

chemistry

July/August 2019

in Australia



Trek to St Petersburg: Maria Mendeleeva's epic journey

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cover story

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Alf Larcher tells a story of Maria Mendeleeva's determination and love for her son Dmitri, and how it changed the course of chemical, scientific and world history.

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Megan O'Mara is an associate professor with the ANU Research School of Chemistry. Her work is focused on computer modelling of cells within the body and how they function in health and disease.

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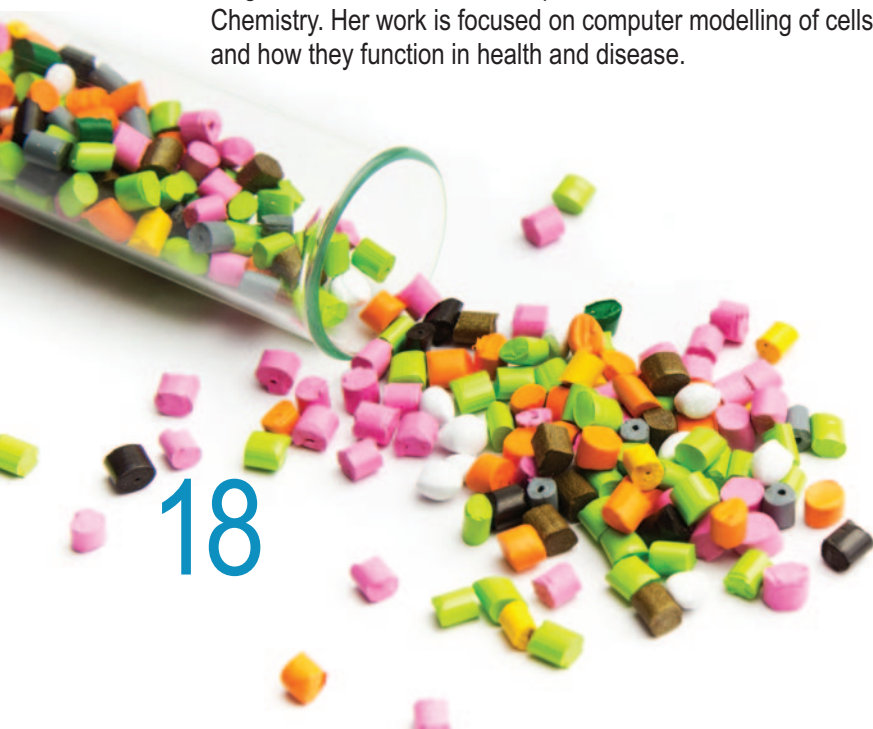
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From the President

I have been watching with excitement the number of people participating in International Year of the Periodic Table activities.

The RACI's Stories from the Periodic Table have been amazing to read. From marrying molecules from outer space, and personal stories about a love of certain elements, to rockstar scientists trashing hotel rooms, I am really glad that members are engaging with the IYPT and RACI.

I count selenium and tellurium among my favourite elements, having used organochalcogenides throughout my PhD and postdoc days. The fantastic yellow, orange and red compounds, which are highly air sensitive and extremely stinky, made for some really interesting chemistry.

Particularly 'interesting' was the time when I stank out most of the chemistry building at Monash University (except for the Raston lab – the fume hoods worked really well and you couldn't smell the stench of my gallane–organoselenide reaction there). And the time when there really was a gas leak in the south building – but they checked to see if it was me.

I love the inclusion in RACI's Periodic Table on Show of images for elements 113–118. The floral image superimposed on the Bohr model of element 118, oganesson, for example, shows there are many ways to tell the periodic table story.

Celebrating chemistry and telling stories as a community is an element (pardon the pun) of member value for me. The sense of belonging, being part of a network of people that have a similar interest and meeting new people from whom I can learn is the value of my RACI membership.

As part of my previous role in Tasmania, I was a convert to *The membership managers' handbook*, by Belinda Moore. The key message of the handbook is that the landscape of membership is changing. It's not just generational change that challenges associations, says Moore – these groups must also adapt to cultural and economic change. The RACI is not immune to this situation, and it needs to continue to look to delivering member value in innovative ways.

But everyone defines member value differently. This could depend on where you are in your career, your location or your industry sector. As I mentioned, member value to me is a sense of belonging. The RACI community, which I have belonged to since 1991, has been a significant influence on my career.

As a student, I attended Inorganic Division conferences. As a researcher, the community helped me and students to form collaborations and gain experience. While working on RACI projects, including the International Year of Chemistry in 2011, I learned a lot about science education and communication. This has helped me to grow my career, even though these experiences were on the fringes of chemistry. My time as an office bearer within the RACI helped me attain my previous position as the general manager of a professional association. Now the RACI is facilitating the opportunity for me to represent the organisation on the international stage as part of the working group to scope the potential of a Commonwealth Chemical Sciences Association Federation.

The RACI continues to offer me member value, although the definition of value has changed over the years. It has helped me to build new skills, increase my profile and engage with the most successful people in the industry, and with government and business leaders.

As RACI President, I am always considering whether the RACI is up to the challenge of offering member value to its younger members, not just now but throughout their careers, as I have experienced. Associations are the facilitators and enablers of communities. And innovations such as online communities, the RACI's recent career webinars, member spotlights and Stories from the Periodic Table are what bring people together to engage, increase members' profiles, build new skills and ensure younger members gain the best possible first career step.

Before leaving you for this issue, I congratulate some RACI members who recently received Queen's Birthday honours: Emeritus Professor Leo Radom AO FRACI CChem, Professor Callum Drummond AO FRACI CChem, Professor Frances Separovic AO FRACI CChem and Professor Mark von Itzstein AO FRACI CChem.

I would also like to recognise and congratulate members who were recently elected Fellows of the Australian Academy of Science: Professor Christopher Barner-Kowollik FRACI CChem and Professor Debra Bernhardt FRACI CChem.



Vicki Gardiner FRACI CChem (president@raci.org.au) is RACI President.

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Did Cornforth attend lectures?

Sir John Cornforth has featured in *Chemistry in Australia* fairly frequently since his death in 2013. In September 2017, the centenary of his birth was marked by a Google Doodle! As the writer of Sir John's entry in the *Oxford dictionary of national biography* (www.oxforddnb.com/view/article/107568), I should like to comment on a statement in Jennifer Foster's article (May/June, p. 14). Jennifer states: 'He [Cornforth] was deaf, so could not attend lectures, and instead learned German so that he could read the original literature'.

I am fairly sure from the research I have done on Cornforth's life that he *did* attend lectures. I have consulted two obituaries; that in *The Independent* says: 'Attending the University of Sydney while still in his teens, Cornforth's disability led him to favour laboratory work over lectures ...'. The obituary in *The Telegraph* says something similar. In any case, he would have been expected to attend lectures as any undergraduate is.

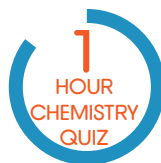
It is typical of Cornforth's enterprise that he read the German literature, but that was no very unusual thing. It was encouraged when I was a student at Leeds, where an optional course on Science German was run.

Clifford Jones FRACI 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.



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The art of the periodic table



No science classroom is complete without a periodic table. Although students new to chemistry are often confused by the uneven shapes that organise the elements, experienced chemists know that this elegant diagram is the key to understanding the natural world. Thus, IUPAC has named 2019 the International Year of the Periodic Table to inspire both scientists and the public to celebrate its beauty. Melbourne-based artists Damon Kowarsky (<http://damon.tk>) and Hyunju Kim (<http://hyunju.tk>) have created a collection that does just that.

In 2017, Kowarsky was approached by Soula Bennett for a project that would marry art and science. Bennett is the Director of Quantum Victoria (www.quantumvictoria.vic.edu.au), one of six Specialist Science and Mathematics Centres established by the Victorian Department of Education and Training. Quantum's mission is to cultivate curiosity and motivation in students and teachers to promote excellence in STEM education. Bennett had a vision for an installation in her Centre that would imagine 'the birth of the universe through the lens of the periodic table'.

Kowarsky is an award-winning artist trained in scientific illustration, making him the perfect candidate to bring her vision to life. Bennett and Kowarsky worked closely to select 49 elements that came into existence in the early universe, along with famous scientists who would be

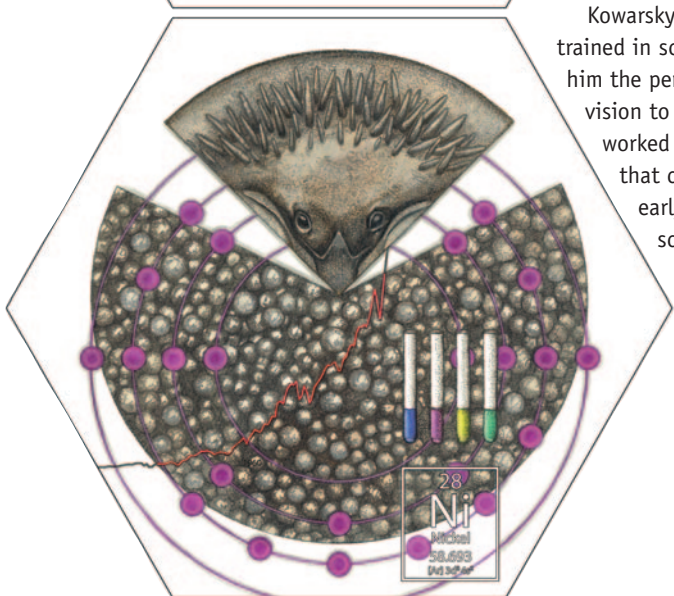
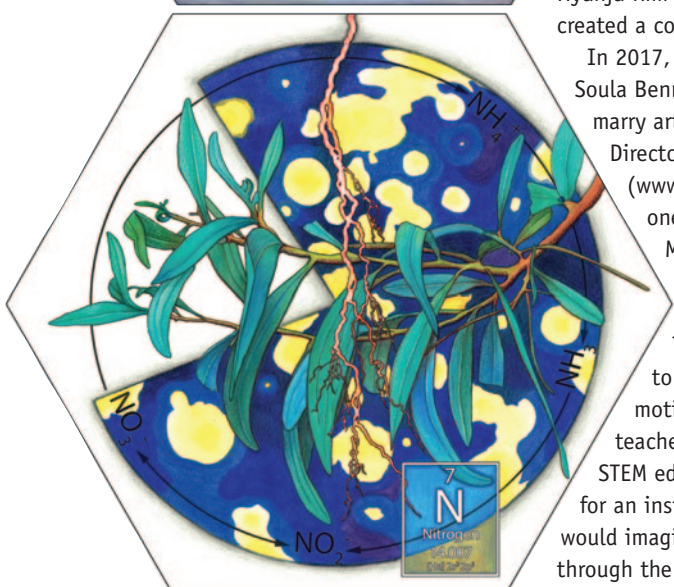
generally familiar to students. Bennett required that each piece included not only the element's symbol and atomic number, but also scientifically relevant information about its properties and use.

Kowarsky did extensive research to compile each aspect of the proposed images. He then hand drew each piece before sending them to collaborator Kim to complete the colour. The final result shows the unique beauty of each element in the collection.

For elements such as sodium, Kowarsky did not want to rely on a depiction of the material's physical form. 'What strikes me about sodium is its reactivity, which depends on the electrons', says Kowarsky. Although the electrons are shown organised in shells as per the Bohr model, the colourful background gives an impression of the complexity of orbitals overlapping in the atom. The image also includes sodium's emission spectrum, a fusion diagram and a series of interestingly shaped sodium light bulbs.

Other pieces emphasise the element's cultural relevance. The piece for uranium features the atomic bomb in front of an aerial view of Hiroshima. The chain reaction that makes uranium so powerful can also be seen alongside test tubes of assays that are used to determine the element's oxidation state.

Several of the elements include distinctly Australian features. 'Wherever I could, I tried to bring in pieces of Australian nature and culture because I want our students to know that the periodic table is a part of their everyday lives', says Kowarsky. For example, eucalyptus leaves are prominent in the



Wherever I could, I tried to bring in pieces of Australian nature and culture because I want our students to know that the periodic table is a part of their everyday lives.

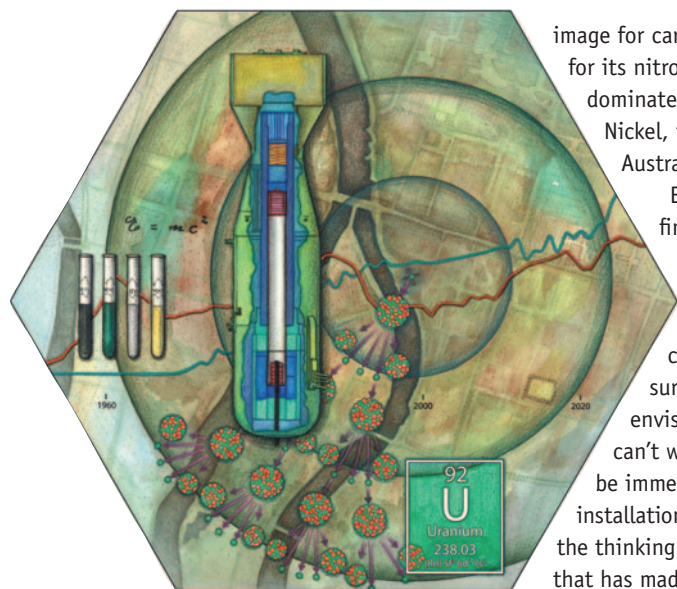


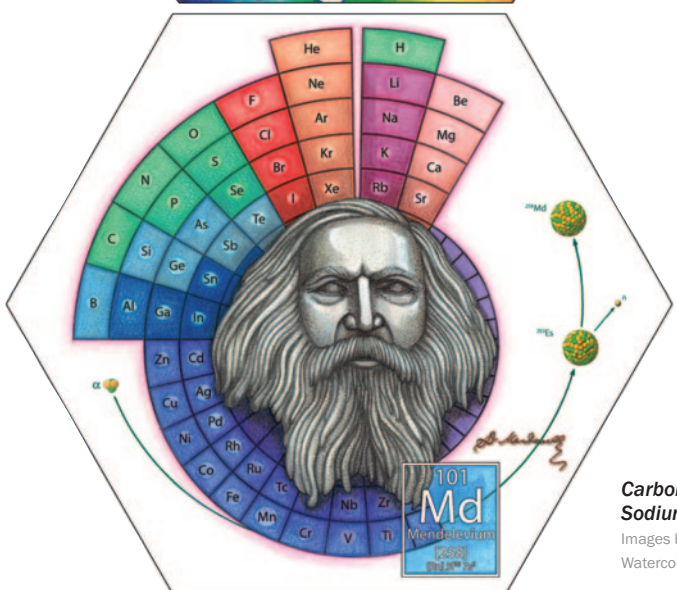
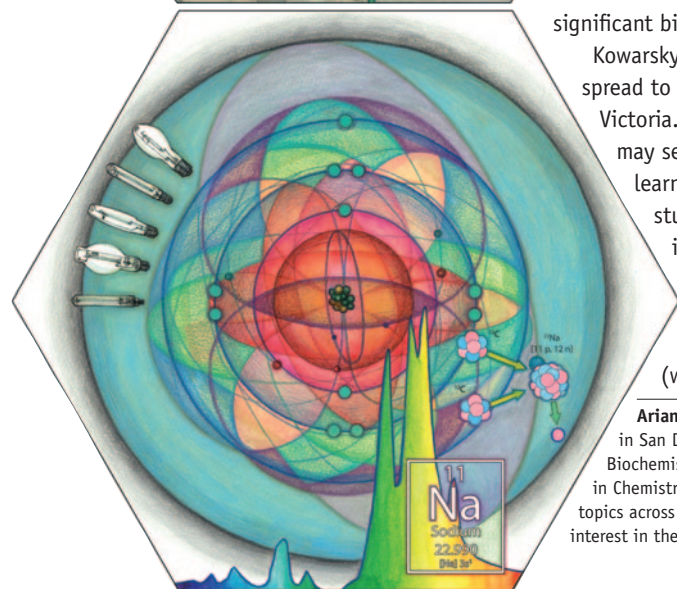
image for carbon. The acacia tree, known for its nitrogen fixation abilities, thus dominates the image for nitrogen.

Nickel, too, shows a piece of the Australian five-cent coin.

Bennett is thrilled with the final results, which will be launched at Quantum Victoria on 18 July 2019 in an event open to the community. 'It so far surpassed what I had originally envisioned', says Bennett, 'I can't wait for Victorian students to be immersed in the beauty of the installation and come to appreciate the thinking behind the periodic table that has made it one of the most significant big ideas in science.'

Kowarsky himself hopes the work will spread to classrooms beyond Quantum Victoria. While the periodic table may seem daunting to early learners, these pieces engage students from all backgrounds in the beauty and creativity of science. The full collection can be found on Kowarsky's website (www.periodictable.ga).

Ariana Remmel is a science writer based in San Diego, California. With a BA in Biochemistry and Molecular Biology and a MS in Chemistry and Biochemistry, Ariana covers topics across the physical sciences with a special interest in the intersection of art and science.



Carbon, Nitrogen, Nickel, Uranium, Sodium and Mendelevium.

Images by Damon Kowarsky and Hyunju Kim. Watercolour, pencil, and ink on paper 2019.

ARC Industrial Transformation Training Centre opens in Sydney

On 14 May, the NSW Chief Scientist, Professor Hugh Durrant-White, hosted the launch of the New South Wales Node of the ARC Industrial Transformation Training Centre for Chemical Industries (ATCI) at the Office of the Chief Scientist in Sydney.

The Centre brings together three leading universities (the University of Melbourne, the University of New South Wales and Swinburne University of Technology), chemical industry companies and Chemistry Australia (formerly PACIA). The Centre will host 30 Masters of Science – Industrial Research (MScIR) students, who will complete industry-led research projects to be undertaken with a minimum one-year placement in industry. The Centre will host postdoctoral fellows to lead advanced industry-led collaborative projects with Centre chief investigators.

This unique collaboration will provide greater alignment between the chemical industry's need for highly-skilled STEM graduates equipped with excellent academic training, relevant industry skills and experience.

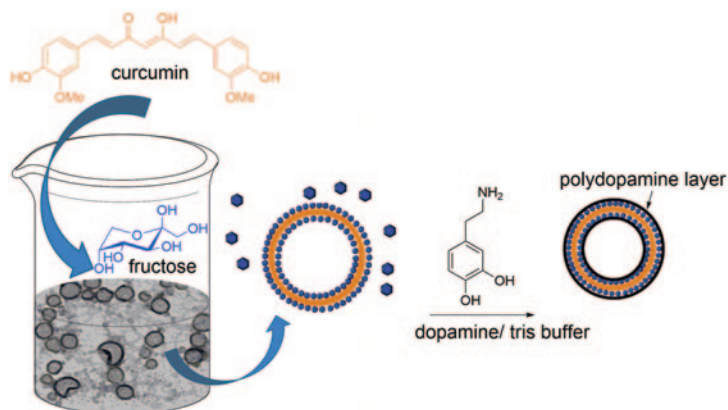
Industrial participants in the program include Dulux Group, Qenos, Boron Molecular, PPG Industries Clarity Pharmaceuticals and DCS Technical/Loop Hydrometallurgy, the latter of which is headed by Dave Sammut, Coordinator of the RACI's Mentoring Programme and regular contributor to *Chemistry in Australia*. All of the Centre's students will be invited to participate in RACI Career Development initiatives.

Enquiries about the centre can be made through Aaron Gosling (agosling@unimelb.edu.au) or Donavan Marney (d.marney@unsw.edu.au). Further details about the centre at www.arc-chemind.org.

Dave Sammut

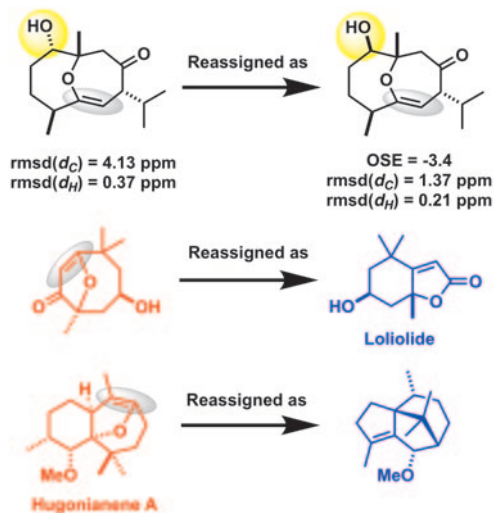
Sugary self-assembly

Amphiphilic glycoconjugates are observed to arrange themselves into higher-order supramolecular constructs than traditional self-assembled spherical structures such as micelles. To date, this kind of self-assembly has been based on a sugar-surfactant combination in which the carbohydrate is covalently bound to a hydrophobic tail. Now, researchers led by Martina Stenzel at the University of New South Wales have shown that simple sugars, in particular fructose, are able to direct the self-assembly of highly insoluble curcumin, resulting in the formation of well-defined capsules based on non-covalent forces (Wong S., Zhao J., Cao C., Wong C.K., Kuchel R.P., De Luca S., Hook J.M., Garvey C.J., Smith S., Ho J., Stenzel M.H. *Nat. Commun.* 2019, **10**, 582). Simply mixing an aqueous solution of fructose and curcumin generates capsules with sizes ranging from 100 to



150 nm, independent of the initial concentrations used. Sugars display sufficiently powerful hydrogen bonding with curcumin. This serves as a simple and virtually instantaneous way of making nanoparticles from curcumin in water, with prospects for template polymerisation and for nanocarriers having wide-ranging pharmacological potential.

Computational correction of structural misassignments

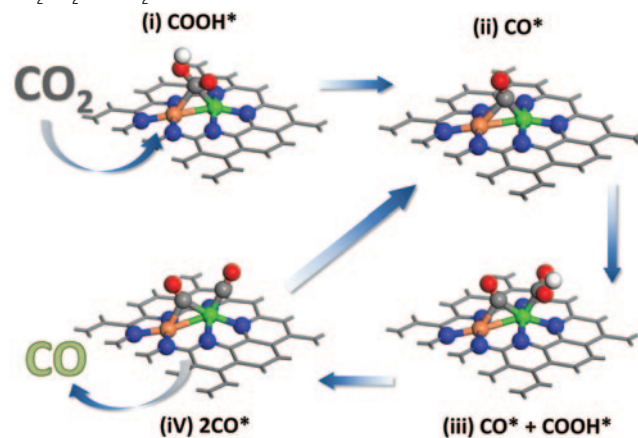


Although the structure elucidation of natural products is a sophisticated science, which often engages a multitude of high-powered spectroscopic techniques, structural misassignments continue to appear in the literature. Unfortunately, such errors generate phantom chemical entities that often capture the curiosity

of biologists and synthetic chemists alike. Therefore, it is of paramount importance to develop methods, and theoretical concepts, to assist in preventing misassignments, as the determination of structure is a fundamental pillar of the discipline of chemistry. In this vein, Craig Williams from the University of Queensland has for some time been developing the application of Bredt's rule to natural products (*Angew. Chem. Int. Ed.* 2014, **53**, 13664), in close collaboration with UQ colleague Elizabeth Krensch (*Angew. Chem. Int. Ed.* 2015, **54**, 10 608), using the concept of olefin strain energy (OSE) first developed by Schleyer. In their most recent work, Williams and Krensch joined forces with Andrei Kutateladze of the University of Denver (USA), combining calculations of OSE and NMR chemical shifts and coupling constants to reassign proposed oxo-bridgehead double-bond-containing natural products (Kutateladze A.G., Krensch E.H., Williams C.M. *Angew. Chem. Int. Ed.* 2019, **58**, 7107–12). This powerful approach provides another tool for natural product chemists in their pursuit to correctly elucidate chemical structures.

Better together: Ni-Fe atom pair for efficient electrochemical CO₂ reduction

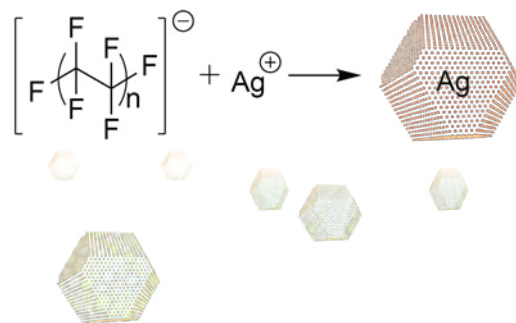
Electrochemical reduction of CO₂ into value-added products provides a promising strategy to realise a carbon-neutral energy cycle. However, the stable C=O bond (806 kJ mol⁻¹) in CO₂ and the competing hydrogen-evolution reaction mean that a single catalytic system must optimise the interplay of selectivity, activity and stability. Recently, an electrochemistry team led by Chuan Zhao at the University of New South Wales developed isolated diatomic Ni-Fe sites anchored to nitrogenated carbon as efficient electrocatalysts for CO₂ reduction (Ren W., Tan X., Yang W., Jia C., Xu S., Wang K., Smith S.C., Zhao C. *Angew. Chem. Int. Ed.* 2019, **58**, 6972–6). Mechanistic studies revealed that the Ni-Fe atom pair works in synergy to decrease the reaction barrier for the formation of COOH* and the desorption of CO. Hence, most electrons and protons are used to reduce the CO₂ rather than being involved in the hydrogen-evolution reaction, resulting in enhanced activity and selectivity for CO₂ reduction. This work opens up enormous possibilities for the rational design of synergistic single-atom catalysts that are adaptable to a range of complex catalytic reactions such as the CO₂, N₂ and O₂ reduction reactions.



Getting a grip on static electricity

Electrically insulating objects gain a net electrical charge when brought into and out of contact. This phenomenon – triboelectricity – involves the flow of charged species, but to conclusively establish their nature has proven extremely difficult. A team of researchers from Curtin University, the Australian National University and the University of New South Wales has studied the redox growth of metal nanoparticles on electrostatically charged polymers and, by means of a Faraday pail, XPS, AFM, TEM and quantum chemistry, they have described, for the first time, a material-

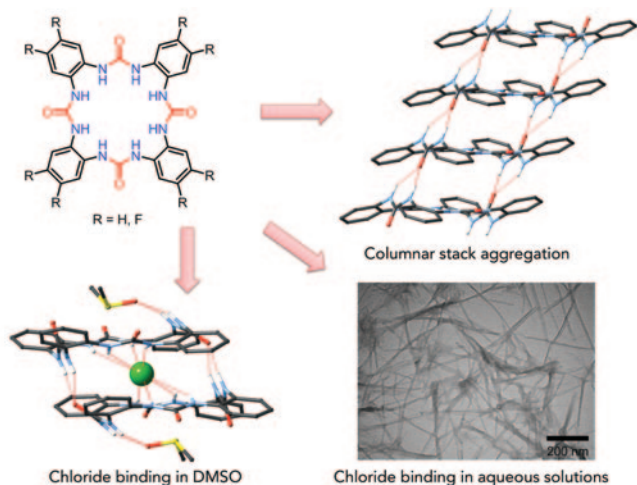
specific relationship between the tribocharging magnitude and the extent of redox work that can be harvested from tribocharged polymers (Zhang J., Rogers F.J.M., Darwish N., Gonçalves V.R., Vogel Y.B., Wang F., Gooding J.J., Peiris M.C.R., Jia G., Veder J.-P., Coote M.L., Ciampi S. *J. Am. Chem. Soc.* 2019, **141**, 5863–70). Interestingly, the amount of work done by an electrified dielectric was shown to exceed the Coulomb reading in the electrometer/Faraday pail, demonstrating that the charged surface is a mosaic of positive and negative charges. By extending



chemical understanding of static electricity, this work paves the way for the design of plastic materials for which electrification upon contact – deliberate or not – can be either maximised or prevented.

Self-assembled selective anion receptor

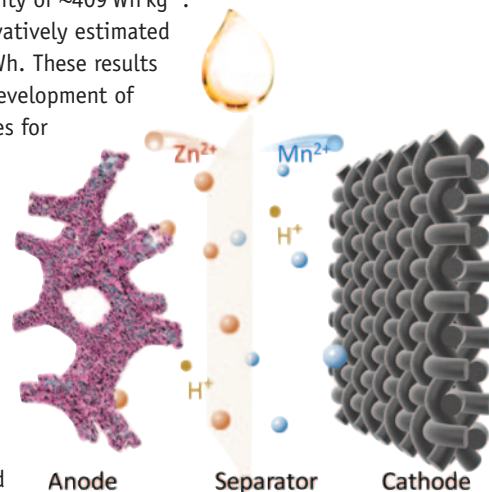
The development of selective anion receptors continues to be an important focus of supramolecular chemistry research due to the many roles anions play in industrial processes, as pollutants in the environment, and as electrolytes in biological systems. Surprisingly, until recently there were no examples of neutral anion receptors that are capable of selective chloride complexation in >50% aqueous solutions. Now, a team headed by Phil Gale at the University of Sydney, together with co-workers at UNSW, has discovered a simple symmetrical tetraurea macrocycle that assembles into aggregates and binds chloride ions selectively in aqueous solutions (Wu X., Wang P., Turner P., Lewis W., Catal O., Thomas D.S., Gale P.A. *Chem* 2019, **5**, 1210–22). The macrocycle has a strong tendency to self-associate into columnar aggregates via intermolecular hydrogen bonds and aromatic stacking. In aqueous solutions, macrocycle aggregation generates solvent-shielding and size-selective binding pockets favourable for hydrogen bonding with chloride. As a result, micromolar affinity and highly selective chloride binding were achieved with this simple small molecule in 60 vol% water/acetonitrile. This macrocycle opens a new path for achieving selective anion binding under highly competitive aqueous conditions within an aggregated receptor.



A drop of acid to power an aqueous battery

The aqueous battery is particularly advantageous for practical large-scale and sustainable electric energy storage because of its relatively low cost and high safety. However, grid-scale applications are severely limited because of the low output voltage and energy density compared with more conventional lithium-ion batteries. Now, a team led by Shi-Zhang Qiao of the University of Adelaide has developed a new low-cost high-voltage electrolytic Zn–MnO₂ battery by adding an extra drop of acid to a traditional zinc-ion battery, in which electrodeposition/electrolysis of a Zn anode and MnO₂ cathode couple is employed (Chao D., Zhou W., Ye C., Zhang Q., Chen Y., Gu L., Davey K., Qiao S. *Angew. Chem. Int. Ed.* 2019, **58**, 7823–8). This new electrolytic battery has an impressive flat-discharge plateau of 1.95 V and long-term rate durability of 1800 cycles, together with a record energy density of ~409 Wh kg⁻¹.

The cost is conservatively estimated at under US\$10/kWh. These results will advance the development of zinc-based batteries for practical energy storage and grid-scale application. This work may also benefit Australia's battery industry and significantly expand applications of Australia's zinc and manganese resources.

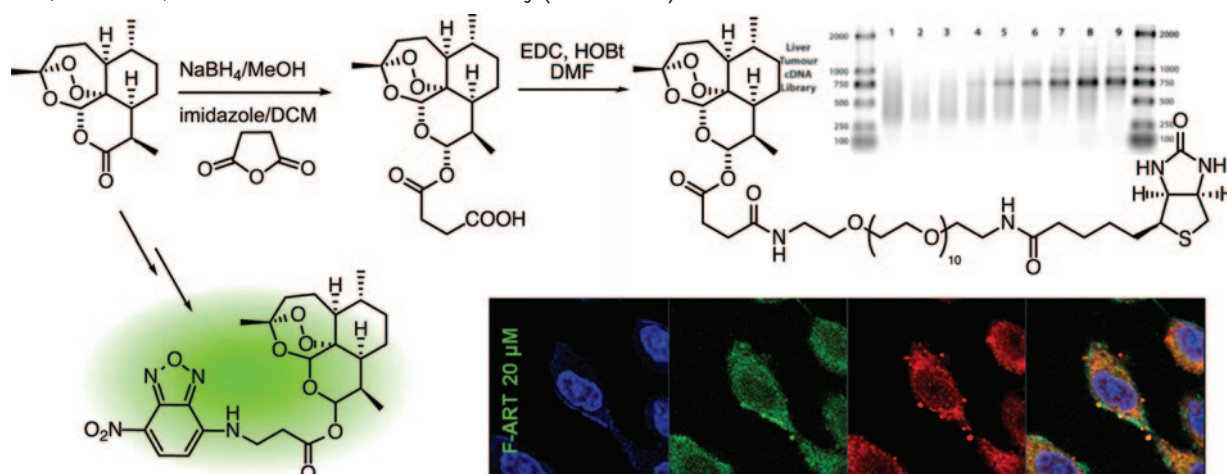


BAD news for cancer

The natural product derivative artesunate is well known as an antimalarial drug. Its parent artemisinin is isolated from the sweet wormwood, a Chinese herbal remedy known for thousands of years. In the last 20 years, artesunate has also been shown to have anticancer activity. However, how exactly it acted was a mystery. Now, a team led by Peter Karuso at Macquarie University has shown that artesunate interacts with a cell-death-promoting protein in human cell lines (Gotsbacher M.P., Cho S.M., Kim N.H., Liu F., Kwon H.J., Karuso P. *ACS Chem.*

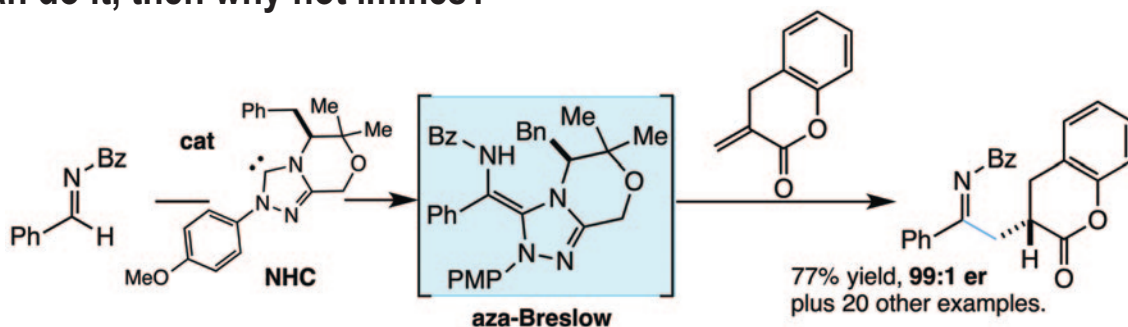
Biol. 2019, **14**, 636–43). This is the first evidence that the molecule directly targets a tumour-related protein and suggests a route to designing novel artemisinin-based drugs to target specific cancers. The team synthesised biotinylated and fluorescently labelled artesunate and used these to interrogate several human cDNA libraries, displayed on bacteriophage T7, revealing a single human target of artesunate: the intrinsically disordered Bcl-2 antagonist of cell death (BAD). Colleagues at Yonsei University (South Korea) then showed

that artesunate inhibits the phosphorylation of BAD, thereby promoting the formation of the proapoptotic BAD/Bcl-xL complex and the subsequent intrinsic apoptotic cascade that leads ultimately to cell death. Besides helping to direct clinical exploitation of artemisinins, this work opens the door to a new technique, phage display, to identify weak interactions between drugs and intrinsically disordered proteins such as BAD.



If aldehydes can do it, then why not imines?

N-Heterocyclic carbenes (NHC) provide access to a wide range of reactive intermediates, with the polarity-inverted aldehyde (Breslow intermediate) most commonly featured in organocatalysis. Although other substrates for NHC-organocatalysis are known, they remain less commonly studied, and in some cases completely overlooked. Imines are easily prepared electrophiles that would appear well suited to polarity inversion (to give an aza-Breslow intermediate). Surprisingly, enantioselective reactions with such substrates are not known. Drawing upon earlier studies in normal polarity NHC

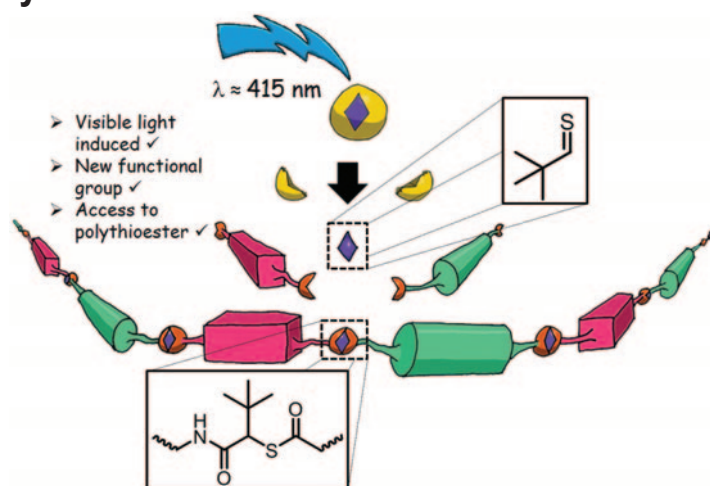


catalysis by the Lupton group at Monash University, studies were recently undertaken to examine the viability of imine umpolung reactions. Although their behaviour is highly distinct, with careful design, reaction discovery was possible. Specifically, a highly enantioselective aza-Stetter reaction was discovered (Fernando J.E.M., Nakano Y., Zhang C., Lupton D.W. *Angew. Chem. Int. Ed.* 2019, **58**, 4007–11). This transformation shows

broad generality, with 21 couplings performed, allowing the synthesis of enantioenriched γ-imino lactones with high selectivity (all > 96:4 er). In addition to defining a new route to enantioenriched materials of potential utility in multistep synthesis, this study defines a general approach for enantioselective catalysis using the aza-Breslow intermediate.

Novel photoinduced multicomponent polymerisation

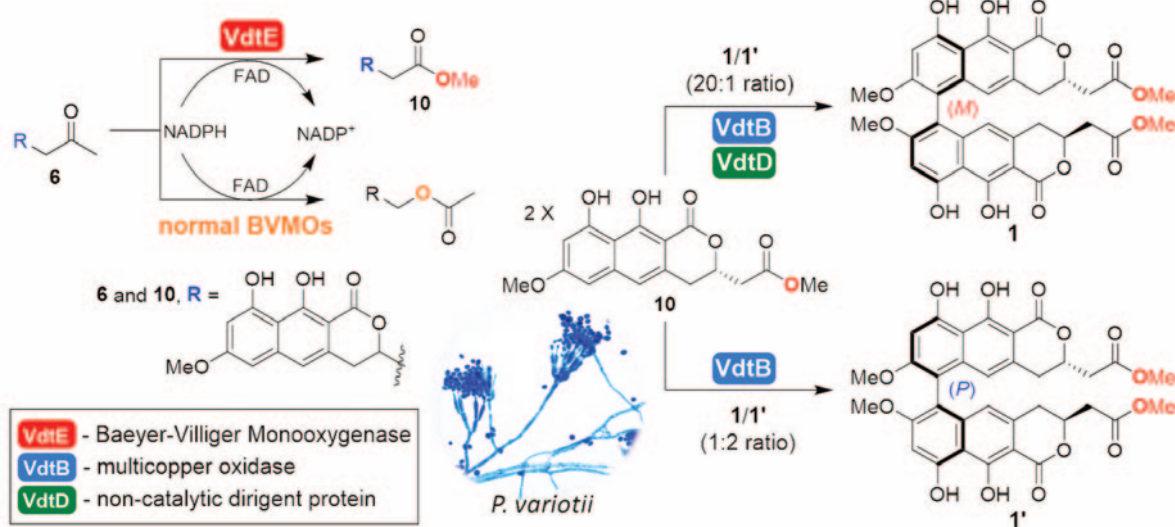
First discovered by Mario Passerini in 1921, the Passerini reaction has been one of the most versatile and powerful multicomponent reactions in organic chemistry for nearly a century. It uses an aldehyde, a carboxylic acid and an isocyanide, which form an amide/ester linkage when combined. Within the last decade, the Passerini reaction has emerged as a powerful tool in polymer chemistry as both a post-polymerisation modification reaction and a multicomponent polymerisation (MCP) technique. Recently, the Soft Matter Materials Laboratory at the Queensland University of Technology led by Christopher Barner-Kowollik, in a concerted effort with the group of Dagmar d'hooge of Ghent University (Belgium), has pushed the envelope on what is possible with this already powerful reaction (Tuten B.T., De Keer L., Wiedbrauk S., Van Steenberghe P.H.M., D'hooge D.R., Barner-Kowollik C. *Angew. Chem. Int. Ed.* 2019, **58**, 5728–32). By harnessing the power of highly reactive photo-caged thioaldehydes, the team has established a Passerini MCP methodology that – for the first time – is photo-initiated with



bioorthogonal blue light. Furthermore, the team showed that thioaldehydes can be successfully used in a Passerini reaction. The use of thioaldehydes in MCPs leads to the incorporation of highly functional thioesters directly into the polymer backbone.

Fungal power: atroposelective coupling and methyl ester-forming fungi

Organic synthesis of biaryl natural products poses unique challenges due to the presence of both regiochemistry and stereochemistry at the biaryl axis. Understanding how Nature controls such oxidative coupling reactions is of great interest due to the increasing demand to access atropisomer axial chirality in drug discovery and



development. Recently, researchers at the University of Western Australia have uncovered that the *Paecilomyces variotii* mould uses a multicopper oxidase (VdtB) to catalyse the regioselective coupling of the monomeric semiviriditoxin (**10**), in combination with a non-catalytic dirigent protein (VdtD) that controls the coupling stereoselectivity, to form the

bisnaphthopyrone antibacterial compound viriditoxin (**1**) in the correct *M* atropisomeric form (Hu J., Li H., Chooi Y.-H. *J. Am. Chem. Soc.* 2019, **141**, 8068–72). The team also showed that another novel enzyme (VdtE) in the same biosynthetic pathway catalyses an unusual Baeyer–Villiger oxidation, which involves the migration of the less

nucleophilic carbon during the Criegee rearrangement against the migratory aptitude, to generate a methyl ester from an alkyl methylketone substrate. The study highlights the catalytic prowess of fungal enzymes and paves the way for the development of green biocatalytic processes for atroposelective synthesis of axially chiral biaryl compounds.

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.

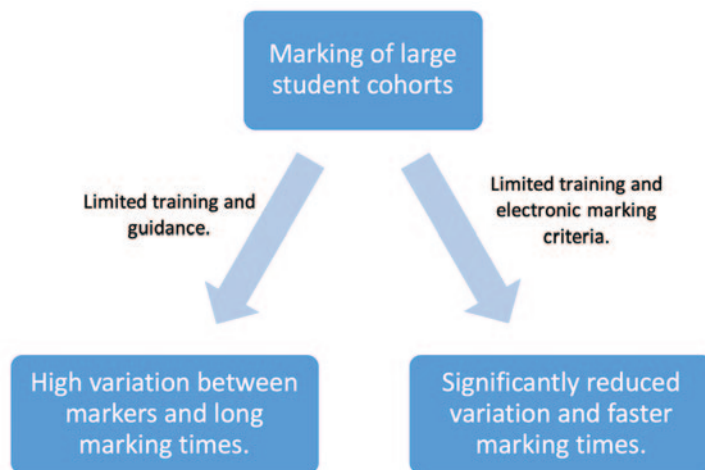
Investigating staff and student perceptions of the chemistry teaching laboratory

How students think, act and feel during any given teaching experience will ultimately affect their performance in that activity. Previous literature has begun to investigate this in undergraduate chemistry teaching laboratories through the use of the Meaningful Learning in the Laboratory Instrument. However, these studies were limited to a few US-based institutions and have never been matched against the expectations of teaching staff with regards to how students behave in teaching laboratories. Researchers at Monash University investigated the perception of both students and teaching staff towards student behaviour during teaching laboratories at three Australian universities and one in the UK (George-Williams S.R., Ziebell A.L., Thompson C.T., Overton T.L. *Chem. Educ. Res. Pract.* 2018, doi.org/10.1039/C8RP00188J). It was found that student perceptions were remarkably positive and appeared to be relatively unchanged as they proceeded through their undergraduate degrees at any of the four institutions. When compared to teaching staff, it was noted that sessional teaching staff believed that students were far more likely to undertake negative behaviours (e.g. be disorganised) and feelings (e.g. frustration) and academic staff tended to believe that students were not even undertaking positive behaviours (e.g. making their own decisions). Overall, there is a clear mismatch between the expectations of students and teaching staff with regards to student behaviours during teaching laboratories.



Rationale Skincare Pty Ltd.

Minimising the variation of assigned marks and feedback in sessional teaching staff



Variation between the assigned marks (and supplied feedback) of sessional teaching staff is a well-known issue in higher education. It was theorised that the sessional teaching staff were likely using their own highly varied academic judgement when marking, which in turn led to the variation noted. While there are many interventions already published in the literature regarding this variation, they often require significant retraining and their implementation may be prohibitively expensive or time-intensive. Electronic marking procedures, such as the use of Microsoft Excel or Learning Management Systems, can combat the issue of academic judgement by restricting the freedom assigned to a given assessor. A case study was performed at Monash University (George-Williams S.R., Carroll M.-R., Ziebell A.L., Thompson C.T., Overton T.L. *Assess. Eval. High. Educ.* 2018, doi.org/10.1080/02602938.2018.1545897) wherein the use of academic judgement was reduced through the use of electronic marking methods. In this case, the use of either an automated Microsoft Excel spreadsheet or automated online quizzes was found to significantly reduce marking variation between sessional teaching staff. Furthermore, sessional teaching staff reported that the new marking procedures reduced marking times and were easy to learn with little to no formal training.

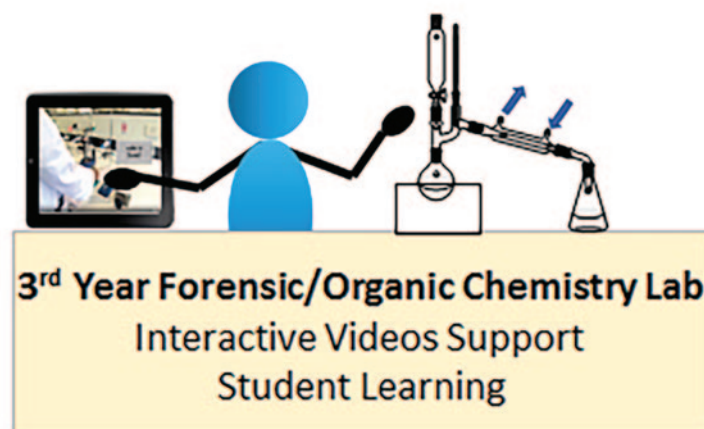
Generating free access learning resources for magnetic resonance



University students majoring in chemistry are expected to encounter magnetic resonance throughout their degree, most commonly in units on NMR spectroscopy. Contrary to popular belief, a background in quantum mechanics is not required to understand magnetic resonance. The topic is, however, not simple and is sometimes taught with little reference to practical applications. As a result, many students (as well as many spectroscopists) find magnetic resonance theory daunting and the subsequent recall and application of the knowledge, very difficult. The challenge lies in combining pedagogic skills with subject-matter expertise. While skilled educators are often abundantly available at universities, experts of the varied fields of magnetic resonance are far rarer. In the paper, a multi-institution team (Kwan A.H., Mobli M., Schirra H.J., Wilson J.C., Jones O.A.H. *J. Chem. Educ.* 2019, doi.org/10.1021/acs.jchemed.8b00523) recently presented a new resource in the form of four high-quality online (YouTube) lecture series produced by the Australian and New Zealand Society for Magnetic Resonance, which are presented by some of the world's best teachers and practitioners of magnetic resonance. The target audience includes postgraduate and final year undergraduates, university teachers and researchers. The videos are free and are designed to teach and reinforce important concepts in magnetic resonance. To date, the four series, each covering a major topic in magnetic resonance and together totalling over 30 hours of lectures, have been viewed over 200 000 times in 168 countries with great feedback from all over the world. The aim is to keep adding to this resource in future years with new topics and new lecturers – so watch this space.

Interactive laboratory videos

Undergraduate chemistry experiments can challenge students to develop effective skills and techniques. Interactive videos for teaching chemical techniques and instrumentation during laboratory sessions were implemented at Griffith University, to support student active learning. Experiments or instrumental activities, in third-year level chemistry laboratories, were filmed from multiple perspectives and teaching videos created. The videos were viewed by students in situ on laboratory-dedicated mobile devices (iPads) or on a laboratory TV screen, in playback mode. Details of mixed approaches for a variety of forensic and organic chemical techniques (ten examples) are compared (Cresswell S.L., Loughlin W.A., Coster M.J., Green D.M. *J. Chem. Educ.* 2019, doi.org/10.1021/acs.jchemed.8b00647). Professional and mobile phone filming and editing provided accurate high-resolution videos that were suitable for teaching. Filming with mobile phone cameras was preferred for accessing multiple angles and experiments in constrained spaces, such as fumehoods. Timely use of videos during lab sessions, particularly on portable devices, aided students in experiment equipment set-up and performance of tasks. The research concluded that the opportunity to watch interactive videos is important to demonstrate the dynamics of chemical experimental techniques to students, who can be potentially disadvantaged if the instructions are solely in a printed laboratory manual.



Compiled by **Reyne Pullen** MRACI CChem (r.pullen@unsw.edu.au). This section showcases exciting chemistry education research carried out primarily in Australia. RACI members whose recent work has been published in prominent chemistry education journals (e.g. *Chem. Educ. Res. Pract.*, *J. Chem. Educ.*, *J. Res. Sci. Teach.*) are encouraged to contribute general summaries, of no more than 200 words, and an image to Reyne.

A mother's love

Maria Dmitrievna Mendeleeva

Portrait of Maria Dmitrievna Mendeleeva (artist unknown).
Wikimedia/Serge Lachinov



Alf Larcher tells a story of Maria Mendeleeva's determination and love for her son Dmitri, and how it changed the course of chemical, scientific and world history.

She must have been determined, ambitious and, above all, completely devoted to her family. This is a story of how Maria Dmitrievna Mendeleeva worked and dedicated tirelessly, sacrificing her health to give the maximum opportunity to her children, in particular her youngest, Dmitri.

Maria's world

Maria (née Kornilyeva) was born into a successful merchant family in 1793 in the Russian city of Tobolsk, in eastern Siberia, at the confluence of the Ob and Irtysh rivers. Her mother died at her birth and she was raised by her father with the help of a nanny. As a

girl, she was not able to attend school but was motivated enough to learn from the books and materials that her brother brought home from his school lessons. The family had also accumulated a large number of books, which she read. Later in her life, she would encourage all her children to read and to appreciate, as she put it, 'the gift of words on paper'.

During this time, Tobolsk was the centre of the Russian Siberian province stretching from the Ural Mountains to the Pacific Ocean, being its main military, administrative, political and religious centre. The Ural Mountains were seen as the natural divide between Europe and Asia, but the Tobolsk region had been extensively colonised by western Russians and it seems Maria's family was mainly of this stock. Many sources, however, quote a family legend in which Maria's grandfather married a 'Tartar beauty', whose death caused him to die of grief. The Tartars originated from the vast northern and central Asia landmass, also inhabited by other various Turco-Mongol semi-nomadic peoples.

This eastern expansion of the Russian empire had been initiated by Peter the Great, who had used Tobolsk as a springboard for the region's development, and this was continued by subsequent rulers. The spectacular Tobolsk Kremlin (administrative centre) was built in 1800 and is known as the 'pearl of Siberia'.

Ivan Mendeleev

In 1809, Maria married Ivan Pavlovich Mendeleev from the Tver province near Moscow. Ivan's father was a Russian Orthodox priest, Pavel Maximovich Sokolov, who had four sons. As per the tradition for priests at the time, they all had different family names, with Ivan receiving the name of a neighbouring landlord, Mr Mendeleev. Ivan trained as a teacher at the St Petersburg Chief Pedagogical Institute, with his first assignment after graduating in 1807



A historical depiction of the Russian city of Tobolsk.

iStockphoto/mrtom-uk

being at the Tobolsk Classical Gymnasium; he became its director in 1828. In this context, a gymnasium was equivalent to a preparatory primary/high school with an emphasis on academic achievement, as a forerunner to university.

Newlyweds

Ivan and Maria set up house and home in Tobolsk, and according to Russian tradition she adopted the feminised version of her husband's surname, usually done by adding an 'a', to become Maria Mendeleeva. The newlyweds were pious Russian Orthodox Christians and had 14–17 children (the exact number is disputed). Not all survived, which is not a surprise for that time, even without considering the harsh Siberian climate and its remoteness from medical facilities. All sources agree that the last, born in 1834, was a boy, Dmitri, with his middle name, according to Russian tradition, denoting he was the 'son of' Ivan. He was thus named Dmitri Ivanovich Mendeleev. He quickly became his

mother's favourite and she started putting money away for him at an early age.

It is interesting to note that Maria's middle name was Dmitrievna, which by the above traditions means 'daughter of Dmitri'. Most sources mention Maria's father and grandfather as pioneers of the Tobolsk region, founding the region's first glass factory and printing press and publishing the first newspaper in Siberia, the *Irtysch*. Maria admired her father's drive to succeed and had perhaps also inherited it. In those days, as in other parts of the world, the lot and rights of women would have left much to be desired and her opportunities were limited. The next best thing, she may have thought, was to put all her efforts into the next generation, in particular her father's namesake and her last child, born when she was 41.

Young Dmitri

Dmitri was home schooled by Maria until he was seven, after which he entered the Tobolsk Classical Gymnasium. Records show that Dmitri

was not a great student, with many episodes of bad behaviour. The gymnasium appeared to be an intellectually limiting place, where the philosophy of the reigning monarch, Nicholas I, was promoted. This may not have agreed with young Dmitri's more expansive preliminary education given to him by his mother. There was a heavy emphasis on the classics, Latin and German, which did not interest Dmitri, but he did well in mathematics, physics and the sciences. Maria must have been pleased with this; I can imagine her poring over Dmitri's every school report. Little did young Dmitri know that his course was set; he would be given the utmost opportunity to excel in this field – but did he have what was needed to make the most of it?

Tragedies

The family suffered a series of tragedies shortly after Dmitri's birth, with his father developing blindness due to cataracts and eventually retiring from the gymnasium. Maria was left to fend for the family and, not being able to support her children on the meagre government pension, took on the management of her family's glass factory – about 27 kilometres outside Tobolsk in a village called Aremzianka – which had been inactive for some time. This would not have been an easy task for a woman then, although not unheard of in Siberia,

where there was a history of 'strong women'.

In this rural setting, the young Dmitri spent the first five years of his life and it is said that he was particularly interested in what would have appeared to be the wondrous transformation of earthy materials (e.g. sand and limestone) under the action of fierce fire to produce beautiful clear, coloured glasses. In later life, he would always have a picture of these glassworks on his office wall.

Ivan's health continued to deteriorate, and he died in 1847. The family experienced more tragedy the following year when a fire burnt and destroyed the glass factory. After this, the family understandably fell on hard times. It does seem that in this stage of the family's history, most of Maria's children were no longer her responsibility, with only the two youngest in her care (Elizabeth and Dmitri). The situation did not deter her from executing her plans for Dmitri. He was now 15 years old and ready for the next step in his education: university.

With the seat of Russian power centred in the west, Maria set her sights in that direction; she would take Dmitri to Moscow University, one of the finest in the land, and 2200 kilometres away. She would not waste any time: using the last of her money, and only a few months after the factory fire, she set upon her way. Perhaps she knew that she was running out of time.

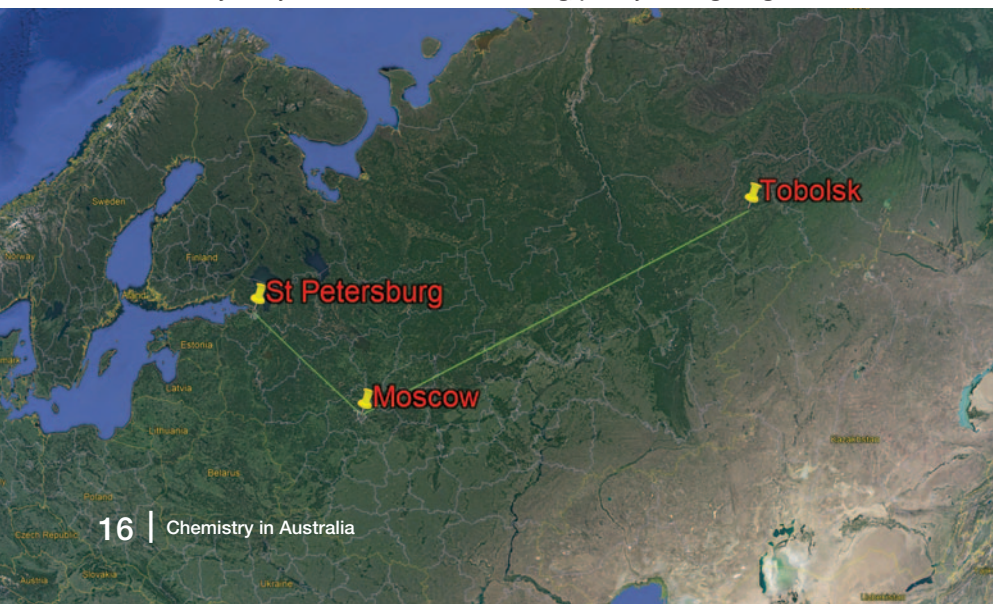
Journeys

The year was 1849, well before highways and Russia's first railway. Maria had travelled to Moscow and surrounds before in the early part of her marriage as Ivan assumed new teaching posts. One source quotes that she had once taken her ailing husband to Moscow for specialist medical advice. She also had a brother who lived there, so presumably she had a place to stay. Much has been made of this journey and perhaps it is over-romanticised, but to cross 2200 kilometres of what would have been then mostly bleak Siberian landscape, including traversing the Ural Mountains, in a state of poverty with two children in tow, would have taken a monumental effort.

Various sources give different methods for how she and her two children completed the journey: sleigh, horseback and walking. One source states that she hitchhiked a ride. Russian prerailed technology for horse-drawn sleighs and carts/coaches was well advanced, so I suspect that this would've been the mode of transport, taking three to four weeks under normal conditions. Whatever transport was used, Maria's determination to give Dmitri a university education drove her on.

Her long, arduous trip over, Maria reached Moscow and its famous university, only to be foiled by the ultimate insult: red tape. The university would not accept a student from Tobolsk, whose educational district fell into that of the local regional university. Maria thought that her brother's

Maria's journeys to Moscow and St Petersburg, portrayed using Google Earth. Google Earth



Maria reached Moscow and its famous university, only to be foiled by the ultimate insult: red tape.

Maria ... died of tuberculosis in September 1850, the same year that Dmitri entered the Institute.

connections could help, but the university administration would not budge. She must have been bitterly disappointed, and I suspect that there would have been a colourful discussion in the enrolments office of Moscow University that day.

Maria clearly wanted Dmitri to attend a recognised educational institution, not content with a lesser known regional university. The next best thing was St Petersburg University, which was 700 kilometres from Moscow and another week of travelling by horse and cart. Once again, she didn't waste any time. The year after the Moscow trip, Maria and her two children endured the arduous journey to St Petersburg.

One source claims that, after reaching St Petersburg, she tried to get Dmitri enrolled in the great city's university, but once again she was foiled. She had to settle for the Chief Pedagogical Institute, where Dmitri's father had studied. The emphasis of the institute had since shifted from training teachers to independent research and was housed inside the University of St Petersburg. Studies were arranged in a number of streams, and Maria enrolled Dmitri in the physical-mathematical stream. Academics from the University often visited and gave lectures in the Institute – Dmitri thrived in this atmosphere and achieved good grades in his studies. He had successfully begun his career as a scientist.

It had been a tumultuous three years for Maria, and this took the ultimate toll – she died of tuberculosis

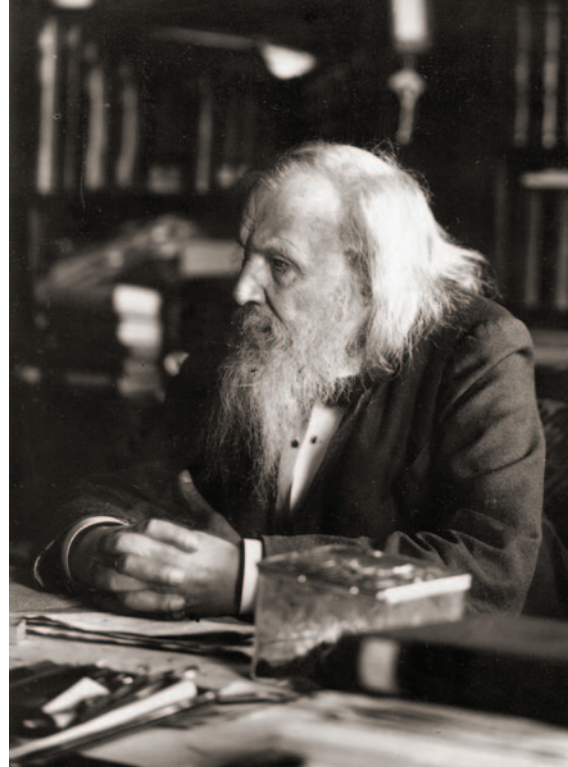
in September 1850, the same year that Dmitri entered the Institute. She must have felt that she had done all that she could and now it was up to Dmitri. It is a great pity that she was not able to see the fruits of her labours and watch Dmitri flourish.

Dmitri Ivanovich Mendeleev

After his beloved mother, and a few months later his sister, were taken by the scourge of tuberculosis, Dmitri was by himself in St Petersburg. He also contracted the disease, and despite a doctor's prediction that 'this one will not survive', he miraculously did. He continued at the Institute, and took up chemistry as his area of study, completing his doctorate and visiting the laboratories of Kirchhoff and Bunsen. He also attended the watershed 1860 Karlsruhe Congress, where he heard the influential talk by Cannizzaro on atomic weights. As an academic, he wrote organic chemistry textbooks, perhaps reflecting his mother's love of 'words on paper', which seemed to have coalesced all current knowledge and his experiences to get his mind ticking.

How Dmitri came up with the periodic table of the elements, and stood out among contemporaries with similar ideas to become a giant of science, is a great story for another time. He was well aware of what his mother had done for him. In 1887, as a Professor in Chemistry at the University of St Petersburg, he published a study on the property of solutions. It contained the following introduction:

This investigation is dedicated to the memory of a mother by her youngest offspring. Conducting a factory, she could educate him only by her own work. She instructed him by example, corrected with love, and in order to devote him to science she left Siberia with him, spending thus her last resources and strength. When dying, she said, 'Refrain from illusions, insist on work, and not on words. Patiently search divine and scientific truth'.



Dmitri Mendeleev in his later life.

Wikimedia/Serge Lachinov

Mendeleev's study was published 18 years after his first draft of the periodic table (in 1869), of which we are celebrating the 150th anniversary this year. I imagine that at the time he was reflecting on his achievement of arranging the chemical elements known then and predicting new ones. Evidently, he was also thinking of his mother, with a wish to honour her love and fulfil the dreams she had for him.

Alf Larcher FRACI CChem is a petroleum, environmental and industrial chemist with an occasional urge to write science articles. Maria's story is mentioned in a number of books, journal articles and online items, all outlining the main events described here, but sometimes differing in some details. The author has used mainstream references (full list available upon request) from recognised sources.



Particulate plastics in soils

BY **NANTHI BOLAN**
AND **LAUREN BRADNEY**

A major source of particulate plastics in natural environments is wastewater discharge into aquatic ecosystems. Less well considered is particulate plastic input to soils during application of biowastes.

Particulate plastics persist both in terrestrial (i.e. soil) and aquatic (i.e. marine and freshwater) ecosystems.

Primary particulate plastics are manufactured and are a direct result of anthropogenic use of plastic-based materials. They are used in a wide variety of applications, such as cosmetics (e.g. microbeads), clothing and industrial processes. Secondary particulate plastics are plastic fragments resulting from the breakdown of larger plastic pieces. Both can enter natural environments.

Particulate plastic inputs to terrestrial and aquatic ecosystems

include a range of particle sizes (including microplastics and nanoplastics) and types of polymer. Although medium and large plastic fragments are generally sieved out during the composting process, a significant portion of small plastics makes it through the sieve. Because compost is subsequently milled, most plastics end up as secondary microplastics or nanoplastics.

Biowastes – including biosolids (treated sewage sludge) and composts – are excellent sources of nutrients and organic matter for agricultural and degraded soils. Although biowastes offer agronomic

Some sources of particulate plastics

Polymer	Applications	Properties
Low-density polyethylene (LDPE) $(C_2H_4)_n$	Squeeze bottles, toys, carrier bags, chemical tank linings, heavy duty sacks, general packaging, gas and water pipes	Low density 0.91–0.94 g/cm ³ Non-biodegradable, most common plastics
High-density polyethylene (HDPE) $(C_2H_4)_n$	Chemical drums, toys, household and kitchenware, cable insulation, carrier bags	Low density 0.92–0.99 g/cm ³ Non-biodegradable
Acrylic (acrylate polymers) $(CH_2=CHCOOH)$	Most used fibres in textiles, knitwear, plastic flakes	High density 1.16 g/cm ³
Polyethylene terephthalate (PET) $(C_{10}H_8O_4)_n$	Drink bottles, oven-ready meal trays, cable lining	High density 1.41 g/cm ³
Polypropylene (PP) $(C_3H_6)_n$	Food containers, microwavable meal trays	Low density 0.90–0.91 g/cm ³
Polystyrene (PS) $(C_8H_8)_n$	Food containers, stuffed animals, protective packaging	High density 1.04–1.13 g/cm ³
Polyvinyl chloride (PVC) $(C_2H_3Cl)_n$	Water pipes, cable insulation, packaging, health care	High density 1.39–1.43 g/cm ³ Non-biodegradable

benefits, they also contain a number of contaminants, including heavy metals, pharmaceuticals, per- and poly-fluoroalkyl substances and particulate plastics. Particulate plastics end up in soils when biowastes are applied to land (<https://ab.co/2HeQHUY>). It has been estimated that 107 000–730 000 tonnes of particulate plastics are added to European and North American farmlands each year. The weathering of plastic film mulch used over agricultural fields is also a source of particulate plastic input in soils.

The United Nations Environment Programme identified that large quantities of particulate plastics found within the marine environment globally have originated from land-based sources (UNEP. *Marine plastic debris and microplastics: global lessons and research to inspire action and guide policy change*, 2016. Jambeck J.R. et al. *Science* 2015, vol. 347, pp. 768–77). Sediment transfer during soil erosion is one process that allows the transport of particulate plastics from terrestrial to aquatic ecosystems. Despite this link to land-based sources, most scientific research on particulate plastics has focused on their effects in aquatic environments.

Impacts of particulate plastics in soils

Particulate plastics input to soils can have both beneficial and detrimental impacts on soil characteristics and organisms. For example, polyacrylamide is used to promote flocculation (particle clumping) and soil aggregation, thereby mitigating soil erosion. Particulate plastics in soils can serve as a hidden source of carbon sequestration, thereby contributing to climate change mitigation. However, since particulate plastics are introduced through human activities, it may not be considered a 'direct action' approach to mitigate climate change.

Particulate plastics affect environmental contaminant interactions in soils by acting as



Plastic film mulch used in horticulture is a source of particulate plastics in soils. iStockphoto/itman_47

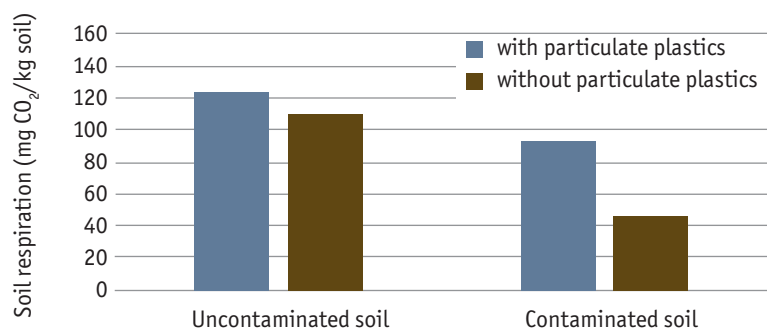
vectors for contaminant transport and by altering contaminant bioavailability. Plastic polymer resins are mixed with various additives to improve their utilisation performance. These additives include inorganic carbon- and silica-based filler materials to reinforce final products, plasticisers to render the plastic polymers pliable, thermal and ultraviolet stabilisers, and flame retardants. Some additive chemicals such as tributyl tin in polyvinyl chloride, phthalates and various bisphenol analogues in polycarbonates are leached when plastics undergo photochemical weathering, and have adverse effects on soil microbial diversity and function.

Particulate plastics interact with a wide range of organic and inorganic pollutants in the environment. Adsorption and desorption processes of pollutants in particulate plastics in the soil environment are influenced by factors such as weathering and surface area, interaction with natural organic matter (NOM), and microbial activity (i.e. biofilm formation). The association of NOM with particulate plastics in



All that glitters is not gold: farmers at a recent Australian field day asked the author what they could see glittering in the soil on their farms. It was microplastics. The microplastics shown here were washed from an artificial turf football field, cushioned by ground tyre rubber, into nearby soil.

Soleincitta/CC-BY-SA-4.0



Effect of particulate plastics on soil respiration in uncontaminated and copper-contaminated soils.

Particulate plastics in biowaste samples and their input to soils through biowaste application

Biowaste	Number/kg	Weight (g/kg)	Input soil (kg/ha)
Biosolids	1180 ± 330	10.5 ± 2.30	105
Green waste compost	780 ± 150	6.80 ± 1.26	68
Manure compost	430 ± 70	1.45 ± 0.78	14.5
Food waste compost	980 ± 270	7.60 ± 2.30	76

terrestrial environments plays a crucial role in promoting particulate plastics as a vector for contaminant transport. The high surface area of particulate plastics, which can be increased through weathering, not only aids adsorption of contaminants, but also supports chemical transport of the pollutants through leaching.

Measuring particulate plastic input to soils

Although particulate plastics are recognised as emerging contaminants in soils, their impact in the soil environment remains largely unclear, particularly on microbial functions and contaminant mobility. An international research group, including our Global Centre for Environmental Remediation at the University of Newcastle, quantified the amount of particulate plastics in a range of biowastes, including biosolids, composts and manures (doi.org/10.1016/j.chemosphere.2018.01.166). We also examined the impact of particulate plastics on microbial activity and contaminant mobility in soils.

In the study, uncontaminated and copper-contaminated soil samples

were treated with particulate plastics. Copper is used agriculturally as a fungicide and is toxic to soil microbial communities. These soil samples were subsequently analysed for bioavailable copper concentration, soil respiration, microbial biomass carbon and dehydrogenase activity. Bioavailable copper concentration is an index for toxicity to soil microorganisms. Soil respiration, microbial biomass carbon and dehydrogenase enzyme activity provide an index of microbial function.

As our results showed, biosolids contain much higher amounts of particulate plastics. We estimated the amount of particulate input to soils through biowaste application as a rate of 10 t/ha as a source of organic matter input to soils. Although the particulate plastic input to soils through biowaste application ranged from only 0.15 to 1.05% as a mass percentage of biowaste input, the number of particulate plastics added to soils through these biowaste applications was 5 000 000–12 000 000/ha.

The incubation study indicated that the bioavailability of copper in contaminated soils decreased with the

addition of particulate plastics. This may be attributed to the adsorption of copper by the NOM associated with the particulate plastics. The results also showed that there was a significant difference in soil respiration between copper-contaminated and uncontaminated soil samples (see graph). Particulate plastics addition resulted in a significant increase in soil respiration in both uncontaminated and contaminated soils. Particulate plastics retain contaminants such as copper, thus reducing their toxicity to soil microorganisms. The improved soil aeration (porosity) caused by particulate plastics addition could be another reason for the increase in the microbial activity. Similarly, uncontaminated and copper-contaminated soils treated with particulate plastics appeared to increase dehydrogenase activity and microbial biomass carbon, indicating increased microbial function.

Conclusions

Particulate plastics in terrestrial ecosystems can have both beneficial and detrimental effects on soil health. Our findings indicate that adding particulate plastics helps modulate contaminant (e.g. copper) toxicity on soil microbial activity. However, it is important to examine the long-term effects of particulate plastics on soil biology and function, which is a major focus of our current research on particulate plastics.

Nanthi Bolan MRACI is Professor of Environmental Chemistry and **Lauren Bradney** is a PhD student at the Global Centre for Environmental Remediation, University of Newcastle.



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Chemistry collaboration *with* Pakistan An opportunity

International review team members and academic visitors report on collaboration in chemistry education and research between Australia and Pakistan.

Pakistan and Australia have a long history of cooperation in the field of education and research that extends back to the formation of the Colombo Plan in 1951. Pakistan and Australia were two of the founding members of the Colombo Plan for Cooperative Economic and Social Development in Asia and the Pacific (its original full title), the others being Canada, India, New Zealand, Sri Lanka and the UK. It now includes 26 member countries, some of whom are not former members of the Commonwealth. The Pakistan country brief of DFAT notes in late 2017 that there were more than 64 000 Pakistan-born people living in Australia (August 2017), just over 12 000 Pakistani students were

enrolled in Australian educational institutions (2016) and 23 Pakistani students were studying in Australia under the Australia Awards program.

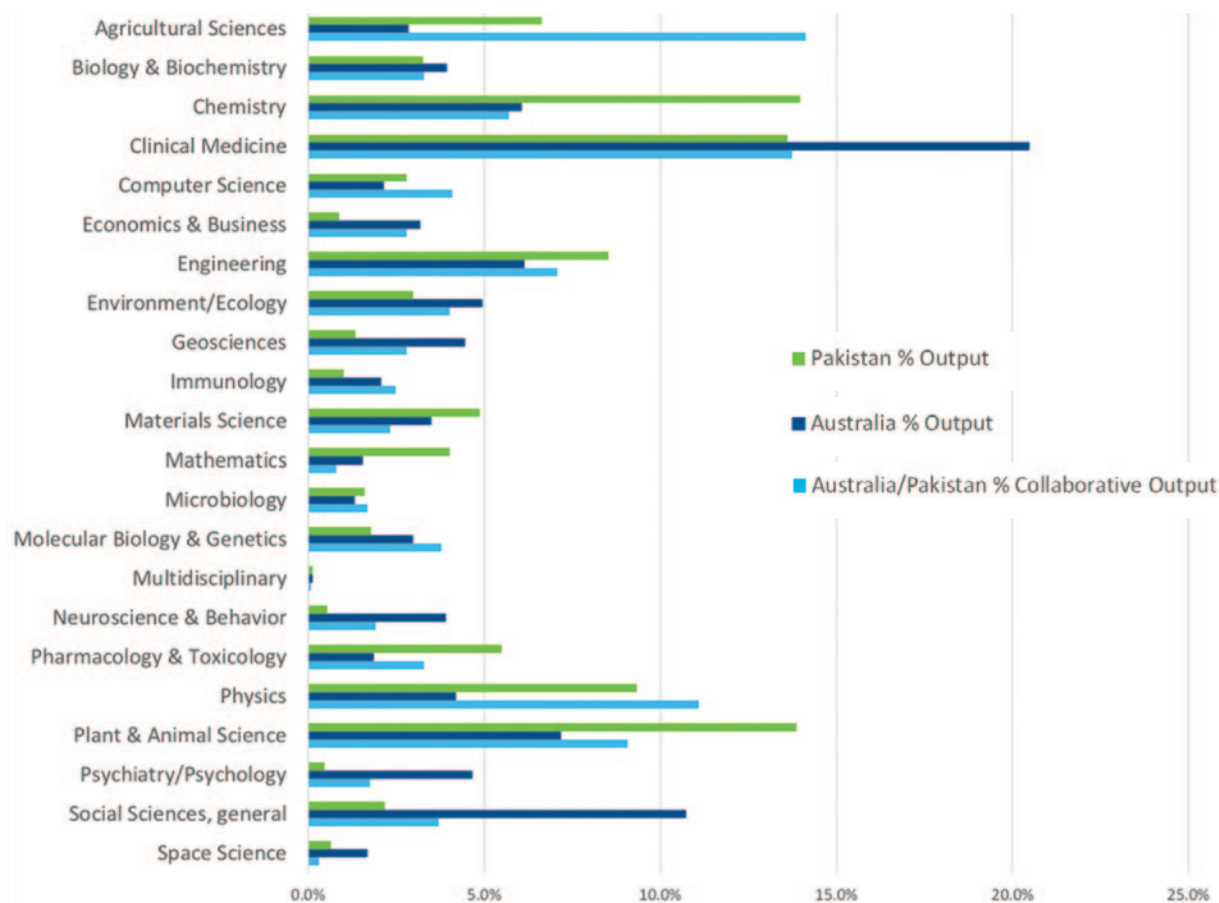
Opportunities for research collaboration with Pakistan have been increased recently through the signing of agreements between Pakistan's Higher Education Commission (HEC) and individual Australian universities to co-support PhD students studying in Australia. The institutions (as of January 2019) are:

- University of Western Australia, Edith Cowan University (Western Australia)
- Monash University, University of Melbourne, Swinburne University of Technology, RMIT University (Victoria)

- Macquarie University, University of New South Wales, University of Wollongong (New South Wales)
- University of Southern Queensland (Queensland).

The number of institutions is expected to grow. Under such an agreement, the HEC provides a living allowance and travel grant to the student, and the Australian university waives the fees. A significant number of such students are already enrolled in various Australian universities, some of whom also provide a 'top-up' to the HEC allowance. The usual agreement does not specify areas of study although the HEC reserves the right to identify priority areas.

The opportunity of cooperation in chemistry is evidence-based through



Science research papers co-authored by at least one author from Australia and one author from Pakistan. (Data extracted from the Web of Science covering articles and reviews for 2007–2016).

our recent bibliometric analysis of research cooperation between the two countries (doi.org/10.29145/sir/21/020101). The Web of Science large database has been searched for science research papers that were co-authored by at least one author from Australia and one author from Pakistan (as revealed in their institutional addresses). The decade 2007–2016 was covered to reveal the national profiles for each country (all papers) as well as the co-authored papers in each of the Web of Science fields of study.

For chemistry, the graph shows that chemistry in Pakistan is a strong component of its national science research output, reaching close to 15% of all research papers, while for

Australia, chemistry is above 5% of national output. The magnitudes are of course quite different, with Australia's national output very much greater than that of Pakistan (by about a factor of ten). Collaboration is strong in agricultural sciences, physics and plant and animal sciences, but not quite so strong in chemistry (as a percentage of collaborative output). In fact, in 2015, there were only 15 collaborative chemistry papers involving Australia and Pakistan authors. However, clinical medicine (biomedical sciences) is similar for collaborative output but lower for chemistry.

We have reported earlier (March 2018 issue, p. 29) the growth of regional chemistry collaboration.

Collaboration with PR China dominates the current situation: it has grown very strongly across that decade to be almost a factor of ten greater than the collaborative output of Australia with Japan or India, the next two countries for research collaboration in chemistry.

Pakistan has a well-developed system of higher education institutions. This strengthened dramatically following the appointment of Professor Atta-ur-Rahman as the chairman of the Higher Education Commission of Pakistan between 2002 and 2008. The recent establishment of the co-funded scholarships for PhD students is a clear opportunity for Australian chemistry researchers to recruit research students.



A poster describing the oldest NMR unit at the HEJ Institute.

The institution that is perhaps best known to Australian chemists is the Hussain Ebrahim Jamal (HEJ) Research Institute of Chemistry, which is now an advanced research centre within the diversified International Centre for Chemical and Biological Sciences (ICCBS) at the University of Karachi.

The HEJ Institute (named after an early benefactor Hassan Ebrahim Jamal) is a centre of excellence for phytochemistry and natural products chemistry linking to medicinal drugs and treatments. The first director of the HEJ Institute was Professor Salimuzzaman Siddiqui, a distinguished Pakistani chemist who

was elected a Fellow of the Royal Society in 1961. He was appointed in 1976. Siddiqui retired as co-director of the HEJ in 1990 but continued to work in his laboratory into his 90s. In 1977, Professor Atta-ur-Rahman was appointed co-director.

Professor Muhammad Iqbal Choudhary was appointed Co-director of ICCBS in 2004 and Director in 2009. Iqbal Choudhary has enlarged the scope of the HEJ Institute's work from the chemistry of natural products to the role of natural products in biomedical science through the Dr Panjwani Center for Molecular Medicine and Drug Research (PCMD).

Under the leaderships of these three people, the Institute has grown remarkably to be an institution of international significance with facilities of international quality. The ICCBS has held and continues to hold high-profile research-based workshops and conferences that offer the opportunity for researchers to engage with the Pakistan community. For example, it hosted in 2013 the Golden Jubilee meeting of the Asian Symposium on Medicinal Plants and Spices and Other Natural Products (ASOMPS XIV). This series of conferences began in 1960 in Peshawar, Pakistan.

The Institute now has 13 Bruker NMR spectrometers in place, working round the clock: three 300 MHz, four 400 MHz, three 500 MHz, two 600 MHz and a recently acquired Bruker Ascend 800 MHz instrument with cryogenic probe. Helium is recovered, and additional supplies are obtained close by, from Dubai. One of the 300 MHz NMR spectrometers is identified as 'the oldest functional superconducting NMR spectrometer in the world' with Bruker manufacturing number of 101. Other instrumentation of comparable quality, including high-resolution mass spectrometers, is also housed in the various institutes on the campus, such as ICP MS, typical molecular biology equipment and biotechnology incubators.

The ICCBS maintains a compound bank of more than 16 000 characterised compounds, more than 100 cell lines for research use and more than 200 microbial strains, including bacteria, fungi and parasites. The value of compound libraries for applied and basic research has been described in an earlier issue (November 2007, p. 14).

A senior institute staff member, Professor Md Raza Shah attended the Ethics Workshop in Kuala Lumpur in 2014 sponsored by the American Chemical Society that generated the Global Chemists Code of Ethics (bit.ly/2PGPRHZ). Subsequently, the Chemical Society of Pakistan has

Australian chemistry is well placed to extend its international research links to Pakistan.



A typical storage chamber of ICCBS Compound Bank (2019), shown by manager Ms Sadia Ajaz.

presented 14 workshops in various cities across the country on chemical safety and security. Participants in a few of these workshops have included chemists from neighbouring Afghanistan.

Australian chemistry is well placed to extend its international research links to Pakistan. The 2015 ARC research excellence report (ERA) notes that, for chemical sciences, ten Australian universities are rated as 'above world standard or higher' with four 'well above world standard'.

Two of us, Noller and Spurling, have visited the Institute on two occasions as members of an international review team (both teams were led by Dr Noller, who had additional visits to follow up on review progress in December 2006 and December 2007). The first review was in 2005 and the second was in 2014. The 2005 review group included Professor David StC Black from UNSW, Professor Kelvin Chan from Hong Kong Baptist University, Hong Kong, Professor Ning-Sun Yang from Academia Sinica, Taipei Taiwan; and Dr Lindsay Sparrow from CSIRO Health Science and Nutrition, Melbourne. Noller, Black and Spurling returned for the 2014 review and were joined by Professor Jack Ng (toxicology and biomedical science) from the University of Queensland to complement the shift to biomedical

sciences and growth of activity in the PCMD (established in 2004).

One of us, Webb, spent two weeks as an Institute visitor in February 2019. At that time, the Centre participated in the global Women in Chemistry breakfast, with more than 200 women attending. At present, more than half the research students are female. Professor Mary Garson, from the University of Queensland and a leader with IUPAC for this breakfast, attended by video link.

We hope that this account will encourage more chemistry collaborations with the chemistry community of Pakistan, through the new opportunity of co-funded PhD research students.

John Webb FRACI CChem and **Tom Spurling** FRACI CChem are at the Centre for Transformative Innovation, Swinburne University of Technology. **Barry Noller** FRACI CChem is at the Sustainable Minerals Institute, University of Queensland. **Adam Finch** is Analyst, Science Impact & Policy, at CSIRO, Adelaide.



The review team at ICCBS, 2005: from left, back row: Lindsay Sparrow, Tom Spurling, Barry Noller, Ning-Sun Yang and David StC Black; front row, from left: Professor Dr Ahsana Dar, Dr Talat Roomi, Dr Farah Zeb (all of HEJ Institute) and Kelvin Chan.

Mary Garson: RSC Australasian lecturer, 2018

Professor Alan Bond (Monash University) invited me in December 2017 to undertake the 2018 Australasian lecture tour on behalf of the Royal Society of Chemistry. I consulted with the 2017 lecturer, Professor Neil Barnett from Deakin University, whose advice and general good humour was well received.

A modular lecture entitled 'Game of terpenes: structures, stereochemistry and chemical ecology of nudibranch metabolites' (see box) was prepared, and included as its central component some research on the chemistry of a phyllidiid nudibranch that involved a collaboration with the group of Professor Chris Vanderwal from UC Irvine, USA. In this way, the integration of computational chemistry and the total synthesis of a diterpene metabolite (pustulosaisonitrile) into a natural product detective story could be explained to the audience.

I first road-tested the lecture at the Research School of Chemistry, Australian National University, in Canberra on 17 March. In common with my 2017 predecessor, the actual building proved elusive until I was rescued from my taxi by my host Martin Banwell. This was my first visit to the new RSC building. A social highlight was eating lunch with an international group of higher degree students and postdoctoral staff representing the organic chemistry research groups.

During June, I travelled to Perth, Darwin and Adelaide to present the lecture. First up was Curtin University on 14 June, hosted by Mauro Mocerino, then the University of Western Australia (15 June) hosted by Heng Chooi. I travelled to Darwin on 17 June for the lecture at Charles Darwin University (CDU), hosted the following day by Vinuthaa Murthy. The audience in Darwin was nicely mixed, including school teachers as well as colleagues from the Northern Territory branch of the Australian Institute of Marine Science. A particular pleasure was the presence at the lecture of CDU staff member Barbara White, the mother of the honours student who had isolated pustulosaisonitrile in my lab in 2014. I reached Adelaide on 19 June, and visited Adelaide University the next day, well hosted by Jonathan George.

The next sectors of the lectureship took place from August onwards. Combining the lecture with attendance at the Southern Highlands heterocyclic meeting (26–28 August) in Moss Vale, New South Wales, I visited the University of Wollongong on 29 August, meeting with many colleagues from my former time there (1986–90), notably Roger Truscott, Garry Mockler and Stephen Pyne. The next day, I lectured at the University of New South Wales, and this provided an

opportunity to deal with some IUPAC-related business (David Black, Martina Stenzel) as well as explore options for hosting a natural products meeting in Australia with David and Naresh Kumar. Then I travelled to Hobart, and after a relaxing weekend exploring the city, I gave the RSC lecture at the University of Tasmania on 3 September, hosted by Alex Bissember.

In mid-September, I undertook the main component of the tour, starting in Townsville with a lecture at James Cook University of North Queensland on 13 September. This enabled me to visit the laboratories in which I had first undertaken marine-related research after my arrival in Australia in 1986. Peter Junk and George Vamvounis looked after the arrangements for my visit. I then travelled from Townsville via Brisbane to Florence in Italy, to attend the 16th International Conference on Organic Synthesis, and then, again transiting through Brisbane, flew directly onto Auckland to undertake the New Zealand component of the lecture tour. James Hutchinson provided excellent advice and arranged the lecture schedule on my behalf. After a lecture at the University of Auckland (Johannes Reynisson/Ivan Leung) on 24 September that was followed by a reception arranged by the local NZIC section, I successively visited University of Otago (Nigel Perry/Bill Hawkins), University of Canterbury (Vladimir Golovko), Victoria University of Wellington (Marcus Cole/Rob Keyzers/Joanne Harvey) and Waikato University (James Hutchinson/Michele Prinsep). Five lectures in five days, including air travel on four successive mornings, was quite tiring, and by this stage I had developed a heavy cold; the final evening in New Zealand was spent in the company of a former postdoc, now professor of marine sciences, Chris Battershill, in Tauranga. The next day, I travelled back to Auckland by road, and flew directly to Melbourne, spending the remainder of the weekend getting fit for the next round of lectures.

On 2 October, I delivered the Lady Masson Memorial lecture at the University of Melbourne, hosted by the Head of School Professor Evan Bieske; this was a different lecture presentation from the RSC lecture series. Next, Alan Bond hosted the RSC lecture and a reception at Monash University on 3 October; we were joined for dinner by Alison Funston, Kelly Tuck and Philip Marriott. During the evening, Kelly and I scanned our phones with great delight when news came through during the meal that Frances Arnold had been awarded one half of the Nobel Prize in Chemistry. The final two RSC lectures in this part of the tour were given at the University of Melbourne (hosted by Jonathan White) and the Waurin Ponds campus of Deakin University; at this latter venue, it was an absolute pleasure to meet Neil Barnett at last, as well as catch up with Madeleine Schultz.

The final sector of the lecture tour was a visit to Sydney, presenting at Macquarie University (Andrew Piggott) on 23 October and then the University of Sydney (Chris MacErlean) the following day.

... it is gratifying to record that the smaller centres that I visited were visibly dynamic and moving ahead ...

'Butterflies' of the ocean

Nudibranchs, the 'butterflies' of the ocean, are a group of brightly coloured marine molluscs that are the source of diverse bioactive natural products. The RSC lectureship presentations described how an ecological study on chemical defence in nudibranchs led to the isolation and characterisation of new terpene metabolites with extensively rearranged carbon skeletons. Case studies discussed included new isocyanoterpenes from *Phyllidia ocellata* and *Phyllidiella pustulosa*, and epoxy-substituted norditerpenes from *Goniobranchus splendidus* (pictured). NOESY data run at 700 or 900 MHz, together with detailed conformational analysis informed by molecular modelling, DFT calculations, and in one example total synthesis in collaboration with a US laboratory, enables assignment of individual configurations. The antimalarial, antifungal and cytotoxic activities of selected metabolites have been explored. The chemistry data was reviewed in an ecological context.

Louise Forster



The lecture tour provided an excellent opportunity to gauge the skill sets, educational climate and research opportunity at the various chemistry centres that I visited; it is gratifying to record that the smaller centres that I visited were visibly dynamic and moving ahead, while in contrast two of the larger university departments surprised me with a small participation for the lecture. A vibrant seminar program across the entire discipline of chemistry is an important quality measure, not just of scholarship, but also of the academic community within an individual institution.

I have much enjoyed the privilege of travelling around Australia and New Zealand describing our recent marine natural products chemistry research to these audiences. Memories of the warm welcomes, excellent research discussions, and hospitality will remain with me long after the frequent and mostly unremarkable episodes of air travel linked to the lecture tour have been forgotten.

I thank Alan Bond and the members of RSC Australasian Section for honouring me with this prestigious lectureship. Thanks are due also to the Royal Society of Chemistry for

generously providing the funding for this lectureship. Finally, I would like to congratulate the 2019 RSC lecturer, Professor Keith Gibson from the University of Otago, and to wish him well in his travels later this year.

Mary Garson FRACI CChem FRSC AM is a professor of chemistry at the University of Queensland, Brisbane.

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Top stories from the periodic table

Storytelling brings people closer together. Conceived by the RACI in recognition of the International Year of the Periodic Table, Stories from the Periodic Table collects, publishes and celebrates the personal connections we have to the periodic table and its elements. We'll share some of the best stories over the next few issues.

Antimony

BY **REBEKAH DUFFIN**

When most scientists think of antimony, they probably think in terms of 'that toxic metalloid'. For me, that's not the case; for me, antimony is an element of surprising medical relevance.

I was first tasked in my early studies with antimony's more popular older sibling, bismuth, but after many trials and many lacklustre experiments I came upon some research into antimony as a medicinal complex. I was intrigued by this research; I had always thought antimony to be the big bad toxic element of group 15, along with the closely related arsenic (turns out oxidation state really matters here!). After synthesis and characterisation, I compared these antimony compounds to my bismuth analogues and was pleasantly surprised to find them not only more selective in their biological activity, but inherently more stable too. I was confused; everything I had previously thought about group 15 was turned upside down: bismuth is not always the 'green' 'non-toxic' metal I thought it was – no, bismuth in this case was a cold hard killer! Antimony, however, exhibited excellent selectivity, solubility and stability, three major constituents of an effective antimicrobial. Not only was it the inherently better choice in my biological research, it also produced the most beautiful, yet simple, crystal structures, something as an inorganic chemist I was ecstatic to obtain.

The more I delved into the world of antimonials, the more I found out about the misunderstood medicinal. Antimony has been used medically for many years; it constitutes the front-line treatment for one of the most neglected, yet somewhat unheard of, tropical diseases on our planet, that being leishmania. Sure, these treatments aren't as easily obtained as pepto-bismol, and their side-effects do range from mild to severe, but they are the most efficient and cost-effective treatments we have to control this devastating illness. My research has turned to focus then on synthesising antimonials that have less severe toxic effects, with increased stability and lipophilicity.

I love what I do, and I love the elements I use. Antimony complexes are a joy to make and characterise, and when they exhibit selectivity activity to the parasite it becomes a bonus, it feels as if this element is worth more than what popular media would portray it to be. To me, antimony is a misjudged



Anita Wanless

element, hidden in the shadow of the more popular bismuth. Antimony is the unsung hero of group 15; antimony is my element.

Rebekah (Bekka) Duffin's MRACI work involves the synthesis and characterisation of group 13 and 15 organometallic complexes. Her skills in synthetic chemistry are complemented by her cell cultivation and handling abilities, used to test the biological activity of her compounds. As a teaching associate for undergraduate chemistry at Monash University, she is also experienced at wrangling more complex biological organisms, aiming to educate and guide the next generation of young chemists into their future careers.

New Periodic Table on Show available

In celebration of the International Year of the Periodic Table in 2019, we are pleased to launch the latest Periodic Table on Show. With new artists' impression artwork completed for elements 112–118 by printmakers Linda Abblitt (113, 115, 117) and Tina Curtis (114, 116, 118), the Periodic Table on Show is now up to date.

RACI Periodic Table on Show posters are now available to purchase online for \$15 plus postage (racichemedcentral.com.au) or discover the science and artists' descriptions at raci.org.au/IYPT.

I married a molecule from outer space

BY **MICHAEL P. HENRY**

'As far back as I can remember', she (Oxygen) began, 'I've been pushed around. First it was that supernova in galaxy DGSAT 1 six billion years ago. I can tell you, I was nearly blinded by all that light. And the heat! Thank God it was a dry heat! I saw strange, blundering, atom-looking things and always enormous clouds of Hydrogens darting about en masse and giving me hay fever.

'In those days I did prefer keeping to myself. It was lonely but I didn't like the idea of sharing my electrons with another Oxygen or two.

'I decided to move to that brand-new planet Earth where I could at least rest on the ground instead of flying around in space. Having a vacuum underneath you twenty-four hours a day gets a bit old after a while.

'Then one day my whole life changed. I fell in love. I found the molecule of my dreams. He was actually a rather tiny pair of Hydrogens, with the cutest electrons I had ever seen.

We had a whirlwind courtship that lasted for about 10^{-6} seconds – too long really – I had wanted to get married sooner, but he said that we should wait. Time passed and on a beautiful spring day, about three billion years ago, we went to the local Rainey Nickel Orthodox Church, and were married in a quiet but extremely fast ceremony.

'Confidentially I must tell you now that my Hydrogen turned out to be an escaped molecule from the Sun. I hadn't an inkling before we were married and so it came as a shock:

"I weren't goin' da hang aroun' in da sun and be toined into a helium atom while I was sleepin'", he said. "So I caught da nootrino express leaving from da nex' sun storm and hightailed it over to oyt. Ta me, oyt was paradise – all doze nubile Ox'gens just driftin' aroun' wid no poipose to dare lives", he said one day after we were married.

'It then dawned on me that I was no longer sure of his fidelity and things became strained for a very, very long time.



'All this began three billion years ago – it seemed like just yesterday. I stayed married to Hydrogen for the first billion of those years. We then agreed to separate and became part of the big trend towards Organic Life. But Organic Life is not forever – five billion years tops, they say. That's when the Sun will expand and melt most things on Earth.

'I have seen a lot of changes in my life when you think about it. My favourite years were those I spent in the Pacific Ocean – there were 500 million of them. Hydrogen and I would spend our days lying on our backs looking at the sun, and just thinking of how lucky we were.

'Those certainly were the good times.'

Despite his best attempts to work in fields with no practical application whatsoever, most of **Mike Henry's** MRACI CChem research since 1962 led to some use being found for his work. From a PhD in physical/organic chemistry, teaching experience including biological and environmental chemistry, and research and development experience in analytical chemistry, his career has touched on most chemical disciplines. Mike refused paid work in 2012 and now tries to write.

Do you have a story connected to a certain element?

Whether it's from your work, studies or everyday life, the RACI wants to hear your personal connection to this element.

Over the course of the **International Year of the Periodic Table** in 2019, the RACI is publishing **Stories from the Periodic Table** on the RACI website and social media to highlight the personal connections that people have to science, and to chemistry.

Submissions from residents in Australia or New Zealand will be entered into a competition for the chance to meet and mingle with the leadership in Australian chemistry at the RACI National Awards Dinner in November 2019. The winners will also have their stories and/or biographies published in *Chemistry in Australia* and will each receive a copy of *A Century of Bonds*.

Submissions in text (up to 500 words) or video (up to 4 minutes) will be accepted and are to be sent to communications@raci.org.au.

For full competition details and terms & conditions visit <http://bit.ly/RACIStories>

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Simulating drug transport in cells

BY JESS FAGAN

Megan O'Mara is an associate professor with the Research School of Chemistry at the Australian National University. Her work is focused on computer modelling of cells within the body and how they function in health and disease. These computer simulations are important for understanding how the human body works and crucial for aiding the development of drugs and chemotherapy. Associate Professor O'Mara has answered some of our questions to give us a better understanding about what computational chemistry is and how it can help people.

What are you working on at the moment?

My group does a lot of different things. One of our main areas of focus is to work out how drugs and other molecules are transported into and out of the cell. We look at a range of proteins called multidrug transporters and we try to understand how they work.

We're involved in experimental collaborations looking at antibiotic resistance, and chemotherapy resistance in cancers. We're also collaborating with other groups to try and develop polymers that can replicate drugs or that can be used to bind RNA to bring that into the cell for gene therapy.

We're doing all of this from a computational background, so we do computer simulations that will then allow us to finesse the design of these things. If we know from computer simulations how a particular drug binds to a protein, perhaps we can design a more effective drug. This can cut down on the amount of experimental time that you need to actually develop an antibiotic or a chemotherapy.

And this is an area that's rapidly evolving?

Yes, particularly in the last five years. Graphics processing units (GPU) really started taking off around 10 years ago, with people using GPU computers for gaming. Since then, researchers have started realising that you can do a lot of simulations on GPU machines, so all of my students have access to top-end gaming machines. We're also very heavy users of the supercomputer. Developments such as GPU computing and the new

supercomputer that's going in at National Computational Infrastructure Australia provide enormous advances in what we can do. They allow us to simulate a much larger piece of the cell for a much longer time, which in turn gives us much more information about how the cell acts at molecular level. It's a rapidly growing area of chemistry and there's a lot that's been happening.

In fact, the Nobel Prize in Chemistry in 2013 was awarded for these multi-scale simulation methods, which is what my work is based on.

Breakthroughs in this field can obviously make a huge difference to people's lives.

Definitely! I'm part of a collaborative team that is working on developing drugs for the treatment of neuropathic pain. It is a bit like a phantom pain, or a persistent chronic pain where you become so sensitised to light touches that you feel them as extreme pain. This is a real problem, because so many people suffer from chronic pain and the only really good treatments at the moment are opioids, which obviously have some negative side effects such as addiction.

So, what we're doing is collaborating with a medicinal chemist, pharmacology experts and people who do animal models. We kind of thought 'How do we fit into all of this?' But we've been able to tell them the chemical basis for why some drugs work and some don't, and then use that information to design better inhibitors of these proteins that will impede pain.

It's really exciting to see how this all fits together and how our simulations can explain some of the experimental results, and in turn, the experiments give a real-world context to the simulations. It's really about how we can use this research to put all the pieces together.

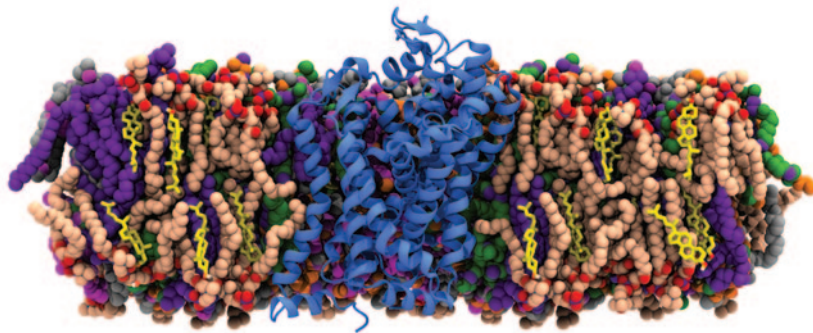
How big is your team?

I've got one postdoc and three graduate students, with a couple more coming this semester, so that's really exciting. There's always a lot of projects on the go, some people will be working on two projects at the same time, so one will be a small project and another will be a big long-term project.

Because there's not all that many people in Australia who do computational simulations, experimental groups are often asking us if we'd like to collaborate on different projects.

Collaboration seems quite key to your work.

Yes. There are some people who work in hard-core methods development and they don't seem to need so many collaborators, but I'm really interested in the biological and medical applications of a lot of these problems, for example how it fits into the context of the human body. In order to accomplish that, you can't just do it on a computer by yourself, it's really good to have a range of collaborators.



Simulating the chemistry of nerve signalling. To propagate a signal to the brain, adjacent nerve cells connect each other via a synapse. Here, neurotransmitters are released from the first nerve cell and into the synapse, initiating the signal in the second nerve cell. The GlyT2 neurotransmitter transporter (blue ribbons) is embedded in the nerve cell membrane. GlyT2 removes glycine from the synapse and recycles it back into the nerve cell. The cell membrane of the nerve cell contains many different species of phospholipids (beige, purple, green and grey space-fill) as well as cholesterol (yellow sticks). For clarity, the water and ions bathing the nerve cell membrane are hidden.


Does your interest in this field of science go way back to high school, or earlier?

I never really knew what I wanted to do, so it's not as though as a teenager I said, 'I want to do computer simulations of drug transport'. I knew I was interested in how the body worked, but I was also interested in physics and chemistry and I didn't really see myself as a medical doctor such as a GP.

Which shows there are a myriad of other options if you have an interest in science in general ...

Exactly, there are so many multidisciplinary approaches available these days. A lot of people think, 'OK, there's medicine and then there's physics, or chemistry, where you have organic or inorganic and it's very lab focused'. People don't realise that chemistry has evolved now – trying to understand the chemical basis of how the human body works is actually one of the most exciting areas of chemistry I can think of. For example, trying to work out how we can get cancer cells to respond better to chemotherapies, which has led to the advent of immunotherapy in cancer treatment – these are things we couldn't do without chemistry.

Jess Fagan is a Communications Officer at the Australian National University. She joined the team at ANU in 2018 after time spent working in journalism in regional New South Wales and Sydney.



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Beyond chemistry: Prions

Most people trained in the sciences have a thirst for new knowledge – call it ‘fundamental curiosity’. My own background led me in many directions, but perhaps the greatest driver, after I became a ‘specialist’, was the embarrassment when asked by a layperson ‘What do you do?’. My answer of ‘I research’ or ‘I teach’ never seemed to be acceptable, and so for years I used the words ‘I’m a nuclear magnetic resonance (NMR) spectroscopist’. Many a doubtful look led me to realise that I was not ‘communicating’, a fault that I urge most practising scientists to examine of themselves.

Over time, my group was involved in synthesising and examining a diverse range of fundamental chemical structures and conformations, first of scientifically significant hydrocarbons, then of the molecules of life, of stereochemistry in analgesic drugs and related compounds, of natural products (some noxious), selected complex carbocations, small proteins, and the chemistry of living cells that metabolise nutrients – all ultimately using NMR spectroscopy to probe structure, often correlated with theories.

Later I published a series of monographs and short reviews on subjects such as lasers, membranes, superconductivity (part of my speciality), biomaterials, electrode materials, and sensors. All had a chemical basis, but with a common theme – medical applications.

Up to a century ago, the major causes of death in the world were infectious diseases caused by bacteria, viruses and parasites. Christopher Dobson (Cambridge) notes: ‘the cause and more effective means of treatment and prevention of such diseases were dramatic following the development of vaccines and antibiotics’. However, ‘the decline in the number of infectious diseases has itself led to major changes in the human condition, not least as a result of greatly increased life spans, and a large increase in cases of non-infectious conditions, notably cancer and cardiovascular diseases’.

The discovery of prions introduced another dimension characterised by fatal neurodegenerative diseases such as scrapie (in sheep and goats), kuru in some hill tribes of Papua New Guinea, BSE (bovine spongiform encephalopathy) in cattle,

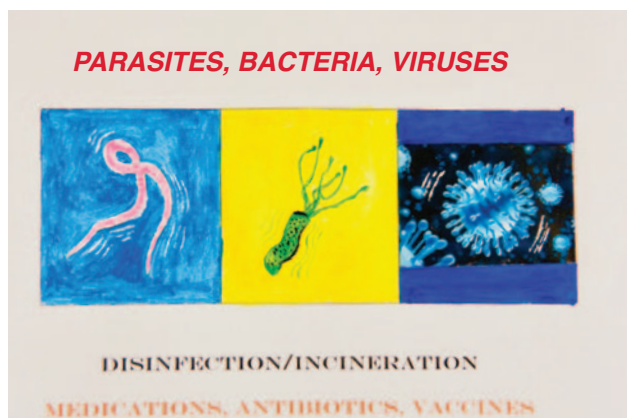
chronic wasting disease (CWS) in deer, elk and moose, and Creutzfeldt–Jacob disease (CJD) in humans. In 1982, Nobel Laureate Professor Stanley B. Prusiner introduced the term ‘prion’ to describe a relatively small protein comprising about 250 amino acid residues. Subsequently, good and bad (‘rogue’) prions were identified – the former appear to perform valuable and specific biological functions, but others undergo a substantial conformational change (from a largely α -helical to a β -sheet structure) and in so doing become the self-replicating ‘rogue’ proteins, which produce fatal consequences in their victims. In addition, many different strains of prions have been identified.

In common with scrapie, kuru, BSE, CWS and CJD, many of the maladies associated with ageing such as Alzheimer’s, Parkinson’s, and Huntington’s disease, even motor neurone disease and type-2 diabetes, result in formation of the ‘spongiform’ character of brain tissue, along with ‘proteinaceous deposits’ in the tissue of all sufferers. There appears to be growing evidence that all these diseases may be associated with a ‘rogue’ prion.

I have educated myself about prions mainly through reading and watching video lectures. I was initially fortunate enough to see the work of Dr Michael Alpers, an Australian medical officer in Papua New Guinea, and realised the history of this topic spans over 60 years (the records on scrapie go back to 1755). The most disturbing finding is that prions survive techniques to eliminate them, including disinfection and incineration; and, dangerously for some parts of the animal kingdom, they survive long term in soils where migrating herds roam. The story of the BSE outbreak in the UK also led to recognition that the production of feed pellets from various protein sources (including infected animals) might have exacerbated the BSE problem. This view was somewhat upheld when those same ‘food pellets’ inadvertently caused fatalities in animals at London Zoo.

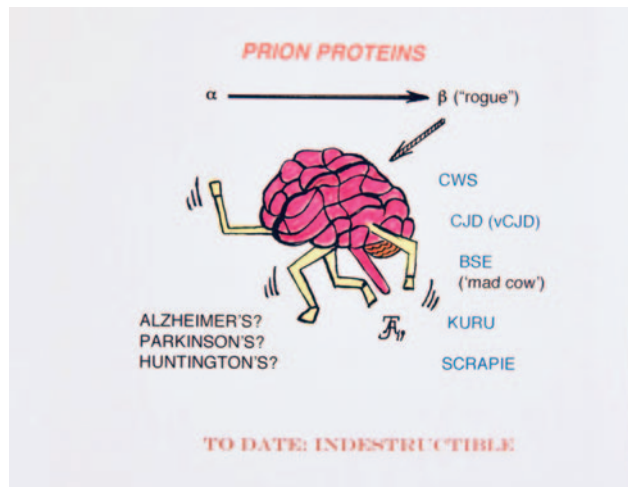
While the structures of many prions have been determined, the mechanism by which they undergo conformation change and self-replication remains uncertain. Resolution of this mechanism may provide the avenue for effective means of treatment and prevention of prion diseases.

Many nations have established specialist research centres focused on prion research. In Australia, Professor Colin L. Masters (University of Melbourne and Florey Institute) characterised the amyloid protein that forms the cerebral plaques observed in Alzheimer’s disease (1985). (Such amyloid proteins have



Up to a century ago, the major causes of death in the world were infectious diseases caused by bacteria, viruses and parasites.

... prions survive techniques to eliminate them, including disinfection and incineration; and ... they survive long term in soils where migrating herds roam.



subsequently been identified in most prion-diseased tissue.) Masters established the Australian National Creutzfeldt–Jakob Disease Registry in October 1993. Subsequently, in 1994, the CJD Support Group Network Pty Ltd (CJDSGN) was established in Sydney. CJDSGN is a non-profit company established to receive grants and donations to fund the work of supporting all Australians affected by CJD or other prion diseases. It is funded by the Commonwealth Department of Health and offers assistance to people 'at increased risk of developing CJD' by promoting an environment in healthcare settings where patients feel comfortable and confident of receiving equity of care when disclosing their 'at risk' status. The CJDSGN provides information, support and assistance to families who are caring for or are coming to terms with the loss of a loved one to CJD.

What is the impact of this 'new' knowledge on my areas of interest, or in applications? I wish I were an active researcher, but alas retirement calls us all eventually. If there are others like me with an interest in prions, then I would be interested to discuss this topic on social media, as long as we aim to steer clear of sensationalism.

My intention is to keep up with the literature, notably reviewing the findings of the main players in the field, not least which is Stanley B. Prusiner (see p. 34), who currently edits some of the major international reviews on the subject.

Alan J. Jones **FRACI CChem**

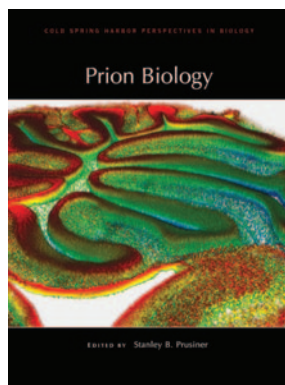
This column features the learning of chemical professionals about a subject outside their area of expertise. Readers interested to contribute are invited to contact the Editor (wools@westnet.com.au) for further information.



Biljana Cvetanovic

Alan's learning list

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Prion biology

Prusiner S.B. (Ed.), Cold Spring Harbor Laboratory Press, 2017, hardback, ISBN 9781621820932, 456 pp., \$US94.50 (on sale)

A significant and exciting recent discovery in chemical sciences is that of the structure of prion proteins, the causal agent in an array of neurological disorders in many animal species, including humans.

My curiosity with prions was triggered in about 2010 by an SBS documentary 'Kuru: the science and the sorcery', which featured the

work of Michael Alpers, an Australian medical officer, who worked with an isolated hill tribe in Papua New Guinea from 1961. Alpers was drawn by the high death rate, particularly among the women and children (up to 200 a year), from a debilitating syndrome that resulted in total paralysis. Alpers observed that kuru arose from a form of cannibalism whereby dead tribal members were honoured through cooking for consumption. The documentary identified analogies with what later became commonly known as 'mad cow disease' in the UK, and at the time the much less documented syndrome in humans, Creutzfeldt–Jacob disease.

Stanley Prusiner (University of San Francisco) first determined a single host-encoded prion protein named as PrP, in 1982 (independently by David Bolton). The mRNA encoding PrP was identified in uninfected cells and mice; PrP in normal cells was also found to be susceptible to proteolysis and was denoted as PrP^C for cellular, in contrast to the protease-resistant and infective form designated PrP^{Sc} for scrapie, where scrapie is the prion disease found in sheep. PrP comprises around 250 amino acids.

In recent years, Prusiner has edited a series of collective international reviews on new developments in prion research, including in 2017 two large volumes, *Prion biology* and *Prion diseases*. The former comprises 22 chapters searched by the reviewer to identify more recent studies of the molecular structure of prions. A number of NMR and crystallographic studies have been used to illuminate the PrP structure, including a solution study by Wüthrich and Riek. In 2000, a model of human PrP^C was obtained that showed some small differences in flexibility compared with mouse and hamster strains. FTIR spectroscopy provided the first evidence of the predominantly β -sheet conformation of the proteolysed form PrP^{Sc}.

A view of the mechanism of the conformational change and subsequent self-propagation is offered in an enlightening chapter by Rodriguez, Jiang and Eisenberg, who suggest three molecular events that appear to influence the conversion of PrP^C to PrP^{Sc}. These are the unfolding of PrP^C, nucleation of PrP^{Sc} and self-propagation of PrP^{Sc}. They postulate that infectivity and species specificity may be tied to the growth of amyloid fibrils.

The chapter by Riek provides some background on amyloid fibrils, a term originating in 1854 although their structures were first described by Astbury (1935) as a cross β -sheet (XRD pattern of poached stretched egg white). In 1983, Prusiner noted that 'some prions' can polymerise into amyloid fibrils. Using solid-state

NMR studies of the amyloid fibrils formed from the prion HET-s (218–289) derived from the fungus *Podospora anserina*, Riek observed the 3D structure, including the overall β -sheet characteristic fold. The question posed is can amyloid formation be a template for self-propagation and the β -sheet conformational change in prions? Some experts suggest not because many amyloids are not pathogenic, not all prions form amyloid fibrils, and not all amyloids are prions.

The chapter by Rodriguez et al. also notes the increasing evidence that neurotoxic prions readily form oligomers (determined from ionising radiation size-data), indicating that the PrP^{Sc} prion is a trimer. More recent studies (Mirbaha 2017) of the PSP tau-prion support a trimeric oligomer as the neurotoxic form. This work has led Prusiner to suggest that prion conformational change assembly into larger polymers (such as amyloid fibrils) could be a mechanism to minimise neurotoxicity. However, the structure and formation of the infective and toxic PrP^{Sc} remain ill-defined.

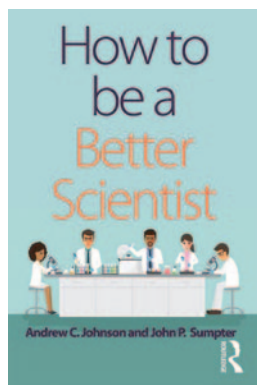
The aggregated state of biologically active prion proteins is emphasised in two chapters by Rayman and Kandel. They note an increasing number of 'prion-like' proteins that perform a wide range of biologically meaningful roles. A compelling example of a functional prion-like protein in mammals is the mitochondrial antiviral signalling protein, 'in some form of aggregated state'. The Rayman group has identified prion-like proteins in the central nervous system, in particular 'CFEB'. They examined how the conversion from a soluble prion-like conformation regulates protein synthesis at the synapse – aggregation of the prion-like protein appears critical. Subsequently, they identified a second functional prion-like protein in the brain, 'TIA-1'. It is an RNA binding protein and its aggregation is described as 'highly regulated'.

Chapters by Wickner; Riek and Saupe; and Chernova, Wilkinson and Chernoff identify prions in several fungal and plant species. Wickner has suggested the study of yeast prions could be important because there exists a vast array of genetic tools that can be applied to yeasts. He emphasises that the central issue in prion research is how the conformational templating occurs.

The chapter reviews presented in *Prion biology* suggest only limited progress has been made in defining how the 'causal agent' operates and indeed self-propagates in the disease-causing form. However, I contend the collective volume is highly informative and points to future directions in which chemists can be expected to play an integral role in the identification of structure and function of prions, as well as the development of therapeutic approaches to inhibiting and/or controlling prion diseases.

A report in *Chemical and Engineering News* (November 2018) praises advances by Rodriguez using a relatively new tool to investigate proteins that 'clump together'. Microelectron diffraction (microED) yields high-resolution structural data from clumped proteins. Rodriguez first published the microED structure of α -synuclein, a protein that produces rope-like fibrils in the brains of people with Parkinson's disease. He is currently applying this technique to study aggregates and amyloids associated with other prion diseases (see *Nature*, 15 January 2018).

Dr Alan J. Jones FRACI CChem



How to be a better scientist

Johnson A.C., Sumpter J.P., CRC Press, 2018, soft cover ISBN 781138731295, 248 pp., \$38

How to be a better scientist offers up a great deal of information in one small and punchy volume. Two university professors from the United Kingdom have joined forces to offer advice about creating 'good science' – anticipating the reader's successful and rewarding scientific career. The book's topics

offer a progression (presumably as a scientist advances in their career) beginning with the hypothesis, moving through to experimental design and finally to science management. While the book is relevant to anyone in science, its focus revolves around the research process and the university environment.

The appeal of *How to be a better scientist* lies not only with the wide range of scientific topics covered, but also in its discussion of the potential challenges scientists may face throughout their careers. Of the themes covered in the book, more than half are related to personal situations or character development – 'lack of confidence', 'how to cope with rejection' or 'when things are not going well'. The honesty and humour are refreshing, with both authors serving up and dissecting how they overcame hurdles that many scientists may face.

Communication is also a big emphasis of the book, with the authors' acknowledgement that many scientific topics are narrow and significant skill is required to engage effectively with wider audiences. Presentations, proposals and scientific papers are all discussed as opportunities to communicate and to promote the details of ongoing study and research. The advice given to a reader preparing for a presentation is concise but significant: 'tell people only what they need and want to know' and 'your job is to ensure everyone can follow your talk, no matter what their background'.

One of the few drawbacks of *How to be a better scientist* is the possibility the reader may feel rushed by the authors' very succinct style. The wide range of topics and the sheer amount of information leaves one feeling that perhaps the book should be four times the length to proceed at a reasonable pace. Despite this, *How to be a better scientist* is comprehensive, well structured and well worth a read for anyone aspiring to a scientific career in a research or a university environment.

Samantha Profke MRACI

For science, king and country. The life and legacy of Henry Moseley

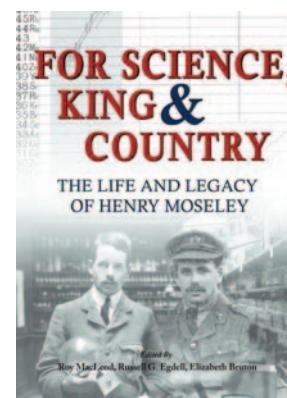
Macleod R., Edgell R.G., Bruton E. (Eds), Unicorn Publishing Group, 2018, ISBN 9781910500712, 256 pp., \$61

The life and work of Henry Gwyn Jeffreys Moseley were commemorated by an exhibition at the History of Science Museum at Oxford University between May 2015 and February 2016. Under the thematic title 'Dear Harry: Henry Moseley, a scientist lost to war', the exhibitors drew on his mother's diaries and other information from the family, a 1974 biography, and recent archival research. They also displayed some fragments of Moseley's equipment recovered from laboratories and historical collections. The exhibitors also took the opportunity, as did other contributors to *For science, king and country*, to re-examine a century-old proposal that Moseley's scientific discoveries would have resulted in the award of a Nobel Prize had he not been killed by a Turkish bullet.

In his chapter 'Henry Moseley and the politics of Nobel excellence', science historian Robert Marc Friedman writes that despite Moseley being nominated for chemistry and physics prizes in 1915, the Swedish academy selection committees were considering a range of other candidates in these fields. The 1915 physics prize went to the Braggs, and organic chemist Richard Willstätter was the chemistry laureate. The Swedish academy electors were desperate not to be seen to be taking sides in the European war, so the 1916 prizes were held over, as was chemistry in 1917. British physicist Charles Glover Barkla, whose work on X-rays had preceded Moseley's, was awarded the Nobel Prize in Physics for 1917, an award that some felt could have been a proxy or belated recognition of Moseley's contributions.

In 11 chapters, the editors and the expert team they assembled describe Moseley's childhood and education, his scientific work and that of others, his military career and much-lamented death, subsequent developments in the field he helped pioneer (including the discovery of new elements), and the museum context for the exhibition. An unusual feature of the collection is that it includes a chapter by John L. Heilbron, author of the 1974 biography, now taking up his pen to reconsider his views in the light of a further 40 years of scholarship.

Henry Moseley (1887–1915) was the son of Henry Ettridge Moseley, a noted naturalist, FRS and Oxford professor of human and comparative anatomy, and his wife Amabel, the fourth daughter of John Gwynn Jeffreys FRS, a qualified lawyer and self-taught conchologist and mollusc expert. Young Moseley went up from Eton in 1906 to read physics at Trinity College, Oxford, where he graduated in 1910 with second class honours. He immediately accepted a laboratory demonstrator position at



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Manchester, joining Rutherford's research group to work on radioactivity. In 1912, Moseley commenced work on X-ray diffraction but when the Bragg's published their definitive work in this field, Moseley moved on to X-ray spectroscopy, having in mind the Bohr–Rutherford model of the atom with a positive charge at its centre. Through studies on elements 20–30, published in December 1913, Moseley found that the square root of the K_{α} ray frequency was proportional to atomic number minus 1. This is often known as Moseley's law.

Moseley's work placed the elements in order of atomic number, now based on the number of protons in the nuclei, rather than the atomic weights that took into account protons and neutrons. It's all so obvious now ... but it wasn't back then. Russell Edgell, emeritus professor of inorganic chemistry at Oxford, as well as his chapter on the discovery of new elements, has contributed an appendix in which he explains how we can understand Moseley's work. 'Although the Bohr model is now mainly of historical interest', he writes, it still provides the basis of modern teaching in chemistry, and undergraduates are encouraged to discuss atomic energy levels in terms of it. Quantum mechanical explanations are needed for a full understanding of X-ray emissions.

Moseley travelled to Australia in 1914 to attend a meeting of the British Association for the Advancement of Science (BAAS), and he took his mother with him.

During the Melbourne sessions of the BAAS, Moseley took part in a discussion of the structures of atoms and molecules at which Rutherford presented the physicists' picture of the atom, while Henry Armstrong spoke for the chemists, who apparently remained to be convinced. 'Although chemists must admire as well as welcome the bold attempt physicists are making to unravel the structure of the atom', Armstrong said, 'they cannot yet with advantage discuss the conclusions arrived at by their colleagues; the arguments are so novel and daring ...'. Moseley showed that his measurements of the frequency of an X-ray line (γ) belonging to one of the series could be described by the equation $\gamma_{1/2} = K(N - B)$, where K and B are constants, and N is an integer 'increasing by a unit as we pass from element to element up the periodic table'. When the meeting moved to Sydney, Moseley gave a fuller account of his work on the high-frequency spectra of the elements.

Moseley comes across as highly focused, driven even, a man of strong opinions with a sense of mission and disdain for lesser beings such as the undergraduates he taught at Manchester. Family correspondence reveals 'more than whispers of snobbishness and arrogance' according to Heilbron in his chapter. His single-mindedness was not confined to science, nor to X-ray spectroscopy in particular: Moseley spent the homeward voyages practising semaphore signalling in preparation for his military career as a signals officer. And he loved his mother. Could he have been just a little way along the autism spectrum?

Ian D. Rae FRACI CChem

Help! Am I infringing someone's patent?

Jacqueline Warner, Special Counsel, FB Rice



You receive a letter from a competitor telling you to discontinue marketing your formulation product because it infringes their patent. What do you do?

These types of letters are often referred to as 'cease and desist' or 'letters of demand' and should not be ignored. The purpose of such a letter is typically to alert you to the existence of a patent and to

give you the opportunity to stop any activity that may result in infringement of that patent as defined by subsection 117(1) of the *Patents Act 1990*.

'Cease and desist' letter

Despite its name, the 'cease and desist' letter should merely notify you of the existence of a patent and identify the potentially infringing product. If the letter contains unjustified threats of infringement, relief may be granted upon application to a court. A threat arises where the language of the letter conveys the intention to bring about infringement proceedings and an unjustified threat includes a groundless threat.

Negative consequences

If you continue to market your product in Australia and the patentee believes you are infringing its Australian patent, the patentee could:

1. seek an interlocutory injunction from a court directing you to refrain from carrying out the potentially infringing act until the matter has been determined by a court; and/or
2. instigate court proceedings for patent infringement. Whilst it is possible to file a counter claim for revocation of the patent based on specific grounds, such as lack of novelty and lack of inventive step, this process is extremely costly.

If patent infringement is found, then a court may grant relief to the patentee in the form of an injunction and damages or an account of profits.

What you should do

If you receive a 'cease and desist' letter, you should contact a patent attorney for immediate advice. The negative consequence of not investigating the patent identified to you could result in a costly law suit and loss of business.

As a first step, your patent attorney will require a detailed description of the components of your formulation product and when your use/marketing commenced. Details of how the formulation is made and what it is used for may also be required. They will check the status of the patent number provided to see if it is a granted patent and in force. The priority date will also be noted for a possible 'prior use' defense to infringement should your use have commenced before the priority date.

Your patent attorney will provide an opinion as to whether there is a risk that the marketing of your formulation product will infringe the identified Australian patent.

Infringement risk

If your product possesses all the essential features of one or more claims in the patent then there will be an infringement risk, and you will be recommended to:

1. withdraw your product from the market to avoid being sued for infringement; or
2. approach the patentee with the prospect of negotiating and obtaining a license to enable marketing of the product.

No infringement risk

If your formulation product is not found to infringe any of the patent claims, then your patent attorney will most likely advise that you are free to use the product in Australia with no risk of infringing the patent.

In conclusion, if you receive a 'cease and desist' type letter don't ignore it and don't panic. Act quickly and approach a patent attorney for advice.

For more information, email jwarner@fbrice.com.au.

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The IP Navigators

Volumetric titrations in the modern curriculum

Volumetric titrations have been used in chemistry since the 1790s, when the first burette (similar to a graduated cylinder) was developed by Descroizilles, with the first true burette being developed by Henry in 1845. Titrations measure the volume of a liquid phase reagent that is required to completely and exactly react with a second reagent. The amount of one reagent is known, enabling the determination of the (unknown) amount of the second reagent. Volumetric titrations have been recognised as a quantitative analytical method since at least Mohr's classic *Textbook of analytical chemistry titration methods* in the 1850s. Even so, a hundred years ago, while titrations were being more common in the chemistry syllabus, most volumetric analyses were still based on the gravimetric methods, based on measurements of mass.

Since then, volumetric titrations have become a standard part of the curriculum, but students often have difficulty understanding their intricacies. In addition to the manipulative skills of using volumetric glassware, other learning outcomes

include being able to read an upside-down burette scale correctly, choose an appropriate indicator, identify the endpoint, and do the titration calculations. These calculations are repetitive applications of the amount–volume–concentration relationship, but involve numbers of differing orders of magnitude, unit conversions, using the correct volume value at the appropriate calculation step, and many other details. Novices are usually presented with a long list of detailed instructions. It is unsurprising that titrations are often perceived to be recipe-driven, boring and mindless activities that do not engage students. 'The sheer pointlessness of it – and the repetition – turned me right off chemistry' is a common complaint from students.

The point at which reaction is complete can also be detected using pH, potentiometric, amperometric, coulometric and photovoltaic (spectrometric) means. The electrical output from these detection methods, in combination with a motorised syringe pump and electronic controls, is the basis of automated titrations. The Australian Curriculum requires students to know that 'techniques such as auto titration ... are used to measure the chemical composition ...'. Why should titrations be retained in the modern syllabus, when there are more advanced quantitative

analytical methods available? At some universities, there has been a tendency to replace titrations and other classical manual techniques with instrumental methods.

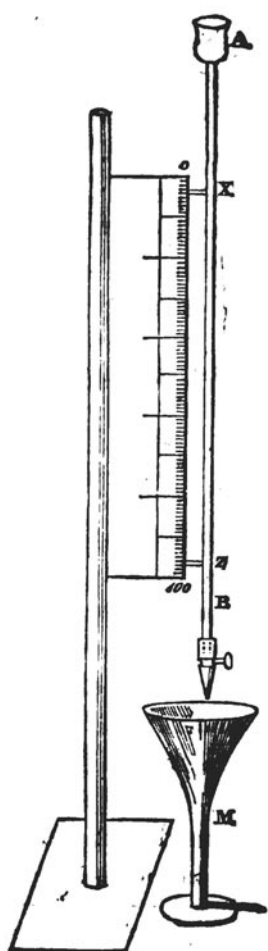
The primary advantages of titrations are that they are relatively simple and use equipment that is much cheaper than more advanced quantitative methods. While automated titrations are being used in many industrial contexts, manual titrations are still widely used in industry and research. For example, the Rymill winery in the Coonawarra region of South Australia uses auto titrations for total acidity and manual titrations for SO_2 , and proudly displays its analysis laboratory within its visitors' centre.

Titrations can be used for several educational outcomes. The obvious outcomes are to visualise when a reaction is complete, and to provide student data to determine the concentration of a solution. Less obvious outcomes are to correctly use glassware; for example, to adjust clamps to fingertight-ness, which will be a useful skill for clamping glassware in distillation, reflux, filtration and so on.

Vygotsky argued the zone of proximal development (ZPD) is that area of learning that students cannot complete by themselves, but can be achieved with guidance or assistance. Activities that lie within the ZPD present doable challenges, while activities that lie beyond the ZPD result in frustration, with loss of motivation and engagement. The problem with titrations is not the lack of relevance, but that they are usually presented as an activity that is beyond the ZPD of many students.

The solution is not to remove titrations from the syllabus, but to adjust the activity so that it lies within the ZPD. For example, as part of the ASELL for Schools project (blogs.deakin.edu.au/asell-for-schools-vic), we developed a fruit-juice titration activity for year 10, set in the context of determining which fruit juice might be the best in lowering some risk factors for kidney stones. Students compare the citric acid content of different fruit juices. The titration volume for total acid content is used as a proxy measure of citric acid concentration, without the need for any calculations. Typical student results for the comparison of fresh organic fruit juice and reconstituted fruit juice are so strikingly different (average titration volumes of 17.60 and 14.74 mL, respectively) that even incorrect rinsing of the glassware and other not-quite-right procedural steps will not affect the fundamental result.

Classical methods, such as titrations, can offer rich learning opportunities for students. When the desired learning outcomes are not achieved, we should think about adjusting the laboratory learning activity, instead of throwing the baby out with the bathwater.



Henry's 1845 burette (from Henry O., *Journale de Pharmacie et de Chimie*, 1845, vol. 7, pp. 214–22).



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Lightening the load on energy

I remember that as a first-year physics student in 1977 I completed an essay assignment on the hydrogen economy. I don't remember how this fitted in with the course content, but we students were made aware that oil was a finite resource and expected to run out soon, and that hydrogen was being touted as a useful alternative. Fast forward to 2019, and the use of hydrogen as an energy source is again being pursued. It seems that there is more enthusiasm for it now, especially as it holds great promise as a carbon-free energy source, and one approach to dealing with climate change.

And so it is that in mid-February 2019, a new process trial received environmental approvals to investigate the use of Victorian (Latrobe Valley) brown coal for hydrogen production. According to the proponent's website, brown coal will be heated to prepare synthesis gas, a mixture of carbon monoxide and hydrogen. (The Victorian Gas & Fuel Corporation attempted this approach in the 1950s as an alternative to manufacturing town gas from New South Wales black coal.) Once hydrogen is separated from the carbon monoxide, further hydrogen can be produced by the reaction of water with the carbon monoxide, via the water gas shift reaction. Carbon dioxide is the other product, and the proposal is that this would then be captured and dealt with by geosequestration.

The chemical reactions are well known, and geosequestration of carbon dioxide is not novel, either. The Norwegian oil and gas industry has been using it in the North Sea oil fields for decades, and it is also being applied in the North West Shelf gas fields. The Latrobe Valley is close to the Bass Strait oil and gas fields, which could be used for sequestration, although the carbon dioxide would still need to be piped a considerable distance, and access agreements negotiated with the operators of those fields. However, something in the EPA's press release announcing the environmental approvals caught my eye and made me think that there may be other wastes to be managed in full-scale production. The press release stated that up to 160 tonnes of brown coal will be used to produce three tonnes of hydrogen in the trial, along with 'small amounts of slag and char'.

Before natural gas was introduced in Australian cities in the late 1960s, the gas industry mainly relied on black coal for town gas production, which produced considerable amounts of slag, char and tarry wastes. These wastes found their way to many locations in the urban landscape as cheap filling, and the legacy is still with us today. The use of gasworks waste was so widespread that even now, 50 years after town gas was phased out in some cities, it is routine to analyse uncontrolled fill for the polycyclic aromatic hydrocarbons that were ubiquitous in gasworks waste. So, even if it could be expected that new processes of coal combustion/pyrolysis might generate less solid waste than in the past, it will be interesting to see what

Edal Anton Letterov/CC BY-SA 3.0



... up to 160 tonnes of brown coal will be used to produce three tonnes of hydrogen in the trial, along with 'small amounts of slag and char'.

the results of the hydrogen production trial tell us in terms of the amount of solid waste per kilojoule of contained energy in the hydrogen product.

This all made me think that, while CO₂ emissions in energy production are important, so too are the amounts of solid and other wastes produced. Coal-fired power stations are usually accompanied by large ash ponds, which grow over time, and which present their own environmental issues. For example, selenium in brown coal ash is an issue in the Latrobe Valley, but Australian black coal is known for its high energy and low ash content (hence the large export industry). Radioactive wastes from nuclear energy present a distinct set of issues, and I have written before about Australia adopting a product stewardship approach and taking back the radioactive wastes derived from its uranium exports. Even natural gas is not without its problems, with naturally occurring radioactive materials sometimes extracted in initial processing.

The more I thought about this, the more it became apparent that, while construction of any energy production facility will generate some wastes, the only energy sources that don't produce wastes (particularly solids) during operation are those that are now referred to as 'renewables': solar (photovoltaic), wind, hydroelectricity, geothermal and tidal. I didn't set out to make a point about renewables, but it is apparent that there is more to consider in the energy debate than just carbon dioxide emissions; other wastes and by-products are important too. Finally, my sense of irony kicked in when I realised that, in 1977, some saw hydrogen as the fuel of the future because we didn't have enough fossil fuels, whereas, now hydrogen is seen by some as the fuel of the future because we are too reliant on the combustion of fossil fuels.



Paul Moritz FRACI CChem CEnvP (Paul.Moritz@douglaspartners.com.au) is a Principal Contaminated Land Consultant with Douglas Partners, and an EPA-appointed Environmental Auditor in Victoria, New South Wales and the Northern Territory. Thanks to Duncan Seddon for initial thoughts and discussion.

Amber, not orange, wine

At a recent tasting class that I presented on natural, organic and biodynamic wines, I was asked if a follow-up class could be arranged on orange wines. The questioner was referring to the new wave, or hipster, white wines that have an orange colour, and not to an alcoholic beverage based on orange juice. When searching the web for ideas, the results frequently referred to sites for wines from the Orange Geographic Indication (GI) zone in New South Wales. Perhaps to limit marketing confusion, Wine Australia has ruled that 'orange' can only apply to wines from the Orange GI and has proposed 'amber' as a replacement term.

In conventional white wine production, the grape berries are crushed and pressed to release the juice. This juice may be clarified to remove pectic compounds before fermentation. The purpose of removing the skins and seeds before fermentation is to limit the concentration of phenolic compounds in the final wine, thereby giving a smoother, possibly silky, palate. In some cases, the white wine may be fined after fermentation to further soften the palate – this is a consumer-driven approach. Extensive contact with the skins is rare and would only take place prior to fermentation.

Amber wines also use white grapes, but the fermentation is performed on skins. This is sometimes referred to as skin-macerated winemaking. The crushed grapes, juice, skins and seeds are placed in a fermentation vessel and left for days, weeks or months, before removing and pressing, perhaps to barrel for further ageing. The final step is bottling, often without filtration. Fermentation can be performed in steel tanks, oak vessels or, traditionally, clay amphorae.

What to try

Tracking down amber wines can be a challenge because many are only available from the winery itself or through online retailers. Airlie Bank Gris fermented on skins and 2017 Cullen Amber Wine (Sauvignon Blanc based) are two good new world examples, while Brash Higgins Zibbibo 2018 (sometimes ZBO) and Ruggabellus Quomodo 2016 (Riesling-based) will give you plenty to think about. Finding Georgian wines is even more of a challenge, although I came across Qvevris Rkatsiteli and Qvevris Kisi on the Tamada website (bit.ly/2JFcQ6f).

Food pairing raises another interesting challenge. The lower fruit aroma and stronger palate structure with higher phenolic content in amber wines compared to conventional white wines means that careful matching of the wine's characters with those of the food is needed. Hugh Johnson, in his 2019 *Pocket wine book*, suggests to forget matching amber wine with scallops, but try with fatty food and spicy food. And 'they go with cheese better than most reds', he writes. It is a case of trial and learn. Recently, I served an amber wine at our family Friday evening 'fish and chip' meal: most found it too overbearing, but it was acceptable to me.

Extraction of phenolic compounds from the skins obviously enhances the concentration of these compounds in the finished wine. There is, unfortunately, a dearth of detailed chemical analysis on skin-macerated wines. One 2015 study from Croatia compared the effect of prolonged skin contact using Malvazija Istarska (local synonym for Malvasia grown on the Istrian coast) with a more conventional white wine production strategy. Although there are some limitations in the experimental design, the skin-contact wines with 21 days fermentation in oak barrels plus 100 days post-fermentation on skins in the same barrels had two to three times the total phenolic concentration of wines made without skin contact (*Food Technol. Biotechnol.* vol. 53(3), pp. 407–18).

The Croatian study also focused on colour intensity. The wine industry commonly uses the absorbance at 420 nanometres as a measure of the intensity of the colour of white wine and a higher value is assumed to be associated with increased browning. The skin-macerated wines had A_{420} values between 0.30 and 0.52, while those for the conventional production method ranged from 0.09 to 0.14. As phenolic compounds polymerise and/or undergo oxidation, the phenolic absorbance moves from the UV to the visible region, leading to an increase in colour. The respective ranges indicate the higher phenolic content of the skin-macerated wines that leads to the amber colour.

The high phenolic content of amber wines undoubtedly affects palate response. Descriptors include 'astringency', viscosity, bitterness and maybe oiliness – something of a surprise when first tasting these wines. A more detailed discussion of white wine taste, including wines with elevated phenolic concentration, but not amber wines as such, can be found in a 2017 publication by Gawel et al. (doi.org/10.1080/10408398.2017.1346584). Aroma descriptors include honeyed, jackfruit, brazil nut, bruised apple, wood varnish and sourdough, all reflecting maturation and/or oxidative development.

The origin of this winemaking style would appear to be in Georgia. The use of amphorae or qvevri, as the pottery or earthenware vessels are known, has long been practised in Georgia for both red and white wine. In 2013, this winemaking style was awarded world heritage status by UNESCO. The white wines may spend five to six months on skins in the amphorae, even longer than red wines, giving what Andrew Jefford calls 'wine's sixth genre ... from a location with an attested 8000-years history of wine creation' (bit.ly/2wlRsdK). So, 'orange may be the new black', but clearly 'amber is the new white'!



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istockphoto/BOLDG

A visit to Russia

In 1992, I attended a conference in Uppsala, Sweden, visited our children, both of whom were studying in England, and came home via Moscow to visit Igor Dolgy, the chemist I had befriended through the medium of philately. Igor and his wife, Marina (also a chemist), offered accommodation but the Russian government would not issue me a visa until I had (a) a formal invitation for a professional visit, and (b) a reservation in hotel chosen for me by the government agency, Intourist.

Igor, who owned a car – a Lada (aka Fiat 124) – met me at the airport and drove me to the hotel, where I checked in and then left to go to the Dolgys' apartment, which was near a Metro station a few kilometres east of the centre of the city. The family was able to use the car – when they could buy petrol, and I saw some very long lines at service stations – to travel outside Moscow. They parked their car outside their apartment block but they were always careful to bring the battery and the windscreen wipers inside to avoid theft.

Another indication that life in Moscow could be tough was their behaviour in the apartment. Once the lights were on, the blinds were always drawn so that people across the way in the next building could not peep in to see the Dolgys' possessions, which included some fine porcelain that Igor had collected in his travels. Igor didn't speak English but was fluent in German, having spent three months in 1974 in Göttingen, West Germany. My half of the conversation consisted of what I could remember from Science German classes (a requirement for the MSc degree when I graduated in the late 1950s). Marina had good English, and as we chatted on the way to the Metro one day, others heard us and joined in to practise their English. At least, that's the reason they gave, but Marina discouraged them and told me later that were likely to be informers. Soviet ways were dying only slowly in the new Russian Federation!

Marina had spent some time in Britain under a youth exchange scheme, but later completed her PhD and worked at the Nesmeyanov Institute of Element-organic Chemistry, where her research group was under great pressure to produce results of commercial significance. One challenge they faced was to do something with the waste yeast from the brewing of beer, a substantial industry in Russia. I mentioned the production of Vegemite from spent yeast and once I got home I sent some samples.

By 1986, Igor and Marina had saved enough to buy a 1200 m² plot in the country and started to build a summer house (dacha). Following a visit to the monastery town of Zagorsk, they took me to see the dacha, where we enjoyed a meal and picked wild strawberries in the woods. As we walked around the small village, Igor pointed out the dacha that had

been owned by the physicist Pyotr (Peter, as he was known in the west) Kapitsa. Kapitsa (1894–1984) worked with Rutherford for ten years at the University of Cambridge. In 1934, he returned to Russia on a visit, but once 'home' he was barred from returning to Britain. He was awarded the Nobel Prize in Physics in 1978 for his work in low-temperature physics, which included the discovery of superfluidity in liquid helium.

On that drive out of Moscow to Zagorsk and the dacha, I was trying to follow our journey on a map I had torn from an Australian magazine, but it didn't seem to correspond to the directions we took and the roads we drove on. Igor laughed when he saw it, and said that maps like that were deliberately distorted and provided by Soviet/Russian authorities to confuse the enemy. There was more along these lines, because the Dolgys had a telephone, and it rang occasionally, but there was no telephone book. If someone wanted you to call them, they would give you the number, I was told.



Composing this reminiscence, I couldn't find a photograph of Igor among the many I took in that brief visit to Moscow. An accident? Maybe, but you don't need to spend very long in Moscow to feel creeping paranoia. I did find the photograph of the dacha that you see here, and firmed in my mind that Igor must have had a privileged position in society and was likely a Party member. In the mid-1990s, however, the letters stopped coming and on three subsequent visits to Moscow I was unable to contact him. By then, there was a telephone directory but it seemed awfully small for a city of ten million people ... and there were no Dolgys in it.



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.

Mendeleev 150: 4th International Conference on the Periodic Table

26–28 July 2019

ITMO University Congress Saint Petersburg, Russian Federation

mendelev150.ifmo.ru

Southern Highlands Conference on Heterocyclic Chemistry

25–27 August 2019

Peppers Manor House, Sutton Forest, NSW

www.chemistry.unsw.edu.au/SHC19

Periodic Table Quiz Show

26 August 2019

Studio, School of Media and Communication, RMIT, Vic.

sherif.abbas@rmit.edu.au

jeff.hughes@rmit.edu.au

Asian Federation for Medicinal Chemistry International Medicinal Chemistry Symposium

8–11 September 2019, Istanbul, Turkey

aimecs2019.org

13th International Symposium on Ionic Polymerization

8–13 September 2019

Beijing, China

ip19.net

21st Mendeleev Congress on General and Applied Chemistry

9–13 September 2019

Saint Petersburg, Russian Federation

mendelev2019.ru/index.php/en

6th International Environmental Best Practices Conference

22–26 September 2019

Olsztyn, Poland

ebp6.eu

International Congress on Engineering and Food

23–26 September 2019, Melbourne Convention Centre, Vic.

icef13.com

Chemeca 2019

29 September – 2 October 2019, Sydney, NSW

chemeca2019.org

Hazards Australasia 2019

13–14 November 2019

Brisbane, Qld

icheme.org/hazardsaus2019

2019 New Zealand Institute of Chemistry Conference

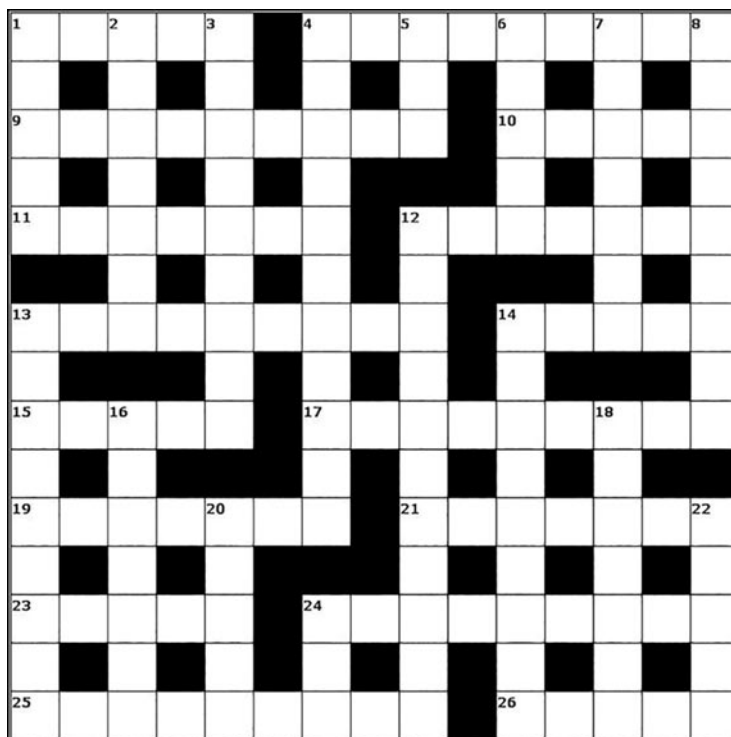
24–28 November 2019

Christchurch, New Zealand

nzic.org.nz

[RACI events are shown in blue.](#)

See outside back cover for National Science Week events.



Across

- 1 Gets up to return iridium, selenium and sulfur. (5)
- 4 Peculiar reaction of Ti and Cr with N₂, I₂ and S. (9)
- 9 Can tin ore make a packet? (9)
- 10 Iodine bargain is as good as it gets. (5)
- 11 Dissolved stuff. Gets less out. (7)
- 12 Rots her socks! Not so high! (7)
- 13 Inhibit and extract resolve. (9)
- 14 Get up platform. (5)
- 15 State: 'Ergo, a hat'. (5)
- 17 Compounds of formula RS-M* breaking up 20 Down oils. (9)
- 19 Former partner named and energised. (7)
- 21 Chemotropism! It calls for putting back in the cyclic carboximide acids. (7)
- 23 3 or 4 elements ago. (5)
- 24 Sets a line to cross. That's crucial! (9)
- 25 Acids sent away? How far? (9)
- 26 H₃Si- in silly mixup. (5)

Down

- 1 Shakes ore. (5)
- 2 One top. (7)
- 3 13 Down tested arc faults. (9)
- 4 Newly sanitised so deposition of films can be enhanced. (3-8)
- 5 Pave with salt. (3)
- 6 Radical discovered in *Weilheim in Oberbayern*. (5)
- 7 Lines spare technetium can. (7)
- 8 Salts new/old riches. (9)
- 12 Experts on silicas step out. (11)
- 13 Fake press in expired spread. (9)
- 14 Compounds take in absurd objects with pointed ends. (9)
- 16 Clans to change designators of position. (7)
- 18 Insignificant drip in test. (7)
- 20 $\theta = 90 + \eta$. (5)
- 22 Samarium? LOL! Phenyl 2-hydroxybenzoate ... (5)
- 24 ... and so on centres new acetone process. (3)

Graham Mulrone FRACI CChem is Emeritus Professor of Industry Education at RMIT University. Solution available online at [Other resources](#).

30 years of inspiration: Questacon celebrates



Dignitaries among tomorrow's scientists following the launch of *Ledusa* at Questacon's 30th Anniversary Gala event. Back: Professor Graham Durant AM; Governor-General, His Excellency Peter Cosgrove; Chair of Questacon Advisory Council, Mr Leon Kempler AM; Lady Cosgrove; Professor Brian Schmidt AC, ANU Vice Chancellor, Chair Q Foundation Australia, Mr Eddie Kutner. Front: Deputy Director, Ms Kate Driver; Founding Director, Professor Mike Gore AM; Deputy Secretary, Mary Ann O'Loughlin AM, The Hon. Karen Andrews MP, Minister for Industry, Science and Technology; Japanese Ambassador, His Excellency Mr Sumio Kusaka and Mrs Ikuko Kusaka; Deputy Director, Dr Bobby Cerini. Questacon

Do you remember your first science experience? Was it playing with a beginner's chemistry set, staring at the stars or maybe your first experiment led by a teacher? For many Australians, the answer is a visit to Questacon.

Officially opened by Prime Minister the Hon. Bob Hawke MP on 23 November 1988 and partly funded by the Japanese Government and business community, Questacon – The National Science and Technology Centre – grew from humble beginnings at Ainslie Primary School. Realising the vision of Founding Director Professor Mike Gore AM, Questacon remains true to hands-on experiences that enhance learning and provide a unique perspective on science and technology.

Questacon has had more than 12 million visitors pass through the doors of its Canberra centre and engaged people through national programs of exhibitions, workshops, teacher development and digital engagement. Its vision for a better future for all Australians through engagement with science, technology and innovation is supported by many partners.

As an influential voice in the global science centre community, Questacon is a vehicle for delivering activities to support the Australian Government's science agenda, as well as contributing to the work of the United Nations in science centre capacity building and implementation of the 17 Sustainable Development Goals.

In its 30th year, Questacon toured its Science Circus program model to Japan, working with Japanese science centres to take our model of outreach to new audiences and share science

engagement methods in schools and communities. The five-week tour was a collaboration with Japanese science communicators in Osaka, Nara, Nagoya and Kochi, as well as the Australian National University. These collaborations inspire us with new approaches and techniques from our peers.

To celebrate 30 years, Questacon invited friends, stakeholders, partners and staff to a gala event where His Excellency the Governor-General Sir Peter Cosgrove AK MC (Retd) launched a spectacular new exhibit, *Ledusa*, in Questacon's foyer. With 45 000 LED lights, *Ledusa* displays a range of natural patterns. Two days later, Questacon opened its doors and filled the surrounding grounds for the Festival of Questacon, setting a new daily record of 8925 visitors.

To ensure our content is fresh, accurate and current for the next 30 years, Questacon continues to collaborate with universities, science agencies and industry. We invite scientists to engage with our audience in *Q Lab*, advise us on our exhibition concepts and host talks and presentations on topical ideas in our Japan Theatre. Recent collaborations have focused on our newly launched exhibition *Born or Built*, which poses the question 'What makes us human?' and explores the ethical implications of technology and artificial intelligence and their increasing integration into our everyday lives.

Questacon is exceptionally proud of its achievements, its staff and volunteers, partners and supporters. We continue to realise our dream of a better future for all Australians through engagement with science, technology and innovation.

national science week 2019

Brisbane Science Festival (Qld)

Smoke cannons, liquid nitrogen, flame tests, explosions, and cool chemistry experiments are headed for Brisbane central. Brisbane Science Festival will bring science to life using a range of interactive activities, guest presentations, and captivating science demonstrations.

Friday, 16 August 2019 till Sunday, 18 August 2019. 9.00 am to 4.00 pm
South Bank Piazza, 410 Stanley Street, Brisbane, Qld
admin@streetscience.com.au
www.brisbanesciencefestival.com.au

Celebrating our women in science (WA)

Students studying STEM or STEAM subjects are invited to meet Kings Park's female science and conservation staff in Kings Park to gain an insight into the rewarding career opportunities in the areas of ecology, seed science, genetics and plant conservation.

Tuesday, 13 August 2019 till Thursday, 15 August 2019. 9.30 am to 2.30 pm
Kings Park Education, 4 Kattidj Close, Perth, WA
education@bgpa.wa.gov.au
www.bgpa.wa.gov.au/education

The decline of insect populations (NSW)

Discover some of the disastrous consequences of climate change, pollution and intensive agriculture on nature's ecosystem as Dr Sanchez-Bayo discusses the global decline of insect populations.

Monday, 12 August 2019. 6.30 pm to 7.30 pm
Stanton Library, 234 Miller Street, North Sydney, NSW
www.trybooking.com/book/event?eid=493420
www.northsydney.nsw.gov.au/Library_Databases/Library_Programs/Live_Science_Engagement_Series

Marvel at the moon and stars with MAGNT (NT)

Embark on a 3D outer space experience in Starlab's Cosmodome Science Theatre & Planetarium at the Museum and Art Gallery of the Northern Territory. Brilliant 3D depictions of our solar system, moon phases, eclipses and tidal rhythms combined with surround-sound effects will captivate you.

Tuesday, 13 August 2019 till Sunday, 18 August 2019. 10.00 am to 5.00 pm
MAGNT Maritime Gallery, 19 Conacher Street, The Gardens, Darwin, NT
info@magnt.net.au
www.magnt.net.au

Meet the author: Dr Chris Ferrie (NSW)

A quantum physicist by day; a dad and author of books for preschoolers by night, Dr Chris Ferrie will show how to introduce the many complex subjects of STEM to children.

Monday, 12 August 2019. 12.30 pm to 1.30 pm
Jervis Bay Maritime Museum, Dent Street, Huskisson, NSW
www.jervisbaymaritimemuseum.com.au

Molecule (SA)

'Molecule' is a visual art exhibition showcasing a series of artworks by Tutti Artist Charlie Taplin. His latest works are an exploration of microscopic-inspired imagery and have a particular focus on medical themes.

Thursday, 1 August 2019 till Monday, 7 October 2019. 9.00 am to 5.00 pm
Royal Adelaide Hospital – Emerging Artist Galleries, Royal Adelaide Hospital, Port Road, Adelaide, SA
www.creativehealth.org.au

Science Alive! 2019 (SA)

Science Alive! is the largest single interactive science exhibition in Australia, and brings together South Australia's big names in science and technology. We'll have over 60 exhibitors providing hands-on fun that is interactive, dynamic, fun and educational for all ages!

Saturday, 3 August 2019 till Sunday, 4 August 2019. 9.00 am to 5.00 pm
Adelaide Showground, Goodwood Road, Wayville, SA
www.sciencealive.org.au/adelaide-tickets
www.sciencealive.org.au/adelaide

Science Gallery Melbourne – DISPOSABLE pop-up (Vic.)

Science Gallery Melbourne's pop-up program DISPOSABLE will highlight experimental and creative ways to tackle our ever-growing excess of waste. DISPOSABLE locations will include the University of Melbourne's Parkville and Southbank campuses, along with unique sites throughout Melbourne.

Thursday, 1 August 2019 till Sunday, 1 September 2019. 12.00 pm to 4.00 pm
The University of Melbourne, Parkville, Vic.
<https://melbourne.sciencegallery.com/disposable-coming-2019>

Science involved in culture – toothpastetrees (Vic.)

A laboratory-style experimental set-up of a steam distillation unit showcasing the live process of eucalyptus oil extraction. The audience can engage through their senses of sight, smell and touch and get actively involved in the discussion.

Thursday, 22 August 2019. 6.30 pm to 8.30 pm
Broadmeadows Global Learning Centre, 1079 Pascoe Vale Road, Broadmeadows, Vic.
Arjumand Khan, Hume City Council, kabj779@yahoo.co.in

SCINEMA International Science Film Festival (national)

SCINEMA is a celebration of the power of the moving image to inspire the young, satisfy the curious, explain the baffling and ask the impossible.

Thursday, 1 August 2019 till Saturday, 31 August 2019. 7.00 am to 10.30 pm
scinema@riaus.org.au
<https://scinema.australiascience.tv/community-program>

Tastrofest – Tasmania's astronomy festival (Tas.)

The largest astronomy festival in the country is beaming in from NASA for the anniversary of the moon landing. The team from Houston will be talking with us live as we catch up about this year's celebrations.

Friday, 2 August 2019. 6.00 pm to 9.00 pm
Ulverstone Stadium, 1 Flora Street, West Ulverstone, Tas.
www.tastrofest.com

Source: National Science Week: An Australian Government Initiative. More events available at www.scienceweek.net.au. See event websites for further information, including booking requirements, costs and entry times.