ensure structural integrity of the framework and viability of the cells. However, this was not discussed immediately with the engineers, resulting in multiple iterations that severely delayed crucial experiments. It is also important to ensure successful transition between team members leaving or joining the team, to avoid miscommunication or a knowledge gap.

With this technique, complex structures can be produced more quickly and the production technology is deployable, enabling service in remote areas.

Similar to the Axcelda project, an appropriate quality management system should have been implemented very early on in the project. This would have facilitated translation and an understanding of the challenges in the regulatory pathway.

Animal trials are one of the most crucial stages in gaining regulatory approval or commercialisation with the appropriate tissue model. This is expensive, time consuming, but has the lowest level of success in grant proposals. Including any animal trials in the initial developmental grants or prototypes will significantly avoid the 'valley of death' in funding in later stages.

An interdisciplinary research team with the right skills is everything to a project's success. A project of this calibre requires a clinical mentor, a material scientist, a mechatronic/software engineer and a biologist. The team needs to be agile in making changes at all stages of the project and have a full understanding of the final goal in translation.



Professor Fiona Wood and Associate Professor Mark Fear (Fiona Wood Foundation; centre) with Professor Gordon Wallace (left) and Stephen Beirne (TRICEP).

3D printed skin

Using in operando 3D printing to facilitate skin regeneration, in particular, in people with burns, is a collaborative project with Professor Fiona Wood at the Royal Perth Hospital.

The need for prosthetic skin

Skin loss through burns and chronic conditions such as skin cancer, diabetic ulcers and genetic blistering diseases cause significant patient morbidity and mortality worldwide. In Australia, 200 000 people suffer burns annually, resulting in a total cost of more than $150 million. Half of hospital admissions are children. Chronic wounds are also a major contributor to mortality, morbidity and permanent disability worldwide. There are more than 400 000 chronic wound cases in Australia at any time, with an estimated direct healthcare cost of $2.85 billion per annum.

Despite progress on developing treatment methods to facilitate skin regeneration, the current gold standard treatment for full thickness wounds remains with skin autografting. This involves harvesting healthy skin from other body sites to graft onto wounds, with severe limitations such as insufficient donor sites in extensive burns cases and the creation of additional injuries with further risk of infection and scarring.

Advances

We have focused on developing bioink formulations, printing hardware and organotypic printing protocol for printing skin cells directly into wounds to produce full-thickness skin structures. For instance, we have developed biologically active ink formulations that support 3D printing dermal-like structures and subsequently promote organotypic interactions with skin epidermal keratinocytes to form full thickness skin-like structures. These include bioink formulations using a sulfate- and rhamnose-rich polysaccharide that resembles mammalian glycosaminoglycans being involved in wound healing and tissue matrix structure and function. These molecules are extracted from seaweed in a collaborative project with Dr Pia Winberg and Venus Shell Systems.

To improve the biological activities of ink formulation, we have developed bioinks based on human platelet lysate, a rich source of growth factors that play an important role in regulating the healing cascade. More recently, we have progressed to investigations into the role of different skin cell types in facilitating repair of full thickness skin defects in a preclinical pig model, and used the knowledge accrued to guide development of a clinical prototype 3D bioprinting platform for use in surgical theatre.

Lessons learnt

There are urgent needs for the development of technologies to improve the functionality of regenerated skin, such as vascularisation and innervation, as well as to reduce processing time consumption and production cost. Bioprinting brings unique opportunities to tackle these critical challenges; however, to realise its full potential, a number of technical hurdles must be overcome. These include the development of safe, effective and affordable stem cells to reduce reliance on human donors and reduce the risk of infections and thus chronic wounds. It is critical to develop a knowledge base on how bioink formulations interact with key skin cell types and sources, and how 3D-printed structures regulate self-assembly of these cell types to enable optimal tissue morphogenesis and further development of skin organ. The clinical and regulatory needs for bioink constituents should be considered at the early stage of bioink development. Last, but not least, there is an increasing appreciation of the need to develop intraoperative skin bioprinters that can print multiple biomaterial–cell combinations into large and complex wound defects at high speed and with high resolution.

Translational facilities

The Translational Research Initiative for Cell Engineering and Printing (TRICEP) at the University of Wollongong is focused on developing materials synthesis protocols and bioink formulations as well as hardware manufacturing governed by an auditable quality management system that pertains to ISO accreditation. Attracting support for development and resourcing of such entities is challenging. The transition of mainstream researchers into such an environment is not without challenge and brings a new dimension to the level of collaboration required to ensure success. Facilities such as TRICEP are critical to this.

Dr Pia Winberg, Venus Shell Systems' seaweed 'farmer' extraordinaire, holding extracts containing biomolecules used in our skin regeneration program.

Positioning to translate

As we clamour to engage and develop more effective deployment of fundamental research findings, a new ecosystem is emerging in (pockets of) our research organisations. There is a growing recognition of the need to partner early to bring in the non-technical skills required to translate research. There is also an acknowledgement that such skills will most likely not be found or retained within research organisations. There is a growing recognition of the need to train our researchers to be 'technology jockeys' – to take ideas to industries and drive the process of translation – dropping technology off at the door doesn't work.

Encouraging industry into research laboratories will also help this process – not just for fleeting visits but to work alongside researchers – experience their journey and the complexities associated with it.

For effective translation in the areas discussed here, an insight into health economics (value-based care), regulatory issues and commercialisation pathways is essential. As an important element of this, positioning the project to create protectable intellectual property that will warrant investment is essential. IP portfolio needs to be developed in partnership with commercial partners. Universities do not have the expertise nor the resources to build portfolios across the whole gamut of university activities. All of these inputs are required early. They are no longer an afterthought in today's research ecosystem.

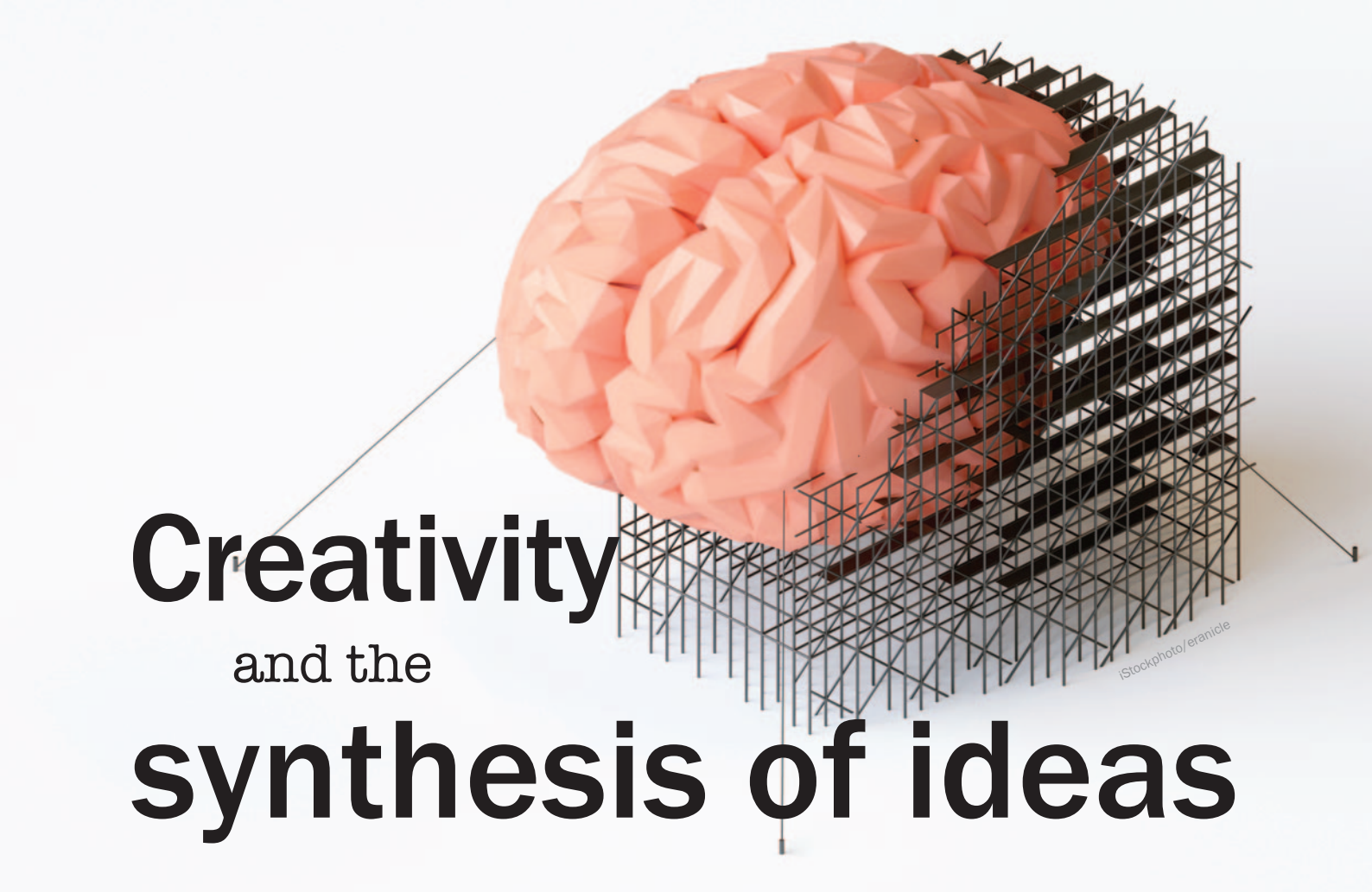
We are well placed in Australia to tap into an amazing ecosystem, including Australian Research Council Centres of Excellence, Corporate Research Centres and Growth Centres. Of particular relevance here is MTP (medical technologies and pharmaceuticals) Connect. All provide access to individuals and teams committed to translation. We are also fortunate to have an amazing array of national facilities supported by the national collaborative Research Infrastructure Strategy (NCRIS). Of particular relevance here is the ANFF Materials Node, providing facilities and expertise for materials synthesis scale-up and access to advanced fabrication capabilities. We also have an exciting new opportunity to facilitate interactions of younger clinicians and researchers through the Beyond Science Program.

The research community in Australia can stand tall – we have listened, we have learnt, we have changed and we are ready to play our part in an emerging ecosystem that supports us in taking ideas to industries.

Acknowledgements

Thank you to all of our collaborators who continue to inspire us, provide incredible intellectual capital and energise through their enthusiasm.

Gordon Wallace AO FAA FTSE FRACI CChem is Director of the Intelligent Polymer Research Institute, University of Wollongong, and Director of ANFF (Materials Node). **Johnson Chung**, **Sepidar Sayyar** and **Zhilian Yue** are at the Intelligent Polymer Research Institute, University of Wollongong.



Creativity and the synthesis of ideas

Synthetic chemist Lorenzo V. White encountered barriers when trying to re-enter Australian research after spending time as a union official in construction. Unusual career histories should be supported to enhance workplace diversity, he says.

In *Unended quest: an intellectual autobiography* (1974), philosopher of science Karl Popper said of creativity:

> *What characterizes creative thinking, apart from the intensity of the interest in the problem, seems to me often the ability to break through the limits of the range – or to vary the range – from which a less creative thinker selects his trials. This ability, which clearly is a critical ability, may be described as critical imagination. It is often the result of culture clash, that is, a clash between ideas, or frameworks of ideas. Such a clash may help us to break through the ordinary bounds of our imagination.*

As Popper explains, a broader range of perspectives is more likely to produce original ideas, and this is one of many benefits of diversity in science. Minister for Industry and Science, the Hon Ed Husic MP, recently announced a review into how federal government programs can support diversity in STEM (bit.ly/3eNwI89), and the Australian Academy of Science (bit.ly/3CMzSkq) is pursuing best practice in equity, diversity and inclusion.

In my experience, Australian universities generally overlook research candidates with non-traditional career pathways. Reflection on my unusual career trajectory emphasises how encouraging workers with non-traditional paths contributes to diversity in science.

I was lucky enough to complete my entire secondary education in Canberra's fantastic public schools. When I made it to university, I decided to pursue a double degree in chemistry and philosophy at the Australian National University. By about halfway through second year, I had decided to work towards a career in total synthesis, and I approached the lecturer for the organic component of my general chemistry course to express this desire. That fateful

meeting has influenced the direction of my life. The lecturer was Professor Martin Banwell, a Fellow of the Australian Academy of Science, who later became my PhD supervisor and, later still, my dear friend and collaborator.

During that very first conversation, Martin hashed out a plan to expose me to the maximum amount of lab work possible while still an undergraduate (through, for example, what Martin described as a 'double-barrelled research project'). Martin's willingness to accommodate and even encourage non-standard arrangements for people in his group was something I always considered most effective about his work approach. An early and important example of this was when he arranged for me to work in Professor Sam Zard's labs at École Polytechnique in Paris during my PhD studies, on an unusual doctoral exchange program.

After a less than ideal experience during my first postdoctoral fellowship overseas, I wanted to acquaint myself with the world of professional work outside academia. I returned to Australia and secured a few remote jobs that were indirectly related to my training as a synthetic chemist. These included working as a freelancer in scientific editing and publishing as well as compliance assessments of government chemical regulations.

The most important experience, in terms of maturing my thoughts, came from a job that at first seemed totally orthogonal to my training as a scientist. At various times during my undergraduate studies, I had worked on building sites in Canberra as a scaffolder. In every instance, I was an active union member. Some of my union contacts found out I was looking for work, and they came to me with an offer to organise structural trades such as scaffolding and concreting on building sites in the ACT. Suffice to say, the bosses discovered that dealing with a doctor of science was a highly non-standard experience.

The cover of a textbook I used in Year 11 declared that chemistry is the 'science of matter and change'. What a beautiful description. Successfully representing workers and even expanding their interests in a hostile political environment demanded a kind of dialectical thinking that pushed me to understand change in new and powerful ways. The dialectical method is extremely powerful when applied to the natural sciences, as demonstrated by a recent article contextualising and even resolving, among other things, contradictions inherent in the Copenhagen interpretation of quantum mechanics (G. Carchedi, *International Critical Thought*, 11 September 2022).

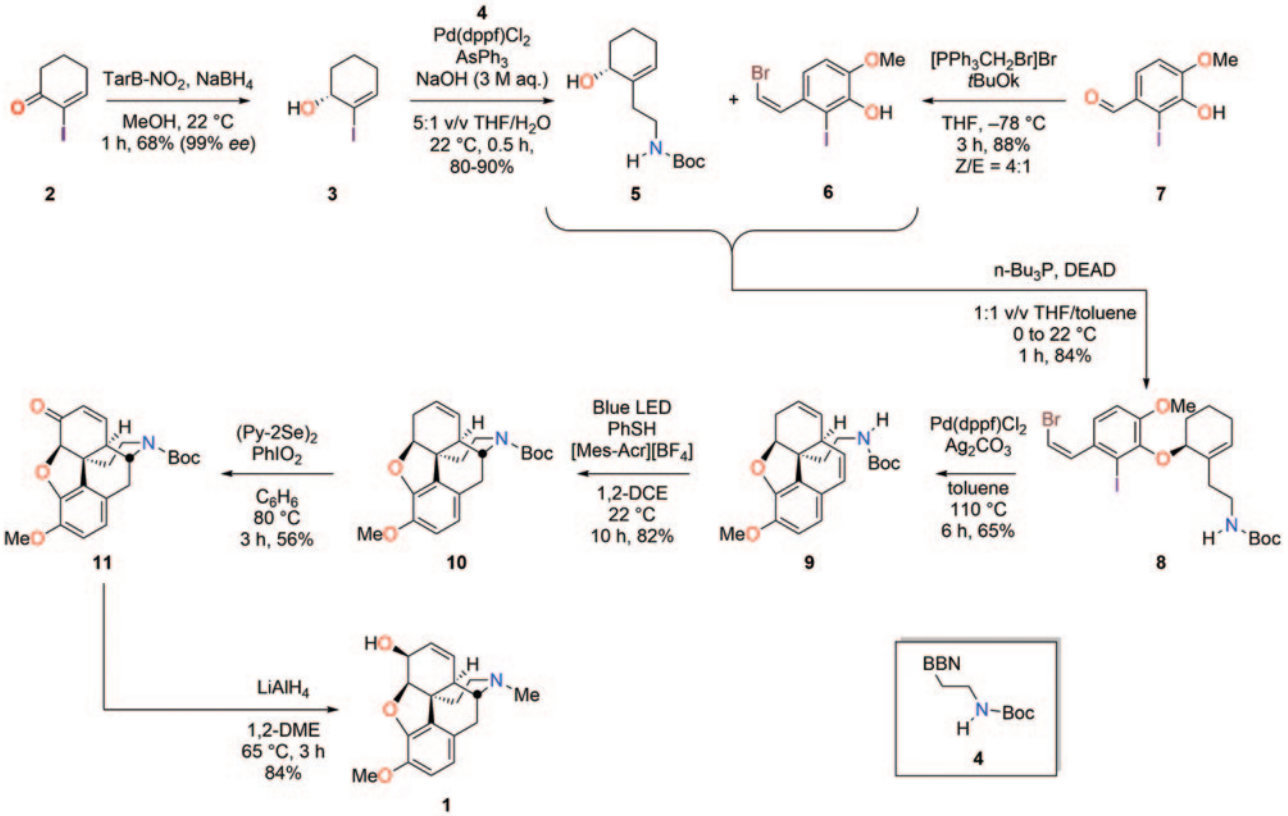
In addition to theoretical insights, active participation in social practice as a union official forced me to think deeply about strategy. This in particular had a direct impact on my ability to plan the synthesis of complex molecules.

After two years as a union official, I desperately missed work as a scientist and became determined to return to the lab. However, despite my strong publication record and numerous academic and professional awards, it would have been almost impossible for me to secure either an academic or a postdoctoral position in Australia immediately after my two-year research hiatus, let alone think about being competitive for an ARC grant.

In addition to theoretical insights, active participation in social practice as a union official forced me to think deeply about strategy.

I have benefited immensely from my training as a researcher in Canberra, interacting with eminent chemistry professors such as Lew Mander and Athel Beckwith. However, more influential to me has been the great emphasis of the Australian undergraduate education system on practical application. Working overseas in various countries, more than once I was struck by the comparative lack of practical synthetic ability of researchers at similar career stages. Despite this, re-entering the research workforce in Australia was difficult.

Lorenzo White (centre) during his time as a union official for the ACT branch of the CFMEU.



A seven-step synthesis of (–)-codeine (1)

This was not the case in China. Indeed, when I contacted former colleague (and now associate professor) Lan Ping to discuss my resumé, he replied with a job offer as a High Level Foreign Talent Research Fellow at the Institute for Advanced and Applied Chemical Synthesis (IAACS) in Guangzhou. The position was funded by a grant from the Central Government, which I was able to secure in a matter of weeks. As it turns out, the director of the IAACS is Martin Banwell. Martin's enthusiastic support for my appointment as a fellow, despite my two years working as a union official, is another example of his encouragement of those with non-standard career paths.

In the planning stages of my route to codeine, the lessons in strategy I had learnt as a union official came to the fore.

Of course no system is perfect, and my experience in China had its challenges. For example, when the COVID-19 pandemic first became global, I was on the way to start my new job in Guangzhou – and the Central Government closed China's borders. I was stranded in Malaysia, and had to endure that situation for 14 months while sorting out a new visa. Perversely, this setback contributed to some of the most important achievements of my research career thus far.

The extended time to sit and think in isolation spurred me to develop a new research program (which I continue to pursue) focused on the synthesis of new antiviral therapeutics inspired by the Amaryllidaceae alkaloids (S. Tan, M.G. Banwell, W.-C. Ye, P. Lan, L.V. White, *Chem. Asian J.* 2022, e202101215). Also, and perhaps more importantly, I was able to devise a benchmark synthesis of (–)-codeine (**1**). This was eventually published in *Angewandte Chemie* and featured in the journal cover art (L.V. White, N. Hu, Y.-T., He, M.G. Banwell, P. Lan, *Agnew. Chem. Int. Ed.* 2022, vol. 61, e202203186).

In the planning stages of my route to codeine, the lessons in strategy I had learnt as a union official came to the fore. I am not advanced enough in my career to have my own series of signature reactions that allow me to present my work in the current style. Thus, to make a significant contribution in this area, I had to go back to basics and develop a route to alkaloid (**1**) in which 'the symphony appears greater than the sum of the notes'. The only way to do this with the chemical knowledge I possessed at the time was to come up with a benchmark synthesis in terms of both total reaction time and number of chemical steps. A summary of my

Lorenzo V. White (right) at the ANU chemistry labs with mentor and close friend Dr Brett Schwartz.

successful synthesis of (–)-codeine, which proceeded in only seven steps from commercially available α-iodocyclohexenone, is shown in the reaction scheme.

In addition to being the shortest route to (–)-codeine and the morphinan framework, the synthetic sequence depicted in the reaction scheme has some other advantages. For example, since stereochemical control throughout the entire route is determined by the configuration of the hydroxyl group in chiral alcohol (**3**) (and since either enantiomer of the chiral borohydride reagent can be easily prepared from the two enantiomers of tartaric acid), the work also represents a formal synthesis of (+)-codeine. Furthermore, the photoredox hydroamination protocol used to effect the transformation (**9**)→(**10**) permits an unprecedented and atom economical construction of the morphinan D-ring, since no prior activation of the tethered nitrogen nucleophile is necessary.

It would have been impossible to bring this work to a successful conclusion without the knowledge and support of my highly capable colleagues. In particular, Professor Martin Banwell endured my rapid-fire discussion of the developing chemistry nearly every day over our regular morning coffees. Professor Yu-Tao He, luckily for me, skilfully operated a blue LED-based photochemical facility in the lab next to mine.

My proposals to extend the initial successes described here were recently awarded a National Science Foundation of China grant. As it turns out, I will be completing at least some of this work in Paris in the labs of Professor Sam Zard, as part of an unprecedented arrangement in which the IAACS will send me to the École Polytechnique for two years as a visiting fellow. Once again, none of this would be possible without the open-mindedness of Professor Martin Banwell.

As part of the important reviews into diversity in STEM currently underway, I hope stories like mine can help policymakers recognise the large dividend that accrues from supporting researchers with unusual career backgrounds.

Dr Lorenzo V. White is at the Institute for Advanced and Applied Chemical Synthesis, College of Pharmacy, Jinan University, Guangzhou, China.

New CEO for RACI

RACI has announced the appointment of Shenal Basnayake as its new Chief Executive Officer (CEO).

Shenal has extensive experience and a distinguished career across the public, private and not-for-profit sector, most recently as the CEO of the Australian Science Teachers Association (ASTA). Previous roles include Director of Major Programs within NSW Department of Industry, CEO of the Northern Territory Farmers Association and overseeing economic recovery efforts for the Cassowary Coast Regional Council following Cyclone Yasi in 2010.

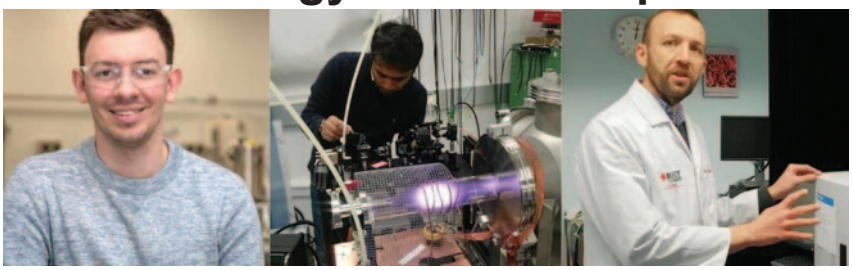
Shenal has also worked pro bono for an Indigenous Corporation building business resilience for Indigenous entrepreneurs. Shenal began the role on 24 October 2022.

Professor Steven Bottle, RACI President at the time of Shenal's appointment, indicated that Shenal's diverse management experience will be a great asset for RACI as the organisation adapts to the changes in industry, government and academia driven by the pandemic and other major global events. 'Shenal was selected for the CEO role from an exceptionally strong field of candidates following a long and highly competitive process. I am delighted to welcome him as the new RACI CEO, knowing that the RACI will be in very capable hands with Shenal', Professor Bottle said.

'Shenal's proven record in engagement with industry, community groups and government will be a great asset for the RACI going forward, as the chemistry community is likely to have an even more important role in Australia in the near future than pre-pandemic' said current RACI President Professor Pall (Palli) Thordarson, who took on the RACI Presidency after the RACI AGM in late November 2022.

Shenal says 'I am incredibly pleased to have been appointed to take RACI forward as its new CEO and I look forward to the opportunity to advance the professional interests of members and the broader chemical sciences sector. The RACI has a rich history built on a strong suite of offerings but there is more that can be done, and I aim to listen, learn and act on the needs of members, as they are the centre of what makes a great professional association.'

2022 Metrology Awards recipients



Left to right: Dr Neil Robinson, Dr Rounak Manoharan and Professor Oliver Jones.
Photos courtesy award recipients

The prestigious Barry Inglis Medal and NMI Prize recognise outstanding measurement-related achievements in Australia or by Australians. NMI's CEO and Chief Metrologist Dr Bruce Warrington and Australia's Chief Scientist Dr Cathy Foley announced the winners at a special event for National Science Week.

Professor Oliver Jones FRACI CChem, from RMIT, received the 2022 Barry Inglis Medal for his extended and careful development of analytical measurement techniques. He applied these to a range of impact areas including environmental monitoring for chemicals of concern, and metabolomics.

The NMI Prize, an award for early to mid-career professionals up to the age of 35, went to Dr Neil Robinson MRACI CChem from the University of Western Australia. This was for his research on the development and application of novel nuclear magnetic resonance techniques for characterising functional porous materials important to energy, environment and society.

'Professor Jones's work is an excellent example of the illustrious achievements the Barry Inglis Medal is intended to recognise. His leadership, collaborations, contribution to professional bodies and commitment to science communication are also notable', Warrington said.

'Equally, the novelty and careful evaluation shown in Dr Robinson's work and the immediate and potentially widespread application to industrial and resource processes were very impressive', Warrington added.

For the first time in 2022, NMI added a new People's Choice category to the awards.

Six finalists were invited to each present a five-minute pitch to a live online audience who voted on their preferred candidate. Dr Rounak Manoharan (Electro-Optic Systems) wow'ed the crowd with an eloquent talk on a fast measurement technique to investigate short-duration pulsed plasmas.

CEO and Chief Metrologist Dr Bruce Warrington will formally present the winners with their awards at ceremonies in Melbourne and Perth in December.

National Metrology Institute

New Green and Sustainable Chemistry National Group

RACI's new Division, the Green and Sustainable Chemistry National Group, welcomes all sustainability troopers.

On 7 July 2022 at the RACI National Congress, a group of members launched the Green and Sustainable Chemistry (GASC) National Group as a new and yet-to-be Division of the RACI. This group is a mix of academics and industry practitioners from chemistry, materials science and engineering, and chemical, mechanical and electrical engineering disciplines, who wish to find a home for like-minded 'chemical' people to find green and sustainable solutions for making things. The evidence of cracks in our over-stretched planetary boundaries is mounting. How can we enable a quick transition to a zero-carbon emission economy, restore biodiversity and clean up our environments? What can we do to make a positive change? These are the matters that GASC members really care about.

At the formation stage of the GASC National Group, a few of us discussed whether we should go with the name of 'green chemistry' or 'circular chemistry'. Academically, we can make a distinction between these two concepts.

Green chemistry was formed in the 1980s and provided 12 guiding principles that focus on the direct sustainability assessment of chemical reactions and are considered to be a suitable framework for the optimisation of linear production routes.

Of course, we all have our respective expertise. How can we break the boundaries and work together towards solutions?

Circular chemistry, coined by the 2019 *Nature Chemistry* paper (vol. 11, pp. 190–5) authored by Keijer, Bakker and Slootweg, is presented as an analogous framework that can make chemical processes truly circular and sustainable, with a focus on using waste as a resource.

As a chemical engineer, I see both frameworks as very enlightening as well as instructive for achieving our sustainable development goals. Circular chemistry is perhaps becoming a more relevant subset of green chemistry, given the exponential growth in human consumption and waste generation. We want our children, grandchildren, great-grandchildren and so forth to continue to enjoy the abundance that we have now instead of living on our ruins – this is the very basic concept of 'sustainability'. So, here we are; we went for the 'Green and Sustainable Chemical (GASC) Group'. Colin Raston, who co-chairs GASC with me, thinks going for a GASC drink sounds really cool – I couldn't agree more.

Of course, we all have our respective expertise. How can we break the boundaries and work together towards solutions? As with building things, there are also two universal pathways, namely 'bottom-up' and 'top-down'. The bottom-up approach is something like a joyful potluck dinner full of surprises and serendipities. The top-down approach needs a clear vision and strong leadership. In this, industry and governments can definitely play a role. With my hat of materials scientist on, I would say a simultaneous top-down and bottom-up approach often works wonders. With this, we welcome all content experts, thinkers and doers with a commitment to sustainability to join us at GASC.

Qin Li MRACI is Professor of Environmental Engineering, Queensland Micro- and Nanotechnology Centre, School of Engineering and Built Environment, Griffith University, Brisbane. **Colin Raston** FRACI CChem is Professor of Chemistry, Flinders University, Adelaide.

Outreach as a chemistry ambassador

During Canberra's second lockdown in 2021, I received an email from RACI's membership officer, Nick Taylor, seeking interest in RACI's new Ambassadors Program. At first, I was unsure about the program, which was in its pilot stage, but I was eager to discover the opportunities available, and to be involved in more science outreach activities in 2022.

During his three years as RACI membership officer, Nick had noticed that the relationship between RACI and Australian universities was based on just an accreditation program. The impacts of COVID-19 and the funding cuts to science-based subjects throughout Australian universities during these unprecedented times were warning signs. Nick believed that this was the perfect opportunity to do something about re-establishing and rebuilding the relationship between RACI and academia, which is how the University Ambassadors Program (which Nick coordinates) was formed.

The RACI University Ambassadors Program is a group of chemists across Australia who are excited to help educate students about the benefits associated with being an RACI member. We are a mix of postgraduate students, postdoctoral fellows and early career chemists across Australia who are passionate about chemistry and want to perform student outreach activities, build networking opportunities, and liaise with local RACI branches to organise workshops. There are currently 24 active ambassadors across Australia, and I am one of two representing the Australian Capital Territory Branch.

For me, the program is a great way to network with the Australian chemical community, and to make opportunities in chemistry more accessible for everyone.

For me, the program is a great way to network with the Australian chemical community, and to make opportunities in chemistry more accessible for everyone. As an RACI University Ambassador, I have liaised with ANU's Chemistry Society (ChemSoc), an undergraduate chemistry club, to help organise promotional, networking and mentoring events at the ACT. For example, ChemSoc and I collaborated to promote RACI through a marketing campaign during ANU's orientation week.

During National Science Week 2022, ChemSoc and I collaborated again with the involvement of the RACI ACT Branch Committee. We invited five speakers (Dr Tom Carruthers (Ogilvy PR Australia), Dr Mei Yi Leow (Science in Australia Gender Equity), Vanessa Vongsouthi (Samsara Eco.), John Morgan (Newcrest Mining) and Owen Hurst (Allan & Hurst Risk)) to give an in-person seminar about how their chemistry background helped guide their career journeys. The focus of the event was to display a wide variety of career pathways for chemistry students after graduation that are not purely in academia. We also used the event to introduce students to the RACI framework, and highlight RACI's networking platform for mentorship, careers and science outreach throughout Australia.

An exciting exercise that I have been actively engaged in as an RACI University Ambassador is preparing interview articles for the ACT Branch newsletter. In this role, I have identified RACI ACT members for 'Chemist of the Month' and 'Chemistry Student of the Month' focus pieces. In 2022, the Chemist of the Month (ACT) initiative aimed to highlight members with a research chemistry background working in non-academic roles, including careers in industrial and pharmaceutical divisions, government policy and regulation, and science communication. So far, I have interviewed Dr Vanessa Robertson and Dr Mei Yi Leow. Dr Robertson is the director of the Chemical Weapons Convention Implementation section of the Australian Safeguards and Non-proliferation Office and is a mentor for the RACI Mentoring Program. Dr Leow is a research and resources advisor at Science in Australia Gender Equity (SAGE) and is the current chair of the RACI Inclusion and Diversity Committee. The one contribution I am most proud of is advocating for the creation of the 'Chemistry Student of the Month' category in the newsletter to highlight research students in the ACT. The new category has now featured two talented PhD students in the RACI ACT Branch newsletter.

As the University Ambassadors Program is in its pilot phase, there is a lot of work to implement to make it more appealing to our tertiary student audiences. For example, we could install educational and fun competitions for university students – like the activities that RACI have prepared for secondary school students. When I first came across the RACI Chemistry and Art competition, I was so excited to participate until I realised that entry was only for secondary school students. I would have loved to see this as a high school student back in New Zealand. There is also potential for the program to organise workshops that encourage students to volunteer and participate in team-building exercises for leadership development – we need to support activities that enable students to grow professionally alongside their academic progress.

I hope that as the University Ambassadors Program becomes more established in the upcoming years, we have a better framework on the RACI platform that caters to university students to help build their career networks, give opportunities to volunteer, and gain leadership experiences. There are some things that the program will need to install for ambassadors too. Nick comments that 'a push needs to be made towards all ambassadors agreeing on and using a contact platform like Slack or Microsoft Teams'. The RACI team will be adding a

For promising University Ambassadors who would like to expand their outreach, I suggest collaborating with your local university chemistry or science clubs.

University Ambassadors field to the member profile page, which will be a place for communication and recognition among members.

A possible future outcome of the RACI University Ambassadors Program is to pave the pathway for the introduction of an industry-based ambassador program (RACI Industry Ambassadors Program), which would tie in perfectly with the overall aim of the current ambassadors program, and for RACI to have a platform that can help students from start to finish, i.e. working with students as they progress from Student Member to Postgraduate Student, then MRACI and so on. RACI aims to be there to support members from their undergraduate studies to employment preparation, career guidance, and assisting in finding work experience and placements. As members progress to the professional stage, the RACI Industry Ambassadors Program would then help members to find a job, create a professional network, and be part of a support group. Nick comments 'what more could one want from membership if [students] can sign up knowing the RACI will be there to assist them through every step of their chemistry journey from the classroom to the research laboratory to their professional careers'.

For promising University Ambassadors who would like to expand their outreach, I suggest collaborating with your local university chemistry or science clubs. The initiative at ANU to team up with the ChemSoc club was a major success, as the collaboration allowed me to promote RACI to a junior audience through an already-existing platform. We also organised a seminar that exposed students to broader career pathways outside of academia. You could also communicate with your local Branch committees. After reaching out to the ACT Branch co-ordinator, I was given the opportunity to interview people, and essentially network with local members, advocate for more student representation, and produce focus pieces for the newsletter. Every Branch committee will have different opportunities for their local ambassadors, and that's when you can transform your experience in the RACI University Ambassadors Program. Recruitment for the next wave of University Ambassadors for 2023 and the introduction of the Industry Ambassadors Program will be coming soon, so keep a look out for the application if you're keen to get involved!

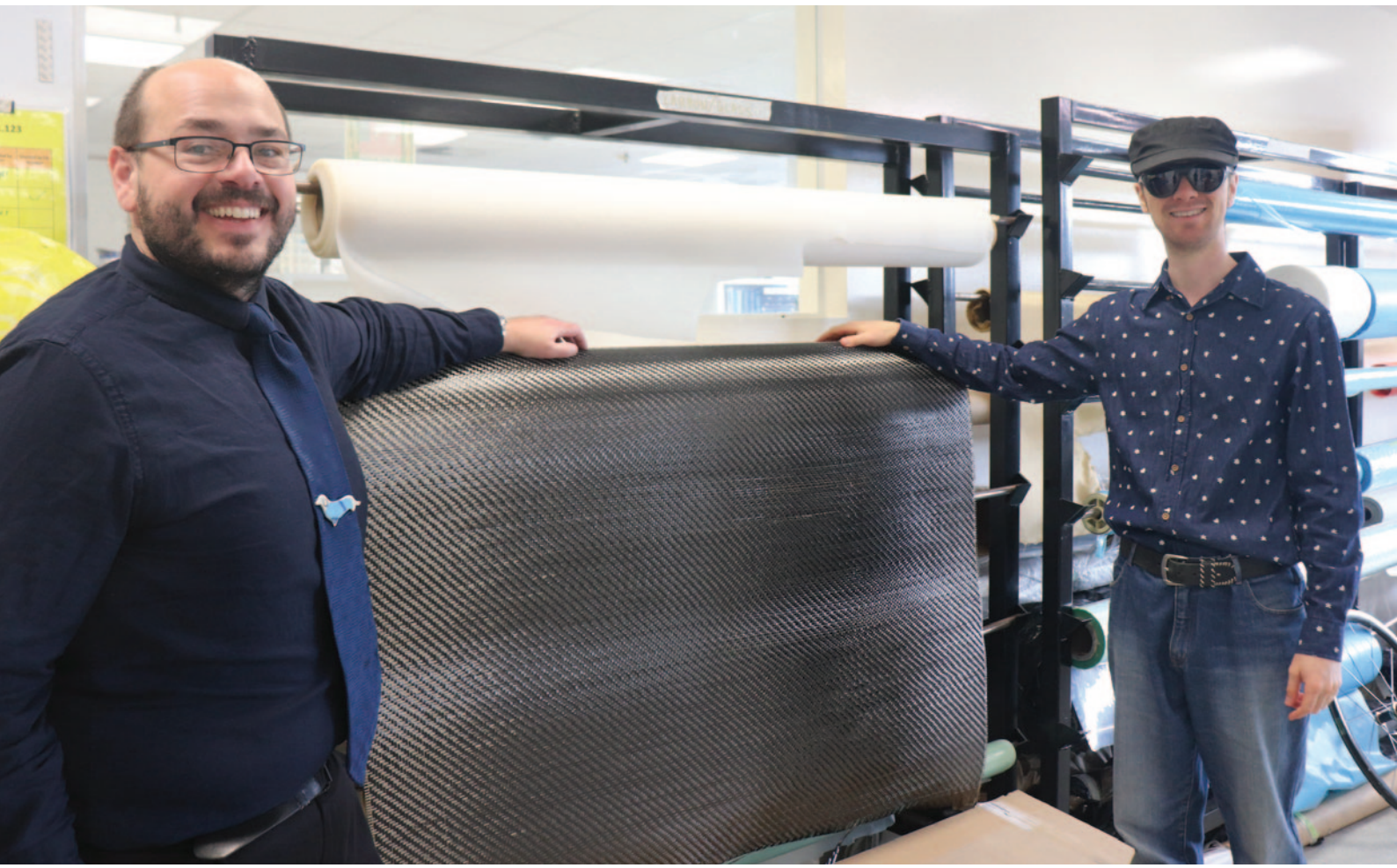
Junming He MRACI (junming.he@anu.edu.au) is a PhD student at the Research School of Chemistry, Australian National University.

About Junming He

Junming He received a BSc with First Class Honours in Medicinal Chemistry from the University of Auckland (2019). Junming is a PhD candidate at the Australian National University under the guidance of Dr Christoph Nitsche, Associate Professor Lara Malins and Professor Colin Jackson, and is engaged in several collaborative research undertakings in the field of peptide chemistry, encompassing synthetic organic, medicinal and biological chemistry to investigate bioactive molecules for drug development. Alongside his PhD studies, Junming has dedicated his time to chemistry outreach, promotional and mentoring programs that serve to enrich the knowledge and academic opportunities afforded to secondary school and undergraduate students, as well as to the general community.

Junming is currently affiliated with the RACI University Ambassadors Program, and the RACI ACT Branch committee, and is a member of the Australian Research Council Centre of Excellence for Innovations in Peptide and Protein Science (ARC CIPPS) Communications and Outreach committee. He has been an ongoing science mentor in Science Mentors ACT since 2021, and a student representative in the ANU Research School of Chemistry's Inclusion, Diversity, Equity and Access (RSC IDEA) committee since 2020. He is the recipient of the RACI 2022 Postgraduate Student Travel Award.

International Day of People with Disability and 'Disability 101'



Tim Harte (right) and supervisor Professor Luke Henderson (left) with a roll of woven carbon fibre at Deakin University's Institute of Frontier Materials.

On Saturday 3 December, Australia celebrated International Day of People with Disability (IDPwD). IDPwD is a United Nations observed day proclaimed by the UN in 1992 and observed by Australia since 1996. It aims to increase understanding of issues experienced by people with disabilities (PwD); muster support for safeguarding the rights, dignity, and well-being of PwD; and promote the integration and inclusion of PwD in all aspects of society.

Australian IDPwD events were hosted by different levels of government, workplaces, schools and universities across the country. The unifying theme of IDPwD events is education of the general public through the voices of PwD. Education, via personal story telling, breaks down perceptions of difference and highlights similarities and shared experiences, thereby humanising PwD in the eyes of non-disabled people. This facilitates understanding and empathy of the daily plight of PwD – assisting the non-disabled population to 'walk in our shoes' and comprehend the lives and experiences of PwD.

The membership of RACI is a subset of the broader Australian population. Australian Bureau of Statistics data from 2018 found that 17.7% of the Australian population, 4.4 million Australians, were PwD. Approximately 13% of respondents to the 2022 RACI Inclusion and Belonging Survey (a voluntary survey) said they were PwD.

What is disability? In Australian society, we recognise that disability can be visible or invisible/non-obvious, and includes physical, intellectual, psychiatric, sensory and neurological disabilities. Disability, defined in this context, is a significant oversimplification, relying on the divergence of an individual's physical or mental state from what is regarded as 'the norm' and is commonly referred to as the medical model of disability. While this model of disability is relevant when accessing treatment/therapy from health practitioners, it does not address that it is the interaction with environmental and attitudinal barriers within society that impede PwDs' full participation, on an equal basis with others, within society.

The social model of disability was developed in the 1970s in the UK and at the time was a ground-breaking shift in disability theory. At the centre of the social model of disability was the separation of an individual's conditions/attributes and the societal environment. The social model of disability defined 'impairment' as the medical or biological difference from 'the norm' (a person who uses a wheelchair may have a physical impairment due to a spinal injury), but defined 'disability' as the interaction of an individual's impairments with the disabling aspects of the physical environment and attitudinal aspects of the social environment. Disability occurs, for example, when a person who uses a wheelchair encounters disabling architecture within the physical environment. The social model of disability was instrumental in enabling PwD to realise that many issues they experience are not caused by their disabilities but by disabling aspects of society.

The biopsychosocial model of disability was developed in the late 1970s to explain the medical conditions and disablement of individuals by more than just biological factors, but by a combination of biological, psychological and social factors. While there are many models of disability, the biopsychosocial model provides a relatively simple, unifying model that incorporates the experiences of PwD, the social barriers (environmental and attitudinal) they encounter, and the psychological impact on individuals of their internal relationship with disability and the impacts of overcoming social barriers. In short, the 'bio' part of the biopsychosocial model of disability covers people's physiological experiences, such as impairment effects like pain; the 'psycho' part covers psychological experiences, such as internalised oppression; and 'social' covers factors both environmental and attitudinal within the social environment, such as stairs.

Internalised oppression is a form of psycho-emotional disablism that occurs from the relationship a PwD has with themselves. Because people within society are conditioned to view disability as a negative, PwD can view their own disabilities as a negative part of themselves, and can physiologically oppress themselves when they view themselves as lesser; it is more likely to affect those who acquire disability later in life because these people are faced with negative representations, preconceived ideas, or stereotypes, of disability, which they held before acquiring disability.

When considering inclusion of PwD, it is important to consider where we are now in achieving an equitable world. The United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) came into effect in 2008, prior to which disability consideration within international human rights instruments was significantly lacking. The UN Convention on the Elimination of All Forms of Discrimination against Women was adopted in 1979, and 43 years later we are still struggling to achieve gender equity. It is 14 years since the UNCRPD came into effect; hence, many advances are yet to be implemented to improve the lives, circumstances and inclusion of PwD and the accompanying knowledge base within disability studies.

Disability awareness and understanding is not about knowing every medical condition or type of disability; it is about developing a sense of awareness of the physical and social environment where you start to recognise barriers.

Most RACI members will have limited control or influence over the physical environment in their workplaces or places of study. We are not architects or builders who can fix inaccessible steps. Don't let this phase you; as discussed above, the social experiences of PwD, such as the attitudes or misconceptions PwD encounter, affect the level of exclusion and degree of inclusion experienced by PwD within society. Disability awareness and understanding is not about knowing every medical condition or type of disability; it is about developing a sense of awareness of the physical and social environment where you start to recognise barriers.

My top tips to increase inclusion of PwD are:

- recognise that PwD are people first, people with feelings, ambitions and experiences, who are not a tragedy, or an object of charity but people who are living reality and overcoming barriers on a daily basis
- recognise that PwD are experts in their own lives – if you have a question, politely ask it, every person's experience of disability is different and we should never assume or speak for others
- recognise that the lived-experience of PwD is valuable – our diversity of experience, values and perspective adds productively to teams and decision making.

R&D investment in assistive technology predictive typing software for PwD in the early 1990s led initially to predictive text features on 1990–2010s 'brick' phones and was further adapted and developed into voice typing and voice-activated digital technology platforms, such as Siri and Alexa, that are widely used today. Today's R&D, focused on overcoming issues for PwD, will feed into the widescale, marketable consumer products of 30 years' time. Moving into research in materials chemistry, I hope to be a conduit for more efficient and affordable assistive technology while providing a socially nuanced, disability lens to the application of our research.

Tim Harte GAICD is a member of the RACI Inclusion and Diversity Committee, an Honours student at Deakin University, and the Victorian State Director for Physical Disability Australia, a national peak Disabled People's Organisation.

Vale John Edgar Lane (1932–2022)

Thermodynamicist without peer

John Lane was well known for his elegant surface thermodynamics, so it seemed appropriate that his family and friends farewelled him in the elegant building that is St John's Anglican Church in Camberwell designed by Louis Williams in the 'Arts and Crafts' tradition.

John was born in Adelaide on 2 December 1932. He was the second youngest of the eight children of Britt and Gertrude Lane. His secondary education was at Adelaide Technical College, where he showed aptitude for woodwork and the limited technical studies available. He decided to train as a laboratory technician at BALM Paints, where his ability to grasp scientific and mathematical concepts impressed his supervisor enough for him to encourage John to go to Adelaide University. He was the first in his family to do so.

John Lane graduated from the University of Adelaide with a BSc (1957) and then a PhD (1963) for his work on the surface properties of liquid sodium and liquid potassium. He spent a year in the metallurgy department at McMaster University in Ontario, applying irreversible thermodynamics to multicomponent diffusion, before spending two years at Bristol University developing a simple model of the solid–liquid interface.

He joined the CSIRO Division of Physical Chemistry at Fishermens Bend in 1965 to work with Bill Mansfield on fundamental aspects of the control of evaporation from dams. The Division changed to Applied Chemistry in 1968 and to Applied Organic Chemistry in 1974, when John was promoted to senior principal research scientist. As computer power grew in the 1970s, he embarked on a project on the simulation of physical adsorption using Monte Carlo methods. This work was described by a referee as 'brilliant, virtually unique, and of great value to me personally and to the scientific community generally'. Some of his organic chemistry colleagues were not quite so complimentary. They described him as an 'entropy administrator'!

John suffered from chronic asthma since his childhood and by the time he reached the age of 50, with the medication then available, he could no longer work. He retired from CSIRO on medical grounds in 1980. With careful management and improved treatment, he lived for another 40 years.

John was very active in both RACI and the International Union of Pure and Applied Chemistry.

He was the book review editor of *Proceedings of the RACI* 1968–70, a Victorian Branch Committee member 1970–71 to 1972–73, and the Victorian Branch Physical Chemistry Group Chairman 1971–72 and committee member 1973–74. He joined RACI in 1958 and was elected Fellow in 1980.

When it was announced that Paul Flory (Nobel Prize in Chemistry 1974) was going to be the guest speaker at the Polymer Division Conference at Mildura in 1971, John decided

that at least a few chemists in Australia should be familiar with Flory's recently published monograph *Statistical mechanics of chain molecules*. He established a book group that met regularly at Monash University and learnt enough about the subject to have useful conversations with Flory in Mildura. In 1972, the group studied *Thermodynamics of materials with memory* by G. Amendola, M. Fabrizio and J.M. Golden. John used his insights from that study in discussions on the properties of competing materials for banknote substrates.

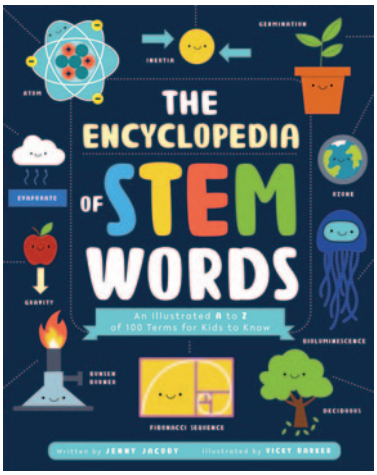
John was a member of the Physical Chemistry Division of IUPAC. He was a titular member of the Division's Commission on Physicochemical Measurement and Standards from 1973 to 1979, enjoying the meetings in Davos, Warsaw, Madrid and Montpellier.

Post retirement, John worked in a voluntary capacity in the School of Chemistry at the University of Melbourne, giving lectures in thermodynamics to undergraduates and assisting research students. His last published paper was in 1989 and was co-authored with his friend Tom Healy and his son-in-law, Jeff Aston. He and his wife, Raelene, were active members of the Genealogical Society of Victoria, where his computing and analytical skills were much appreciated.

As John's collaborator, Jean Swift commented 'John was a real gentleman and a great role model for younger scientists. His door was always open to all for advice'.

John is survived by his wife Raelene, his daughter Rachel and three granddaughters.

Rachel Aston is John Lane's daughter and **Tom Spurling** FRACI CChem is a friend and colleague.



The encyclopedia of STEM words: an illustrated A to Z of 100 terms for kids to know

Jacoby J. (author), Barker V. (illustrator), CSIRO Publishing, 2022, paperback, ISBN 9781486316632, 112 pp., $27.99

The encyclopedia of STEM words is an attractive and approachable book about science (and technology, engineering and maths) aimed at eight- to twelve-year-olds.

Jacoby has chosen 100 words covering a wide range of STEM topics. Each word is explained in simple language with accompanying graphics that reinforce the explanation. You will learn more than 100 words, though, because key terms introduced in the explanations are shown in bold and explained further in the index at the back of the book. In this way, the index also acts like a glossary. For example, the entry on 'kidney' also introduces the reader to urine ('the science word for wee'), ureter, bladder and nephron.

The broad coverage of science topics includes terms from botany, zoology, ecology, geology, chemistry, physics, astronomy and palaeontology. If any A-to-Z book warranted X-ray as the entry for X, it is this one, and sure enough you will find it. Other science terms range from adaptation to zoology. The activity of doing science is also touched upon with terms such as hypothesis and variable. Jacoby has also done justice to the maths, engineering and technology components of STEM, including terms such as zero, prime, machines, AI (artificial intelligence), fibre optics and Wi-Fi.

Interestingly, the explanation of STEM at the start of the book includes the 'A' word (art) that gets incorporated into the broader term some prefer – STEAM. In this context, art involves creative activities to inspire and express STEM ideas. Topics that fit into the art category include sketching, perspective, italic (lettering) and hatching (as in shading and hatching in drawings). These nicely complement the STEM topics and should be relatable to children doing science at school, for example.

The encyclopedia of STEM words, although published in Australia by CSIRO, was first published by a UK company. This would explain why the entry 'deciduous' describes evergreen trees as growing in places where winters are long and cold – a statement difficult to relate to Australia's largely evergreen tree flora and relatively warm or hot climate. But that is an exception, and the book is otherwise relevant to Australia.

If CSIRO had produced the book itself, I suspect it may have avoided a couple of errors of science that have slipped through. For example, the kingdoms of living organisms are said to include fungi, plants, 'animals and insects'. Although there are various schemes of classifying kingdoms, they all classify insects as part of the animal kingdom.

I was also surprised to read the 'ozone layer is only a few millimetres thick'. Online, I find NASA does indeed say that the amount of ozone in the atmosphere is about 300 Dobson units, equivalent to a layer three millimetres thick – but that is how thick it would be if you extracted just the ozone molecules from the atmosphere and compressed them at a pressure equivalent to that at Earth's surface. In fact, the ozone occurs in the stratosphere in a layer more like 30–50 kilometres thick, which is quite a different image.

I wonder if CSIRO's accessibility standards would have allowed the various instances of black text on a dark blue or purple background that could make it hard to read for people with a visual disability. Those shortcomings aside, there is much in this book to interest young readers and get them started in investigating STEM topics.

Margie Beilharz

Discovering cosmetic science

Barton S., Eastham A., Isom A., McLaverty D., Soong Y.L. (Eds), The Royal Society of Chemistry, 2021, paperback, ISBN 9781782624721, ebook ISBN 9781788017138, 350 pp., $56–100

Discovering cosmetic science is a really, really great little book. It is well written, filled with interesting and informative discussion about the world of cosmetic science. I am not a cosmetic scientist, initially believing the cosmetics industry was all 'froth and bubble', concerning itself with things people use to adorn their faces, temporarily push back the ravages of ageing or surround themselves with pleasant smells to mask human aroma. And, yes, cosmetic science and the cosmetics industry are about these matters, but very much more besides. There is a lot of very interesting and complex science, including surface science, the science underpinning scents and aromas and the science behind skin and skincare products, all lurking behind the skin-thin veneer of beauty.

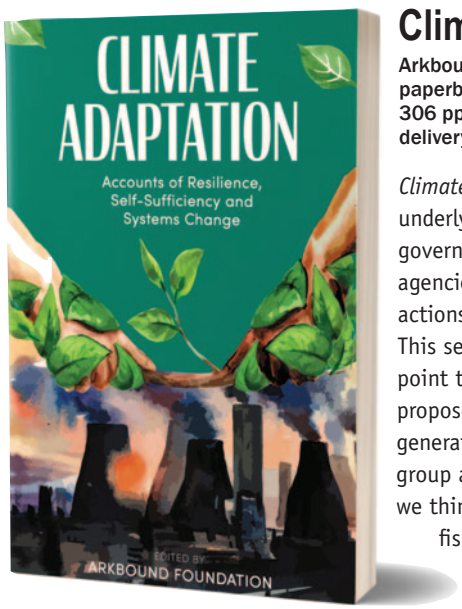
There is an impressive array of five editors and 20 (including the five) contributing authors. Their brief CVs all suggest they are superbly appropriate and well credentialled/experienced to assemble this book. Possibly, cosmetic scientists are a calmer species, but the thought of getting editorial agreement and convincing 15 other contributors to fall into line fills me with awe! Yet, the book comes together very well. You may have noticed the broad price range quoted for the book (as at May 2022). It certainly pays to shop around and, regrettably, that probably means shopping internationally.

Part of the raison d'etre for the book is essentially to make neo-graduates aware of the extent of the industry, its reliance on science and, to an extent, the wide range of interesting and fulfilling careers (including those areas listed above) to be found under the umbrella of 'cosmetics'. *Discovering cosmetic science* meets this objective splendidly and any graduate seeking to find a career or diversify to another career will find this book a real eye opener.

For other readers, there is much fascinating knowledge to be gained from its (relatively few) pages. It will expose you to ideas and complexities you have probably never thought about. That's got to be good! All in all, it is well worth reading. As the Foreword says, '*Discovering cosmetic science* is not just another textbook but more an informative journey which takes the reader through the most important and interesting aspects of cosmetic science'. Although 'not just another textbook', the book would be an excellent textbook for a one-semester course in cosmetic science at, say, second-year university level in science and/or arts-based programs. It also certainly set me thinking about deep issues way beyond the scope of the book, like what exactly is 'beauty', why do people paint and tattoo their bodies, and why do we work so acidulously to disguise our human smell. Do I have any answers? Not on your Nellie!

The book is well worthy of attention by any curious chemist who wants to know a tad about the cosmetic sciences.

R.J. Casey FRACI CChem



Climate adaptation

Arkbound Foundation, 2021, paperback, ISBN 9781912092123, 306 pp., approx. $23, including delivery from Amazon Aust.

Climate adaptation has an underlying assumption that governments and international agencies are not taking sufficient actions to tackle climate change. This seems a reasonable enough point to start. The solution proposed in the book lies in generating and promulgating group actions to adapt the way we think; the way social and fiscal entities function; the ways in which we live our lives, to ameliorate climate change. The message is encouraging as well as, possibly, just a tiny bit subversive.

The book is organised into three main sections. The first section, 'Overview', provides an excellent and extensively referenced review of the current global environmental situation and where it (we?) is heading. The second section, 'Impacts, responses and solutions', is a series of case studies as per the title, drawn from a reasonable cross-section of nations. It covers a wide variety of situations and activities. As you might expect, some of these studies are more interesting/relevant than others. They range from developing transformative adaption strategies in Nepal across agro-ecological transitions in Brazil to climate migration issues. The third section of the book, 'Systemic change', is most interesting, creative and thought provoking. It canvasses some reasonably fundamental changes in the way the world works and the ways we humans live in it. Some of these ideas are quite challenging, but certainly not crazy. For example, we are invited to envision the future as 'an act of subversive democracy'. They provide food for considered thought, and that is always worthwhile.

The Arkbound Foundation is a small British charity supporting the publication of books covering important social and environmental issues. There are 20 contributing authors, including Dr Morgan Phillips (UK), Dr Renuka Thakore (UK), Andrew Suggitt (UK), Dr Janis Steele (USA, Canada), Fazeela Mubarak (Kenya), Rodrigo Machado Moreira (Brazil), Professor Rupert Read (UK) and Dr Ester Barinaga (Denmark). They are somewhat biased towards academia, but come from numerous countries and disciplines and bring their own perspectives to the area of climate adaption.

There can be no doubt that world climate is changing. Few doubt that anthropomorphic activity is, if not causative, at the very least accelerating this change. There appear to be three main courses humans can pursue to ameliorate this change: we can do nothing, which we seem rather good at, and live with the consequences; we can seriously and rapidly try to decarbonise the globe to remove a major element of anthropomorphic influence on the climate, a solution widely preached but perhaps less vigorously pursued than it needs to be; or we can adapt to our increasingly bleak future, which frequently means we need to walk more gently on Earth. The reality, in my view, is that we humans have fiddled ineffectively for so long that our world is now well and truly afire and both decarbonisation and adaptation need extraordinarily vigorous, genuine pursuit if we are to save our collective bacon (albeit real or ersatz).

So, is *Climate adaptation* simply another doomsday book? Well, no it is not. It does preach a message that things can be done, that collective action can achieve good outcomes. It is worth reading by anybody with an interest in climate change and adaptive strategies that might mitigate its consequences.

R.J. Casey FRACI CChem

Connect with our chemistry readers

2022–23 media kit out now

Published four times a year, *Chemistry in Australia* has served its readers for more than 30 years. Our publication gives you access to:

- a diverse chemistry readership
- unique editorial content
- a nationwide print and online distribution four times a year
- products and services advertorial.

Now is the perfect time to use *Chemistry in Australia* to tap into a difficult-to-reach but influential market of chemistry consumers.

Chemistry in Australia is the flagship publication of the Royal Australian Chemical Institute.

raci
ROYAL AUSTRALIAN CHEMICAL INSTITUTE

chemaust.raci.org.au

chemistry in Australia

The changing nature of the Australian wine industry

In 1997, I was offered the position of Professor of Oenology at Charles Sturt University. The offer came with the challenge of managing the teaching school responsible for the degree programs in oenology and viticulture as well as establishing a centre that focused on research, education, training and extension for the wine industry.

My appointment came at a time of massive expansion of the wine industry. Exports were strong, especially to the UK. This demand created a shortage of grapes. Priority was given to the export markets, with some larger companies actually importing wine from Europe to satisfy the lower-price-range domestic market.

In 1995, the industry released its 30-year Strategy 2025 outlook plan with the claim that 'by 2025, the Australian wine industry will achieve $4.5 billion in annual sales by being the world's most influential and profitable supplier of branded wines'. This bold claim led to a massive expansion in grape plantings across the country, driven by high grape prices as well as significant taxation advantages for new primary production activities. The new plantings were pushed to produce a crop in their second year. Extensive irrigation helped drive the new plantings.

The export market did not grow at the rate expected in the Strategy 2025 plan, leading to high stock-to-sales ratios. Fortunately, Yellow Tail opened up the US market, absorbing a large volume of excess grapes. In 2001, Yellow Tail sales to the US were about 225 000 twelve-bottle cases per year, increasing to 7.5 million cases in 2006.

Export markets are fickle. The increase in the value of the Australian dollar pushed up the export price. Wine exports are also something of a political football as recent events with China demonstrate, and the industry is now back in an oversupply situation.

Two factors have contributed to Australia's success.

First, we are able to blend wine using grapes sourced from many different regions in the country. While we do have many excellent regional wines, our export markets were seeking wine that tasted the same from one year to the next. By blending from multiple sites, we were able to achieve this goal with great success.

karandaev/iStockphoto

Second, the industry has established a creative culture through education and research. Undergraduate degrees in viticulture and oenology as well as an industry-managed Vocational Education and Training (VET) program gave confidence to experimentation in grape growing and winemaking, resulting in successful production strategies.

The industry has always been committed to research, with its financial support being dependent on research focusing on industry priorities. The funding body required the research outputs to be developed into industry outcomes and the research to be shared across the industry. This highlighted the need for extension officers as the interface between researchers and industry.

The industry's creative culture allowed winemakers to determine what additives should be used and when they should be added to get the most desirable outcome from the grapes. This led to the accusation that the 'high tech' approach produced industrial wine that did not reflect the characters of the region from where the grapes had been sourced.

Apart from the vagaries of the export market, the wine industry is now facing several challenges. Consumer demands are changing, with an increasing expectation that wines are made using sustainable practices. There is a clear move to organic and biodynamic wines. Natural wines and minimal-input winemaking are finding a niche market here, while being an expanding market in Europe. The focus for natural and minimal-input wines is hand-picked single-vineyard grapes that are fermented using indigenous yeast and bottled without fining or filtration.

Increasingly, wine companies are focusing on regionality. Many of the company tastings that I now attend are exploring single-vineyard wines produced by indigenous yeast fermentation to provide a clear representation of terroir. When I started in the wine industry, 'terroir' was considered a nonsense term and indigenous yeast fermentations would 'only lead to spoilt wine'. We now have a better understanding of these concepts, and this is leading the way to open up new markets.

In my December 2021 column (p. 40), I described how sensory analysis is moving away from classical descriptive analysis to more consumer-focused methods such as 'Rate-All-That-Apply' and Pivot© Profiling. Sensory analysis using artificial intelligence (AI) has been examined (bit.ly/3gVptfd). The researchers noted that the purpose was 'not to build an AI sommelier', but a means of designing an energy efficient AI system.

The biggest challenge facing the wine industry is adaption to climate change. This is now a major focus of industry research and experimentation.

This is my final regular Grapevine column. It has been a great retirement activity over the last 11 years. In my first column on aged Hunter Valley Semillon in April 2012, I commented that the wine style 'suggests that age has advantages over youth'. There does come a time when the wine stored in a cellar needs to be rejuvenated. The same also applies to those who write about wine!

Geoffrey R. Scollary FRACI CChem (scollary45@gmail.com) has been associated with the wine industry in production, teaching and research for the last 40 years. He now continues his wine research and writing at the University of Melbourne and Charles Sturt University. This is his final column.

Poisonous underpants?

I found some unexpected chemistry in an article published in the *Victorian Historical Journal* about the Australian Knitting Mills (AKM). Based in the Melbourne suburb of Richmond, with iconic buildings that still stand (although now put to other uses), AKM was a major producer of underwear in the first half of the 20th century. When I was young, it was woollen underwear that slowly changed in colour as it was repeatedly dried on the clothesline. The light-initiated yellowing was a worry to AKM and other manufacturers, but it was something else that caught my eye – a legal case that cost the company a lot of money.

Adelaide physician Dr Thorold Grant bought some of the company's Golden Fleece underwear in 1931, and a few days after wearing it he developed severe dermatitis that he blamed on 'a chemical or some substance of an irritant nature', to quote the press report. Unable to return to work, in November 1932 he initiated legal action against the company and the retailer from whom he had purchased the underwear, claiming £1075 for loss of income, £105 for medical expenses, £130 for nursing expenses and £39 for chemist's, £150 for the recuperative holiday he took in New Zealand, and £500 for damage to professional reputation.

The proceedings occupied the court for more than three weeks, with Chief Justice Sir George Murray presiding. One of the first people called by the Defence was the company's chemist, Herbert Davies, who said that the company did not use oil as a lubricant during knitting, and that any free sulfur dioxide would have been broken down by other chemicals used in wool processing. The court also heard from a dermatologist, Dr Robert Charles Brodie (called by the Defence), that 'mechanical interference' caused by wool was more likely than a chemical irritant, and that perhaps Dr Grant was just unduly prone to what he described as 'idiopathic eczema'. This was denied by other experts who tendered their opinions to the court. Grant's lawyers called a local man who had also worn the Golden Fleece underpants and experienced similar but less severe dermatitis.

The most detailed chemical arguments came when the Defence called V.G. Anderson, a public analyst registered under the Victorian Public Health Act and lecturer at the University of Melbourne. (In a parochial aside, I note that the court was not told that he was a foundation member of the Australian Chemical Institute.) Anderson found no foreign fibres in the wool and no evidence of chlorine, hypochlorite or other oxidants such as chromate. Nor was there any lead, mercury or copper, but he did find 'minute amounts' of arsenic, in the range 5–10 ppm, only detectable by an extremely delicate test. These levels are below that permitted in foods in South Australia. Under questioning, Anderson said he had investigated other brands of woollen underwear and found them to contain slightly higher concentrations of arsenic and some sulfur dioxide. The South Australian Government Chemist,

Dr Hargreaves, added that sheep could be exposed to arsenic in sheep dip, but that he had been unable to detect any arsenic in the underwear. Cedric Stanton Hicks, professor of physiology at the University of Adelaide, detected sodium sulfite in the underwear, and pointed out that sweat was sufficiently acidic to release sulfur dioxide and hence sulfurous acid from the sulfite salt.

In March 1933, Chief Justice Murray found in favour of Grant, on the grounds that his dermatitis was most likely caused by chemical residues in the underwear, and observed that their concentrations would have been much higher in the original product than in the samples examined by the analysts, which had been already washed several times. He awarded £2450 plus costs. The defendants appealed, and the case went all the way to the High Court. Unfortunately for AKM, it endorsed Murray's judgement.

Ian D. Rae FRACI CChem (idrae@unimelb.edu.au) is a veteran columnist, having begun his Letters in 1984. When he is not compiling columns, he writes on the history of chemistry and is an editor of *Historical Records of Australian Science*.

sudoku

Difficulty rating: moderate.
The symbols for the nine precious metals are used. Your challenge is to complete the grid so that each 3 × 3 box as well as each column and each row contains all nine metals.

Ru		Rh	Ir				Ag	U
	Ir			Pd	Pt	Os		
Pt						Ru		
		Pt	Pd	Au				
Au	U						Os	Ru
				U	Ag	Au		
		Ir						Pt
		Ru	Ag	Rh			Pd	
Pd	Ag				U	Rh		Os

events

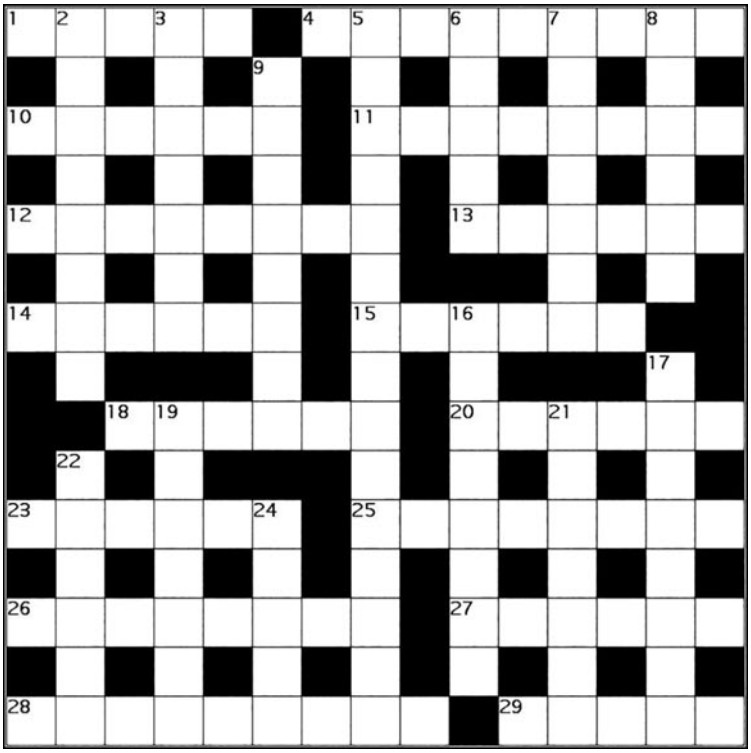
IUPAC Global Women's Breakfast
14 February 2023, locations across Australia
raci.org.au/events

European Congress on Chemistry and Applied Sciences
20–21 March 2023, Belstay Roma Aurelia, Rome
scisynopsisconferences.com/chemistry

Twentieth International Conference on Biological Inorganic Chemistry (ICBIC20) Conference 2023
16–21 July 2023, Adelaide, SA
icbic2023.org

IUPAC World Chemistry Congress 2023
18–25 August 2023, World Forum The Hague
iupac.org/event/iupac-world-chemistry-congress-2023

cryptic chemistry



Across

1 Presents fellow some AZASAN tablets. (5)
4 Sets time asset appraisals. (9)
10 Very much liked to make further comment about mineral. (6)
11 Stinky compound? (8)
12 Pressure re a tenth compound. (8)
13 Named by design. (6)
14 Coming to be associated with 1 Across. (6)
15 Executes and the rest can elect in return. (6)
18 One or two elements race around. (6)
20 We have six of these; science defines just four which are observable in everyday life. (6)
23 Compound done with I_2 giving a greyish-black crystalline solid that sublimes to a dense violet vapour. (6)
25 Compound acid measure. (8)
26 Blows a fuse on radical five-membered ring. (8)
27 Positive there are four elements. (6)
28 Seems tile breaks from a distant shock. (9)
29 Compound initiated electron stream transmission efficiency review. (5)

Down

2 Compound held a dye application. (8)
3 Compound Spooner's bold youngster. (7)
5 Metals becoming less saline: tests. (9,6)
6 Figures out coins. (5)
7 Shrink a chemist. (7)
8 Stereochemistry concept causes empire collapse! (6)
9 Stated two electrons are needed to produce salts and esters of ethylenediaminetetraacetic acid. (8)
16 Digest take away. (8)
17 Compound sorted over flame to form a monosaccharide. (8)
19 Compound iron axe implement. (7)
21 Compounds are at us to move. (7)
22 Dissolved colloid with little truck. (6)
24 Run off with energy: canter. (5)

Graham Mulroney FRACI CChem is Emeritus Professor of Industry Education at RMIT University.
Solution available online at chemaust.raci.org.au, Other resources.

TRANSFORMING THE FUTURE

The Master of Green Chemistry and Sustainable Technologies couples an in-depth understanding of environmental issues with hands-on learning to design and implement new chemical products and processes to create a more sustainable future.

"Green chemistry is a paradigm shift. It is the ability not to just learn to effectively deal with and regulate the use of hazardous materials but to think outside the box and create products without using hazardous materials."

DISTINGUISHED PROFESSOR JOHN C WARNER
School of Chemistry, Monash University

monash.edu/science/mgcst

MONASH University

Call for Abstracts & Early Bird Registration

OPENS Friday 25 November 2022

The 20th International Conference on Biological Inorganic Chemistry, incorporating IC23 - the RACI Inorganic Division Meeting, will be held in Adelaide in 2023.

Exciting plenary and keynote speakers have been lined up for the fabulous convention centre venue in the heart of Adelaide.

The conference is calling for registrations and abstract submissions under the following themes.

ICBIC 20 Themes

- Homeostasis and regulation (incl. redox)
- Metalloproteins and metallonucleotides - structures, models, and chemical biology
- Analytical methods - spectroscopic and molecular probes
- Metals for diagnosis and therapy (incl. radio)
- Metallomics and bioinformatics (systems approaches)
- Energy, environment and sustainability
- Metals in disease and host response

IC 23 Themes

- Main Group, Inorganic and Organometallic Chemistry
- Supramolecular Chemistry
- Materials and Structural Chemistry

ICBIC20

20th International Conference on Biological Inorganic Chemistry

held jointly with IC23 - the RACI Inorganic Division Meeting

16-21 July 2023 | Adelaide Convention Centre

www.icbic2023.org

raci ROYAL AUSTRALIAN CHEMICAL INSTITUTE

ADELAIDE CONVENTION CENTRE

Business Events Adelaide

THE UNIVERSITY of ADELAIDE