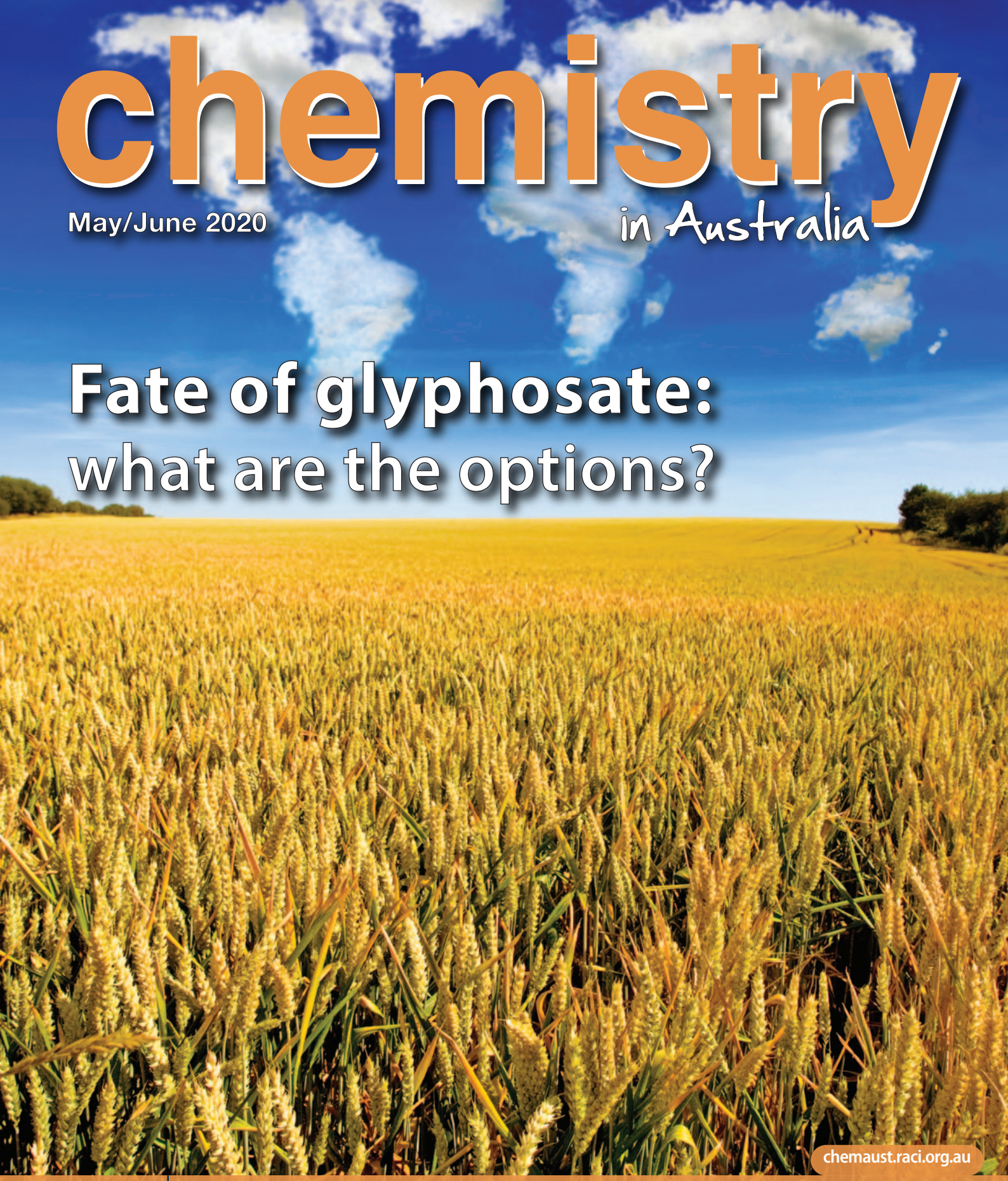
chemistry in Australia
May/June 2020

Fate of glyphosate: what are the options?



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chemistry in Australia

May/June 2020

cover story

Risky solution? The flawed case against glyphosate

Contrary to sensational media reports and class actions, global regulators consider glyphosate not to be carcinogenic. Consequences could be dire if market forces dictate its phase-out.

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Young people centre stage at Science Gallery Melbourne

At the Australian Science Communicators' Conference earlier this year, one of the most engaging and enthusiastic presentations was by Tilly Boleyn, Curator of the Science Gallery Melbourne (melbourne.sciencegallery.com).

Due to open later this year, Science Gallery Melbourne is part of the Melbourne Connect innovation precinct being developed by the University of Melbourne on the corner of Swanston and Gratton streets, just north of the CBD.

Science Gallery Melbourne is aimed at 15–25 year olds and Boleyn said that she wants to 'challenge the traditional narrative about whose opinion matters, how to engage young people in important issues and what makes a transformational experience'. The results of her work with young people on the gallery's Sci Curious Advisory Board to generate ideas, plan exhibitions, select works, promote the gallery and engage stakeholders seem to be doing just that.

At the Urinotron, part of the Re-imagining Your Waste pop-up program, a large-scale battery powered by human urine was used to charge mobile phones.
Nicole Cleary/Science Gallery Melbourne

The gallery is one of eight in the Science Gallery Network, with others in Dublin, London, Bengaluru, Venice, Detroit, Rotterdam and Atlanta. All are associated with universities, with the aim to 'ignite creativity and discovery where science and art collide'. The new Melbourne building will include immersive exhibitions, learning spaces, and areas for workshopping and socialising. Blood, Perfection and Re-imagining Your Waste are programs that have already run as 'pop-ups' over the past three years.

Boleyn cheekily announced that Science Gallery is 'university promiscuous'. She is keen to embed research in its programs, welcoming new ideas and possible future collaboration. Responsible for outreach and program themes are the 'Leonardo group', comprising scientists, artists, media experts, educators and business leaders.

A high-tech art commission is underway for the official opening, and to this end the gallery has put together a Collision Commission – a multidisciplinary team with expertise in such areas as performance, lasers, robotics and systems design – to work with Melbourne-based audiovisual artist Robin Fox.

Boleyn was clearly enthused about her work with the Sci Curious Advisory Board and strongly encouraged conference participants to consider having a mentor younger than 30. It forces you, she said, to stop talking and start listening – resisting the urge to jump in with your own perspectives and to give advice. From the examples I saw in her presentation, the ideas emerging from the gallery's young minds are exciting and unconventional.

To find out more about collaboration with Science Gallery, email research@melbourne.sciencegallery.com.

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Books about chemistry

I can thoroughly endorse R.J. Casey's review of *The basis of everything* by A. Ramsey (March/April, p. 34), as I recently finished reading it, enjoying and learning a lot about the lives of Ernest Rutherford and Marcus Oliphant – two local heroes and remarkable scientists. Much of this book revolves around the development of atomic physics, the atom bomb and the Manhattan Project under the guidance of J. Robert Oppenheimer.

While reading this book, I went and re-read a related chapter in a book that was given to me as a present on my bar mitzvah (13th birthday) by my school mates. This book also had some influence on my future working life. In the article 'Atomic Warfare, Past and Future' by Jacob Sacks (extracted from *The atom at work*, 1951), although all the main personnel from Szilard and Wigner to Einstein, Bohr, Fermi, Groves and Fuchs, etc. are mentioned, J. Robert Oppenheimer is completely omitted. This rewrite of history is in *A treasury of science* (3rd edition, 1954, as edited by Harlow Shapley, Samuel Rapport and Helen Wright), but may be understandable in the context of those times. (McCarthyism at work and there are many books about this subject.)

After reading Ian Rae's two recent letters, I went for a rummage in my library and found two old chemistry textbooks, which make interesting browsing. They are *A school chemistry* by F.R.L. Wilson of Charterhouse and G.W. Hedley of Cheltenham College (both in UK), 1912, and *Modern inorganic chemistry* by J.W. Mellor, 1927. Although space here prevents highlighting some interesting and largely forgotten approaches, one fact that caught my eye, particularly after the 2019 International Year of the Periodic Table, was that in Wilson and Hedley (1912) there were only 50 elements listed while Mellor (1927) had about 95 in his periodic tables. Uranium in the Wilson and Hedley periodic table has an atomic weight of 238.5, compared to 238.2 in Mellor and a present-day value of 238.029.

The following table includes some specifically selected elements with their atomic numbers, elements and atomic weights (as actually shown).

Current		Wilson and Hedley (1912)		Mellor (1927)	
1 Hydrogen	1.008	Hydrogen	1	0.95 Hydrogen	1.008
4 Beryllium	9.012	Not included	–	4 Beryllium (Glucinum)	9.02
41 Niobium	92.906	Not included	–	41 Niobium (see Columbium)	93.5
70 Ytterbium	173.054	Not included	–	70 Ytterbium (Neo-ytterbium)	173.5
86 Radon	222.018	Not included	–	86 Niton (Radium emanations)	222
92 Uranium	238.029	Uranium	238.5	92 Uranium	238.2

Tony Zipper FRACI CChem

Federation of Commonwealth Chemical Societies and SDGs

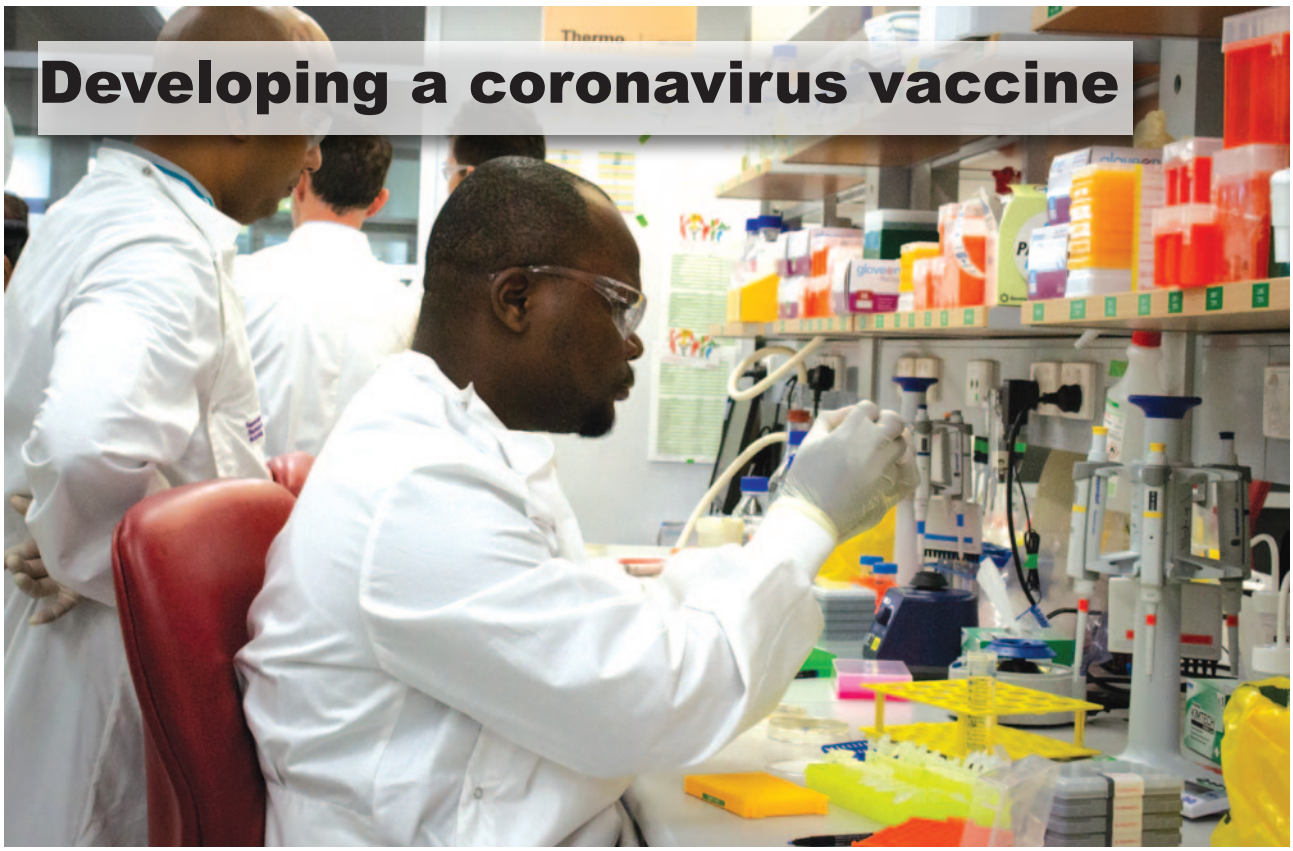
I was pleased to see that the new Federation of Commonwealth Chemical Societies will develop policies in line with the United Nations Sustainable Development Goals (SDGs) (March/April, p. 4). Chemists have had a vital role to play in combatting the AIDS pandemic since 1981. This disease is singled out within SDG 3 (Good health and well-being). Communication of elements of the new pandemic that is COVID-19 has been led by the United Nations World Health Organization. Chemists have been playing a more urgent role in addressing the health aspects of this pandemic – largely unheralded and unexplained in most media.

Michael P. Henry MRACI CChem

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.

Developing a coronavirus vaccine



The University of Queensland is developing a vaccine for the coronavirus outbreak at unprecedented speed, using new technology.

The Coalition for Epidemic Preparedness Innovations (CEPI) asked the university to use its recently developed rapid response technology to develop a new vaccine, which could be available worldwide in as little as six months.

University of Queensland Vice-Chancellor and President Professor Peter Høj AC said the fluidity of the current outbreak represented a significant challenge to the international community. 'There is a lot that is still unknown regarding how easily the virus is able to be transmitted between humans,' he said.

Head of University's School of Chemistry and Molecular Biosciences Professor Paul Young said the University of Queensland had novel technology for the rapid generation of new vaccines from the knowledge of a virus's genetic sequence information.

'The team hopes to develop a vaccine over the next six months, which may be used to help contain this outbreak,' he said.

'The vaccine would be distributed to first responders, helping to contain the virus from spreading around the world.'

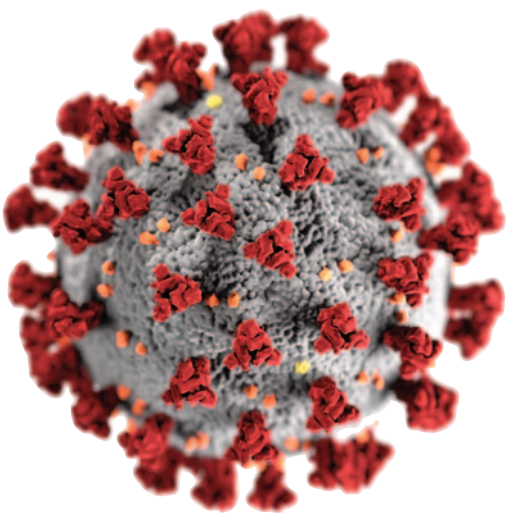
Dr Keith Chappell, from UQ's School of Chemistry and Molecular Biosciences and the Australian Institute for Bioengineering and Nanotechnology, said the key to the speedy development of this potential vaccine was the 'molecular clamp' technology, invented by UQ scientists and patented by UniQuest.

'The University of Queensland's molecular clamp technology provides stability to the viral protein that is the primary target for our immune defence,' he said.

'The technology has been designed as a platform approach to generate vaccines against a range of human and animal viruses and has shown promising results in the laboratory targeting viruses such as influenza, Ebola, Nipah and MERS coronavirus.'

University of Queensland

The illustration below, created at the US Centers for Disease Control and Prevention, reveals ultrastructural morphology exhibited by coronaviruses. Note the spikes that adorn the outer surface of the virus, which impart the look of a corona surrounding the virion, when viewed under an electron microscope.



COVID-19 distancing driving remote collaboration innovation

Many Australians have become newly acquainted with remote collaboration technologies such as Slack and Zoom, as the nation adjusts to working from home in response to COVID-19 requirements for social distancing.

With many regions of the world in lockdown, many industries are relying on remote collaboration technology, whether it's for day-to-day interaction with colleagues or major international conferences.

The University of South Australia's Australian Research Centre for Interactive and Virtual Environments (IVE) specialises in developing techniques to enhance virtual interactive experiences, and IVE director, Professor Bruce Thomas, says the COVID-19 pandemic could prompt a wave of innovation in virtual and augmented reality applications.

'Necessity really is the mother of invention, and the current pandemic situation is going to push users and developers of remote collaboration technologies to find out what works and what doesn't, and what solutions really need to be delivered,' said Thomas.

'Higher uptake and demand usually lead to a technology being scrutinised and refined, so I expect we'll see some real innovation in this area over the coming months.'

With existing interest in remote collaboration technology already strong due to its potential to reduce the carbon footprint of many businesses, Thomas's team is currently engaged in a range of projects that aim to increase the richness and versatility of the shared experience for remote users.

'For example,' Thomas said, 'one of our research teams, led by Professor Mark Billinghurst, is working on a system that allows a remote expert to guide an individual through a complex task at another location through a combination of augmented reality and 360° video.

'This will allow highly skilled experts in fields such as medicine, engineering and maintenance to apply their knowledge in multiple locations without having to travel there physically. It's a bit like when you share your computer desktop with an IT expert, but you are able to share your whole, real-world working environment.'

IVE researchers are also developing virtual reality interfaces that will allow large numbers of users to share the same virtual space, which could allow for virtual meetings in which participants can share a full range of emotions, gestures and presentations.

'The back-end capability for this sort of thing is already in place,' Thomas said. 'The challenge is the front end, the interface – how do you share the experience in a meaningful way. How do you have people interact in a lifelike fashion?

'Related to this, we're looking at a system that uses physiological data to allow the computer to track emotion and responses, so these can be included as part of the experience, making the interaction far more lifelike.'

With IVE researchers currently following work-from-home protocols themselves, Thomas believes the next few months could see the team undertake some real-world testing of various technologies.

'I think initially we'll stick with the existing, established communications methods while we get used to the situation, but as we become accustomed, we can start to trial some of the more experimental systems we are working on,' Thomas said.

University of South Australia

Academies launch COVID-19 Expert Database

The learned academies of Australia – representing more than 3000 of the nation's best and most eminent scientists, researchers and other experts – have launched a searchable database of experts to help Australia tackle COVID-19. The database is championed by Australia's Chief Scientist, Dr Alan Finkel.

The COVID-19 Expert Database is a collaborative effort between the Australian Academy of Science, Australian Academy of Health and Medical Sciences, Australian Academy of the Humanities, Australian Council of Learned Academies, Academy of the Social Sciences in Australia and Australian Academy of Technology and Engineering.

Australian Academy of Science Chief Executive, Ms Anna-Maria Arabia, said the COVID-19 Expert Database has been created to provide a mechanism for governments, the business sector, the research sector and other decision-makers to easily access the expertise they need across many fields.

'Cross-disciplinary research has been the key to solving many of the world's greatest challenges and tackling COVID-19 will be no different,' Arabia said.

Australia's ability to navigate this fast-changing environment and to recover from it needs inputs from a range of researchers and other experts. All fields of expertise, including science, technology, engineering, mathematics, health, humanities, arts and social science, are needed.

'Australia and the world will benefit from quick access to expertise that provides insights into the COVID-19 pandemic and its scientific, health, social, cultural and economic implications,' Arabia said.

If you have expertise that can contribute to the national and global effort to tackle and recover from COVID-19, please register at www.science.org.au/covid19/experts.

Australian Academy of Science

Natural origin of COVID-19 coronavirus epidemic

The novel SARS-CoV-2 coronavirus that has caused the COVID-19 pandemic is the product of natural evolution, according to findings published in *Nature Medicine* (doi.org/10.1038/s41591-020-0820-9). 'By comparing the available genome sequence data for known coronavirus strains, we can firmly determine that SARS-CoV-2 originated through natural processes,' said Kristian Andersen, an associate professor of immunology and microbiology at Scripps Research and corresponding author on the paper.

Coronaviruses are a large family of viruses that can cause illnesses ranging widely in severity. The first known severe illness caused by a coronavirus emerged with the 2003 severe acute respiratory syndrome (SARS) epidemic in China. A second outbreak of severe illness began in 2012 in Saudi Arabia with the Middle East respiratory syndrome (MERS).

Shortly after the COVID-19 epidemic began, Chinese scientists sequenced the genome of SARS-CoV-2 and made the data available to researchers worldwide. The resulting genomic sequence data has shown that Chinese authorities rapidly detected the epidemic and that the number of COVID-19 cases has been increasing because of human-to-human transmission after a single introduction into the human population. Andersen and collaborators at several other research institutions used this sequencing data to explore the origins and evolution of SARS-CoV-2 by focusing in on several tell-tale features of the virus.

The scientists analysed the genetic template for spike proteins, armatures on the outside of the virus that it uses to grab and penetrate human and animal cells. More specifically, they focused on two important features of the spike protein: the receptor-binding domain, a kind of grappling hook that grips onto host cells, and the cleavage site, a molecular can opener that allows the virus to crack open and enter host cells.

The scientists found that the receptor-binding domain portion of the SARS-CoV-2 spike proteins had evolved to effectively target a molecular feature on the outside of human cells called ACE2, a receptor involved in regulating blood pressure. The SARS-CoV-2 spike protein was so effective at binding the human cells, that the scientists concluded it was the result of natural selection and not the product of genetic engineering.

This evidence for natural evolution was supported by data on SARS-CoV-2's backbone – its overall molecular structure. If someone were seeking to engineer a new coronavirus as a pathogen, they would have constructed it from the backbone of a virus known to cause illness. But the scientists found that the SARS-CoV-2 backbone differed substantially from those of already known coronaviruses and mostly resembled related viruses found in bats and pangolins.

'These two features of the virus, the mutations in the receptor-binding domain portion of the spike protein and its distinct backbone, rules out laboratory manipulation as a potential origin for SARS-CoV-2,' said Andersen.

Josie Golding, epidemics lead at UK-based Wellcome Trust, said these findings are 'crucially important to bring an evidence-based view to the rumours that have been circulating about the origins of the virus (SARS-CoV-2) causing COVID-19.'

'They conclude that the virus is the product of natural evolution,' Golding added, 'ending any speculation about deliberate genetic engineering.'

Andersen and his collaborators concluded that the most likely origins for SARS-CoV-2 followed one of two possible scenarios.

In one scenario, the virus evolved to its current pathogenic state through natural selection in a non-human host and then jumped to humans. This is how previous coronavirus outbreaks have emerged, with humans contracting the virus after direct exposure to civets (SARS) and camels (MERS). The researchers proposed bats as the most likely reservoir for SARS-CoV-2 as it is very similar to a bat coronavirus. There are no documented cases of direct bat–human transmission, however, suggesting that an intermediate host was likely involved between bats and humans.

In this scenario, both of the distinctive features of SARS-CoV-2's spike protein – the receptor-binding domain portion that binds to cells and the cleavage site that opens the virus up – would have evolved to their current state before entering humans. In this case, the current epidemic would probably have emerged rapidly as soon as humans were infected, as the virus would have already evolved the features that make it pathogenic and able to spread between people.

In the other proposed scenario, a non-pathogenic version of the virus jumped from an animal host into humans and then evolved to its current pathogenic state within the human population. For instance, some coronaviruses from pangolins have a receptor-binding domain structure very similar to that of SARS-CoV-2. A coronavirus from a pangolin could possibly have been transmitted to a human, either directly or through an intermediary host such as civets or ferrets.

Then the other distinct spike protein characteristic of SARS-CoV-2, the cleavage site, could have evolved within a human host, possibly via limited undetected circulation in the human population prior to the beginning of the epidemic. The researchers found that the SARS-CoV-2 cleavage site appears similar to the cleavage sites of strains of bird flu that have been shown to transmit easily between people. SARS-CoV-2 could have evolved such a virulent cleavage site in human cells and soon kicked off the current epidemic because the coronavirus would possibly have become far more capable of spreading between people.

Study co-author Andrew Rambaut cautioned that it is difficult if not impossible to know at this point which of the scenarios is most likely. If the SARS-CoV-2 entered humans in its current pathogenic form from an animal source, it raises the probability of future outbreaks, as the illness-causing strain of the virus could still be circulating in the animal population and might once again jump into humans. The chances are lower of a non-pathogenic coronavirus entering the human population and then evolving properties similar to SARS-CoV-2.

Scripps Research Institute

Better pregnancy test for whales

It's not easy to do pregnancy tests on whales. For decades, the only way scientists could count pregnant females was by sight and best guesses based on visual characteristics. For the last several years, researchers have relied on hormone tests of blubber collected via darts, but the results are often inconclusive.

Research from the US National Institute of Standards and Technology (NIST) and Griffith University (doi.org/10.1038/s41598-020-58933-4) points to a weakness of that testing and provides a new method for hormone testing that offers better results. 'We found that androgens, and especially androstenedione in combination with progesterone, are much more likely to be a reliable marker of pregnancy,' said Ashley Boggs, a research biologist at NIST who helped to develop the new tests.

Being able to determine whale pregnancy offers insight into the health of a population. Whales are sensitive to changes in their environment, including the health of food webs, ocean noise and contaminant exposures.

In recent years, humpback whale numbers have increased dramatically in many places, although they are still considered endangered. The animals' size makes it difficult to count or study them by traditional methods. Like most protected whales, this species cannot be held in captivity, and most of the information about them must be gained through observation in the wild. But humpbacks can serve as an indicator species for other, more endangered, large whales, and by developing bioanalytical measurement techniques for these species that are doing well, scientists can confidently apply them to other, more protected, species.

'Up to this point, most measurements had been conducted using immunoassays, which require a "one at a time" approach to hormone measurements,' Boggs said.

'We know that hormones act together in suites to cause large physiological changes. If you focus on only one hormone at a time, you might miss the major hormone of interest or simply run out of money or samples.'

The research team studied female humpbacks along the east coast of Australia during two stages of migration. Fifty-two individuals were randomly sampled before reaching the calving grounds in June–July and again after departing the calving grounds in September–October. Before reaching the calving grounds, only one had a high concentration of progesterone, the hormone that has previously been used as an indicator of pregnancy in this species. This number seemed too low to be reliable. The evidence indicated that the animals' hormone profiles change in late pregnancy, since multiple calves were seen later.

Finding chemical indicators for pregnancy in marine mammals is very different from finding them in humans, where a protein hormone called human chorionic gonadotropin (hCG) is detected right after the implantation of the embryo. Other protein hormones are difficult to use as a standard indicator for pregnancy because their levels vary from one species to the other.

Previous whale reproductive research had relied on the measurement of the hormone progesterone using an enzyme-linked immunosorbent assay (ELISA). ELISA has been the 'go to' assay for years, but NIST scientists have determined that not all species rely on the same hormones during pregnancy, and in addition, some species' hormone levels exhibit significant shifts during different phases of the gestation process.

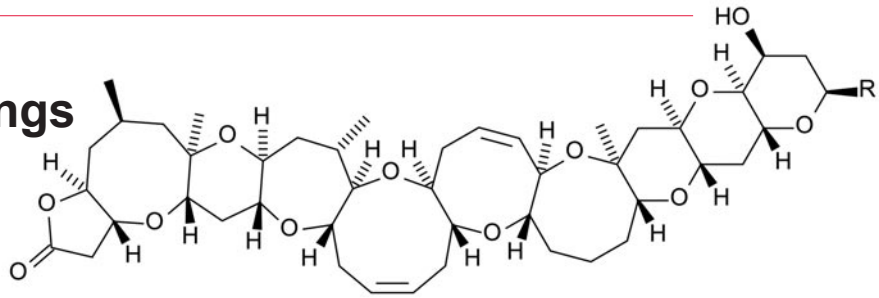
NIST researchers realised that mass spectrometry would potentially allow the measurement of many hormones simultaneously and could help biologists to understand which hormones can be found at different stages of pregnancy.

The new analysis allowed for gathering a simultaneous measurement of 11 steroid hormones in each sample of whale blubber, using liquid chromatography tandem mass spectrometry. The technique identifies hormones based on molecular size and mass rather than attachment of the hormone to an antibody (as in the current method), ensuring higher accuracy and selectivity.

'By casting a wider net and looking for more hormones, we were able to get a better set of biomarkers,' said Boggs. The same technique will also likely be applicable to other species, including North Atlantic right whales, which are dying at alarming rates and considered to be a species in peril.

National Institute of Standards and Technology

Access to forbidden rings



Brevetoxin A is a neurotoxin produced by dinoflagellates such as *Karenia brevis*. Minuteman/public domain

Cyclic molecules are everywhere, and everything around us stems from the way they are assembled: not just taste, colour and smell, but also (for example) pharmaceutical drugs. Nature by itself forms molecular rings of different sizes and chains of rings of varying lengths that scientists are able to reproduce artificially. Chemists from the University of Geneva (UNIGE) have now devised a new technique for creating these chains of molecular rings that do not use standard chemical interactions but contact with large molecular surfaces that are electron poor and do not exist in nature. Unlike with standard procedures, this new technique works by autocatalysis – the rarest, but also the most ambitious, type of transformation that exists in chemistry. The results of this research, published in *Angewandte Chemie* (doi.org/10.1002/ange.202000681), open up new prospects for molecular cyclisation and also provide the first part of the answer to an old contradiction in classical chemistry.

The molecules that surround us are often arranged in the shape of cycles, forming steroids, sugars, perfumes and drugs, for example. These molecular rings can be synthesised by using catalysis: the selected molecule, called a substrate, is placed in contact with the molecule that realises the transformation – the catalyst – usually through hydrogen bonds. But with this single method of interaction, the creative possibilities are reduced. Incorporating new ways of interaction would convert them differently, thereby creating new materials with the potential to solve scientific and societal problems that are intractable with conventional methods.

Professsor Stefan Matile is at the Department of Organic Chemistry in the School of Chemistry and Biochemistry of UNIGE's Faculty of Sciences. He is also a member of the NCCR Chemical Biology and the NCCR Molecular Systems Engineering. 'Our laboratory has specialised in implementing new contacts between molecules, one of them based on very large molecular surfaces, known as aromatics, which are poor in highly-delocalised electrons.' Professor Matile adds that contacts with these large, empty molecular planes, which are absent in nature, seemed promising for the cyclisation of molecular rings that are chained to each other. But what are the consequences?

The aims of the Geneva chemists were to reproduce cycles of different sizes, i.e. consisting of a number of defined atoms (steroids, for instance, are formed from three rings of six atoms plus one of five), and to link several rings together without using the hydrogen bonds but a molecular surface low in delocalised electrons (known as anion–π interactions).

'The main characteristic of this molecular plane is the empty space it provides for molecules to assemble,' said Miguel Paraja, a researcher in UNIGE's Department of Organic Chemistry. On contact with this new, spacious and electron-deficient surface, the molecules formed rings of different sizes (4–8 atoms) and various sequences. 'But the big news was the way the transformations occurred,' added Paraja.

All these cyclisations took place autocatalytically. 'With a conventional catalyst, the cyclisations are fast at the start, and then – since there is less and less substrate – they increasingly slow down,' explained Xiaoyu Hao, a researcher in the same laboratory. 'But with autocatalysis, it's the very opposite that happens.' Indeed, the molecular transformations accelerate on a massive scale. 'Although this autocatalysis is a very rare transformation phenomenon in chemistry, it is also the most astonishing, said Matile. 'It's based on mutual aid between molecules: the first molecules transformed help the next to transform, which isn't the case during normal catalysis, which decelerates rather than accelerates.'

This discovery helps answer one of the oldest contradictions in classical chemistry. 'There is a very well-known chain of molecular rings, called a brevetoxin, which is found in the red tide and which has the effect of killing fish,' explained Matile. It was discovered by Koji Nakanishi, who proposed that this extraordinary chain formed from eleven consecutive molecular rings in a single reaction. But this hypothesis did not agree with Jack Baldwin, a famous chemist who produced the rules explaining the formation of cycles that are now accepted as the basis of classical chemistry. The 'Nakanishi hypothesis' violates these rules for every of the eleven rings.

'Our rings can be formed according to Baldwin's rules if we want them to', reported Paraja. 'More importantly, we can also break the Baldwin rules on demand with our new catalysts and create those forbidden rings that Koji Nakanishi dreamed of.'

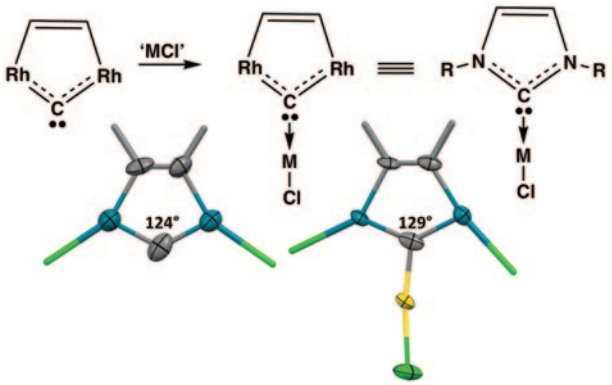
'The key to success', explained Hao, 'is the large empty space offered by our new catalysts.'

Matile said, 'With the discovery of autocatalysis in forming cyclic molecules, our anion–π contacts have helped us understand the most subtle way to transform the molecules that exists in chemistry. And this will help us create new chains of molecular rings.'

The chemists will be able to influence and direct the nature of the transformation of the next substrate, creating new materials, one of the main objectives also of the NCCR Molecular Systems Engineering

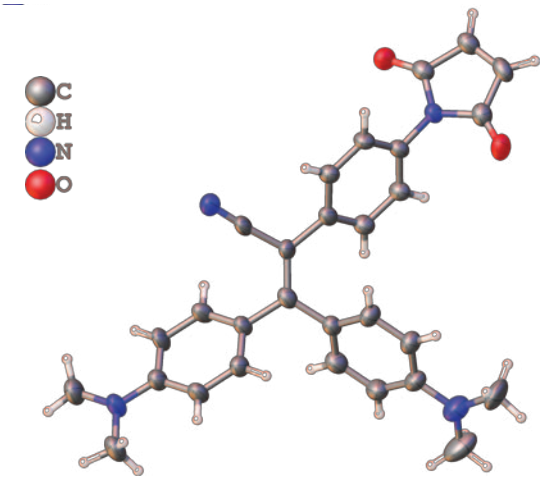
University of Geneva

Bending carbon: a metalla-heterocyclic carbene



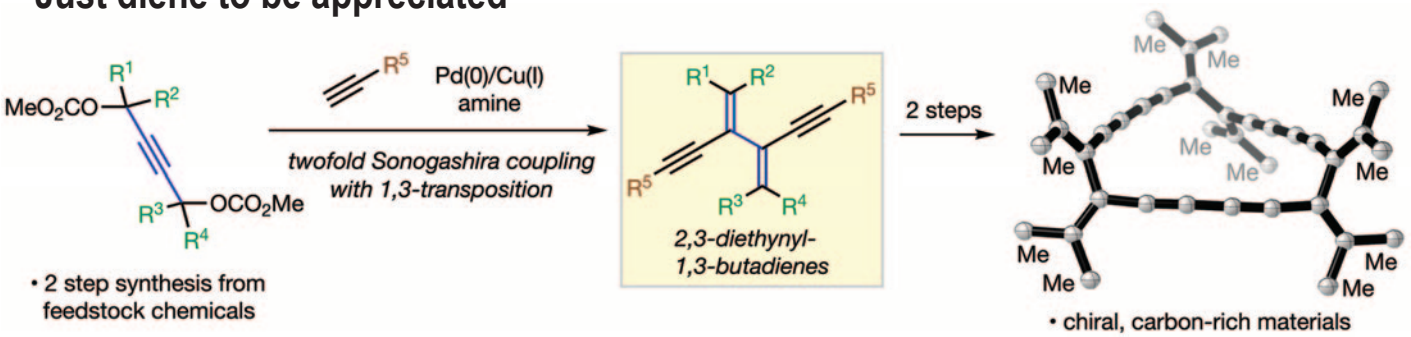
Binuclear μ-carbido complexes feature a single atom of carbon held between two metals and, to date, all examples have involved a *linear* MCM geometry. *N*-heterocyclic carbenes (NHCs), e.g. imidazolylidenes, are now ubiquitous ancillary ligands in coordination chemistry, enjoying extensive use in homogeneous catalysis. This raises the question of whether the two classes of compound might be combined by replacing the NCN component of the imidazolylidene with isolobal metal–ligand MCM fragments, which would in turn require the geometry at the intervening carbido atom to be bent. This goal has now been achieved with the first isolation, by researchers at the Australian National University, of a transition-metal analogue of an NHC (a *metalla*-heterocyclic carbene or MHC) (Hill A.F., Barnett H.J. *Angew. Chem. Int. Ed.* 2020, **59**, 4274–7). The addition of an activated alkyne (DMAD = dimethylacetylenedicarboxylate) to a *linear* cumulenic (Rh=C=Rh) μ-carbido complex $[Rh_2(\mu_2\text{-}C)Cl_2(\mu\text{-}dppm)_2]$ occurs across both rhodium centres to form a metalla-aromatic C_2Rh_2C core in which the μ-carbido ligand is by necessity *bent* (at an angle of 124°). The frontier orbitals of this metallacycle are remarkably similar in topology to those of an NHC, suggesting nucleophilic character at the carbon, which would allow coordination of further metal centres. This hypothesis was confirmed by coordination of the bent carbido to coinage metal chlorides to provide trigonal μ_3-carbido complexes $[Rh_2M(\mu_3\text{-}C)(\mu\text{-}DMAD)Cl_3(\mu\text{-}dppm)_2]$ (M = Au, Cu).

Molecular chameleon maps dielectric constant in live cells



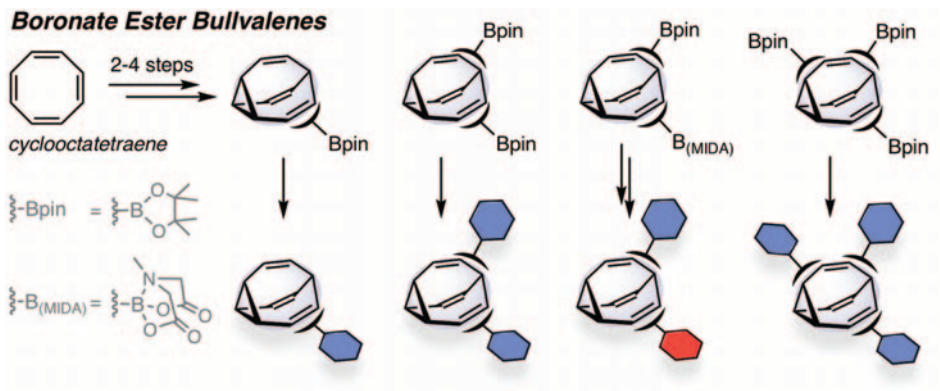
The dielectric constant of a solvent is a measure of its polarity. So what is the dielectric constant inside a living cell? And how does protein unfolding affect the intracellular dielectric constant? To answer these questions, a team at La Trobe University and the University of Melbourne has developed a general strategy based on a multi-responsive molecular probe, NTPAN-MI, to report on changes to subcellular polarity in response to protein unfolding (Owyong T.C., Subedi P., Deng J., Hinde E., Paxman J.J., White J.M., Chen W., Heras B., Wong W.W.H., Hong Y. *Angew. Chem. Int. Ed.* 2020, doi.org/10.1002/anie.201914263). NTPAN-MI is non-fluorescent unless reacting with unfolded proteins with exposed cysteine residues. Its fluorescence reveals the increase of the unfolded protein load caused by toxins or virus infection that jeopardise protein quality control. Once its fluorescence has been turned on, NTPAN-MI can change its emission colour, like a chameleon, to reflect the local polarity. The spatial distribution of the dielectric constant can be obtained by spectral phasor analysis, which reveals communication between the cytoplasmic and nuclear protein quality control networks. Such a strategy will assist in understanding the mechanisms of protein aggregation and phase transitions in cells for developing therapeutic interventions to regulate these processes.

Just diene to be appreciated



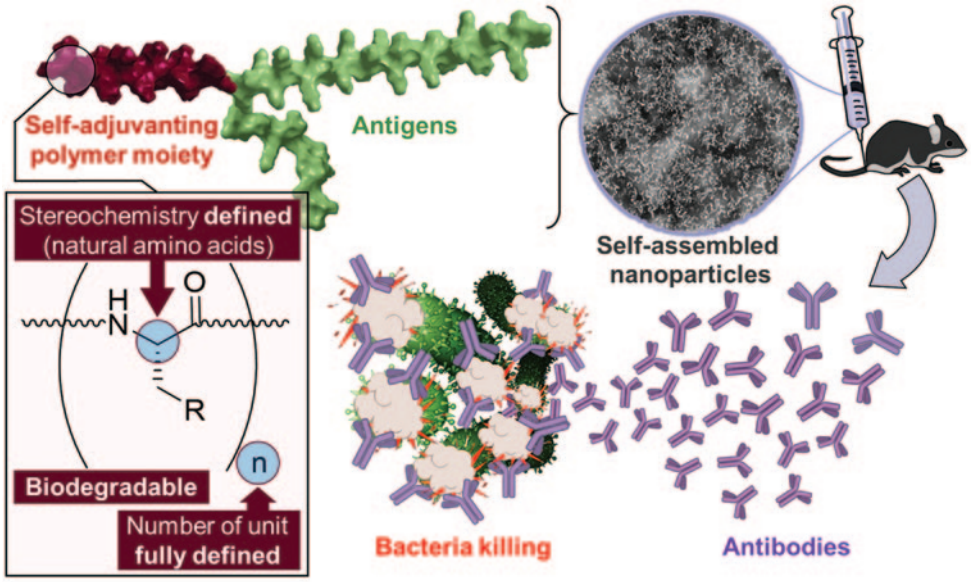
Despite their diminutive size, 2,3-diethynyl-1,3-butadienes pack quite a punch. They are valuable Diels–Alder dienes, giving *cis*-endiynes, which have been used in Bergman cycloaromatisations to cleave double-stranded DNA, and to produce heterocycles with potential in photodynamic therapy. Despite their value, no general synthesis of 2,3-diethynyl-1,3-butadienes had been reported. The first broad-spectrum preparation of these molecules has now been reported by synthetic chemists at the Australian National University (Sowden M.J., Ward J.S., Sherburn M.S. *Angew. Chem. Int. Ed.* 2020, **59**, 4145–53). The user-friendly method is a new take on the venerable Sonogashira coupling reaction. The method cross-couples feedstock terminal alkynes with carbonate derivatives of 2-butyn-1,4-diols (easily prepared from commercial aldehydes and ketones by reaction with acetylene). More than 30 examples are described, with all possible substitution patterns prepared. Substituents have a significant impact on the kinetic stability of 2,3-diethynyl-1,3-butadienes, which decompose through cycloaddition–dimerisation. Alkyl and silyl groups are stabilising, whereas alkenyl and aryl substituents are destabilising. Still, most analogues can be stored in the freezer without significant decomposition. Unprecedented, chiral carbon-rich macrocycles were prepared from 2,3-diethynyl-1,3-butadienes through cyclo-oligomerisation reactions. A depiction of the molecular structure of one such compound, obtained from single crystal X-ray analysis, is shown in the reaction scheme.

New route to shape-shifting molecules



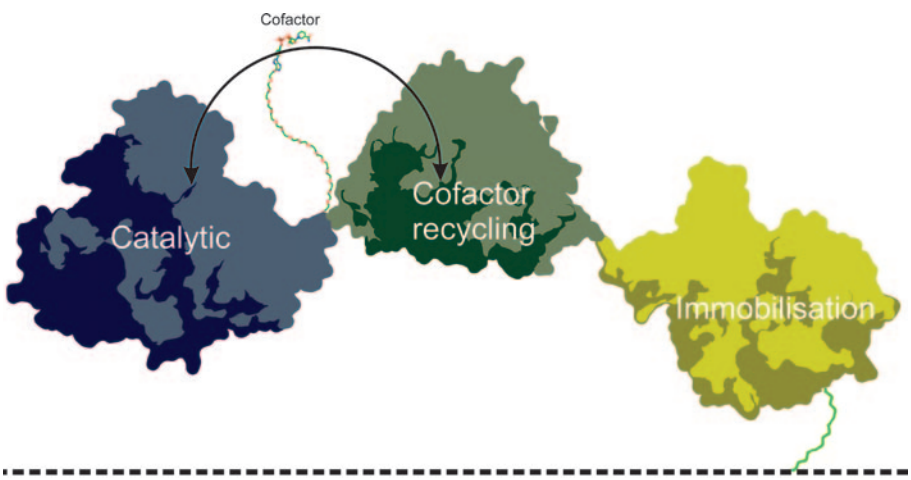
Bullvalene is the only stable organic structure with the property of complete degeneracy, whereby all positions in the molecule exchange through unending sequences of sigmatropic rearrangements. The shape-shifting nature of this molecule is amplified by the introduction of substituents, which dynamically explore all possible relative arrangements. Despite interest in this chemistry for more than 50 years, synthetic methodology for making bullvalenes has been lacking. Now, researchers at the University of Adelaide have devised a collection of boronate ester functionalised building blocks that opens up general synthetic access to substituted bullvalenes (Patel H.D., Tran T.-H., Sumby C.J., Pašteka L.F., Fallon T. *J. Am. Chem. Soc.* 2020, **142**, 3680–5). This was demonstrated through simple cross-coupling reactions to give a library of arylated bullvalenes. This also allowed the first comparative analysis of isomer preferences in the solution and solid state. The practical syntheses and reliable reactivities of these building blocks open up a wealth of opportunities to deploy shape-shifting molecules within molecular machines, medicinal chemistry, and materials.

Poly(amino acids) as a delivery system for nanovaccines



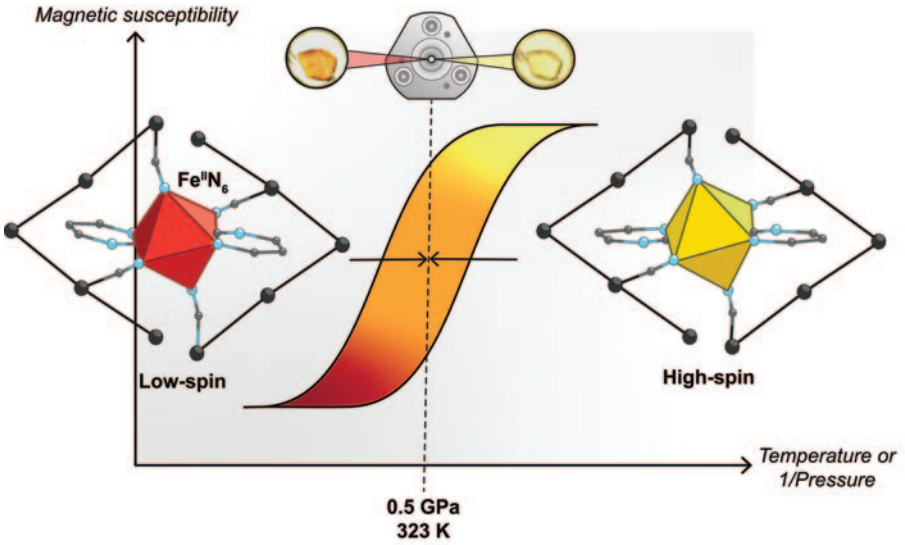
One of the major obstacles in the development of safe and effective vaccines is limited availability of immunostimulants (adjuvants) accepted for human use. A team from the University of Queensland, in collaboration with RMIT University, Griffith University and the Translational Research Institute (Queensland), has developed a novel antigen delivery strategy, using a unique polymeric system (Skwarczynski M., Zhao G., Boer J.C., Ozberk V., Azuar A., Cruz J.G., Giddam A.K., Khalil Z.G., Pandey M., Shibu M.A., Hussein W.M., Nevagi R.J., Batzloff M.R., Wells J.W., Capon R.J., Plebanski M., Good M.F., Toth I. *Sci. Adv.* 2020, **6**, eaax2285). Although synthetic and natural polymers have been widely investigated for vaccine delivery, the new system is the first example of a fully defined polymer used for this purpose. The polymer, which was built from natural hydrophobic amino acids (e.g. leucine), was conjugated to a Group A *Streptococcus* antigen and self-assembled into nanoparticles. The nanoparticles, without the presence of any external adjuvant, induced strong humoral immune responses, which protected mice against streptococcal infection. Importantly, this strategy can be fully tailored to match properties of any antigen/pathogen of choice.

Bionanomachines for continuous-flow synthesis of high-value molecules



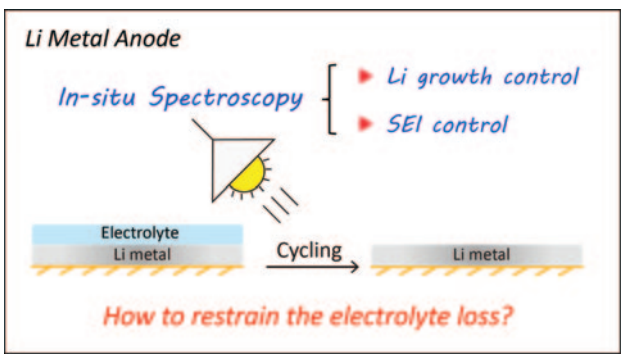
Researchers at the CSIRO and the University of Manchester have developed a method to use enzymes to synthesise high-value molecules in continuous flow. They demonstrated the technology by synthesising the anti-diabetic drug D-fagomine from glycerol by an enzyme-cascade reaction in continuous flow, achieving high cofactor turnover and product manufacture (Hartley C.J., Williams C.C., Scoble J.A., Churches Q.I., North A., French N.G., Nebl T., Coia G. Warden A.C., Simpson G., Frazer A.R., Jensen C.N., Turner N.J., Scott C. *Nat. Catal.* 2019, **2**, 1006–15). In the new method, cofactor-dependent enzymes are prepared as fusion proteins with a cofactor-recycling enzyme to prevent cofactor loss and to allow their continuous recycling. A third fused enzyme enables site-selective immobilisation of the fusion biocatalyst (nanomachine) to a surface for use in continuous flow. Each cofactor is covalently, and site-selectively, tethered via a PEG linker between the functional enzyme and the cofactor recycling enzyme, and can move freely between both active sites, enabling continuous recycling. The first nanomachine is responsible for an ATP-dependent phosphorylation and the second is responsible for an NAD-dependent oxidation, demonstrating efficient recycling of both cofactors. Individual nanomachines compiling the cascade form exchangeable components of a versatile, stable and efficient nanofactory for the synthesis of high-value small molecules.

Untangling structural changes in spin crossover complexes



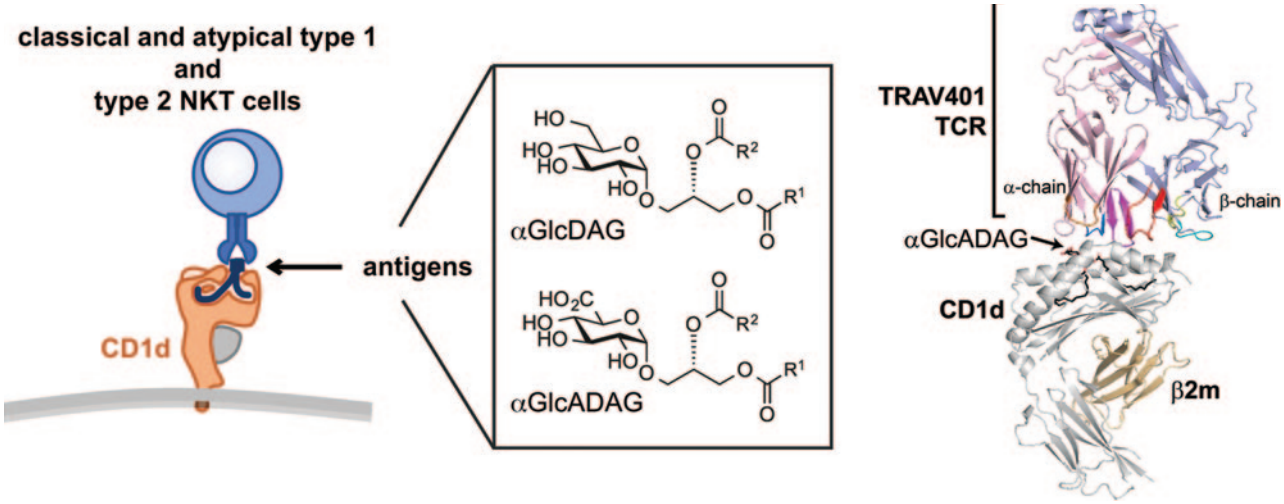
Spin crossover (SCO) complexes reversibly switch between the low-spin (LS) and high-spin (HS) electronic states in response to an external stimulus. The spin transition prompts significant structural changes and is often hysteretic, conferring a memory effect applicable to switching technologies such as sensors. To optimise the performance of SCO materials, the structural response to the spin transition must be predictable. However, this requirement is usually unmet, since structural changes induced by the spin transition are convoluted with those imparted by the external stimulus, as reducing temperature or applying pressure results in a reduction in bond lengths. Now, a team of researchers from the University of Western Australia, the University of Edinburgh (UK), Durham University (UK), Universitat Politècnica de València (Spain) and Universitat de València (Spain) has used a combination of temperature and pressure to trap the LS and HS states of an iron(II) Hofmann framework, $[Fe^{II}(pmd)(H_2O)][Ag(CN)_2]_2 \cdot H_2O$ (pmd = pyrimidine), under identical conditions, allowing the structural effect of the SCO to be isolated (Turner G.F., Campbell F., Moggach S.A., Parsons S., Goeta A.E., Munoz M.C., Real J.A. *Angew. Chem. Int. Ed.* 2020, **59**, 3106–11). The researchers were able to determine, for example, that 82.5% of the volumetric expansion of the Fe octahedra in the thermally induced LS–HS transition is caused solely by the spin transition. This study presents only the second SCO system in which the structural changes caused by the spin transition have been deconvoluted from the external stimulus, and is the first to trap both spin states under identical experimental conditions using a combination of temperature and pressure.

In situ spectroscopy uncovers pathway to energy-dense lithium batteries



Lithium metal anodes show great potential for boosting the energy density of next-generation batteries – theoretically by three to six times – over that of current commercially available Li-ion batteries. Previous work has demonstrated good cycling stability of Li metal anodes in the presence of excess electrolyte, but stability with limited electrolyte has not received much attention. The amount of electrolyte significantly affects a battery's energy density, because the electrolyte constitutes a large proportion of a battery's weight and volume. Now, a team led by Shi-Zhang Qiao at the University of Adelaide has shown that electrolyte consumption under low-electrolyte conditions can severely affect cycling stability and has uncovered design principles to reduce electrolyte loss in Li metal batteries by using a series of in situ techniques (Li H., Chao D., Chen B., Chen X., Chuah C., Tang Y., Jiao Y., Jaroniec M., Qiao S.-Z. *J. Am. Chem. Soc.* 2020, **142**, 2012–22). By combining in situ synchrotron X-ray diffraction, Raman and electrochemical impedance spectroscopies, the team found that both uneven Li deposition and cracks at the solid–electrolyte–interface layer should be controlled to lessen electrolyte loss. Then, they demonstrated a low-surface-area but defective graphene host for lithium deposition that addresses these issues. This work provides valuable insight into the design of low-electrolyte Li metal batteries.

Immune recognition of microbial glycolipids



The immune system can recognise foreign molecules, triggering a range of protective immune responses, yet many antigens remain unknown. Researchers at the University of Melbourne and Monash University have identified a class of previously unappreciated glucosyl and glucuronosyl diacylglycerols that are produced by bacteria and fungi and can be recognised by unconventional lipid-reactive T cells. An efficient total synthesis of this class of molecules provided pure materials that were used to discover and characterise the T cells (Burugupalli S., Almeida C.F., Smith D.G.M., Shah S., Patel O., Rossjohn J., Uldrich A.P., Godfrey D.I., Williams S.J. *Chem. Sci.* 2020, **11**, 2161–8). A 3D X-ray structure of the T cell receptor complex with glycolipid bound to the presentation molecule CD1d was obtained that structurally defined binding and recognition (Almeida C.F., Sundararaj S., Le Nours J., Praveena T., Cao B., Burugupalli S., Smith D.G.M., Patel O., Brigl M., Pellicci D.G., Williams S.J., Uldrich A.P., Godfrey D.I., Rossjohn J. *Nat. Commun.* 2019, **10**, 5242).

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.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to David.

Can you help with COVID-19 testing or reagents?

The Australian Society for Microbiology (ASM) is putting together a database of qualified people who are willing to be called upon in case of a potential staff shortage to assist with COVID-19 testing (or any other requests required) at hospitals or any other diagnostics lab across Australia.

This database will be shared with local public health hospitals and diagnostic labs. It is envisioned that, in the event of a staff shortage, volunteers can be trained to support ongoing COVID-19 testing.

ASM is also looking for people who can donate molecular biology reagents for COVID-19 testing, in particular viral swabs and unopened RNA extraction kits.

Submit your details at buff.ly/3biYv90.

Please contact laurence.luu@unsw.edu.au if you have any questions.

The Australian Society for Microbiology
bringing Microbiologists together

Risky solution?

The flawed case against glyphosate

Contrary to sensational media reports and class actions, global regulators consider glyphosate not to be carcinogenic. Consequences could be dire if market forces dictate its phase-out, says Ivan Kennedy.

The herbicide glyphosate was released by the Monsanto agrochemical company to the global market, with the trade name of Roundup, in 1974. Because of its unique properties, this new chemical met many of the requirements for an ideal product for controlling weeds, with minimal environmental and human impacts. Yet despite this wonderful beginning, a half century later glyphosate now finds itself accused in courts as harmful, the subject of global class actions.

Glyphosate has a highly specific action in mimicking phosphoenolpyruvate (PEP), substrate to the plant enzyme EPSP synthase. EPSP synthase is essential for shikimate synthesis, a precursor for aromatic amino acids such as phenylalanine and tyrosine and for lignin needed for wood. This enzyme is not found in animals because aromatic amino acids are dietary, explaining this unique specificity of action.

Another advantage is glyphosate's very low toxicity to animals, with LD_{50} values greater than those for common salt. (The LD_{50} value is the acute dose that will cause fatality in 50% of a population of test animals.) As a moderately water-soluble salt ionising from each of its carboxylic acid, amino and phosphate moieties, glyphosate is rapidly excreted in urine if ingested. As a zwitterion salt that dissociates, it has little or no volatility, even under acid conditions.

Glyphosate is quickly inactivated in soil from strong binding to its

phosphate group, giving a residue that is degraded mainly by decarboxylation to aminomethyl-phosphonic acid (AMPA), which may be persistent when soil is dry, also bonded to soil by its phosphate group. If concentrated formulations are diluted with water containing soil, glyphosate is rendered inactive by this binding reaction.

Two aspects of its properties led to it becoming the world's major marketed herbicide (Duke and Powles, doi.org/10.1002/ps.1518), almost one million tonnes annually in many different commercial formulations, since it is now out of patent.

First, it is a broad-spectrum herbicide, which is highly toxic to most annual plant species when applied to leaves but has no residual activity in soil; this inactivation makes it ideal for low tillage and no-till agriculture. This more sustainable agriculture has become very popular because it removes the need for costly ploughing of land in fallow before planting of crops. This has improved crop yields, reducing erosion and the cost of weed control. It also conserves water and nutrients in the soil profile and reduces the use of fossil fuels for ploughing with tillage implements, producing far less CO_2 emissions.

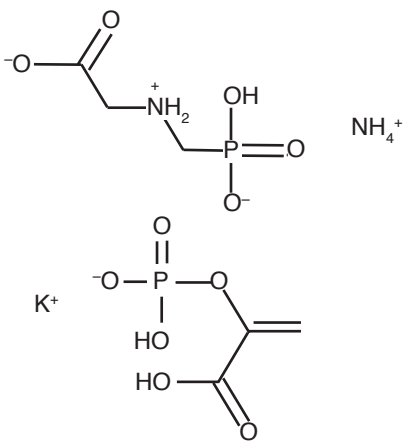
Second, Monsanto's success in producing genetically modified (GM) plants with closed EPSP synthases made it a favoured target for Roundup Ready crops designed to be herbicide resistant. Several crops have been provided with alternative EPSP genes from bacteria resistant to the herbicidal effect of glyphosate, such as soybeans, cotton, canola (rape) and maize.

Risk and regulation

Given these properties, it is not surprising that glyphosate is so highly favoured by world agriculture. No substitute technology is available that provides such a broad range of advantages. However, the many glyphosate-based formulations, but particularly Roundup, have been under attack by those opposed to GM technology, partly because of its use in Roundup Ready crops. Indeed, some unscientific papers published in poorly reviewed journals seemed to have had no other reason for their publication than to oppose its use. Such papers include speculation that glyphosate could be the cause of many unexplained diseases, but with no epidemiological evidence of an increase in occurrence as the use of glyphosate increases. One of my own students, fearing negative effects of glyphosate in the environment, found it did no harm when tested for effects on growth of beneficial environmental microbes such as *Chlorella*, and nitrogen-fixing *Rhizobium* and *Anabaena*. The effects were either null or actual stimulation of growth.

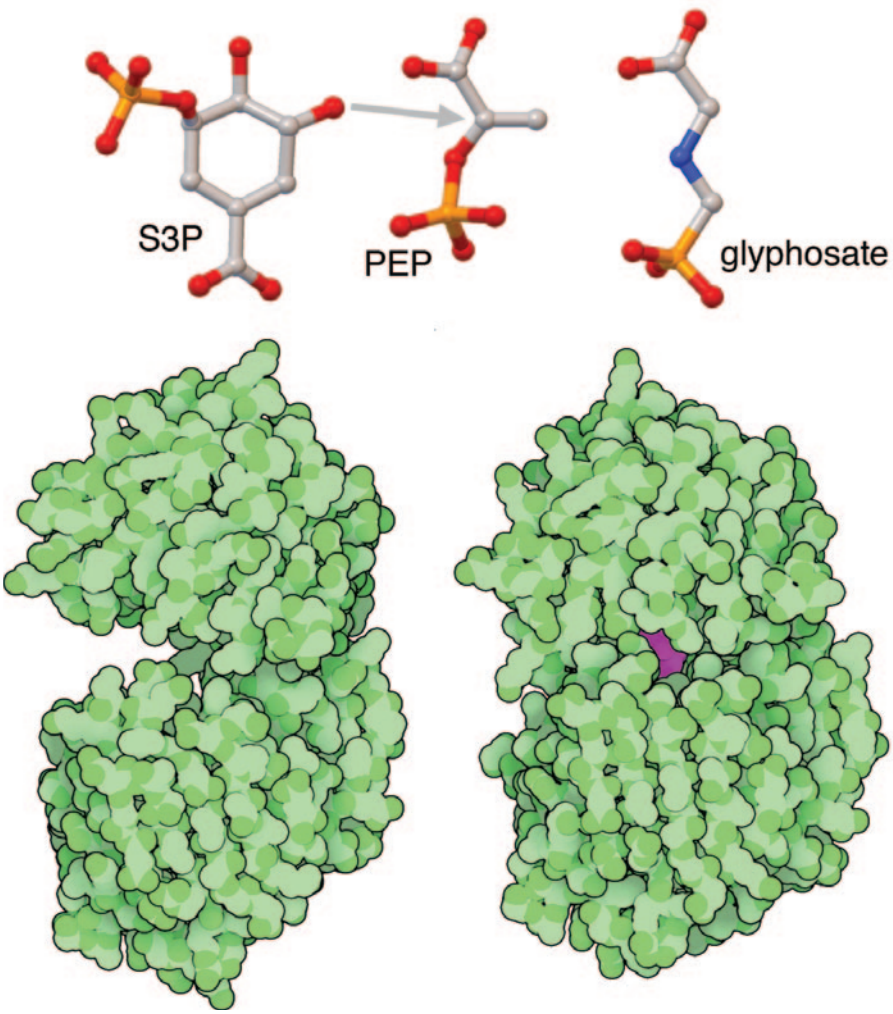
This is not to claim that glyphosate has no management problems. Increasing resistance to its action through genetic mutation of weeds is one issue, requiring that other more residual herbicides also be applied strategically. The search for other chemicals with a similar range of advantages is highly desirable but no ideal substitute for glyphosate is on the horizon (Beckie et al., doi.org/10.3390/plants9010096) and more toxic chemicals might be needed if glyphosate is not available. However, targeted spraying using digital technology might assist by reducing the intensity of applications.

Many chemical pesticides are hazardous and their use is legally regulated to maximise their effectiveness and safety. My experience is that the Australian Pesticides and Veterinary Medicines Authority (APVMA) is highly professional regarding its independence in risk management. Pesticides are usually applied in a mixture containing adjuvants such as emulsifiers or solvents to minimise the need for active ingredients. Individual toxicity to animals is indicated by the LD_{50}. Conditions for use given on product labels aim to ensure that the probability of chronic exposure to the active ingredient is orders of magnitude less than such values, although accidental or deliberate ingestion of formulations can be dangerous and is the main cause of global mortality. Typically, laboratory rats or mice are used to establish inherent toxicity, including testing in vitro for mutagenicity and carcinogenicity. Tests required by



The zwitterion structure of glyphosate (top), with net charge of –1 at pH 4 and –2 at neutral pH, shown as the ammonium salt, fully dissociated when aqueous; pK_1 phosphate 1 = 0.8, pK_2 carboxylate = 2.3, pK_3 phosphate 2 = 6.0, pK_4 amine = 11.0. PEP (bottom) shown as a potassium salt, has pK_1 phosphate pH 0.8 with carboxylate half ionising at pH 2.6, with the second phosphate half dissociated at pH 5.6, thus charge is –3 at neutral pH. Fortunately, the zwitterion property, difference in charge and conformation at neutral pH prevents glyphosate interfering with other enzymes.

Glyphosate is quickly inactivated in soil from strong binding to its phosphate group, giving a residue that is degraded mainly by decarboxylation ...



Open and closed forms of EPSP synthase, with its normal reactants and the strongly inhibitory glyphosate molecule active against the open form; note the similar structure of the terminal carboxylate and phosphate groups of PEP and glyphosate.

From PDB Protein Data Bank pdb101.rcsb.org/motm/218

regulators must be performed under conditions that mimic likely modes of exposure in humans, such as by ingestion, by respiration or through the skin. Establishing a legally approved label for a new product intended for global sales can cost hundreds of millions of dollars.

Pesticide effects on human health

To measure the effect of significant human exposure to any industrial chemicals, medical authorities conduct epidemiological surveys of human health to identify linked patterns or clusters of disease. Such surveys may rely on anecdotal recall of chemical usage from many years previously. Moreover, surveys are confounded by the multiplicity of chemicals used in particular industries. For example, farmers may have been exposed to many chemicals thought carcinogenic, including fuels containing benzene, cleaning solvents such as trichloroethylene, as well as several halogenated pesticides now discontinued.

Since 1974, a very large body of quality-controlled evidence on glyphosate has been critically reviewed by specialist scientists working for regulatory agencies in the European Union, the US, Canada, Japan, Australia, Brazil, and the Food and Agricultural Agency of WHO, as well as in the US Agricultural Health Study. None of these studies shows a significant causal link between glyphosate and cancer. In New South Wales, the incidence of all cancers (Depczynski et al., doi.org/10.1186/s12885-017-3912-2) in farm residents 45 years and older was lower than in urban residents, with no differences for non-Hodgkin lymphoma in farmers compared with urban residents.

These results are consistent with glyphosate's benign structure consisting of connected groups of carboxylate, amino and phosphate. Its main degradation product in soil, AMPA, also a zwitterion and shown to be no more toxic than salt, is even simpler in structure. Its likely maximum concentration when bound in soil is about 50 times lower than the no-effect concentration on a range of soil animal species and microbes – a similar safety margin to that observed with glyphosate (von Mérey et al., doi.org/10.1002/etc.3438).

Glyphosate also has low immunogenicity – despite several attempts using glyphosate as a hapten linked to proteins injected into rabbits, we failed to raise sensitive antibodies. In glyphosate, the amino acid glycine is bonded to phosphate by a methylene bridge, yielding a molecule showing none of the characteristics usually associated with mutagenicity or carcinogenicity, such as free radical formation, aromaticity, heavy metal content or fat-soluble halogen content. Furthermore, no residues of glyphosate can accumulate in animals.

Although the International Agency for Research on Cancer (IARC) deemed glyphosate to be 'probably carcinogenic to humans (Group 2A)', this surprise decision gave no quantitative weight to risk of exposure and it may have been meant to encourage further research on genotoxicity. This approach contrasts starkly with Paracelsus' dictum that 'the dose is the poison'. With only a limited data set from scientific journals being

considered, IARC claimed that there was strong evidence of genotoxicity and oxidative stress in tissue cultures at high concentrations (*IARC Monograph* 2015). This conclusion is strongly contested by much previous regulatory data and the 'strong evidence of genotoxicity' involved an incorrect interpretation of a key paper regarding micronuclei IARC cites (Bolognesi et al., doi.org/10.1080/15287390902929741; see critique in Solomon, doi.org/10.1564/v28_aug_08).

IARC's hazard-based classification contrasts with the more stringent risk-based, weight-of-evidence approach used by all international regulatory agencies, including WHO (IARC's parent agency), the European Food Safety Agency, Health Canada, US Environmental Protection Agency (USEPA), the APVMA (2017, see website) and several others. Perhaps influenced by the highly precautionary attitude in the European Union where the decision was made, IARC should have given a more guarded warning instead, such as 'possibly carcinogenic'. The other internationally regarded authority for classifying carcinogens, the National Toxicology Program supported by the American Cancer Society, does not even list glyphosate as possibly a carcinogen.

In my opinion, IARC should reconsider its classification or reform its methods to be more transparently quantitative, using a risk approach that includes the likelihood of exposure. IARC claims it prefers to rely on peer-reviewed literature for its decisions, but this literature is of variable quality and the IARC's working party failed to consider many quality-assured studies conducted for national regulators. These stringent requirements to meet regulatory guidelines are the main reason for the high costs (approximately US$250 million) of bringing any new chemical product to market. It will be difficult for the global agricultural industry to trust IARC in future without some reform and this threatens affordable food production globally.

In 2019, a Washington University meta-analysis (Zhang et al., doi.org/10.1016/j.mrrev.2019.02.001) suggesting that glyphosate increased the risk of non-Hodgkin lymphoma (NHL) by 41% was seized on by the media as a 'compelling link'. The statistical result of their reanalysis selecting longer exposures was that NHL had an increased 'meta relative risk' (RR) of 1.41 from a previous RR of 1.23, less than RR 2.0 required for significance. Their use of a subset of applicators with longer exposure to glyphosate, who are more likely to have been exposed to other carcinogenic compounds, explains the slight increase in RR value. Their conclusion that their meta-analysis 'suggests a compelling link between exposures to GBHs [glyphosate-based herbicides] and increased risk for NHL' was only weakly supported by their study, bolstered with speculative effects regarding immunosuppression and endocrine disruption. Furthermore, the updated Agricultural Health Study of 54 251 applicators in the US (Andreotti et al., doi.org/10.1093/jnci/djx233) found no association between glyphosate and NHL, disproving their hypothesis of a 41% increase. If glyphosate does have a causal influence on lymphomas, one would also expect to see a dose response in test mice. Even in the small proportion of studies with mice and rats indicating a marginal statistical effect, no dose response has been observed.

Consequences of 'knee-jerk' bans

Research to provide new pesticides has many similarities to research in medicinal chemistry. Both require the screening of large numbers of possible candidate chemicals followed by confirmation of their effectiveness and freedom from unintended consequences. Only after years of such expensive trials can they be legally registered for use. World agriculture will resist attempts to restrict the use of glyphosate. However, market forces in trade may dictate that glyphosate will be phased out, whether by government decree or from commercial decisions. This would be a very frustrating outcome, given the huge intellectual and financial investment in this successful technology and the uncontrolled risk of negative consequences on human health from substitute herbicides.

Substituting glyphosate with other less safe herbicides or even returning to mechanical control would be a huge backward step for productivity of farmers and safety in the environment.

So, what might be used instead? Substituting glyphosate with other less safe herbicides or even returning to mechanical control would be a huge backward step for productivity of farmers and safety in the environment. Substitutes will be more toxic and probably less effective, having to be used more often. Even if the precautionary principle is applied, it should retain the use of glyphosate because it is less harmful than any of the likely substitutes. Only when a substitute can be found that has similar advantages to glyphosate should glyphosate's use be discontinued. In any case, its arguable overuse at present may be gradually reduced by new approaches to weeding, such as targeted digital technology available to modern agriculture.

Robots such as Agerris' Digital Farmhand carry out targeted mechanical and chemical weeding with precise control capability. Agerris

Court actions

Unfortunately, IARC's decision fostered a flurry of court actions in the US and elsewhere regarding Roundup, seeking damages from Monsanto and its current owner, the German company Bayer. These actions have focused on cases of non-Hodgkin lymphoma claimed to result from exposure to glyphosate. However, it is debatable whether juries have the capability to make objective decisions of such a technical nature, particularly when judges decline to allow evidence from USEPA experts. Jury decisions based at least partly on sympathy for such claimants are inevitable. The reaction to IARC's decision in 2015 is gathering pace, with moves to discontinue weed control using glyphosate in many jurisdictions, such as local councils and schoolyards. This only amplifies the increased risk from more toxic substitutes, or allergic reactions from uncontrolled weeds producing pollens near schools. Sri Lanka initially banned glyphosate because it feared kidney disease, but on review this decision was reversed for lack of causal evidence and the needs of farmers. Thailand and Vietnam have banned glyphosate more recently because of adverse court decisions in the US, but Thailand also reversed this decision when farmers protested.

Chemical principles are key

It will be chilling for agricultural chemistry and effective pest control if this attack in media and court leads to glyphosate being abandoned without good alternatives. More research has been published on glyphosate generally validating its human and environmental safety than for all other pesticides combined. Even Rachel Carson's *Silent Spring* suggested more nuanced technical means of pest control, like making use of the *Bacillus thuringiensis* peptide crystals toxic to chewing insects. This more subtle approach is now obviating the need for many thousands of tonnes of highly toxic insecticides, by expressing the Bt-toxin genes in GM crops of maize, cotton, potatoes and soybeans. Rachel Carson might even have approved.

The a priori case for suspecting ill of glyphosate, considering all its chemical substituents occur very frequently in biochemical pathways, is weak. No freely soluble zwitterion has been shown as carcinogenic. One can seriously ask whether such a rapidly excreted compound, with all its substituents remaining functional and ionisable in vivo, could be genotoxic. Chemical principles must decide whether this compound, lacking a single feature suggesting mutagenicity, can be seriously carcinogenic. Ultimately, the effects of specific binding activities (or lack of them) with other cell substituents must decide this question. Given the high concentrations used to test tumour formation and even higher levels for genotoxicity, it could be salutary to include common salts as relative controls.

Eventually, given the significant risks to world food supplies and human safety, a rapprochement between the IARC's methodologies of toxicologists and the regulators of use of agricultural chemicals seems essential.

... it is debatable whether juries have the capability to make objective decisions of such a technical nature, particularly when judges decline to allow evidence from USEPA experts.

Ivan Kennedy AM FRACI CChem is Professor Emeritus in Agricultural & Environmental Chemistry, Institute of Agriculture, University of Sydney. His research with some 50 research students has sought solutions for a range of environmental problems, partly described in several books. He is the RACI's topic chair and reviewer for symposia in environmental and sustainable chemistry for Pacifichem 2020, to be held in Hawaii this December.

A burning issue

Volatile organic compounds from bushfire

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Beyond immediate concerns for life and property near firefronts are the less acute but wider effects of bushfire smoke, including exposure to particulates and volatile organic compounds.

BY **NANTHI BOLAN**

Bushfires across southeastern Australia last summer focused national and international attention on the harm they cause to living things and the environment. Smoke from bushfires is one of the major biogenic sources of air pollutants in Australia. The major pollutants in smoke are carbon dioxide, carbon monoxide, methane, fine particulate matter, volatile organic compounds (VOCs) and oxides of nitrogen and sulfur. VOCs released from many common household materials are well known as indoor pollutants. Outdoors, bushfires release a cocktail of VOCs, including acetone, benzene, ethylene glycol, formaldehyde, methylene chloride, phenol, perchloroethylene, toluene, terpene and xylene. Globally, biogenic sources emit VOCs at an estimated 1250 Tg (1.25×10^{12} kilograms) of carbon each year, which is 5–10 times greater than VOC emissions from anthropogenic sources (doi.org/10.5194/gmd-5-1471-2012).

The ambient outdoor VOC concentration from biogenic sources is much less than the indoor VOC concentration from anthropogenic sources. However, the outdoor concentrations of specific VOC compounds in bushfire smoke are much higher than ambient outdoor concentrations. Concentrations of benzene (27–54 mg/m^3) and phenol (12–29 mg/m^3) in bushfire smoke were reported by Johnston et al. (doi.org/10.1016/j.envres.2011.05.007) to exceed the respective short-term exposure limits of 0.32–16 mg/m^3 and 15.6 mg/m^3, respectively. Similarly, Wentworth et al. (doi.org/10.1016/j.atmosenv.2018.01.013) noticed that the major VOC constituents in fire-influenced samples were methanol (37–44%, v/v), acetaldehyde (14–20%), acetone (8–15%), benzene (<1–6%), 1-butene (<1–4%) and formaldehyde (<1–7%). The concentrations of these VOCs are less than the short-term exposure limits of these VOCs as set by Health and

Safety Executive's (UK) Approved Code of Practice to the Control of Substances Hazardous to Health Regulations (bit.ly/2QjedsT) and WHO Air Quality Guidelines (bit.ly/38YTZLG).

Australian bushfires are well known for releasing significant amounts of VOCs (19% of total VOC emissions and more than 80% of total biogenic VOC emissions) due to the prevalence of oil-rich vegetation such as eucalypts. With more than 800 species, eucalypts are the dominant tree in the Australian landscape, and are found in all but the driest environments. They have three very closely related genera: *Eucalyptus*, *Corymbia* and *Angophora*. In addition to their extensive natural distribution, eucalypts are planted widely in Australia and overseas, primarily for pulp and fibre production, or for structural timber.

Eucalypts are some of the highest emitters of biogenic VOCs. They emit more isoprene and monoterpenes, formaldehyde, acetaldehyde and acetone than other vegetation such as conifers. Each year, an estimated 500 Tg of isoprene and 128 Tg of monoterpene VOCs are produced by biogenic sources. Because plant species naturally differ in rates of VOC production, land use and other global changes that result in shifts in species composition are likely to profoundly alter biogenic VOC emissions to the atmosphere.

Health effects of VOC exposure range from simple irritation to respiratory paralysis. Breathing low levels of VOCs for long periods in indoor environments has been shown to pose a risk to human health. VOCs such as formaldehyde and benzene are considered to be proven or probable human carcinogens in instances of long-term exposure (see table). These VOCs are also anthropogenic; health effects of VOCs in biogenic contexts have not been widely studied.

Globally, a growing body of epidemiology reports indicate increased rates of respiratory-related hospital admissions and premature deaths from exposure to bushfire smoke (which includes fine particulate matter (PM2.5) and VOCs). A recent study by Fann et al. (doi.org/10.1016/j.scitotenv.2017.08.024) estimated the cost of short-term exposures to bushfire PM2.5 that led to premature deaths or hospital admissions in the US at $63 billion in 2016 and long-term exposures at $450 billion in the same year. Johnston et al. examined the link between air pollution events (using PM10 levels) and mortality in Sydney from 1997 to 2004 and noticed that air pollution from smoke events was associated with a 5% increase in non-accidental mortality. Both studies focused on the impact of particulate matter, rather than VOCs in particular.

VOCs can react with other compounds in the atmosphere to produce secondary organic aerosols, which can exist in the gaseous and particulate states (bit.ly/3brOXtp). Because the formation processes of biogenic secondary organic aerosols and their amounts are largely uncertain, predicting their potential health effects is difficult (doi.org/10.5194/acp-15-12029-2015).

The major impacts of biogenic VOCs on the atmosphere include:

- production of ozone in atmospheres of high nitrogen oxides (NO_x)
- enhanced hydroperoxyl free radical (HO_2) formation, which is further involved in the conversion of NO_x to ozone
- release of CO due to photo-oxidation of biogenic VOCs (accounting for 10–20% of global CO)
- generation of organic nitrates, which participate in ozone formation.

These biogenic VOCs contribute to increased ozone formation, which contributes (modestly) to climate change and global warming. Aside from the adverse health effects in humans and animals, increased ozone concentration can affect plants: a higher risk of disease, an inability to fight off pests and environmental stress, reduced growth and survival of tree seedlings, and reduced agricultural yields (doi.org/10.3390/plants8020034).

VOCs released from bushfires can also damage the ozone layer. This happens in the upper atmosphere through secondary organic aerosol

Major non-methane biogenic VOCs released during bushfire and possible health effects

VOC	Possible health effects*
Benzene	Harmful effects on bone marrow and can cause a decrease in red blood cells, leading to anaemia
	Causes excessive bleeding and can affect the immune system, increasing the chance of infection
Dichlorobenzene	Headaches, numbness, sleepiness, nausea and vomiting
Formaldehyde	Watery eyes; burning sensations in the eyes, nose and throat; coughing, wheezing, nausea and skin irritation
Terpene	Skin and eye irritation
Toluene	Eye and nose irritation; weakness, exhaustion, euphoria, dizziness, headache; dilated pupils, lacrimation; anxiety, muscle fatigue, insomnia; numbness or tingling of the skin; dermatitis; liver and kidney damage
Xylene	Headaches, dizziness, drowsiness and nausea; more serious exposure can cause sleepiness, stumbling, irregular heartbeat, fainting or even death
Phenol (benzenol)	Highly irritating to the skin, eyes and mucous membranes after acute (short-term) inhalation or dermal exposures; quite toxic to humans via oral exposure

*Depends on source, concentration, length of exposure and interactions with other substances present.

formation, thus reducing the protection this offers from harmful UV rays.

Extreme air pollution events due to bushfire smoke are expected to increase as a consequence of climate change, and they are the major sources of outdoor biogenic VOCs. For her 2016 PhD thesis at the University of Wollongong (some of whose campuses were under threat in last summer's bushfires in New South Wales), Dr Elise-Andree Guerette carried out mass spectrometric measurements of biogenic VOCs at ambient conditions and at the sites of prescribed burns (ro.uow.edu.au/theses/4855). She indicated that her research 'can help validate atmospheric models and further our understanding of atmospheric composition and chemistry in the relatively clean conditions of south-eastern Australia and in the highly polluted conditions of bushfire smoke plumes.' Similarly, Emmerson et al. (doi.org/10.5194/acp-16-6997-2016) estimated the emission rates of isoprene and monoterpenes from Australian vegetation, using the Model of Emissions of Gases and Aerosols from Nature version 2.1 (MEGANv2.1). They concluded that 'there is no single increase/decrease factor for the emissions which suits all seasons and conditions studied'.

Many studies have examined the human health impacts of anthropogenic VOCs ('sick building' syndrome), but limited work has been done on the health impacts of outdoor biogenic VOCs. Although the health effects of bushfire smoke are largely related to the inhalation of PM2.5, exposure to specific VOCs such as benzene can pose long-term health risks. In light of this impact on health (doi.org/10.1016/j.envint.2013.08.002), there is a need to undertake epidemiological studies examining the long-term health impacts of exposure to biogenic VOCs in bushfire smoke in various populations and for various bushfire scenarios, perhaps using chemical markers of biogenic secondary organic aerosols.

Nanthi Bolan MRACI is Professor of Environmental Chemistry at the Global Centre for Environmental Remediation, University of Newcastle. He is also Leader of Program 3 (New Products) of the Cooperative Research Centre for High Performance Soils.

Bushfire science roundtable: impacts and opportunities

In January, the Hon Karen Andrews MP, Minister for Industry, Science and Technology, hosted a roundtable meeting of top scientists and experts in response to the devastating bushfires.

Andrews highlighted that disaster response, recovery and resilience activities should be informed by multi-disciplinary research that draws on a wide range of disciplines, including the natural and physical sciences, engineering, humanities and social sciences.

Research and technology is playing a critical role in supporting the efforts of emergency management agencies and other government departments to prepare for, and manage, the threat of bushfires, and help communities recover from the impact of fire events.

The group of experts was brought together to understand the state of our current science and where the opportunities are for future science. Participants discussed contributing factors to bushfires, including the impacts of a changing climate, Australia's bushfire research capability, and how to leverage research and technologies to deliver real impacts on the ground, including in mitigation and adaptation.

Andrews called on the group to improve scientific communications regarding bushfires and other natural hazards. It was agreed that the CSIRO would develop a document, in consultation with the group, for the public to understand key facts around the contributing factors to bushfires.

It was noted that members of the community are eager to practically assist and there are opportunities for individuals to be engaged through citizen science.

Participants noted that fire volunteers and communities affected by events are essential to the response and knowledge base. Furthermore, participants agreed to greater collaboration across science and research efforts.

Specifically, Earth observation resources were identified as an immediate area where the Australian Space Agency, CSIRO, Geoscience Australia and the Bureau of Meteorology can better work together to improve access. The Office of the Chief Scientist will coordinate research capability mapping to assist with collaboration. Participants also agreed to encourage their networks to register for Expert Connect, a platform that aims to boost industry–researcher identification and collaboration.

The group agreed that research and technology collaboration efforts should include businesses, volunteers, first responder organisations and different levels of government to ensure new products, services, processes and practices are delivered to where they are needed. It is essential that industry is involved in the development of mitigation and adaptation solutions. CSIRO, in consultation with the Bushfire and Natural Hazards CRC, will convene a number of industry sessions to bring relevant parties together.

It was also noted that as new technologies emerge, such as digital twins and autonomous vehicles, our ability to model and respond to bushfires will evolve. To this end, the Bushfire and Natural Hazards CRC will convene a working group to examine technology advances than can assist fire response and management.

Minister for Industry, Science and Technology

iStockphoto/Dr_Microbe

FUNGI at the frontline

BY **DAVE SAMMUT** AND **CHANTELLE CRAIG**

The arsenal we have against bacterial outbreaks is dwindling, but there are opportunities to develop new defences.

World Antibiotic Awareness Week came and went in November 2019, with barely a mention outside medical media to remind us of the importance of these drugs in the fight against bacteria. Just five weeks later, a pneumonia of unknown cause was reported in Wuhan, China. Now, the world has no choice but to pay attention to another type of microbe: coronavirus. COVID-19 is a viral rather than a bacterial disease, but the damage it does to the lining of the lungs can make them more susceptible to invasion by bacteria and thus to secondary infections. In fighting bacteria – sometimes indiscriminately – we are seeing greater resistance to antibiotics as time goes on.

The first commercial* antibiotic chemotherapeutic drug was developed at the Bayer Laboratories of I.G. Farbenindustrie in Germany. Prontosil (1932) was a sulfonamide used with broad effect against certain gram-positive cocci. German chemist and pathologist Gerhard Domagk received the 1939 Nobel Prize in Physiology or Medicine for its development as part of his research into the antimicrobial activity of azo dyes.

The first antibiotic resistance was identified in *Staphylococcus* in 1940. In 1945, Alexander Fleming warned that 'The overuse of antibiotics clearly drives the evolution of resistance'. Since then, resistance has been observed for nearly all antibiotic drugs that have been developed.

The 1960s through to the 1980s were the halcyon days for new antibiotic discovery. Most of the antibiotics in clinical use today derived from natural defence chemicals (natural products) produced in a laboratory setting by bacteria and fungi to defend against attack from other microbes. These substances

*Alexander Fleming discovered penicillin in 1928, but it wasn't until after Howard Florey and Ernst Chain developed penicillin for use as medicine that the first patient was successfully treated in 1942. The prominence of penicillin as 'the first antibiotic' is a combination of its subsequent extensive use and the geopolitics of the era, but the first synthetic antibiotic actually used for widespread clinical purposes was prontosil.

were then replicated and often modified to amplify their antimicrobial activity.

By late last century, the low hanging fruit of readily accessible microbial natural products with antibiotic potential had been deemed exhausted, prompting the pharma industry to look elsewhere for inspiration. Some 20 or so years on, and confronted with a severely depleted antibiotic drug discovery pipeline, and increasing levels of antibiotic resistance, the need to be inspired is unrequited and more urgent that ever.

In their article 'Seven ways to preserve the miracle of antibiotics' (doi.org/10.1093/cid/cit070), John G. Bartlett and colleagues at Johns Hopkins University School of Medicine described this stagnation bluntly:

> *Pharmaceutical development that previously kept us ahead of resistance is now stalled due to economic and regulatory barriers. Fifteen of 18 large pharmaceutical companies have totally left the antibiotic field, and there has been no new class of antibiotics for gram-negative bacilli in 4 decades; only 2 drugs with new microbial targets (linezolid and daptomycin) have been introduced since 1998. The pipeline is sparse, the problem is global, and the prognosis is poor.*

The impact of this sparse pipeline is equally sobering. In their Action Plan on Antimicrobial Resistance 2016–2020, the UN Food and Agriculture Organization stated:

> *In humans, [anti-microbial resistance, which includes bacteria, fungi, viruses and parasites] also threatens to undo decades of improvements in human health care outcomes, with direct impacts on the ability of people to live full and productive lives.*

Up to 99% of bacteria can't be readily cultured in the lab, which severely limits our ability to observe the chemicals they produce under attack. Although there have been minor breakthroughs in technologies to help culture recalcitrant bacteria, and although researchers have cast a wider net to samples from marine bacteria, tropical rainforests and other frontiers, the basic numerical problem remains. And while some pharmaceutical companies are going back over old screening with newer, more sensitive techniques, the return on investment for this is dropping markedly.

Given these problems, new drug discovery this century has tended to move away from 'natural products' research, and more towards genomics, proteomics and other 'omics' research. These studies have looked more closely at alternative mechanisms for inhibiting infection (see box, p. 27), and new approaches to activate 'silent genes' that code for antimicrobial weapons.

In recent years, microbial genomes have been shown to be rich in genes that code for many more defence molecules (potential antibiotics) than detected in lab cultures. These genes are under tight regulatory control, and are only activated in response to unknown environmental cues. But how to access this untapped molecular reservoir?

Enter Professor Rob Capon, RACI Fellow and a group leader at the University of Queensland, Institute for Molecular Bioscience, who describes the silent capacity of genes as the holy grail of antimicrobial research.

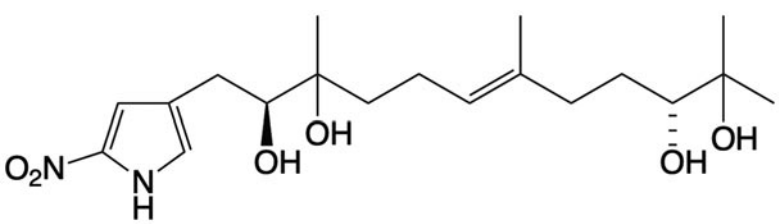
While pursuing basic research into bacteria and fungi isolated from beach sand on Queensland's Heron Island, Capon and his team identified complex inter-kingdom chemical communication that he believes sheds light on a future path to antibiotic discovery.

Natural products chemists change the media for a bacterial culture to challenge the bacteria. Or, if they are being more elegant, they use a 24-well plate and rapidly challenge the organism through different culture media. But this doesn't necessarily produce the chemical cue(s) to activate the genes.

By contrast, Capon said that the 'gene jockeys' chop the gene into bits and try to express these in another organism. But this is time consuming, with accessibility issues and high costs.

Starting with a beach sand-derived bacteria, a *Streptomyces* species, Capon and his team identified a new class of natural products featuring an unprecedented 2-nitropyrrole, which they named the heronapyrroles. The heronapyrroles exhibited promising antibacterial activity against pathogenic gram-positive bacteria, which was interesting, but not patentable, despite similarity to synthetic nitroimidazoles with anti-tuberculosis properties. It's at this point that the story takes an unexpected turn.

In an effort to study heronapyrrole antibiotic properties, Capon attempted a simple experiment. He added a synthetic nitric oxide synthase inhibitor (aminoguanidine) to the live *Streptomyces* culture, with the aim of inhibiting the biosynthesis of the nitro functionality. What was to be a quick 2–3-week study led to a more than five-year adventure, which involved synthetic chemistry, genomics and transcriptomics, and imagination, to decode an intricate cycle of attack and counter-attack between two warring microbes.



Heronapyrrole B is showing promise as an antifungal agent. Zeinab Khalil

There's a lot of technical detail from here, so we'll jump to the big discovery. Capon and his team found a chemical conversation going on between two species in the beach sand: the *Streptomyces* bacteria and a fungus. Each tries to outcompete the other.

The Heron Island *Streptomyces* only produced the heronapyrroles when in co-culture with a fungus co-isolated from the same sample of beach sand. The researchers found that an antibacterial chemical defence (diketopiperazine) produced by this fungus stimulated the *Streptomyces* to produce nitric oxide, which in turn proved to be the secret regulator of the silent genes responsible for producing heronapyrroles. The heronapyrroles were in turn uniquely antifungal. Remarkably, this battle had a twist. When confronted by antifungal heronapyrroles, the fungus responded by diverting all its energy into producing and secreting more diketopiperazine, only to further antagonise the *Streptomyces* into making more heronapyrroles. Eventually the fungus succumbed, and as its cell count slipped below the level needed to stimulate the *Streptomyces*, a very lopsided armistice ensued.

This is a cycle of attack, defence and counter-attack. And now, knowing what to look for, the researchers have found the same behaviour in other organisms.

But how does this help guide the future discovery of new antibiotics? Capon reasoned that, because it was too difficult to find and identify all the secret chemical cues that regulate so many of the silent genes hidden in so many microbial genomes, why not bypass the cues altogether, and just add nitric oxide to *Streptomyces* cultures?

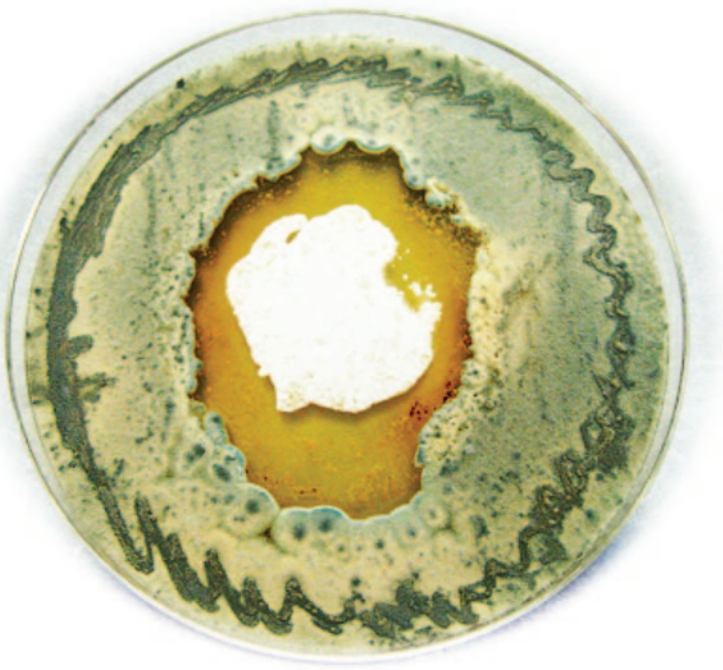
In a process Capon and his team refer to as nitric oxide mediated transcriptional activation, or NOMETA, they add a small amount of the vintage angina medication sodium nitroprusside to the cultures of both bacteria and fungi. Sodium nitroprusside slowly breaks down to release nitric oxide and, presto, many cultures respond by producing new defensive chemicals.

'The reason we've missed these genes in the past is that we've been growing our microbes in monoculture – there's no threats, there's lots of food and no competition, so a bacterium won't turn on its armoury because it doesn't feel threatened,' Capon said.

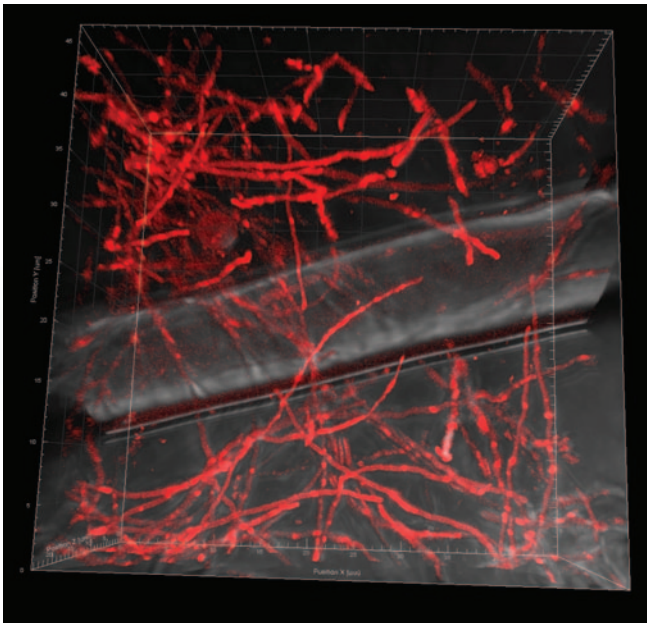
Capon reflected that 'Nature's use of toxic gas in an inter-kingdom beach warfare between bacteria and fungi was a revelation to us. We can only hope that our discovery provides an opening salvo in another war – the one being waged against infectious pathogens that are growing ever more resistant to our current arsenal of vintage antibiotics.'

This is a hope that we all share. Because this is a war that will never end – microbes evolve too swiftly. All we can do is seek to slow the battles until the political will builds to improve our currently poor antibiotic practices.

Dave Sammut FRACI CChem and **Chantelle Craig** are the principals of DCS Technical, a boutique scientific consultancy providing services to the Australian and international minerals, waste recycling and general scientific industries.



A co-cultivation agar plate of *Streptomyces* sp. (bacteria), shown in the centre, and *Aspergillus* sp. (fungi), shown on the outside.



In this image of a mixed culture of fungus and bacteria, the fungus (the grey tube-like structure) has produced a defensive antibacterial, to which the bacteria responds with nitric oxide (and glows red due to an NO detection agent), stimulating the release of a powerful antifungal that defeats the fungus. Dr Nicholas Condon

The antibiotic arms race

According to Jeff Goldblum's character, Dr Ian Malcolm, in *Jurassic Park* – a film (in)famous for its scientific accuracy – 'Life, uh, finds a way'. When it comes to microbes, they find *lots* of ways.

'Resistance' denotes the ability of a bacterium to survive a specific antibiotic treatment. Some bacteria are naturally resistant. Resistance can occur through spontaneous chromosomal mutation, but it can also be transmitted extra-chromosomally, such as when bacteria exchange plasmids or transposons (horizontal gene transfer).

The 'golden age' natural product antibiotics (1940–70) target structures unique to bacteria and not present in mammals (to minimise side effects) – to destroy the bacterial wall, cell membrane or crucial bacterial enzymes involved in nucleic acid and protein synthesis. Basically, the idea was to disrupt essential bacterial processes, ultimately killing the cell.

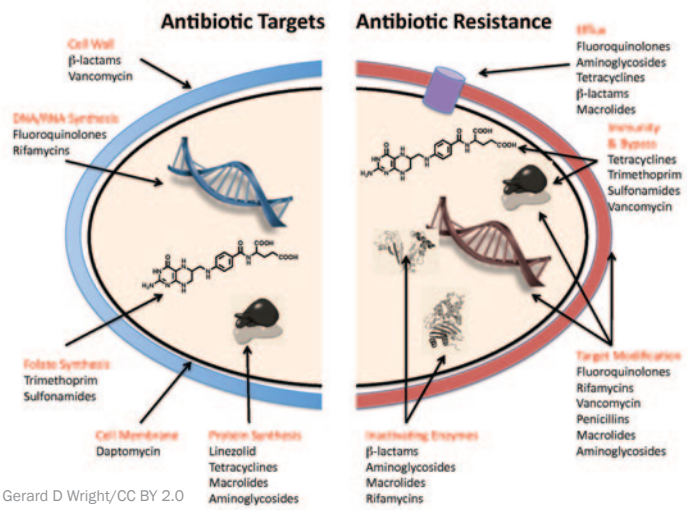
Antibiotic treatment creates substantial adaptation pressure. By removing drug-sensitive competitors, the field is left wide open to the survivors – typically those with greater capacity to produce genetic variability.

Common mechanisms for antibiotic resistance evolved to include the appearance of efflux pumps (which remove antibiotics from the bacterial cell), changes to membrane permeability (keeping the antibiotic out), changes to the bacterial target site(s), or modification or deactivation of the antibiotic itself.

Subsequent generations of antibiotics mostly tried to improve the efficiency of attack on these same target sites, meaning that the resistant bacteria were already well primed to adapt. Researchers then adapted their approach to look for novel, unexploited targets, to seek a molecule that is effective against the target and safe to use.

New drugs have also been created through bioinformatics and rational design. Using detailed knowledge and libraries of how variations to a molecule's structure affect its behaviour, activity and performance (bioinformatics), virtual models can be created to design molecules for specific functionality. For example, a new drug was designed in 2017 to fight resistant bacterial strains by combining three antimicrobial mechanisms: increased potency, increased cell wall permeability and inhibition of cell wall biosynthesis.

Alternatively, targets are now being sought that take advantage of processes that are not critical to bacterial survival. By leaving the bacteria alive, but 'declawed', this decreases the evolutionary pressure for adaptation, and leaves more competition in place for the remaining harmful organisms.



Gerard D Wright/CC BY 2.0

… virtual models can be created to design molecules for specific functionality.

It would take another article to discuss the chemical mechanisms that bacteria used to adhere to, invade and recode host cells to their purposes; or the chemical communication between bacteria known as 'quorum sensing' (by which bacteria can communicate their numbers to hold off an attack until critical mass has been reached, to avoid triggering an immune response until it is too late); or the formation of defensive structures such as biofilms, which allow individual bacteria to act in concert as multicellular organisms. Suffice to say, bacteria are clever and inventive.

That necessarily means that the design of our response gets equally complicated, equally quickly. We might focus on disarming the pathogens, blocking parthenogenesis, neutralising toxins or interfering with host–pathogen interactions at the protein level. We might even boost the fight by enhancing the host immune system.

ANCQ award ceremony in Sri Lanka

His Excellency David Holly, Australian High Commissioner for Sri Lanka, delivering the chief guest address.

The 23rd award ceremony of the Australian National Chemistry Quiz (ANCQ) for 2019, hosted by the Institute of Chemistry Ceylon, was held on 20 January 2020 at Adamantane House, Rajagiriya, Sri Lanka. Australian High Commissioner for Sri Lanka, His Excellency David Holly, graced the occasion as the chief guest. Professor P. Paranagama, President of the Institute of Chemistry Ceylon and Professor S. Ekanayake, Dean of College of Chemical Sciences, were among the dignitaries.

Last year, 175 schools and almost 6500 students in Sri Lanka took part in the ANCQ. Among 154 award winners, nine students from the senior section, who obtained full marks for the competition, received full scholarships from the Institute of Chemistry Ceylon to follow the Graduateship in Chemistry Program at the College of Chemical Sciences in 2021. Ten other students were awarded with plaques and certificates of excellence.

Dr C.N. Ratnaweera, senior lecturer at the College of Chemical Sciences, delivered a presentation on the Chemistry Olympiad and critical problem solving in chemistry, and the vote of thanks was delivered by Ms Nishmitha Ramraj. The award ceremony ended on a high note with a captivating magic show, organised by the College of Chemical Sciences.

Andrew Holmes awarded honorary doctorate

Lauded chemistry professor and previous President of the Australian Academy of Science, Professor Andrew Holmes FRACI CChem, has been presented an Honorary Doctorate of Science by Curtin University.

Holmes is a distinguished chemist whose pioneering research interests span molecular organic, polymer and biological chemistries and materials science.

In particular, his work on conjugated polymers has helped revolutionise the way we think of plastics and paved the way for the emerging field of 'plastic electronics' – in which semiconducting polymers can replace traditional materials such as silicon in the displays of 'smart' devices, including televisions and smartphones. Among his achievements in the area of bioactive molecules, he has contributed to the discovery of key proteins implicated in downstream intracellular signalling processes.

Curtin University Vice-Chancellor Professor Deborah Terry said she was honoured to present Holmes with an Honorary Doctorate in Science for his outstanding contribution to the field of chemistry, as well as his inspirational leadership.

'Professor Holmes is a true science statesman and advocate, who is a leader in the promotion of science in Australia and Australia's scientific contributions internationally. He plays a major part in science policy development and is a passionate advocate for the promotion of STEM learning in schools,' Terry said.

'Under his leadership, the Australian Academy of Science initiated the Science in Australia Gender Equity (SAGE) initiative, which is designed to catalyse gender equity action to improve the promotion and retention of women and gender minorities within STEM.

'This important work by Professor Holmes outside the laboratory is just as valuable as his research, where he continues to inspire science professionals and those aspiring to enter the field to achieve great things.'

Holmes's most recent work was focused on developing flexible printed solar cells that could one day be used in large arrays to provide a cheap source of renewable energy.

Holmes has published more than 600 scientific papers and was the second most highly cited UK physical scientist of the first decade of this century. He has also been the deserving recipient of many prestigious accolades, including Australia's highest honour – Companion in the General Division of the Order of Australia.

Holmes was presented with his Honorary Doctorate in Science from Curtin University at a graduation ceremony on 13 February.

Curtin University

Professor Andrew Holmes (left) and Curtin University Council Member Mr Damian Gordon.

New Fellows

Associate Professor **Sylvia Urban** is a natural product chemist based at RMIT University. She was awarded her PhD (Chemistry) from the University of Melbourne (supervisor Professor Robert Capon). She then was appointed as a research fellow working on the AstraZeneca/Griffith University natural product drug discovery program with Professor Ronald Quinn, followed by a postdoctoral research fellowship at the University of Canterbury, New Zealand, in association with PharmaMar, with Professors Murray Munro and John Blunt.

She commenced her appointment at RMIT University in 2002 and her independent research career by being awarded an American Society of Pharmacognosy Starter Grant and significant funding from the Victorian Institute for Chemical Sciences. She is currently Associate Professor, Indigenous Coordinator and Reconciliation Facilitator for the School of Science as well as the Program Manager of the Bachelor of Science program.

Urban is one of Australia's leading natural product chemists in bioactive natural product discovery, including anticancer natural products, which has led to a patent with industry. Her research focuses on the chemical diversity and biological activity of natural products derived principally from Australian plants and marine invertebrates, and methods to expedite their discovery. She has 95 journal, one book and three book chapter publications and has received the Gerald Blunden Award for best paper in *Natural Product Communications* (2011).

Urban is a Senior Fellow of the Higher Education Academy, a passionate educator and a leader in advancing the teaching of chemistry at RMIT University. She created a community of practice for early adopter academics to redesign their teaching practices in the School of Science at RMIT across many disciplines. This has led to national, RMIT University and School of Science teaching awards, including a 2019 Australian Award for University Teaching Citation. She is a long-standing member of the RACI, having various involvement in the Chemical Education, Natural Products Chemistry, Division of Organic Chemistry and Bioactive Discovery and Development groups of the RACI over the years. She is an advocate for better opportunities for women in STEM, exemplified by her roles as a committee member of Women in STEMM, the RACI's Women in Chemistry group, the RMIT University Women Researchers' Network and the Athena Swan initiative at RMIT.

Urban is of Italian descent, married in her mother's northern Italian village, and has two boys aged 11 and 7. When not at work, she enjoys spending time with her family, travelling, gardening and photography.

Dr **George Vamvounis** studied at St Francis Xavier University, Canada, where he obtained a BSc (Hons, Chemistry) in 1998. He obtained a PhD in polymer chemistry under Professor Steven Holdcroft at Simon Fraser University, Canada, in collaboration with the Xerox Research Centre of Canada in 2005.

Following graduate studies, Vamvounis held two postdoctoral positions: a KAMI postdoctoral fellow at the Royal Institute of Technology (KTH) in Sweden, under the leadership of Professor Anders Hult; and a senior research fellow at the University of Queensland's Centre for Organic Photonics & Electronics (COPE), under the leadership of Professor Paul Burn. During his time at COPE, Vamvounis was awarded an Australian Research Fellowship by the Australian Research Council (2010). He moved to James Cook University in 2014 where he has been a senior lecturer in chemistry and now chemical engineering.

Vamvounis's research interest is translational in nature with an emphasis on polymer and organic semiconductors. To that end, he has published 60 peer-reviewed journal articles in high-impact journals such as *Advanced Materials*, *Advanced Functional Materials*, *Macromolecules*, *Polymer Chemistry* and *Chemistry of Materials*. His *h*-index is 20 with a total citation count of roughly 1500. From an applied perspective, Vamvounis has filed five patent applications based on OLEDs with four of these patents licensed to LG Electronics. In the past five years, he has given eight keynote or invited lectures in local and international conferences.

Vamvounis has been actively involved with the RACI since 2013. In particular, he has been the North Queensland Representative of the RACI Queensland Branch Committee. In this role, he helped organise various RACI events, including the Townsville RACI Titration Competition (2015–present), RACI Queensland Emergency Plans workshop (2019), IUPAC100 and RACI Global Women's Breakfast (2019–2020) and 2022 RACI National Congress. In 2015, Vamvounis was named the RACI O'Donnell Schools Lecturer for which he engaged with regional high schools from Rockhampton to Mareeba.

Wilfred (Wilf) Ernest Ewers (1919–2020)

Centenarian, RACI President, scientist and science leader

On 27 February 2020, in the idyllic town of Augusta on the south-west corner of the continent, we lost Wilf Ewers, one of the nation's most gifted scientists, science leaders and administrators. He was responsible for establishing the CSIRO's minerals research program in Western Australia in 1963, turning it into one of the organisation's most successful enterprises.

Wilf Ewers was born in Perth, Western Australia, on 23 December 1919. He was the third child of Lilian and Ernest Ewers. Ernest had two sons from his first marriage. The older, Donald Ernest, enlisted in the 44th Australian Infantry Battalion on 2 May 1916 and 'died of wounds' on 4 April 1918. The younger was John Keith Ewers, the highly regarded Western Australian writer, who was a mentor to his gifted young stepbrother. His father died in 1939 after a long period of illness.

Wilf was too young to sit the entrance examination to Perth Modern School in his final year at West Leederville State School so attended Perth Boys School for his first year of secondary education. He won a scholarship to Perth Modern School from Perth Boys School and repeated first year in 1932.

Wilf entered the University of Western Australia in 1937 and completed an Honours degree in Chemistry in 1940 and a Masters degree in 1944. He commented, in his National Library of Australia oral history interview, on the arrival of Professor N.S. Bayliss to the university in 1938:

'Everyone was elated at having a lecturer who could talk coherently about chemistry.'

Wilf joined the CSIR Division of Industrial Chemistry in 1941 and was seconded to the Department of Chemistry to work on the alunite project. Alunite (potassium aluminium sulfate) occurs in Lake Campion and other salt lakes in Western Australia and Wilf's research was undertaken to see whether alunite could be exploited as a wartime source of potash and alumina. This was the basis of both his Honours and Masters projects.

With the surrender of Japan in August 1945, the wartime emergency no longer existed and concern with the alunite project reduced, so Wilf was transferred to the Division's headquarters in Fishermens Bend, Victoria, and joined the Physical Chemistry Section. He worked in the surface chemistry group on various projects, including flotation processes for mineral separation, the use of monolayers to control evaporation in dams and measurement of surface viscosity. His work must have impressed his Chief, Dr Ian Wark, because he was promoted to the position of Divisional Secretary in 1955.

In 1959, Charles Court became Minister for Industrial Development in the newly elected Brand government in Western Australia. He mounted pressure on CSIRO to extend its research activities in Western Australia beyond areas relevant to agriculture. This was a remarkably prescient initiative because the mining industry was then at a very low ebb. Gold mining barely existed, beach sand and bauxite mining were in their infancy and proposed mining for iron ore was a few years away. These offered research opportunities in mineral processing, but it was not until the discovery of nickel at Kambalda in 1966 sparked the 'nickel boom' that exploration took off and demonstrated a need for research in all aspects of discovery.

In 1962, Wilf joined the Division of Applied Mineralogy (later Mineralogy) and the Chief, Arthur Gaskin, gave him the task of setting up a branch laboratory in Perth. His brief was very broad: 'to work on minerals and related topics'. He spent the first six months on the task 'to acquaint myself with the mineral industry in the State, establish connections with the industry, the University and the Geological Survey'. In the National Library of Australia interview, he summarised his view on mining research: 'in approach to mining, there should be more of an integration of the roles of the geologists, the miners and the metallurgists – and the chemists, the chemists are involved in everything!'

In 1963, a small group of CSIRO staff moved from Melbourne to Perth and were initially located at the University of Western Australia. Early studies were on potential ore minerals such as glauconite (for potash), spodumene (lithium) and titaniferous magnetite (vanadium). Drilling using high-pressure water and mechanisms of diamond drilling were also studied. In 1966, the Division moved to a new laboratory at Floreat Park, in time to capitalise on the surge of exploration of the nickel boom. Over the next few years, Wilf continued to appoint staff with qualifications relevant to the task of improving mineral exploration through a better understanding of the primary ore environments, and the mineralogical and geochemical effects of deep chemical weathering. Wilf himself was involved in early studies of nickel sulfide deposits, but adopted more of the role of

facilitator and supporter of the weathering studies, which were aimed at developing new approaches to geochemical exploration – initially for nickel, uranium and gold. Development of the huge accumulations of iron in the Hamersleys was an enduring interest and, in consultation with the companies involved, Wilf embarked on a project to understand the controls of phosphorus in the ores. These programs of strategic research each involved both field-based observational projects and laboratory-based experimental projects – the latter reflecting Wilf's particular interests and expertise. Each program has been highly successful and remain as priorities of minerals research.

Wilf encouraged research staff to stray into other disciplines and encouraged collaboration with counterparts in other divisions at Floreat Park. This not only resulted in good working relationships but also extended into social functions – an active social club, development of sporting facilities on site, including cricket (with turf wicket), tennis, bowls and soccer, and family-oriented events. The annual golf day, almost a compulsory event, was Wilf's specific contribution. The relationships forged in that era resulted in an active chapter of the CSIRO Alumni when that was created some 25 years after Wilf retired. Wilf himself was widely regarded by alumni of all Divisions and was the recipient of the alumni's Brodie-Hall Award, named for Sir Laurence Brodie-Hall, Chair of the Western Australian State Committee and a committed supporter of CSIRO, especially in Wilf's minerals research initiatives.

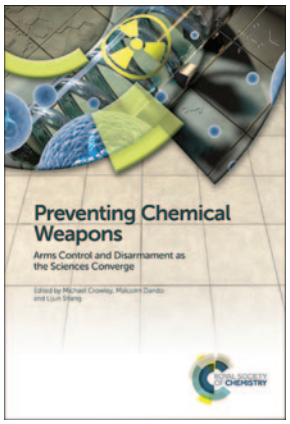
Wilf was very active in the (R)ACI. He joined in 1944 before the Royal Charter and was elected a Fellow in 1957. He was Western Australian Branch President for two terms 1967–69 and the national President 1973–74. He was not an active participant in the Divisions but was very keen to see the Physical Chemistry Division form at the 1974 National Convention.

Wilf retired from CSIRO in 1981. He served on the first Board of the Western Australian Mining and Petroleum Research Institute and then on the Board of its successor, the Mining and Energy Research Institute of Western Australia. He also served on the Council of WAIT for six years, finally becoming Deputy Chairman of the Council. In 1987, WAIT became the Curtin University of Technology and Wilf was appointed as a Foundation Fellow of the University.

Wilf Ewers is survived by daughters Anne Boud and Penny Williams, son Graeme, eight grandchildren and eight great-grandchildren. His wife Marie, to whom he was married for nearly 73 years, died in 2017.

Tom Spurling FRACI CChem interviewed Wilf Ewers for the National Library of Australia Scientists in the CSIRO oral history project in 2012. **Charles Butt**, a geologist, was a colleague of Wilf's at CSIRO in Perth.

Preventing chemical weapons: arms control and disarmament as the sciences converge



Crowley M., Dando M., Shang L. (Eds), Royal Society of Chemistry, 2018, 652 pp., ISBN 9781782626497, £99

Just over a century ago, the first large-scale use of chemical weapons took place on the battlefields of Europe during World War 1, made possible only because of the rapid development of the chemical industry in Europe in the latter part of the 19th century. Thousands of soldiers were killed or injured by chemical weapons, initially with chlorine and subsequently with more toxic chemicals such as phosgene and mustard blister agent. In response, the League of Nations negotiated the 1925 Geneva Protocol, an agreement prohibiting the 'first-use' of chemical and biological weapons. However, this agreement has had limited effectiveness, as exemplified by the large-scale use of chemical weapons by Iraq in the Iraq–Iran war in the 1980s.

In 1992, the negotiation of the Chemical Weapons Convention (CWC) was concluded in the Conference on Disarmament in Geneva. This treaty, which prohibits the development, production, stockpiling and use of chemical weapons, became operational in 1997 with the establishment of the Organisation for the Prohibition of Chemical Weapons (OPCW). Within 15 years, most of the declared stockpiles of chemical weapons had been destroyed under strict verification by the OPCW, and in 2013 the organisation was awarded the Nobel Peace Prize. With 193 states now party to the treaty, including Russia and the USA as well as most other countries known to have possessed stockpiles of chemical weapons, the CWC is widely regarded as the most successful and comprehensive disarmament treaty, striking a balance between prohibited activities associated with chemical weapons and the protection of economic and industrial interests related to the peaceful uses of chemistry.

However, the decade of the 2020s is shaping up to be a very challenging time for the CWC and the OPCW, which is why *Preventing chemical weapons* is so timely. Written by several well-known international experts in the fields of chemical and biological weapons and disarmament, scientific and medical ethics, science policy research and defence and security studies, this book considers the changing international security environment, the increasingly contentious politics of arms control and disarmament, the future of chemical and biological warfare, the impacts of converging sciences on the CWC and the Biological Weapons Convention, and the role of civil society in supporting the strengthening of the CWC in order to prevent the re-emergence of chemical weapons in the 21st century.

This is a high-quality thoroughly researched book spanning 652 pages and 21 chapters. A book of such substance could not be adequately reviewed in 800 words, so I have focused on what I regard as the book's three major themes.

Preventing chemical weapons commences with a very useful discussion of the increasingly unstable international security environment since the beginning of the 21st century, and the resultant changing nature of armed conflict, which may encourage certain states to retain and use existing chemical weapons, as well as increase state interest in creating new types of chemical weapons. At the same time, states, armed opposition groups, terrorist and criminal organisations may seek to employ a diverse range of toxic chemicals as improvised chemical weapons. The chemical weapons attacks in recent years in Iraq and Syria, and also the recent more targeted chemical assassination operations using VX nerve agent in Malaysia and Novichok nerve agent in the UK, provide indications of the types of potential future threats posed by chemical weapons.

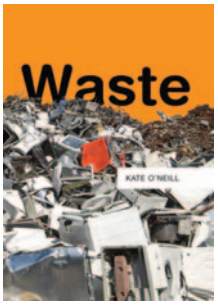
Preventing chemical weapons then discusses how these geopolitical developments are taking place in a period of rapid and revolutionary developments in science and technology, sometimes referred to as the 'convergence' of chemistry and biology, including the neurosciences and nanotechnology. These developments will undoubtedly bring transformational societal benefits, including more effective pharmaceuticals and medical treatments. However, as the book discusses in some detail, the same advances in science may also result in the development of new classes of toxic chemicals suitable for use as chemical weapons, as well as enhanced methods of delivery.

The book also provides a particular emphasis on the roles that chemists and other life scientists, health professionals, and wider informed activist civil society can play in helping to protect the prohibition of chemical weapons, including in close cooperation with states as they attempt to build effective and responsive measures to ensure that the rapid scientific and technological advances are safeguarded from hostile use and are instead employed for the benefit of all humankind.

This book is most definitely essential reading for all researchers working on chemical disarmament projects. It is also essential reading for chemists and other life scientists, health professionals, and wider informed activist civil society who are interested in playing a role in protecting the prohibition against chemical weapons. Scientists working with states/national authorities to ensure the ongoing effectiveness of the CWC, including through effective national implementation measures, taking into account the rapid scientific and technological advances, will also find the book essential reading.

This book is also highly recommended reading for students and research communities working in the fields of pharmacology, toxicology, chemistry and social science, and those with an interest in the legal and ethical aspects of chemical and biological weapons prevention.

R.J. Mathews FRACI CChem



Waste

O'Neill K., Polity Press, 2019, paperback, 240 pp., ISBN 9780745687407, $35 approx.

Waste is a timely, well-crafted, well-referenced, scholarly book, full of useful insights into one of the globe's more significant challenges – the 'creation' and disposal of the stupendous amounts (estimated to be hundreds of millions of tonnes per annum) of human-generated rubbish. We are, metaphorically, drowning in our own excrement. As we have seen in recent times in Australia, waste can turn from a valuable resource for export to a troublesome liability at the stroke of a legislative pen by legislatures at home or abroad.

There is an ill-informed public perception that almost all packaging is a waste of resources and the answer is to return to a simpler lifestyle. This is a nonsense. Food packaging, for example, has had major beneficial impacts for human health, on food wastage from spoilage and spillage, for food safety, and on ensuring that goods reach you in good and wholesome condition. Freight packaging ensures the integrity of goods moving around the globe by air, sea, rail and truck. As for a return to some sort of simpler Utopia, realistically, this is very unlikely to happen.

This is not to say we should do nothing. In a series of international case studies, this book explores waste as a resource. For example, furniture can be made from up-cycled wood, gold can be extracted from electronic circuit boards, food wastes can be utilised for soil amelioration, while plastics materials can be recycled or reused in many creative ways. Naturally, there are opportunities and there are risks, both financial and to human and environmental health (e.g. printed circuit board recovery in developing countries). With the emergence of waste governance initiatives and better control of the global trade in waste materials, the picture is far from doom and gloom. Certainly, we are not entirely on top of the business of 'mining' wastes as a valuable resource, but the omens are at least favourable. There is a growing awareness of the old saying 'where there's muck, there's brass'. We are also reminded of 'waste-pickers', who eke out their (often environmentally shortened) lives picking over garbage for saleable resources. It keeps food on their tables, although not much more. We are starting to see emergence of transnational waste-pickers' alliances, hopefully leading to an improvement in their lot.

Author Kate O'Neill works in the Department of Environmental Sciences, Policy and Management at the University of California, Berkeley. Her book is made even more enjoyable by its dedication to her parents and 'childhood trips to the Canberra tip, where, according to my dad, you could rely on finding diplomats, politicians and retired admirals prospecting for second-hand treasures'. Yes, indeed, those were the days!

In summary, this is an excellent book. Read it to get a balanced view on the problems, opportunities and risks arising from waste 'creation' and disposal. There are a lot of knee-jerk reactions, and crisis-inspired decisions going on in this area, and a look at the bigger picture is always worth pursuing. This book will give you that in a gripping, well-written manner.

R.J. Casey FRACI CChem

SCI Australia essay competition

To encourage Australian STEM students to demonstrate their written communication skills, the SCI Australia Group is offering essay prizes to BSc (or equivalent) Honours students for original work carried out as part of their Honours project. As a kindred society of the SCI, the RACI is proud to promote this event.

The competition is open to all BSc or equivalent Honours students of chemistry, chemical engineering or a related discipline attending an Australian university.

Competitors will be required to submit an essay describing the work conducted in their Honours project. They will be required to include contextual aspects of their project, key results and findings, and a discussion about the relevance and applicability of their work to the wider community, particularly the business and industrial community. They should comment if any of their work is being published in peer-reviewed scientific journals or is the subject of a patent application.

The essay should be approximately 2000 words in length but not longer than 4000 words. For more information about the application, please read the Award's judging criteria (at website below).

The essay should be submitted electronically as a Microsoft Word document to the Chair of the SCI Australia Group, Dr Richard Thwaites (Richard.thwaites@bigpond.com).

Up to three prizes will be awarded, valued at $250, $500 and $750.

In addition, prize winners will be offered one year's free membership to SCI, which will include access to the monthly publication *Chemistry & Industry*, and be eligible to obtain other SCI publications at a substantial discount.

The top three winning articles will also be published at www.soci.org.

Applications deadline is 30 October 2020.

To apply and for information about judging criteria, visit www.soci.org/awards/society-prizes/australia-essay-competition.

Universities need to train lecturers in online delivery, or they risk students dropping out

Most Australian universities are moving courses online to prevent the potential spread of COVID-19. This includes lectures and tutorials, which will likely be delivered via the university learning management systems such as Moodle or Blackboard.

Some students believe universities are waiting until the census date (the date students can withdraw from the course without incurring a fee) before the transition, so they are locked into an inferior online experience while paying money for what they believe is a superior mode of teaching.

When done right, online learning can actually be as effective as face-to-face education. But Australian universities haven't upskilled their staff to deliver this kind of quality online education.

If Australian universities don't provide intensive upskilling to lecturers to deliver online classes and support effectively, they might see many students disengaging and dropping out early.

Why online learning can fail

Australian universities introduced online degrees more than a decade ago. The hope was, and still is, that online learning would provide access for students who have historically been prevented from completing a higher education because they were unable to attend university in person.

These include students from low socio-economic backgrounds, students with a disability, and regional and remote students.

Completion rates for students studying fully online in many countries are considerably lower than for those studying face-to-face. In Australia, dropout is at least 20% higher for online students compared with on-campus students and degree completions are 2.5 times lower.

Those most likely to drop out are the very groups access to online learning was meant to reach.

A national 2017 study (bit.ly/2Ur6482) investigated these dropout rates. It found many academic and professional staff at Australian universities perceived online delivery as less important or lower priority than face to face.

The same report also identified a lack of skill and experience among many academic staff when it came to online course design and online teaching, which, in turn, impacted negatively on student learning and engagement.

A 2016 study (bit.ly/2JnvAVJ) showed a lot of online learning in Australian universities consisted of lecturers simply uploading materials they used in their face-to-face courses to online learning platforms.

Many university teachers have had no experience themselves of online learning and have not been upskilled in online course design and pedagogy.

Where online students are out of sight and out of mind and lecturers do not have the skills to teach in an online environment it's the perfect storm for disengagement and dropout.

When online learning is done right

Learning management systems such as Moodle are designed to support online learning. These systems effectively organise learning resources, including multimedia resources, that students can easily access.

Students can engage in collaborative activities with their peers and lecturers, through tools such as discussion boards and wikis (a website or database developed collaboratively by a community of users, allowing any user to add and edit content).

An analysis of studies conducted between 1995 and 2004 (bit.ly/2Usx47i) compared achievement for students who had completed online and face-to-face tertiary education courses. It found the results were largely similar.

Students who completed online courses learnt as much as those in face-to-face instruction, achieved as well and were equally satisfied with their overall experience. The key word here is completion. There are higher dropout rates and lower completions across the higher education sector internationally for students who study online.

When online learning is well designed, conducted in a learning management system and is in the hands of skilled teachers, it offers a comparable learning experience to face-to-face.

What many uni courses may look like online

In the current scenario, a lecturer may deliver the same lecture or tutorial via video that they would deliver face to face. They may use online discussion boards or chat rooms to try and replicate small group work in tutorials.

Students may work through course materials on their own and have little connection with each other or their lecturer beyond the real-time video or chat interactions. They may not get the opportunity for the kinds of peer-to-peer and student–lecturer interaction that support engagement and learning.

Students who completed online courses learnt as much as those in face-to-face instruction, achieved as well and were equally satisfied with their overall experience.

iStockphoto/AlekseiMorozov

Research (bit.ly/2QUtjFy) shows these sorts of practices – which can be more accurately described as 'remote learning' rather than 'online learning' – promote student disengagement and dropout.

So, what can lecturers do to improve learning?

In the immediate future, university staff moving to online teaching can use some of the following tips to help students stay satisfied and engaged.

1. Communicate with students as much as possible

- Get to know your students in the online environment. Ask them to introduce themselves by completing an 'about you' page.
- Students are likely to have many questions. One way to manage this is to set up a Frequently Asked Questions discussion board and ask students to post their question on it. In that way, all students can see the response.
- Set up a weekly 30-minute live, but also recorded, Q & A session. Students can send in questions for you to respond to or ask you live. This way, students will see you 'in person'.

2. Make sure students know where to get support

- Make clear to students where they can access support for the different areas that impact them, such as academic advice and finance. You will need to work closely with student support services to do this.
- Set up a student support services discussion board in your subject, which student support officers could manage.

3. Help build your students' technology skills

- Help students who aren't so sure about the online platform to learn the technological skills they need. It's not just you who needs upskilling.
- You can ask your student group to self-nominate as online mentors if they have good online skills. It's a great way to build connections.

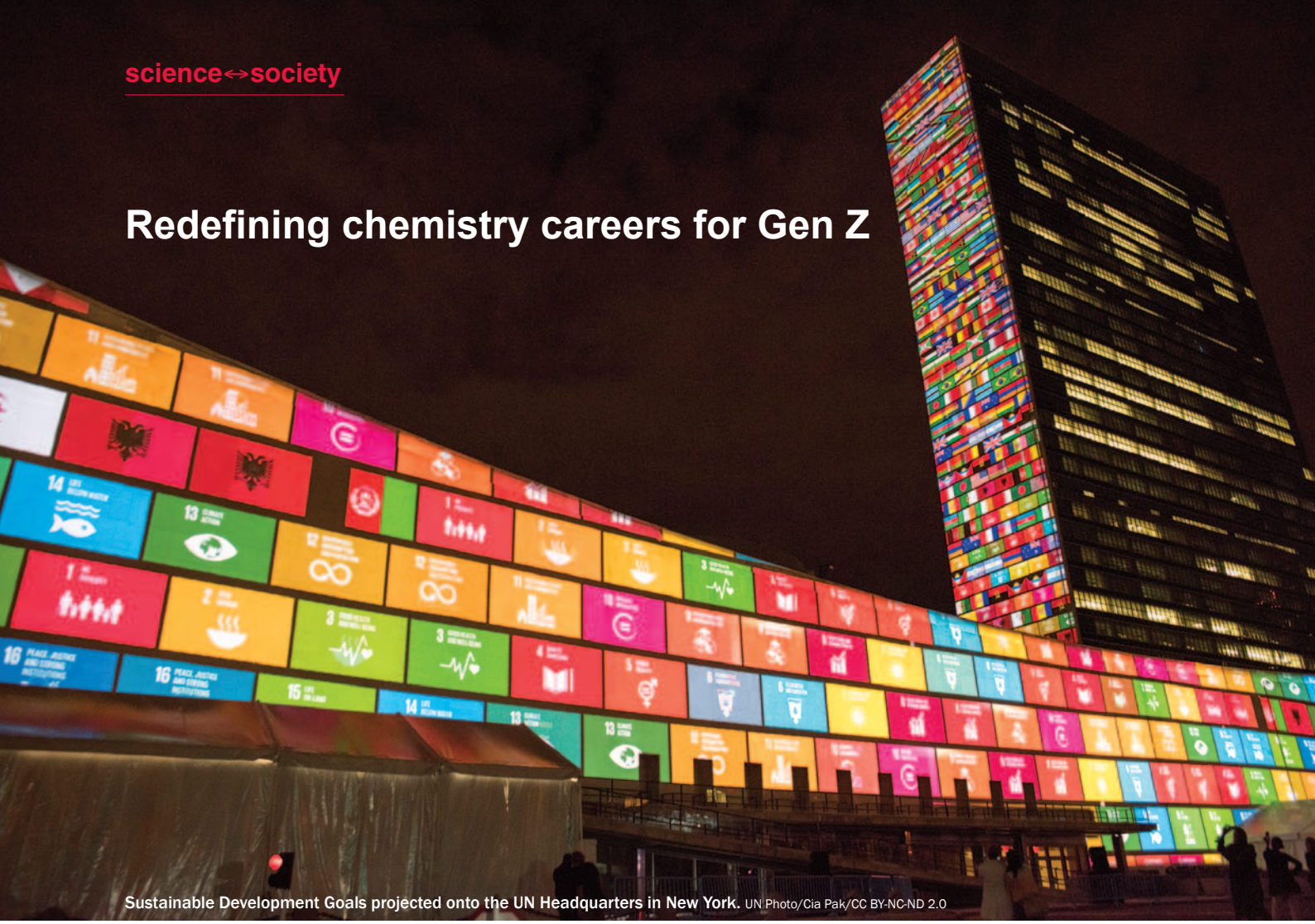
4. Get across the resources

- Your students will need to collaborate and share knowledge in new ways now they are not in the same physical space. Use discussion boards and wikis to encourage them to work on collaborative activities. If you don't know how to do this, ask your learning and teaching specialists at your university. Edinburgh University (bit.ly/2vY4JMN) also has some helpful resources. Stephen Downes' 'Creating an online community guide' (bit.ly/2JkY5Dg) is also helpful.
- For course design ideas, Professor Gilly Salmon's carpe diem resources (bit.ly/33ZOUDt) are excellent.

Universities should also move, as quickly as they can, to provide intensive training in online course delivery to their lecturers.

Pauline Taylor-Guy is Professor, Australian Council for Educational Research. **Anne-Marie Chase** is course coordinator, Australian Council for Educational Research. First published 25 March at www.theconversation.com. Opinions expressed are those of the authors.

Redefining chemistry careers for Gen Z



Sustainable Development Goals projected onto the UN Headquarters in New York. UN Photo/Cia Pak/CC BY-NC-ND 2.0

Since 2015, I have had the opportunity to present chemistry to and discuss chemistry careers with secondary school students throughout Victoria, building on the RACI Victoria Branch's Hartung Youth Lecture series, which I delivered that year. These students have been inner-city, suburban, regional, rural and from both government and non-government systems. I have been encouraged by their desire to understand chemical principles, but concerned about their opinions on chemistry in general and dismayed by their views on undertaking a career in the chemistry professions. Chemistry has become so strongly linked with many of society's problems in their eyes that it has become imperative to redefine a career in chemistry for Gen Z.

Many students display a strong disconnect in their relationship with chemistry, viewing chemical careers as perpetuating problems rather than also being part of the solution. I have come to realise that much of this negativity and disapproval relates to issues facing society and the role of chemistry in creating them. These include climate change, air pollution, plastics and their build-up in the environment and oceans, pesticide and herbicide degradation of natural ecosystems, fertilisers and synthetic chemicals and their links to adverse human health, as well as water and soil contamination. These concerns are completely justified; however, students don't recognise that these issues are multi-faceted and thus require a range of complex solutions, and sometimes many years of effort, to address.

This disconnect for students, I believe, strongly stems from society's perceptions of a 'chemical career'. Chemical engineers are synonymous with the oil and natural gas industry, therefore seen as contributing to climate change. Industrial chemists are associated with plastics and hazardous chemicals, therefore responsible for waste, pollution and environmental degradation. And agricultural chemists fabricate pesticides, herbicides and insecticides, and are marked responsible for ecosystem destruction and native species decline. Gen Z students see themselves as being the generation that must fix the mistakes of their predecessors; with such a negative view of chemistry and chemistry professionals, why would they want to pursue chemistry as a career?

Increasingly, secondary students seem to see a way forward mainly through political action: rallying, lobbying and voting for particular political parties. This is most notable in action on climate change, with thousands of students protesting for government action. This is completely understandable; however, many students I have spoken with have the naive belief that, when they reach voting age, their support of climate change action will lead to government policy changes and the problem will be solved, irrespective of scientific solutions. Banning of

Chemistry in the Sustainable Development Goals

2 Zero hunger
Chemistry role: developing sustainable fertilisers and environmentally benign chemicals to increase the productivity of agricultural land by limiting nutrient depletion and enabling pest eradication.

3 Good health and well-being
Chemistry role: achieving better nutrient and food quality through additives and supplements, as well as development of pharmaceuticals and treatments for diseases.

6 Clean water and sanitation
Chemistry role: improving and expanding the purification of potable water, especially to remote regions, as well as expanding and developing effluent treatment processes for agricultural and rural regions.

7 Affordable and clean energy
Chemistry role: developing battery and energy storage technology, as well as improving hydrogen production from water to address tomorrow's energy needs.

9 Industry, innovation and infrastructure
Chemistry role: reducing the carbon footprint of metal and material manufacturing, such as cement, as well as transitioning these sectors to the hydrogen economy.

11 Sustainable cities and communities
Chemistry role: developing recyclable materials for storage and packaging to generate a sustainable closed loop sector, while also expanding the recovery of chemical materials from wastes.

12 Responsible consumption and production
Chemistry role: developing recycling strategies for non-perishable materials, as well as developing new green methodologies to generate vital chemicals.

13 Climate action
Chemistry role: reducing carbon emissions to the atmosphere from a range of sectors and developing technology to actively remove carbon from the atmosphere.

14 Life below water
Chemistry role: developing and implementing biodegradable plastic alternatives, along with prevention of chemical run-offs from land to oceans.

Gen Z students see themselves as being the generation that must fix the mistakes of their predecessors ...

certain agricultural chemicals to improve health and the environment is a focus of political activity, as demonstrated by the backlash against Roundup, but there is no public discussion about alternatives for farmers. This intense focus on politics detracts from developing sustainable solutions, which requires strong scientific and technical literacy in the workforce of the future.

To direct students into the chemical professions, we must show secondary students the importance of chemistry in these issues, redefining and promoting chemistry's role. I have engaged their interest in chemistry by associating the chemical professions with the United Nations' 2030 Sustainable Development Goals. They are a superb example of the need for chemistry to create solutions. Gen Z is clearly very conscious of global and sustainable issues, more so than previous generations, and they strongly identify with and are willing to pursue careers focused on addressing these challenges. Of the 17 goals set out by the UN, chemistry is intrinsic to nine of them (see box).

I have found these sustainability goals and their link to chemistry to be good springboards from which students can explore how scientific and technical careers will have a positive impact on many people's lives. Importantly, the diversity of the goals provides the opportunity to tailor the message about the chemistry career pathways to prospective students based on their perceived areas of concern.

Equally important in engagement is direct contact of students with chemical professionals and the diverse fields of chemists and chemical engineers, as well as the diverse people in the chemical profession. This can only be achieved by professionals taking the time to go to schools and talking with students at all year levels. I believe this direct interaction is the best way to counter the popular media image of chemistry and simplification of the field. This is difficult and takes time, but direct interaction with students is important for their progress, and is rewarding in its own right.

Colin A. Scholes FRACI CChem is at the Department of Chemical Engineering, the University of Melbourne.

iStockphoto/Filip Warulik

Patenting opportunities in the fragrance industry

It is well known that the fragrance industry is big business. Annual sales from each of the four main global fragrance producers are in the billions of dollars. The intellectual property invested in commercial fragrances is extensively protected.

How does the fragrance industry protect its intellectual property?

Traditionally, industry secrecy was the main form of protecting proprietary information. The proprietary information included, for example, key fragrance compounds (known as 'captives'), formulations, essential oil extraction processes, and analytical techniques. Use of trade secrets is still an adequate form of intellectual property protection in the fragrance industry, provided that the 'secret' proprietary information can be identified, and suitable safeguards are put in place to block secrets from getting out to competitors. The reality is that misappropriation of proprietary information is a real threat because frequent job and career changes within a person's life is now the norm. Once proprietary information is exposed, establishing misappropriation can be a challenge, if action against the perpetrator is to be pursued. Worse still, after court proceedings are instituted, the difficulty lies in revealing the proprietary information itself, to the public, during the proceedings. Trade secrets alone can no longer constitute an adequate form of protection.

Patents are an alternative form of intellectual property protection, which are available to protect proprietary information. Patents grant the patent owner an exclusionary right for a general term of up to 20 years from the date of filing. A key advantage of patents is that they are enforceable, without identifying the specific proprietary information being misappropriated by a former employee (or his/her employer), provided that the infringement falls within the scope of the patent claims. Patents can therefore be a useful tool to protect proprietary information.

Patents can be obtained for any man-made innovations. It should be noted that in some countries, such as the US, naturally occurring compounds cannot be patented. Fortunately, at least in Australia, isolated forms of the naturally occurring compounds can be patented, as long as they are not perceived as constituting 'information', such as genetic information that is incorporated into the isolated nucleic acid sequence. Patents can also be obtained for novel and inventive synthetic pathways for making natural products, as well as for any non-naturally occurring derivative compounds of natural products. Formulations comprising at least one novel and inventive component in the formulation would also be patentable. If the components are known, the formulation may nevertheless be patentable if the components interact in a manner in which they provide a new and non-obvious characteristic or property.

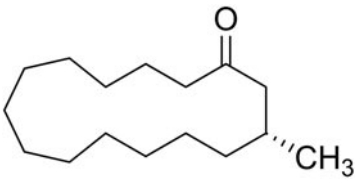
Perfume formulations

Perfume formulations are fascinating in that they allow the re-creation of fragrances found in natural environments. They also allow the creation of new pleasant fragrances not found in nature. Identification of captives isolated from nature and investigating their properties, including any of their synthetic derivatives, may yield the discovery of new pleasant fragrances, unique characteristics or new applications in perfume formulations. High rewards are therefore possible in this billion-dollar industry.

Modern perfumes comprise three parts: a top note, a heart note and a base note. The top note is the first impression of the scent. Due to the high volatility of these small and lightweight captives, they provide the immediate smell upon application to skin. The top note usually mimics leafy green and fruity fragrances. The heart note is the main scent and comprises heavier and less volatile captives. The heart note usually mimics flower fragrances, such as jasmine, lily, cherry blossom and the like. The base note is the last scent to emerge and involves the heaviest captives. These are the least volatile and remain on the skin the longest. The base note usually mimics vanilla, musk, precious woods and the like. Beyond these 'notes', the formulations would include surfactants to make the captives water-soluble and to reduce their surface tension, making the various components miscible in the formulation. Additives in the form of colourants, stabilisers (such as chelating agents and UV absorbers) and antioxidants are often included. The main component of all perfume formulation is the solvent medium, usually distilled water and ethanol, which assists with dispersing the fragrance over the skin.

Naturally occurring compounds

Naturally occurring compounds in perfume may include jasmone from jasmine flowers, civetone from civet cats and/or muscone from musk deer. Natural muscone is no longer used because it is isolated from the glands of musk deer, which is an endangered species. The synthetic alternative, l-muscone, can be used, but is expensive. Fortunately, only a small amount of synthetic muscone gives a musk effect, comparable to that of the natural product.



l-muscone

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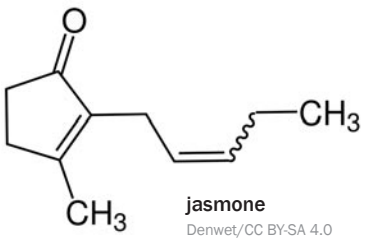
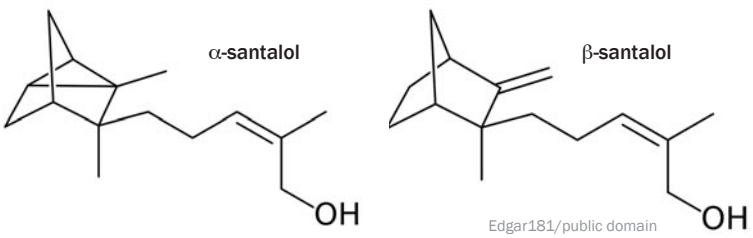
Jasmone can be extracted from a natural source or synthesised. Interestingly, synthetic jasmone has a stronger odour than its natural counterpart. This means that the synthetic version can be used sparingly, thereby reducing manufacturing costs, therefore making the resulting perfume more ecologically friendly.



jasmone

Denwet/CC BY-SA 4.0

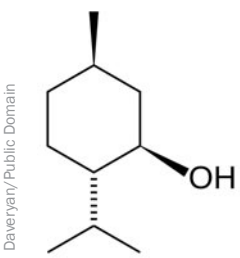
For woody fragrances, natural sources of sandalwood oil may be used. These can be derived from East Indian sandalwood, West Indian sandalwood, African sandalwood or West Australian sandalwood. Of these, the East Indian sandalwood is most prized, because of its high α-santalol and β-santalol content and composition consistency. However, due to extensive deforestation and environmental concerns, Indian sandalwood is now declared an endangered species.



Edgar181/public domain

While modern perfumes use a combination of natural and synthetic ingredients, where the natural ingredients are often cultivated in developing countries, one problem with natural ingredients is in maintaining consistency of the quality of the ingredient, which may vary as a result of annual variations in climate-cultivating conditions.

In the search for innovative nature-inspired synthetic derivatives, researchers have identified that moving the location of substituents or bonds within the captive can have a drastic effect on smell. For example, α-terpene has a lemon-like odour whereas terpinolene, its isomer, has a woody-pine odour. Menthol is another useful component in fragrances. The natural product is primarily one stereoisomer, shown here.



Daveryan/Public Domain

(1*R*,2*S*,5*R*)-(−)-menthol

Chiral-catalysed hydrogenation reactions have been used for the chiral synthesis of menthol and other fragrance compounds. The use of these reactions has shown that chiral compounds have different fragrances.

The identification of the signature fragrance molecule associated with a target smell of interest can be done relatively easily using current chemical analytical technologies and chemical synthetic techniques. The conventional technique in the industry involves using headspace analysis to sample volatile chemicals, followed by isolating and identifying each molecule through GC-MS. This technique has made reverse engineering of fragrances faster, cheaper and simpler.

What opportunities might be available?

As noted, there is a need for new smells and smell-alike compounds in the fragrance industry. This, in part, would support the conservation of endangered species and minimise environmental impact of natural habitats of wildlife. We would like to encourage researchers to re-visit their laboratory notebooks and identify whether any compounds made in the course of their past research projects possess a scent. If the scent is woody or flowery, that compound may be a stepping stone to the discovery of a potentially useful new captive. Perhaps the newly identified captive has a more potent aroma, or can be synthesised cheaply? If the newly identified captive is safer and less allergenic than the natural product, then it would be even more valuable.

Patents could be pursued for protecting these newly identified captives, for their synthesis pathway (i.e. methods of making the captives), and perfume formulations involving the new captives. Ideally, patents should be pursued on all these forms to plant a thicket of patents to be used as obstacles to deter competitors. However, in reality, pursuing all these forms individually in a patent can become very expensive. The best pathway forward would depend on the goal to be achieved. For example, if you are a scientist employed by a research institute or a university, a patent owner may monetise its patent by selling it, or licensing it to interested parties and then collecting royalties from them. Patents are therefore valuable commodities.

Do you have something worth patenting?

It may be prudent to consult with a patent attorney before you file that old lab notebook away, just in case you have inadvertently synthesised something worth patenting. Perhaps a short remark made about a woody smell scribbled on a corner of your notebook page, previously overlooked, may lead to a future, valuable practical use in the fragrance industry.

Jim Onishi MRACI and **Elizabeth Houlihan** FRACI CChem are at Houlihan[2] Patent & Trade Mark Attorneys.

Authentication, regionality and typicality

Authentication of a wine's origin has been an issue in the European Community for many years as the wine industry tries to minimise the potential for fraud and/or adulteration. Extending Bordeaux wine with wine from northern Africa was one such case. Much of the early work was based on element distribution and isotopic composition. The team of Professor Gérard-Jean Martin at the University of Nantes was at the forefront of geographical origin identification. For example, working with wines from the 1990 vintage, carbon, hydrogen and oxygen isotope analysis coupled with the analysis of eleven metals allowed the discrimination of wines from four regions in France as well as four subregions within Burgundy (*J. Sci. Food Agric.* 1995, vol. 67, pp. 113–23).

When I first started as Director of the National Wine and Grape Industry Centre (NWGIC), I raised the issue of establishing a basis for authentication of origin. At the time, however, there was little interest in the concept, especially as the success of the Australian wine industry in the export market was based around style and consistency of style from year to year. Blending across regions was necessary to achieve this consistency. Jacob's Creek Chardonnay was a classic example of this strategy. One interesting side effect of this approach was the difficulty in communicating to overseas markets that there were wine regions in Australia. A survey of UK wine consumers on Australian wine regions gave the top three named regions as Hunter Valley, Barossa Valley and Chardonnay!

Times change, perhaps driven more by the realisation that some top-bracket Australian wines were the subject of fraud in overseas markets. Dr Martin Day at the Australian Wine Research Institute, previously with the Nantes research group, is leading a project on origin authentication. Martin makes the significant point that stable isotopes selected for origin analysis need to reflect the geology and water source in the vineyard, but are not influenced by winemaking. This rules out many metals found in wine – see Eric Wilkes' article in the November/December issue (p. 37). Successful (98%) discrimination between 60 Australian and overseas wines could be achieved with this strategy (bit.ly/39YZzir), making the approach useful in detecting fraud.

The establishment of geographical indications (GIs) has been a positive step not just to authentication of origin but to defining regionality. The main purpose of a GI is 'to protect the use of the regional name under international law, limiting its use to describe wines produced from wine grape fruit grown within that GI'. There is much more about GIs and their legal impact, as well as a list of GIs, on the Wine Australia website (bit.ly/3da7jQo).

A GI is in reality a physical description of a zone, region or sub-region. For example, the Hunter Valley (NSW) zone includes the Hunter region within which there are the Broke Fordwich, Pokolbin and Upper Hunter subregions. At the other extreme, the South Eastern Australia zone extends from North Queensland through Ceduna to the Great Australian Bight and includes all wine grapes grown to the south-east of that line. The legal definition and its use require 85% of the grapes to be grown within the claimed GI.

While the GIs are well defined in terms of place, little is known about the chemical composition of wines in a selected region and how this may differ between regions. That is, can compositional profiles, possibly coupled with sensory analysis, allow a region to be clearly identified in a blind tasting? This is now a major research endeavour, both here and in Europe.

A recent publication from the NWGIC described the use of 2D gas chromatography coupled to time-of-flight mass spectrometry to discriminate the Shiraz wine volatome between two regions in NSW (*J. Agric. Food Chem.* 2019, vol. 67, pp. 10 273–84). 'Volatome' was a new 'ome' word to me: it simply refers to the composition of volatile components. Wines were made in triplicate at two harvest dates according to a standard winemaking protocol, to remove winemaking influence of the profiles. The cooler region (Orange GI) showed a higher concentration of grape-derived volatile compounds than the warmer (Riverina) region. Fermentation-derived compounds were not related to the difference in climate. Harvest date also turned out to be an effective regional discriminator.

Can compositional profiles … allow a region to be clearly identified in a blind tasting?

The next step in this regional differentiation is to try and establish the typicality of a varietal wine from a region and use this to discriminate between regions. Dr Wendy Parr has commented that 'typicality estimates the degree to which a wine reflects geographical origin and varietal purity' (bit.ly/390iuIj), whereas Dr Yves Cadot has proposed that typicality is the 'perceived representativeness' of the region (*Anal. Chim. Acta* 2010, vol. 660, pp. 53–62). The intriguing aspect of Cadot's approach is that it requires a group of 'wine experts' to come up with descriptors of the region's characters, often leading to heated debate.

Wine Australia is continuing to fund work on the regionality of Shiraz in the Barossa, Canberra, Heathcote, Hunter Valley, Yarra Valley and McLaren Vale regions (bit.ly/3bgkZI7). The results to date indicate that all six regions can be separated by their volatile composition, but that some compounds showed 'large within region variations', possibly reflecting 'the different viticultural and oenological practices' used by the individual wineries. Significant advances in understanding regionality and typicality are clearly being made.

Geoffrey R. Scollary FRACI CChem (scollary@unimelb.edu.au) 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 the National Wine and Grape Industry Centre at Charles Sturt University.

Some extracurricular chemistry

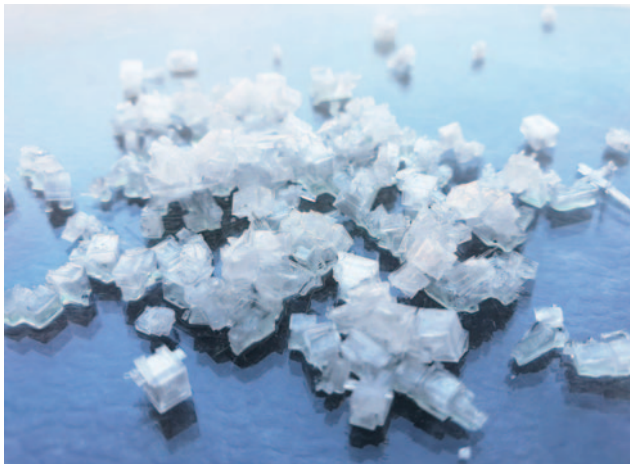
Frankston is a bayside suburb some 40 kilometres south-east of central Melbourne. It's always been known for its beach and until well into the 20th century it was a popular camping holiday resort for Melburnians. The soil for some distance back from the coast is sandy, typically 85% silica with a little alumina, suggesting that the beach once extended well past the present shoreline.

It's hardly the place for a volcanic eruption, but local residents feared that was what they were in for early in 1915 when white smoke was observed issuing from the ground near the football field. Closer inspection by brave citizens revealed that white crystals – 'beautiful cubes and interlacing needles' – had formed on the edge of the vents.

To investigate the phenomenon, they turned to experts from the University of Melbourne, but perhaps their fears of volcanic activity had eased, because they called in the chemists rather than the geologists. Responding to the call, Ernst Hartung and David Rivett visited the site and collected some samples for analysis. It was quickly ascertained that the substance was ammonium chloride (sal ammoniac), but the authors in their report to the Royal Society of Victoria didn't say exactly how they reached this conclusion. One can imagine a test with a hot copper spiral showing the presence of a halogen, most likely to be chlorine, and the smell of ammonia when the solid was treated with sodium hydroxide. What they did report was that reaction of a solution of the white substance with silver nitrate gave sufficient silver chloride to show that the salt was 99.4% pure ammonium chloride, the balance being probably moisture or a trace of ash.

Aware that ammonium chloride was present in volcanic vents and could also be formed by smouldering fires of vegetable material ('buried fires'), the chemists went back to Frankston for a second look at the conditions there. What they found was that the soil in that area was rich in decaying wood, mainly ti-tree roots. Somebody had started a fire there, and although the surface conflagration was quickly extinguished, combustion had spread to the peaty layer, which continued to burn. The source of the nitrogen for the ammonium chloride was obviously the vegetable material, and it was surmised that the chlorine must have come from sodium chloride since the near-coastal soil was likely to be salty.

To support their proposition, the chemists took a soil sample that contained 0.84% nitrogen and 1.06% sodium chloride, and burned it slowly while collecting the solid that sublimed with the other combustion products. Weighing the silver chloride formed from it in their gravimetric analysis allowed them to calculate that the mass of ammonium chloride equalled 0.092% of the weight of dried soil. Adding 10% salt to another soil sample, and repeating the experiment, yielded 0.29% ammonium chloride, so the salt seemed to be a limiting factor in the chemical reactions taking place. It was hard to reproduce the conditions of natural combustion, they observed, but I think they were unduly modest in their conclusion that 'the result is inevitably unsatisfactory'.



Ichwarsnur/CC BY-SA 4.0

In discussion of their findings, Hartung and Rivett mentioned the occurrence of ammonium chloride 'near volcanoes such as Etna, Stromboli, Vesuvius and others' where 'lava spreads over soil and vegetation'. They also wrote that in Egypt ammonium chloride is obtained from the soot of burnt camel dung (this is an item juicy enough to be included in the Wikipedia entry on ammonium chloride), and that there was commercial production by burning coal with salt, animal offal and clay. Something that was not in their written account, but did form part of their presentation at the July meeting of the Royal Society of Victoria (and newspaper reports of it), was their suggestion that burning salt-impregnated peat offered a way to produce ammonium chloride at low cost. Their suggestion was never adopted here.

E.J. Hartung (1893–1979) and A.C.D. Rivett (1885–1961) were two of the 'white-haired boys' of Melbourne chemistry. We remember them for their later eminence as, respectively, professor of chemistry at the University of Melbourne (1928–53), and head of CSIR (1926–49). But in 1915 they were just two of his promising young colleagues that professor and head of department David Orme Masson dispatched to look into the Frankston phenomenon. Rivett graduated BSc in 1906, won the Rhodes Scholarship in the following year and proceeded to Oxford where he worked with N.V. Sidgwick and then for six months with Arrhenius in Stockholm before returning to Melbourne in 1911 as lecturer. Hartung graduated BSc in 1913 and, failing to gain an overseas scholarship, worked with Masson on binary liquid mixtures and their vapour pressures, for which he was awarded the DSc 1919. In that year he was appointed as lecturer, a position in which he already had some experience since he had already played that role while Rivett was in Britain helping with the production of ammonium nitrate in 1917–18.

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 provides advice on chemical hazards and pollution.

SciMeetings service

SciMeetings, a service developed by the American Chemical Society (ACS), will expand the reach and impact of early-stage research and globalise professional networking through its online poster and presentation publication service.

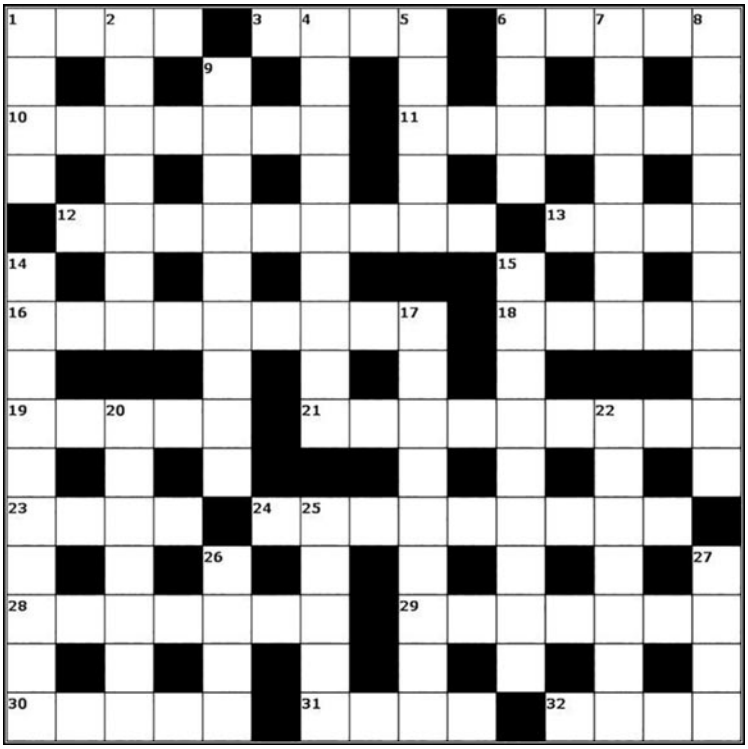
SciMeetings, powered by Morressier, is a fully open access product that is freely searchable, citable and shareable. Posters and presentations receive a doi number and creative commons license upon upload, and video or audio can be embedded to enhance the submission. Content is fully indexed and will be searchable on the ACS Publications and Morressier platforms. With SciMeetings, innovations presented at conferences can now be widely shared, advancing the pace of science and maximising professional exposure.

'Now, more than ever, it is tremendously important for scholarly posters and presentations to be widely accessible,' said Sami Benchekroun, Morressier co-founder and managing director.

This service is intended to provide a timely option for presenters and conference organisers of meetings that are postponed, delayed or cancelled, such as the ACS Spring 2020 National Meeting & Expo, which was to be held in Philadelphia in March. ACS is adopting SciMeetings for the more than 14 000 posters or talks that were scheduled for this event, many of which will now be held in a virtual environment. SciMeetings will be available to enhance future events among the global scientific community as well, supporting the communication of high-quality research.

Interested parties are invited to contact Tammy Hanna, Director of New Product Innovation (t_hanna@acs.org) to learn more.

American Chemical Society



Across

1 Splits shots. (4)
3 Spread sound post. (4)
6 Tests flame with a mass spec. (5)
10 2-Naphthol and picric acid, perhaps, from New Orleans. (7)
11 Tip: coal is out (regarding light). (7)
12 Assessing gum resin: a mess. (9)
13 Brace put together. (4)
16 Backup at Ten: real change. (9)
18 Close pub for long time resident. (5)
19 Contingent on three or four elements. (5)
21 Polybutadiene, for example, produced from metal ores?! (9)
23 Chop up three elements. (4)
24 Half-life acted year out. (5,4)
28 ROR′ mixed with nickel is similarly negative. (7)
29 One or two, maybe, make it green. (7)
30 Look! And mass spectrometer appears! (5)
31 Three elements are big. (4)
32 Alone – barely. (4)

Down

1 Gravity bang into mass. (4)
2 Be, perhaps, used to heat. (7)
4 Created a broad set which is bound to a surface. (9)
5 Colour of four elements. (5)
6 Revised date for production of compound. (1.1.1.1.)
7 Old-fashioned chair broke in a joint. (7)
8 A sudden flash of brightness: work safer or all fail. (5,5)
9 Maintained study delivered. (9)
14 Cycloalkanes he pans then uses. (10)
15 Inclusion compound to clear that solution. (9)
17 Coming out to manage tin reaction. (9)
20 Include novel observable atomic species characterised by its nuclear constitution and energy state. (7)
22 Augment reaction which alters genetic material. (7)
25 Where we live is considered to have zero potential. (5)
26 The one indicated in the north island. (4)
27 Return extraordinary Ar-Xe inclusion discovered by Röntgen. (1-3)

Graham Mulroney FRACI CChem is Emeritus Professor of Industry Education at RMIT University. Solution available online at Other resources.

CRC Association: 'Continuing Collaboration' webinars

The CRC Association is continuing its webinar series on how organisations can work productively through the coronavirus pandemic.

Past and scheduled webinars include:

- 'Continuing collaboration: Partnering through the crisis', presented by Prof. Valerie Linton (University of Wollongong), Mr David Chuter (Innovative Manufacturing CRC) and Dr Tony Peacock (CRC Association)
- 'Operating a safe cyber environment with a dispersed, home-based workforce', presented by Rachael Falk, CEO, Cyber Security CRC
- 'Managing your data remotely', presented by the Australian Research Data Commons.

View the Eventbrite page (bit.ly/2UTuQwD) to view forthcoming webinar details as they are added and subscribe to the CRC Association YouTube channel to view previous webinars.

The CRC Association typically charges non-members for its webinar offerings; however, in light of coronavirus, everyone's attendance is welcome.

RACI–SCI webinar

RACI Victorian Branch Health Safety & Environment Group and Society of Chemical Industry Australia Section present:

Identifying emerging contaminants in the environment with QTOF MS – Dr Brad Clarke, University of Melbourne

18 June, 5.30–7.00 pm

Dr Brad Clarke, lead researcher of the Australian Laboratory for Emerging Contaminants, will discuss the illicit chemical stockpile fire in Footscray and how LCQTOF 'untargeted analysis' allows for the identification of contaminants released into the environment.

Contact Ms Alyce Scanlon-Batt (raci-vic@raci.org.au)

IChemE online courses

In response to COVID-19, IChemE has accelerated plans to offer some of its most popular training courses online.

Each course will be delivered on a modular basis and comprise live sessions with trainers, supplemented by independent study and pre-recorded content. These online courses are based on the same learning outcomes as our face-to-face programs, taught by our expert trainers and using peer-reviewed materials.

The courses are being offered at a reduced rate, with further discounts available to IChemE members and employers booking multiple places. The number of places available on each course is capped and early booking is advised.

New courses, new course dates and additional time zones will be announced in the coming weeks. For further information, contact Matt Stalker (mstalker@icheme.org).

RACI Vic Branch virtual lunches

The RACI Victorian Branch Retirees Group are holding monthly 'virtual lunches' at midday on the first Tuesday of each month, starting on 5 May.

raci.org.au/events/event/victorian-branch-retired-chemists-virtual-lunch

Education and careers

Successful women in chemistry (RACI Career Development Programme webinar)

A panel of experts will talk about their experiences working in an industry still heavily dominated by one gender

14 May 2020, 6.30 pm (AEST)

raci.org.au/events/event/webinar-successful-women-in-chemistry

AgVet chemicals regulatory reforms (webinar)

19 May 2020, 12 pm (AEST)

raci.org.au/events/event/agvet-chemicals-regulatory-reforms-discussion-webinar

Effect of bushfires on grapes and wine (webinar)

Professor Kerry Wilkinson, University of Adelaide

26 May 2020 (AEST)

Contact raci-vic@raci.org.au

Good job applications (RACI Career Development Programme past webinar)

raci.org.au/events/event/webinar-good-job-applications

Medicines that changed the world: a brief history of drug discovery and development

Online lecture activity for SACE 1/2 students

Contact Matt.Sykes@unisa.edu.au

Why does soap work so well on SARS-CoV-2?

youtube.com/watch?v=g0fIL9_s2Ss

RACI National Awards: call for nominations

The RACI is calling for nominations for the National Awards in 2020. The presentation evening is planned for Friday 27 November 2020, when we hope to be able to celebrate the success of awardees.

Applications and nominations are open until 12 June 2020. Awards are available in the following areas:

- Academia: for achievements in academia
- Education: for excellence in the education sector
- Distinction: for innovation and distinction in chemical science
- Young Chemists: for undergraduate and postgraduate chemistry students
- Women in Chemistry: recognising the work of outstanding women in chemistry.

Visit www.raci.org.au/events-awards/awards to view the criteria for each award.

Response to COVID-19

Dear members,

The RACI Board is extremely conscious of its duty of care to members and staff, and its role to prevent the spread of coronavirus (COVID-19). Our thoughts go out to those who have been significantly impacted by the virus.

Social distancing plays an important role in preventing the spread of the virus but this affects most RACI activities, from simple committee meetings to complicated conferences. The Board has noted government, education providers' and other organisations' responses to the pandemic and have put in place the following restrictions in order to minimise harm and protect its members and other community members.

- Face-to-face events will not be held for the next six months and those that were already organised will be postponed. This position will be reviewed on a regular basis. Members and non-members who were involved in these will be contacted by the organisers.
- Volunteer meetings will be held via video conference.
- A number of conferences that were planned within the next few months have been either postponed or cancelled. Please monitor your emails or social media for the latest news on these events.

During this time the Board is conscious of its members' well-being and will be working with the Assembly and volunteers to ensure the chemical science community remains connected both socially and professionally. More information will be circulated on this in due course, but I encourage you to stay connected via the RACI social media accounts.

The RACI Board has also made the decision for its staff to work from home for the foreseeable future. Our staff will continue to provide member services and are contactable via the normal channels. Contact numbers remain the same, with the main number being (03) 9328 2033. I appreciate your patience during this time as there may be delays in the staff responding to your enquiries.

The situation we find ourselves in is unprecedented in our generation. My thoughts go out to each of you and hope that you and your families stay safe. The latest information on COVID-19 can be found at the following links.

- www.who.int/emergencies/diseases/novel-coronavirus-2019
- www.health.gov.au
- www.abc.net.au/news/story-streams/coronavirus

As I mentioned, the RACI Board is reviewing its position regularly and will keep you updated on any changes in policy.

With kindest regards

Vicki Gardiner
RACI President