chemistry in Australia

April 2016

Recruiting antibiotic candidates

chemaust.raci.org.au

raci
Royal Australian Chemical Institute

- Nobel Prize in Chemistry part II
- Mentoring – an open invitation
- RACI youth lectures across the nation

National Awards 2016

The RACI National Awards recognise and promote the contributions and achievements of our members.

The awards cover a broad range of areas and are aimed at the full membership demographics.

They are open to all members of the RACI. Some can be applied for by the candidate; others have to be nominated by third parties.

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Academia: Applied Research Award
Cornforth Award
CS Piper Award
HG Smith Memorial Award
Rennie Memorial Award

Distinction: Citation
Distinguished Contribution to Economic Advancement (Weickhardt) Award
Distinguished Fellowship Award
Leighton Memorial Award

Education: Fensham Award for Outstanding Contribution to Chemical Education
RACI Chemistry Educator of the Year Award

Young Chemists: Masson Memorial Award

MRACI Post Graduate Student Travel Bursary

An amount of $2000 to assist Post Graduate Student members of the RACI to travel professionally from their home institution, to collaborate with a research group, at another Australian university or overseas, or to make use of specialised research facilities (e.g. an advanced light source), or to deliver a paper at a meeting overseas.

Full details of the awards and the requirement criteria can be found on the RACI website at: www.raci.org.au/events-awards/national-awards-2016

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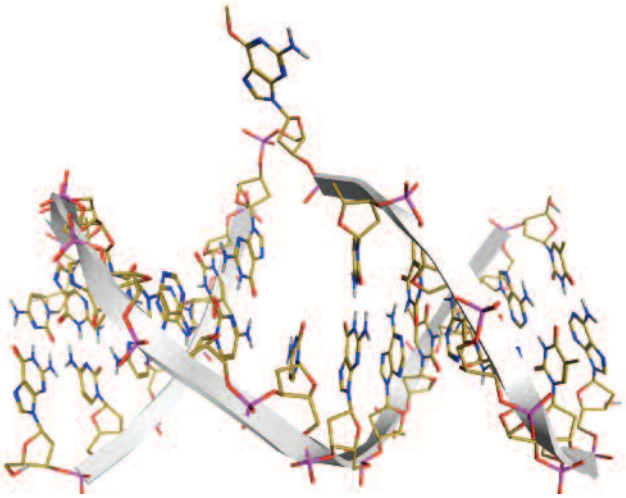

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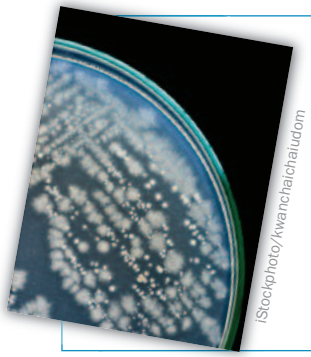

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cover story

Keeping up with the microbes

The Community for Open Antimicrobial Drug Discovery sees collaboration as key to the search for new antibiotic candidates.

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From the President

More than 25 years ago, all Australians were first reminded with a friendly jingle that 'It's your ABC' (Australian Broadcasting Corporation). Well, in the same fashion, 'It's your RACI'.

Previously, I have pointed out what the RACI does (and does not do) for you in your professional life. The greatest member benefit, I believe, is involvement with RACI activities. By that I don't just mean registering for and participating in an event, but going an extra step and co-organising an RACI event at local Branch or specialist Division level or even establishing a new Division or Group. These events are central to RACI's reason for existence.

During recent years, I have seen an upturn in engagement with the membership, and members willing to run new kinds of events. We have a still quite new but very active Health, Safety and Environment Division, which has filled a vacuum in RACI's expertise in chemical safety that impinges on a variety of sectors (industry, education providers and government) and provides advice to regulators. The emergence of Young Chemist Groups in the Queensland, South Australian and Victorian Branches is another example of spontaneous establishment of collaborative groupings of chemists in pursuit of a common goal. RACI provides the network and financial support. What's up next?

There is an extra level of governance that oversees all of RACI's operations – the RACI Board, the governing body of the Institute. In 2016, we will have a federal election in Australia where we will collectively decide who will govern the country for the next four years. On a somewhat smaller scale, RACI will be holding its own elections this year for vacancies on the RACI Board. This year we will elect the next Honorary General Treasurer (2016–18) and one non-executive Board member (2016–18) from the RACI membership. We will also choose the next President Elect (2016–18), who will become President in late 2018 for a second two-year term on the Board.

Although RACI Board positions are constitutionally elected from the membership, history shows that competition is not always fierce. Ironically, the least sought-after position is that of President Elect. It may surprise you but it has been more than a decade since we have had a contested election for this position, i.e. all recent RACI Presidents have been elected unopposed.

Why is this? On one hand, members might be put off by the perceived time commitment of being RACI President. There is no doubt that it is a significant commitment (on a voluntary basis), but I know from personal experience that it can be managed concurrently with a 'real' job; the immediate Past President, the President Elect and I are all in full-time employment. The rewards are many and I am privileged to work with and learn from my fellow Board members (and CEO) while at the same time interacting with many other RACI members across the country. Another (less appealing) explanation for the lack of nominations for President Elect is that RACI members don't care who is President of the Institute. If that was ever true, then I sense that things are changing.

At our last Board elections in 2015, there was quite a dramatic turnaround when we received spontaneous nominations from six excellent candidates for the two vacant non-executive Board positions. The ensuing election also saw the greatest RACI member voting turnout that I can remember.

So this year, *you* (as an RACI member) have the opportunity to nominate for President Elect (or either of the other two vacant Board positions). There are no prerequisites other than being an RACI member. You do not have to be a current or former Board member. You need not be a current or former office bearer of an RACI Branch or Division committee. Experience in the structure and governance of RACI is useful but that can be learned. The most important thing you need to bring with you is a commitment to help strengthen and advance RACI (specifically its membership) as we move into our second century as an Institute. I'm more than happy to give additional insight to this position and the others on the Board if you have any questions (email president@raci.org.au). Remember, it's your RACI.

Paul Bernhardt FRACI CChem (president@raci.org.au) is RACI President.

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ISSN 0314-4240 e-ISSN 1839-2539

Which or that?

I kept Ian Rae's November 2014 article 'Which way is best?' as an interesting commentary on 'that versus which' and other issues that worry writers who care about their usage of English or who might want to reduce the use of editorial blue pencil on their submitted papers. It didn't leave me with a secure guide for the that/which issue and I felt that I had a reliable solution in the back of my mind needing only to be set out in print … as the novelist E.M. Forster puts it: 'How can I know what I think until I see what I say'.

Ian quotes our long-time mentor Bob Schoenfeld (*The chemist's English*) for an answer. However, Bob's conclusion, though of course unchallengeable and beautifully illustrated by many chemical examples, was not quite what I wanted because, as he says himself, the distinction is explained in grammarian's language. I wanted one in simple, memorable, form.

Here it is, inspired by a discussion in 'Column8' of *The Sydney Morning Herald* a month or two ago (you need only remember the words in boldface):

'That' makes a selection, as in 'The buildings that were designed after the 2009 earthquake (*just those ones*), were merely shaken' or 'The fractions that contained melanin (*and only those so selected*) were rejected' (a Schoenfeld example).

On the other hand, **'which' looks back to something already named**, usually in the same sentence, **and does more with it**, as in 'Copies of the *Herald*, which (*referring back to 'the Herald'*), as you know, is the only paper worth reading, are delivered to your door.' or 'The witness' account of the accident, which (*refers back to 'the witness' account', a slightly bigger grouping*) is not necessarily an accurate one, was quite different', or 'The Earth's surface is heating up, which (*all of the previous clause*) means that the Barrier Reef is doomed'.

I offer this for trial – it works for me – and look forward to trenchant criticism from my amiable professional colleagues.

Bruce Graham FRACI CChem

Editor's note: The 'that, which' conversation is extremely common amongst editors. Another way to remember the difference is this: if you can remove the clause (e.g. 'which means that the Barrier Reef is doomed') without changing the sense of the sentence, it's a 'which'; if you can't, it's a 'that'.

Disappearing indigo

The headline 'Ancient indigo dye as a new electron acceptor in organic photodiodes' as a note in the 'Research' section of the December 2015/January 2016 issue (p. 15) required closer inspection because I knew from practical experience that indigo and light are not very compatible. On reading the complete article, I realised that although the indigo backbone is the basis for the new compound, it is no longer the indigo dye as used as a food colour.

Indigo carmine or indigotine is still a permitted food additive, but it is reported as possessing 'poor stability' to light. I discovered this fact as a part-time RMIT Applied Chemistry student in 1968, in my elective Food Analysis.

The final exam was a three-day exercise in which we were given two foods to analyse: (i) 100s and 1000s in two colours (thank goodness, in little stick form and not balls) and (ii) the protein and fat contents of tinned sausages. My colours were blue and orange but no standard colours for comparison were provided (we had dye swatches prepared in an earlier prac).

Paper chromatography was the only option; after furious frustration in physically separating the two colour types, every sprinkle was important, it was an exam! The next morning I discovered that my two colours were sunset yellow and ? – the blue sample had completely disappeared after leaving the glass jar on the bench exposed to November light.

It obviously was not the only other food blue colour – brilliant blue FCF – but what was it and what had I done wrong? Failure loomed. During the next two days, between alternating visits to the Oxford Pub and tending to the group's soxhlet extractions, I found that indigo carmine had poor light stability. I received a Credit.

Three years later while I was in my early years at BBA (Flavours, Fragrances and Colours etc.), I was called urgently to Heinz Co., who was developing an electrolyte drink for Ron Clarke, the middle- and long-distance athlete, and the green colour was becoming yellow with time. The green colour, as are most green food colours, was a mixture of a yellow dye (in this case tartrazine) and a blue dye, preferably brilliant blue, but in this drink, indigo carmine. Problem resolved in five minutes. Plenty of subsequent brownie points but the source of the instant knowledge remained my secret.

Tony Zipper 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 editor@raci.org.au.

Professional scientists remuneration survey summary report 2015

Professional Scientists Australia have released their 2015 survey results on remuneration for STEM (Science, Technology, Engineering and Maths) workers in Australia. Their findings suggest that many STEM professionals are looking increasingly towards the international market for employment and that science-based organisations need to provide attractive recognition and reward strategies to ensure Australia's ongoing science and technology capabilities.

View the summary report at bit.ly/1PYrLPT.

SCIENCE AND TECHNOLOGY AUSTRALIA

Optimising wastewater resources

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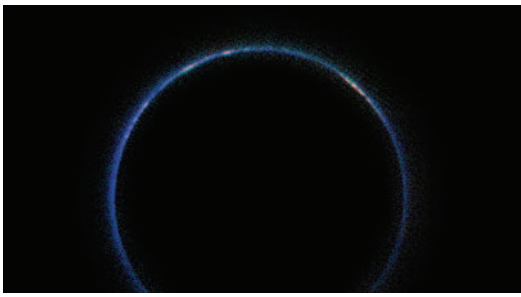
Population growth, increasing demand for natural resources, rising costs and community expectations are affecting management of Australian water resources. These pressures require the water industry to develop innovative and more efficient processes to optimise resource recovery from wastewater, according to *Wastewater – an untapped resource?*, a report by the Academy of Technology and Engineering (ATSE).

The report, developed by a working group led by chemical engineer Dr John Burgess, notes that Australian wastewater contains nutrients, carbon, energy and other inorganic and organic resources worthy of recovery, and examines the potential industry opportunities for resource recovery in Australia. It reviews international case studies, considers the Australian regulatory framework and evaluates the key technologies and products, as well as analysing several investment options. The report shows that there are several significant value-creating opportunities to pursue for investors in Australia in the medium term.

View the full report at bit.ly/1UWAs1G.

ATSE

Pluto's blue atmosphere in the infrared



This image from NASA's New Horizons spacecraft is the first look at Pluto's atmosphere in infrared wavelengths, and the first image of the atmosphere made with data from the New Horizons Ralph/Linear Etalon Imaging Spectral Array (LEISA) instrument. In this image, sunlight is coming from above and behind Pluto. North in this image is around the 10 o'clock position.

The blue ring around Pluto is caused by sunlight scattering from haze particles common in Pluto's atmosphere; scientists believe the haze is a photochemical smog resulting from the action of sunlight on methane and other molecules, producing a complex mixture of hydrocarbons such as acetylene and ethylene. These hydrocarbons accumulate into small particles – a fraction of a micrometre in size – which scatter sunlight to make the blue haze. The new infrared image, when combined with earlier images made at shorter, visible wavelengths, gives scientists new clues into the size distribution of the particles.

NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

Whistleblowing strengthens public trust in chemical engineering

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A revision to the Institution of Chemical Engineers (IChemE) Rules of Professional Conduct and Disciplinary Regulations obliges practising chemical engineers to 'whistle blow' in circumstances where they feel that the public interest is being compromised.

The revision promotes and supports a collaborative approach to safe and sustainable working in the chemical and process industries. On becoming aware of any danger, risk or malpractice within an organisation, chemical engineers are obliged to offer full support to colleagues involved in reporting and escalating their concerns to senior management. This approach addresses fears that whistleblowers might be ostracised by their employer or fellow employees.

View IChemE's Rules of Professional Conduct at bit.ly/1T3LfJt.

INSTITUTION OF CHEMICAL ENGINEERS

Secrets of elastin's flexibility during assembly

Elastin has a remarkable combination of flexibility and durability – it is one of the body's most long-lasting component proteins, with an average survival time comparable to a human lifespan. During a person's life, the elastin in a blood vessel, for example, will have gone through an estimated two billion cycles of pulsation.

Researchers at the University of Sydney, MIT in the US and the University of Manchester in the UK have carried out an analysis that reveals the details of a hierarchical structure of scissor-shaped molecules that gives elastin its remarkable properties.

The findings have been published in *Science Advances* (http://doi.org/10.1126/sciadv.1501145) in a paper by the University of Sydney postdoctoral research associate Dr Giselle Yeo and Professor Anthony Weiss in the Faculty of Science and Charles Perkins Centre, with co-authors including MIT graduate student Anna Tarakanova and Professor of Civil and Environmental Engineering Markus Buehler.

Elastin tissues are made up of molecules of the protein tropoelastin, which are strung together in a chain-like structure. In this work, Weiss and his team have collaborated with Buehler and Tarakanova, who have specialised in determining the molecular structure of biological materials through highly detailed atomic-scale modelling. Combining the computational and laboratory approaches provided insights that neither method could have yielded alone.

Because of synchrotron imaging done by Clair Baldock at the University of Manchester, the research revealed the shape and structure of the basic tropoelastin molecules. But these were snapshots – still images that could not illuminate the complex dynamics of the material as it forms large structures that can stretch and rebound. Those dynamic effects were revealed through the combination of computer modelling and laboratory work.

Tarakanova explained that in Buehler's lab, 'we use modelling to study materials at different length scales, and for elastin, that is very useful, because we can study details at the submolecular scale and build up to the scale of a single molecule.' By examining the relationship of structure across these different scales, she said, 'we could predict the dynamics of the molecule'.

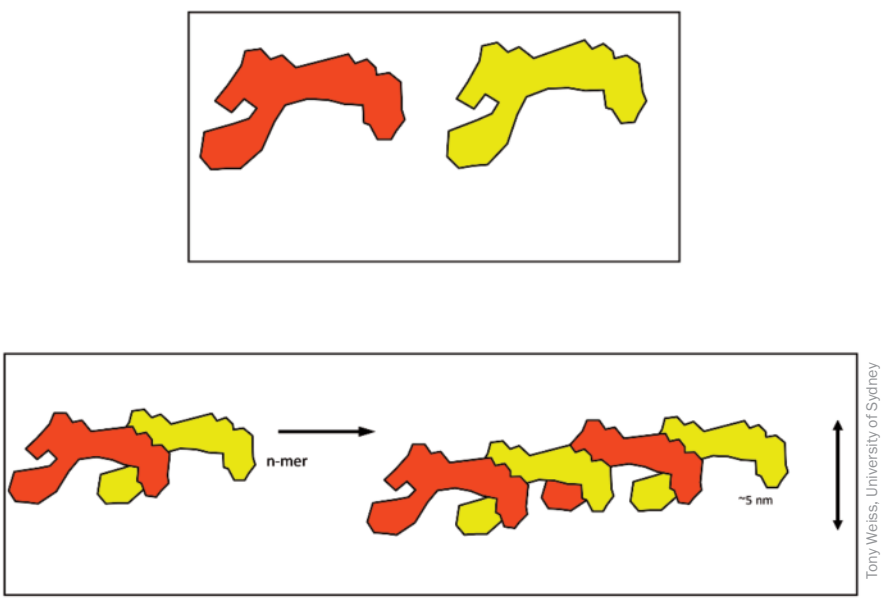
The dynamics turned out to be complex and surprising, Weiss said. The scissor-like appendages of one molecule naturally lock onto the narrow end of another molecule. This process continues rapidly, building up long, chain-like structures.

A key part of the puzzle was the movements of the molecule itself, which the researchers found were controlled by the structure of key local regions and the overall shape of the protein.

The scientists tested the way this flexibility comes about by genetically modifying the protein and comparing the characteristics of the modified and natural versions. They revived a short segment of the elastin gene that has become dormant in humans, which changes part of the protein's configuration. They found that even though the changes were minor and just affected one part of the structure, the results were dramatic. The modified version had a stiff region that altered the molecule's movements. This helped to confirm that certain specific parts of the molecule, including one with a helical structure, were essential to contributing to the material's natural flexibility.

'The integration of experiment and modelling in identifying how the molecular structure endows materials with exceptional durability, elasticity, and studying how these materials fail under extreme conditions, yields important insights for the design of new materials that replace those in our body, or for materials that we can use in engineering applications in which durable materials are critical,' Buehler said.

UNIVERSITY OF SYDNEY



A 2D schematic of tropoelastin molecule assembly.

Sequencing complex sugar molecules for the first time

Researchers from Berlin have succeeded in an effort to fundamentally improve carbohydrate analysis. With the new method, developed by Kevin Pagel (Free University Berlin and Fritz Haber Institute of the Max Planck Society) and Peter Seeberger (Max Planck Institute of Colloids and Interfaces and Free University Berlin), complex glycans, building blocks of life such as DNA and proteins, can now be sequenced. The quality control of synthetic carbohydrates is now possible as minimal impurities can be traced faster and more precisely. The new method is essential for the development of novel carbohydrate vaccines, drugs and diagnostics.

Seeberger explained: 'The new method is fast, reliable and sensitive. The glycosciences will get a push, comparable to the advances when gene sequencing was first developed.'

The structure of carbohydrates is much more complicated than that of genetic material or proteins. Carbohydrate chains can be formed from more than 100 building blocks that can be linked together in branched chains and these can have different spatial structures, called anomers. In comparison to that, DNA molecules that consist of four building blocks, and proteins that are based on 20 amino acids are comparatively simple.

Seven Nobel Prizes were awarded in the glycosciences until 1974. After that, however, the advances in analytical methods did not keep up with those made in genetics. Glycans are important because sugars that cover human and bacterial cell surfaces are an essential part of the immune response and recognition events such as fertilisation.

The incredible diversity of carbohydrates is a general challenge for chemists. Carbohydrate building blocks can link in many different ways. Even simple carbohydrates that have the same number of atoms and the same mass may differ in only one binding angle. These isomers, such as glucose and galactose, exhibit very different biological functions.

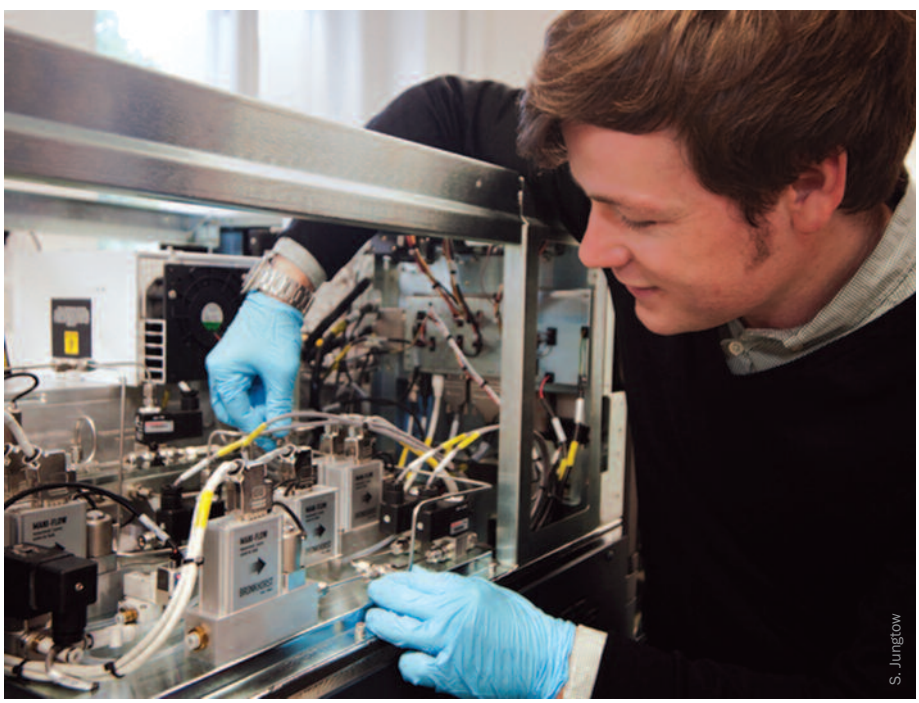
Carbohydrate molecules consisting of the same number of specific atoms can differ in their composition, connectivity and configuration. Until now, their differentiation was a laborious and time-consuming task that required large amounts of sample.

The scientists from Berlin and Potsdam take advantage of the different shapes of carbohydrates. Depending on their shape, the molecules require different times to pass through a gas-filled tube – comparable to the drag coefficient in a wind tunnel. Kevin Pagel and his colleagues combine this ion mobility measurement with mass spectrometry to find differences in composition, connectivity and configuration. Larger molecules are broken into fragments; during this fragmentation, however, the structural properties of the resulting parts are not altered so that the sum of fragment properties reflects that of the large molecule.

Combined with a database, currently under development, and enlarged through the rapid collaborations of other scientists, this method will be generalised in the future. Once a molecule is entered in the database, automated processes can be used to recognise them.

The new method will enable quality control for synthetic carbohydrates, produced by synthesis robots, adding building blocks like pearls on a string. Until now, impurities were hard to detect at levels below 5% while the new carbohydrate 'wind tunnel' drastically lowers the sensitivity to 0.1%.

MAX PLANCK INSTITUTE OF COLLOIDS AND INTERFACES



Kevin Pagel with the ion mobility mass spectrometer.

First self-assembled superconductor

Building on nearly two decades of research, a multidisciplinary team at Cornell has blazed a new trail by creating a self-assembled, three-dimensional gyroidal superconductor.

Ulrich Wiesner, a materials science and engineering professor who led the group, says it's the first time a superconductor, in this case niobium nitride (NbN), has self-assembled into a porous, 3D gyroidal structure. The gyroid is a complex cubic structure based on a surface that divides space into two separate volumes that are interpenetrating and contain various spirals. Pores and the superconducting material have structural dimensions of only around 10 nanometres, which could lead to entirely novel property profiles of superconductors.

Currently, superconductivity for practical uses such as in magnetic resonance imaging (MRI) scanners and fusion reactors is only possible at near absolute zero, although recent experimentation has yielded superconducting at a comparatively balmy –70°C.

'There's this effort in research to get superconducting at higher temperatures, so that you don't have to cool anymore,' Wiesner said. 'That would revolutionise everything. There's a huge impetus to get that.'

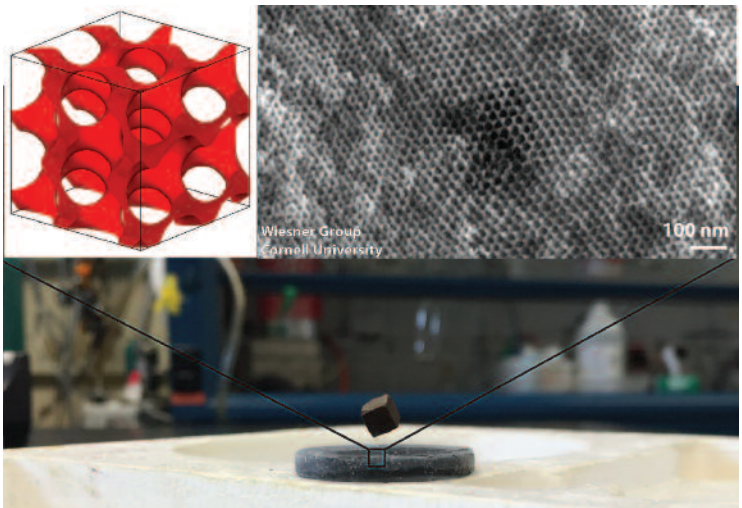
Wiesner and his co-author Sol Gruner had been dreaming for over two decades about making a gyroidal superconductor in order to explore how this would affect the superconducting properties. The difficulty was in working out how to synthesise the material. The breakthrough was the decision to use NbN as the superconductor.

Superconductivity, in which electrons flow without resistance and the resultant energy-sapping heat, is still an expensive proposition. MRIs use superconducting magnets, but the magnets constantly have to be cooled, usually with a combination of liquid helium and nitrogen.

Wiesner's group started by using organic block copolymers to structure direct sol-gel niobium oxide (Nb_2O_5) into 3D alternating gyroid networks by solvent evaporation-induced self-assembly. Simply put, the group built two intertwined gyroidal network structures, then removed one of them by heating in air at 450°C.

The discovery featured a bit of 'serendipity', Wiesner said. In the first attempt to achieve superconductivity, the niobium oxide (under flowing ammonia for conversion to the nitride) was heated to a temperature of 700°C. After cooling the material to room temperature, it was determined that superconductivity had not been achieved. The same material was then heated to 850°C, cooled and tested, and superconductivity had been achieved.

Wiesner said the group is unable to explain why the heating, cooling and reheating works, but 'it's something we're continuing to research,' he added.



Example of a bismuth-based superconductor levitating a magnet, with simulated and electron microscope images of the nanostructured material.

Limited previous study on mesostructured superconductors was due, in part, to a lack of suitable material for testing. The work by Wiesner's team is a first step toward more research in this area.

'We are saying to the superconducting community, "Hey, look guys, these organic block copolymer materials can help you generate completely new superconducting structures and composite materials, which may have completely novel properties and transition temperatures. This is worth looking into",' Wiesner said.

The group's findings are detailed in a paper published in *Science Advances* (doi: 10.1126/sciadv.1501119)

CORNELL UNIVERSITY

Nitrogen determination – Dumas combustion and Kjeldahl methods

C. Gerhardt, German manufacturer of analytical equipment, offers two alternatives regarding nitrogen determination.

The DUMATHERM works using the Dumas combustion method, where a sample is burned in an oxygen-rich atmosphere at high temperatures and the resulting gases are analysed by a nitrogen detector. The clever design of the furnace chamber in combination with the direct analysis of all resulting gases provides the user with results within 2–4 minutes, depending on the type of sample. Thanks to its construction, the DUMATHERM has low wear and tear on parts, which reduces costs for service significantly, and the oxygen required during a test can be up to 90% less than with other brands. The new improved version comes with an auto sampler that holds 64 samples, allowing more productivity.

For analyses that require the Kjeldahl method, KJELDATHERM and TURBOTHERM offer digestion systems with aluminium block or infrared heating respectively, with a selection of tube sizes and number of positions. To complement the TNK system, the new generation of the distillation equipment VAPODEST is now available. Four models with different levels of automatisation offer totally new and unrivalled technical features. It is simply smart: up-to-date operation and control via 7-inch colour touch display. It complies with the data-management requirements of ISO 17025 for accredited laboratories. A version with a carousel autosampler is available, allowing continuous analysis for up to 20 tubes. Models with external or built-in titrator are included on this VAPODEST series.

For further information, contact Perten Instruments, ph. (02) 9870 3400, email Support.australia@perten.com or visit www.perten.com.

12 free tips to help keep test weights accurate

How test weights are handled can make a big difference in accuracy. Download METTLER TOLEDO's latest free reference article and explore 12 important cleaning and storage suggestions that will help maintain precision and reduce rework, disposal and recall costs in the long term.

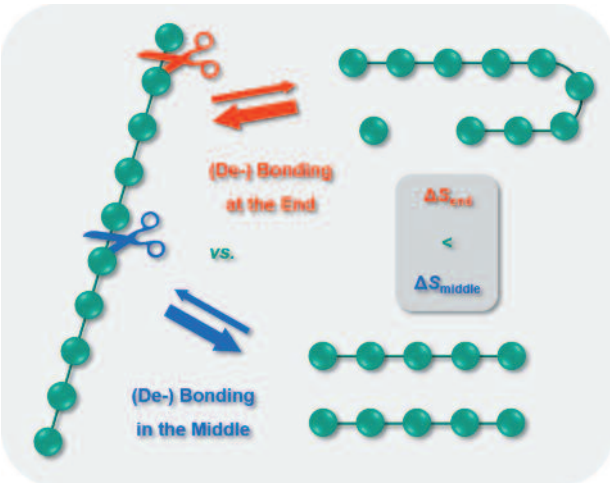
METTLER TOLEDO is pleased to present *Correct weight handling: 12 practical tips*. This free guide details actions operators can take to protect the accuracy of test weights, as well as actions that should be avoided to preserve precision.

Test weights are an indispensable resource for testing and calibrating scales and balances – and they require manual handling. As such, issues such as skin oils, dirt and shifting ambient temperatures can affect their accuracy. When these issues are not addressed, operators may conduct tests with inaccurate weights, resulting in weighing errors as well as costs associated with rework, waste disposal and product recall.

Fortunately, a simple series of 12 practical strategies, including choosing the right storage techniques, can help protect the usable life of test weights and avoid inaccuracies.

Learn these strategies today by downloading the free article at bit.ly/1TRJ1fT.

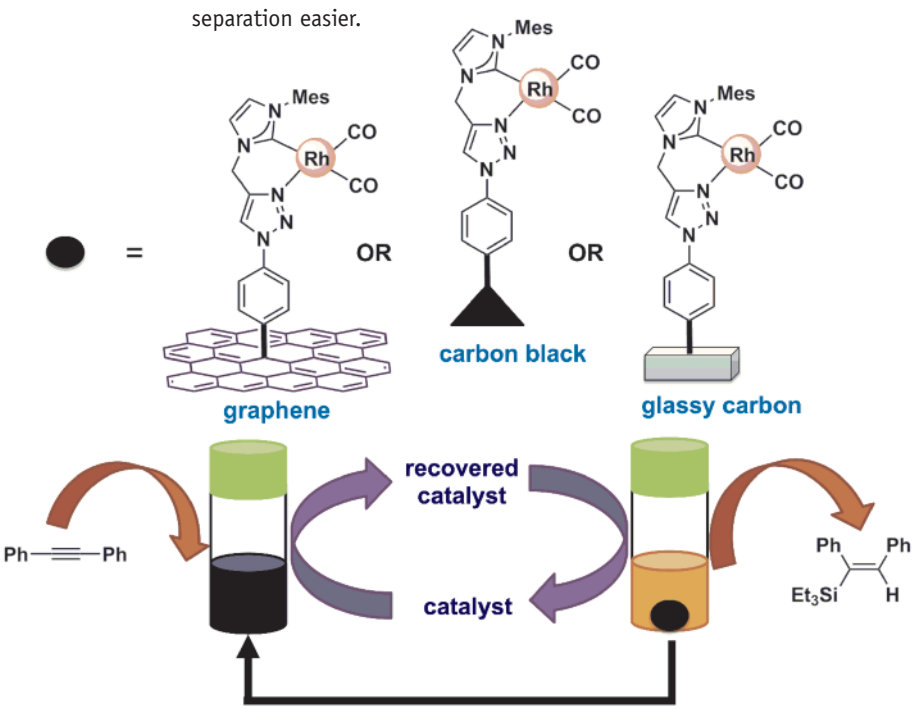
Where macromolecules cleave: entropic selectivity for chain scission



Reversible covalent and supramolecular bonding is increasingly being employed in applications such as self-healing and stimuli-responsive materials, complex macromolecular architectures, and protein mimics. Normally, dynamic ligation equilibria are tuned by modifying the ligating functional groups to alter their electronic properties and thus reaction enthalpy. However, researchers from the Karlsruhe Institute of Technology, the Australian National University and the Leibniz Institute for Polymer Research have demonstrated that the equilibria can be tuned by altering the molecular weight and chain stiffness of the linking groups without changing the actual bonding motifs, thus taking advantage of entropy instead of enthalpy. They showed that an important consequence of these entropic effects is a significant preference for cleavage of macromolecules in the middle of long chains, rather than at the ends (Pahnke K., Brandt J., Gryn'ova G., Lin C.Y., Altintas O., Schmidt F.G., Lederer A., Coote M.L., Barner-Kowollik C. *Angew. Chem. Int. Ed.* 2016, **55**, 1514–18). The results were predicted by model calculations and confirmed via experimental analysis of reversible covalent and supramolecular adducts. An important consequence of the work is the prediction of long-range chain-length effects on chemically controlled polymer–polymer reactions such as chain transfer, polymer degradation, and control agent addition.

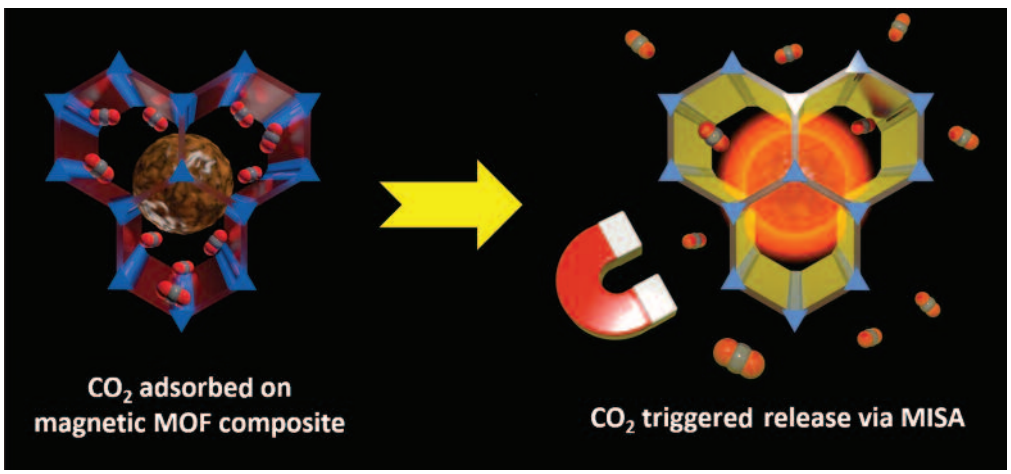
Recyclable catalysts

Chemical industries rely heavily on catalytic processes to produce many fine and bulk chemicals efficiently and selectively. These industries are always looking for new means to modify current industrial catalytic processes to make them more sustainable. As homogenous transition metal catalysts become more widely used, strategies for developing immobilised catalysts that retain the high efficiency and selectivity of the homogeneous catalysts, while allowing easy catalyst–product separation, are highly desired. The Messerle research group at the University of New South Wales and Macquarie University has developed a new experimental method for synthesising immobilised rhodium catalysts on a range of carbon surfaces, including graphene, carbon black and glassy carbon, directly from the optimised homogeneous complex (Wong C.M., Walker D.B., Soeriyadi A.H., Gooding J.J., Messerle B.A. *Chem. Sci.* 2016, doi: 10.1039/c5sc03787e). The immobilised complexes showed comparable catalytic efficiency and selectivity to those of the parent homogeneous catalyst for the hydrosilylation of disubstituted acetylenes. These catalysts are the most efficient reported to date for the hydrosilylation of disubstituted acetylenes. The immobilised complexes further demonstrated an advantage over the homogeneous complex as the hybrid catalysts were highly recyclable, with no leaching of rhodium over 10 catalytic cycles. This research provides a new experimental approach to developing immobilised catalysts from industrially suited homogeneous catalysts, making product separation easier.



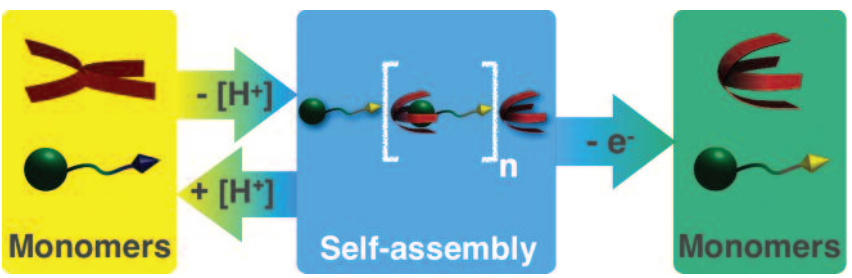
Scaling up regeneration of ultraporous gas adsorbents

Metal-organic frameworks (MOFs), the world's most porous materials, have emerged as ideal adsorbents for gas capture owing to their exceptionally high surface areas and chemical versatility. However, widespread deployment remains challenging in part because the insulating nature of MOFs is incompatible with the need to deliver heat to drive off adsorbed gas in order to regenerate the pristine MOF for repeated use. To overcome this challenge, a so-called magnetic induction swing adsorption (MISA) process has recently been developed by the MOF research team at CSIRO (Li H., Sadiq M.M., Suzuki K., Ricco R., Doblin C., Hill A.J., Lim S., Falcaro P., Hill R.M. *Adv. Mater.* 2016, doi: 10.1002/adma.201505320). In the MISA process, magnetic MOF composite materials are used for gas capture. When exposed to an alternating magnetic field, the embedded magnetic nanoparticles within the magnetic MOFs serve as 'nanoheaters' to generate heat locally. Such remotely induced heat triggers the release of the adsorbed gas within the MOF. Distinct from other forms of radiation such as light, magnetic fields can penetrate throughout large quantities of MOF, making MISA a potential method to remotely regenerate MOF adsorbents on an industrial scale.



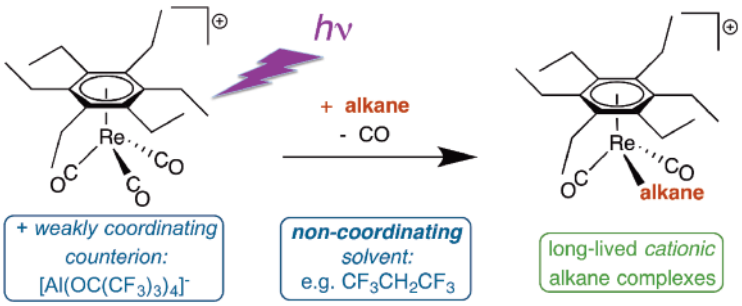
Orthogonal switch for supramolecular self-assembly

Adaptive smart materials that can be precisely manipulated with external stimuli are of great interest due to the promise they hold for drug delivery and self-healing materials. Materials that show orthogonal responses to different stimuli, such as hydrogen-bonding and metal–ligand interactions, are of particular interest as their properties can be controlled by multiple inputs. In a first for a self-assembled system based on heteroditopic monomers, Professor Jonathan Sessler of the University of Texas at Austin, Dr Jinho Chang of Sungshin Women's University, Associate Professor Pall Thordarson at the University of New South Wales and co-workers have recently reported supramolecular oligomeric materials that can be self-assembled and disassembled by chemical (base) or electrochemical stimuli (Kim D.S., Chang J., Leem S., Thordarson P., Sessler J.L. *J. Am. Chem. Soc.* 2015, **137**, 16 038–42). A key feature of this work was the application of the Hamelin–Jullien model for an aggregating host–guest system to obtain equilibrium constants for the process. The highly orthogonal nature of the control techniques detailed in this research is expected to aid the design of stimulus-responsive systems in which external factors are used to modulate structure and function over a range of length scales.



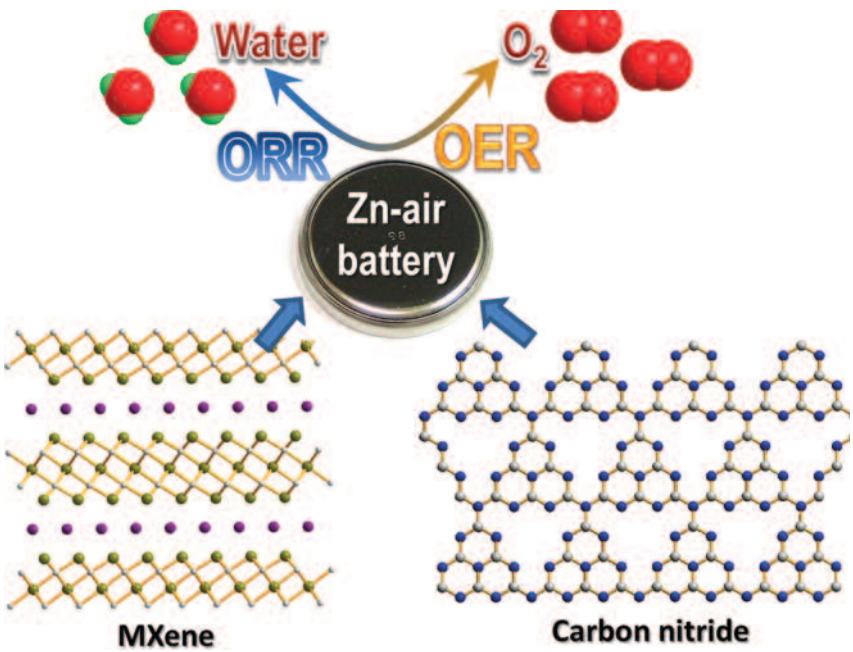
Alkane complexes get charged

Transition metal–alkane complexes are key intermediates in C–H activation reactions of alkanes, but no alkane complexes are known that are stable in solution at room temperature. The great majority of studies of neutral alkane complexes have used alkanes as solvents because common non-alkane solvents displace the weakly bound alkane ligand. However, insolubility precludes observation of *ionic* alkane complexes in alkane solvents. To address this issue, a team led by Dr Graham Ball at the University of New South Wales has used photolysis to generate cationic alkane complexes in a hydrofluorocarbon solution (Yau H.M., McKay A.I., Hesse H., Xu R., He M., Holt C.E., Ball G.E. *J. Am. Chem. Soc.* 2016, **138**, 281–8.) Using a hydrofluorocarbon solvent that binds to the metal centre more weakly than the alkane, in tandem with the solubilising and weakly coordinating $[Al(OC(CF_3)_3)_4]^-$ anion, overcomes the technical difficulty of combining ionic species with alkanes in solution without the solvent rapidly displacing alkane ligands. The $[(HEB)Re(CO)_2(alkane)]^+$ complexes (HEB = η^6-hexaethylbenzene; alkane = cyclopentane, pentane) were observable at –47°C, making them more stable than the corresponding neutral alkane complexes. Employing hydrofluorocarbon solvents should enable the study of many new alkane complexes, furthering the quest for alkane complexes that are stable in solution at room temperature.



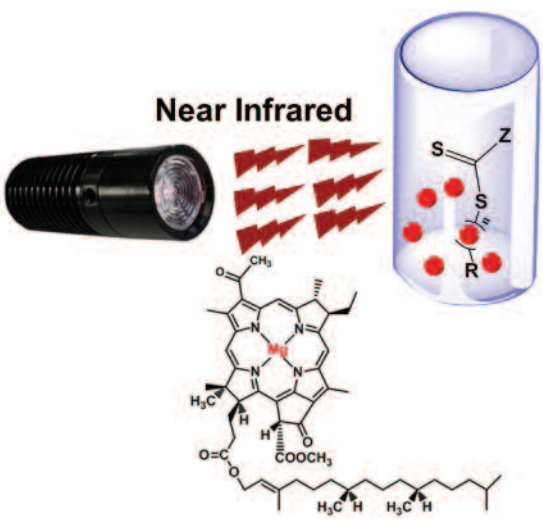
Hybrid nanosheets for better battery electrodes

State-of-the-art metal–air batteries use oxygen in air directly as a reagent and can store a lot of energy very densely. Nevertheless, sluggish cathode kinetics is currently a bottleneck for this technology, which must be overcome with more efficient eletrocatalysts. Professor Shizhang Qiao and co-workers at the University of Adelaide have developed a free-standing flexible film made of 2D conjugated graphitic carbon nitride and 2D conductive metal carbide (MXene) that catalyses metal–air battery reactions exceptionally well (Ma T.Y., Cao J.L., Jaroniec M., Qiao S.Z. *Angew. Chem. Int. Ed.* 2016, **55**, 1138–42). The carbon nitride and MXene are strongly coupled through the Ti–N interaction to form a hybrid film with bimodal hierarchical porosity and a high specific surface area of 205 $m^2\ g^{-1}$. The film is super-hydrophilic, making it ideal for use with aqueous electrolytes in energy storage and conversion devices. This film can efficiently and stably catalyse the reversible oxygen reduction and oxygen evolution reactions at the cathode of a Zn–air battery, which respectively correspond to the discharging and charging processes. The performance of the film surpasses commercially used noble metal catalysts such as Ru, Ir and Pt. This work paves the way to a large variety of hybrid catalysts produced by coupling different 2D materials and creates new opportunities for clean-energy storage systems.



Controlling polymerisation with infrared light

Hydrothermal vents are inhabited by phototrophic bacteria able to carry out photosynthesis in sun-starved conditions. These organisms rely on a special form of chlorophyll called bacteriochlorophyll to harvest light in the longer-wavelength visible and near-infrared range. The ability of bacteriochlorophyll to absorb in the near-infrared region has inspired the synthesis of new porphyrins for photodynamic therapy (PDT) to treat cancer. In addition, recent developments in the field of photopolymerisation have seen porphyrin dyes used to regulate living radical polymerisation under a broad range of visible wavelengths (435–655 nm). Although visible light has been able to provide spatial, temporal and sequence control to polymerisation, it does not penetrate very deeply into materials, thus limiting applications of visible-light polymerisation. Near-infrared radiation, on the other hand, is more penetrating but until now had not been used with a single photocatalyst to regulate photopolymerisation. Realising the potential of near-infrared polymerisation, Associate Professor Cyrille Boyer and co-workers at the University of New South Wales have used bacteriochlorophyll a (BChl a) to promote polymerisation in the near infrared ($\lambda_{max} = 850$ nm) (Shanmugam S., Xu J., Boyer C. *Angew. Chem. Int. Ed.* 2016, **55**, 1036–40). They successfully produced well-defined polymers and activated polymerisation on the opposite side of a translucent barrier to the light source. The new technique could be applied to photopolymerisations requiring deep light penetration.



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.

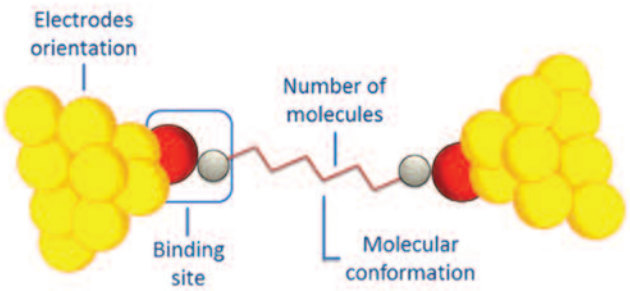
Priming your research

I look forward to the challenge of helping guide the national journal, the *Australian Journal of Chemistry*, into the future, with John Wade; and hopefully we will be able to aspire to the exceptional example of our predecessor, Curt Wentrup.

Many years ago when I joined the staff in Chemistry at the University of Western Australia, a senior colleague took me aside and gave me some great advice. Chief amongst this was the exhortation to not become bogged down in the same scientific rut but to branch out into new areas of research. This, he suggested, would keep the job fun and lead to an enriching career in science; he, after all, changed direction on average every ten years! Engaging in a new area of endeavour is not without its pitfalls, chiefly the perception of grant reviewers that you lack sufficient expertise to prosecute the proposed new research.

In heeding my colleague's advice, I was struck by the feeling that reading primary review articles detailing the latest results in an area often didn't provide enough information on how to actually perform the potentially unfamiliar reaction, measurement or experiment. It's for this reason that a new type of article was introduced to *Aust. J. Chem.*, the Primer review. The intention is that these Primer reviews will provide an accessible point of entry into a topical area for lecturers, researchers and students. Here you will find the solid background to the area as well as the *how-to* with seminal references, which will provide a starting point for a deeper foray into the topic at hand.

The first of these Primers involves the area of molecular electronics, in particular the fascinating history of its development and some of the underlying fundamental concepts – a very topical subject driven by the demands of miniaturisation in the electronics industry. Paul Low and Santi Marqués-González (*Aust. J. Chem.* http://dx.doi.org/10.1071/CH15634) have provided an excellent example of what the Primers hope to achieve. Indeed, Paul suggests:



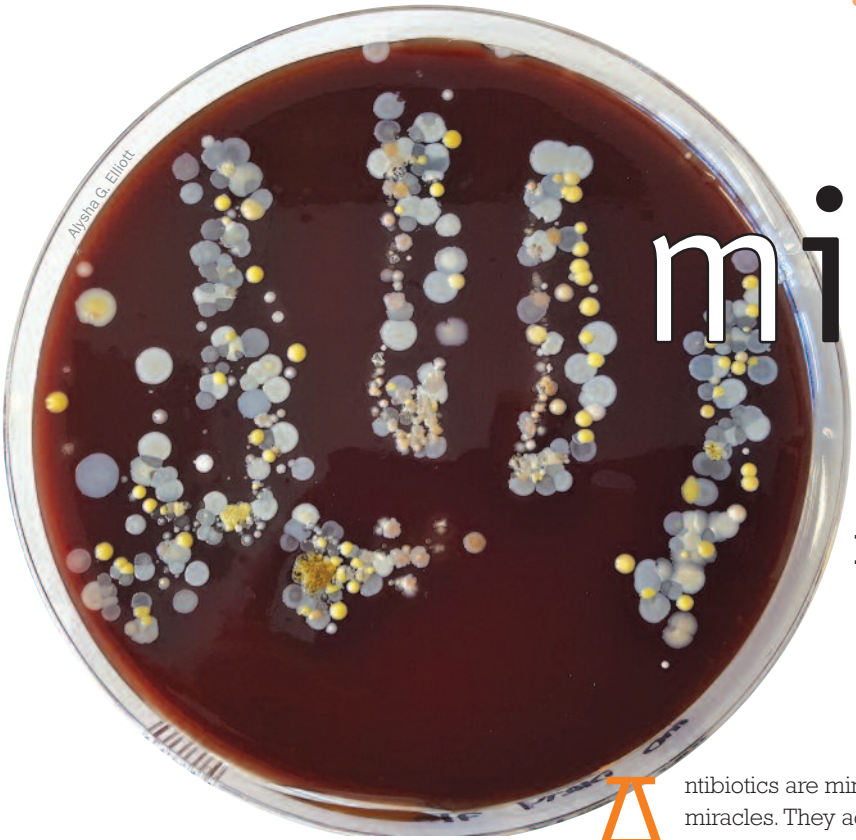
> The Primer is an exciting format, certainly for the authors and hopefully for the reader as well, allowing opportunity to contextualise a research field to a new audience. The format allows emphasis to be focused on the crux of a problem or the essence of a research field, which is an excellent way to be reminded of the nature of the current challenges. As single molecule electronics enters, at least, its third renaissance, we were able to use the opportunity afforded by the Primer to take a look back at the history of the area, and hopefully use that to develop a line of reasoning behind some of the contemporary challenges and research problems that are the topic of so much interest today. We certainly hope that the reader will find the story we have told interesting, and enjoy reading it at least half as much as we enjoyed writing it.

The Primer is available for download to all for the next six months.

So I ask the broader chemical community, academics and industrial practitioners to think about their own area, favourite analytical technique or procedure and see whether they can distill it down to about ten pages with 50 references and illuminate the path for the novitiates. Interested parties can contact either the editors in chief directly or the journal (publishing.ajc@csiro.au) to discuss their ideas.

George Koutsantonis FRSC, FRACI CChem (george.koutsantonis@uwa.edu.au)

Keeping up *with the* microbes



The Community for Open Antimicrobial Drug Discovery sees collaboration as key to the search for new antibiotic candidates.

Microbiome in an agar plate after a hand was pressed briefly onto it, followed by a 24-hour incubation. Bacteria have evolved a range of ways to avoid being killed by antibiotics, including pumping them out before they can work, mutating the target so the antibiotic does not inhibit its activity anymore, and developing enzymes that de-activate the antibiotic.

BY **MARK BLASKOVICH**

Antibiotics are minor miracles. They actually prevent people from dying of disease (most drugs are treatments rather than cures), quite possibly saving more lives than any other product of human innovation.

During the 'golden age' of antibiotic discovery in the 1940s to 1970s, scientists discovered hundreds, if not thousands, of new antibiotics, mainly natural products isolated from microbiological sources. The best of these were developed into drugs able to cure life-threatening infections. These early discoveries involved collaborative research largely unencumbered by confidential disclosure and material transfer agreements, with academic and industrial researchers working together to help save lives.

Unfortunately, bacteria have rapidly adapted to every new antibiotic introduced into clinics over the past 70 years. This has led to an 'arms race' in which scientists have continually developed more potent or novel antibiotics to stay a step ahead of the growing bacterial resistance. However, our discoveries of new antibiotics have not kept up with bacteria's ability to become resistant to existing therapies. A growing number of infections, particularly in countries such as Greece and India, where antibiotic misuse is rampant, are proving fatal because they are unable to be successfully treated by any antibiotic. These extremely drug-resistant bacteria are becoming increasingly common, readily swapping their resistance genes with other bacteria, and being carried around the world by international travellers. If this continues, infections that were previously innocuous may lead to death. If we are unable to use antibiotics preventatively, most surgeries will be impossible.

How has this happened? One cause is the misuse and overuse of

Left to right: CO-ADD coordinators Mark Blaskovich, Alysha Elliott and Johannes Zuegg.

antibiotics. Antibiotics have been widely used as growth promoters in animal feed. They are often prescribed to treat viral infections, where they have no effect. Patients often do not complete a full course of antibiotics, allowing a resistant subpopulation to survive. Poor hospital management, with a lack of handwashing and other appropriate infection controls, provides localised centres where resistant species can become established and thrive. The other main issue is a lack of new antibiotics in the clinical pipeline, particularly for the more difficult-to-treat Gram-negative infections (see box p. 18). The traditional source of new antibiotics, the large pharmaceutical companies, have largely abandoned antimicrobial research because research in this field is hard to justify economically – they can sell a new anticancer therapy that prolongs a life for nearly $US100 000 per year, but are unable to charge much more than $US5000 for a two-week course of antibiotics that can save a life.

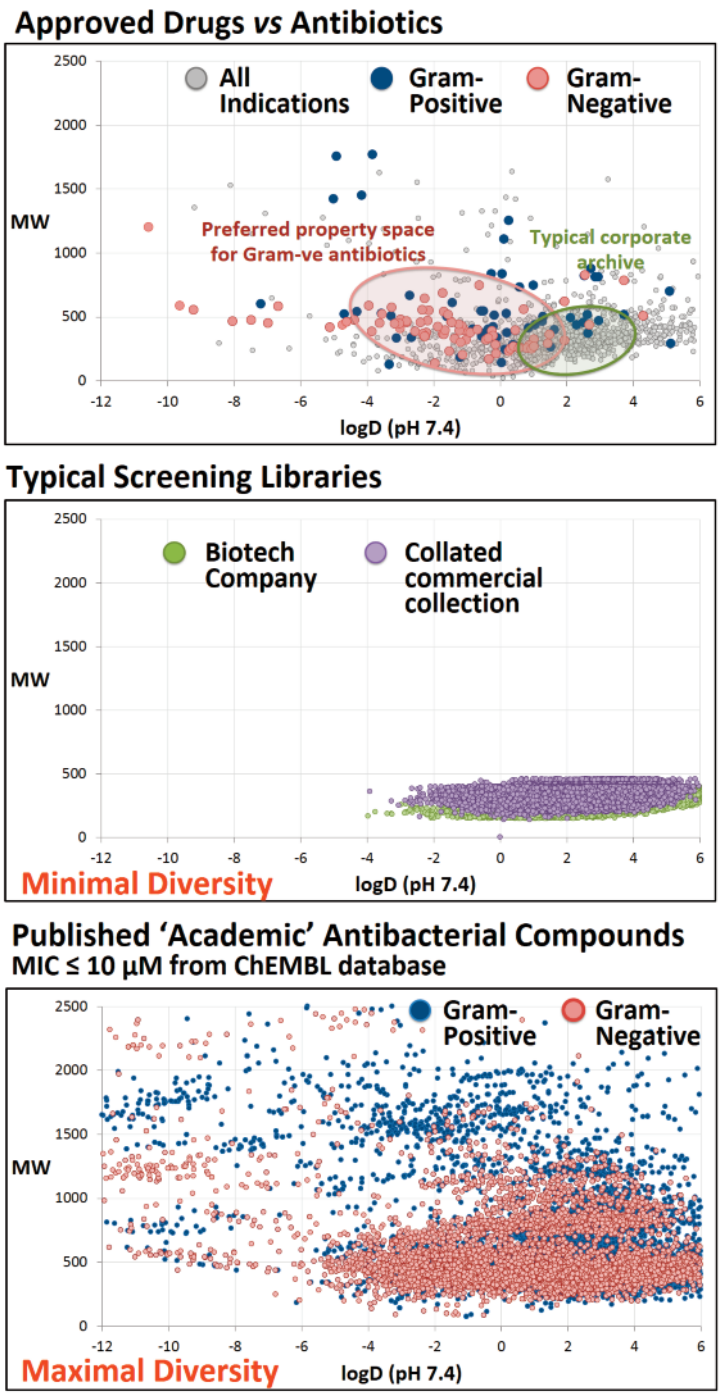
There is a public misperception that we may not need antibiotics. Indeed, alternative approaches for treating infections do exist. Vaccines have proved remarkably effective at reducing infections for certain pathogens, such as the meningococcal vaccine preventing meningitis caused by *Neisseria meningitides*. Unfortunately, vaccines are highly specific for the bacteria they are designed for, and are preventative, not a treatment once infection has happened. Phage therapy, used for decades in Eastern European countries, is a potential approach enjoying a renaissance, but once again it is highly specific for individual pathogens: a phage designed to treat an *E. coli* infection will not work for an MRSA (methicillin-resistant *Staphylococcus aureus*) infection.

'Natural' therapies that kill bacteria, such as a thousand-year-old Medieval Anglo-Saxon onion and garlic eye remedy that was recently shown to kill MRSA, are sometimes covered in the popular press. Although many of these natural extracts can kill bacteria exposed on a surface, if they were used to treat an infection within the body, where life-threatening infections occur, they would either be inactivated by and/or be highly toxic to the body itself.

We need new ways to discover new antibiotics. Antibiotics are different from many other types of drugs, and a lot of the rules developed over the last 20 years for drug discovery projects that focus on 'drug-like' properties mean that potential antibiotics might be discarded before they are even tested. If you look at two common descriptors for 'drug-like' properties – size (molecular weight) and

lipophilicity (log *P*) – most large pharmaceutical companies and commercially available screening libraries have a very limited distribution (see middle graph), as this range covers the chemical space of most orally available approved drugs (top graph). Approved antibiotics exhibit a much more diverse range (top graph), partly because many are administered intravenously. Published academic compounds that have reported antimicrobial activity show a similar diverse distribution (bottom graph), so if only those with 'drug-like' properties are considered, potential life-saving antibiotics may be missed.

The Australian-based Community for Open Antimicrobial Drug Discovery (CO-ADD) is our attempt to develop a collaborative pipeline of new antibiotic candidates by mining the diverse chemical space of synthetic chemists around the world. Chemists make new molecules for all sorts of reasons, and many of these molecules have unusual structures. However, once made, many compounds are either thrown away or just get stored on shelves and in fridges in the backs of labs, and are certainly never tested for antimicrobial activity. With funding from the Wellcome Trust and support from the University of Queensland, CO-ADD is offering free testing to see if compounds can kill any one of five key pathogenic bacteria or two fungi. Importantly, whoever submits the compound keeps all the rights to publish or patent, and develop any promising compounds. CO-ADD will use the screening data to generate a publically accessible database to allow other scientists to see what types of molecules have antimicrobial activity and, just as importantly, what types don't.



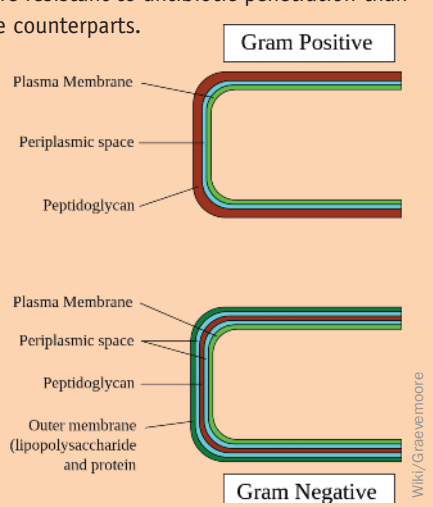
Chemical diversity of approved drugs, antibiotics, screening libraries and academic compounds with antimicrobial activity.

Johannes Zuegg

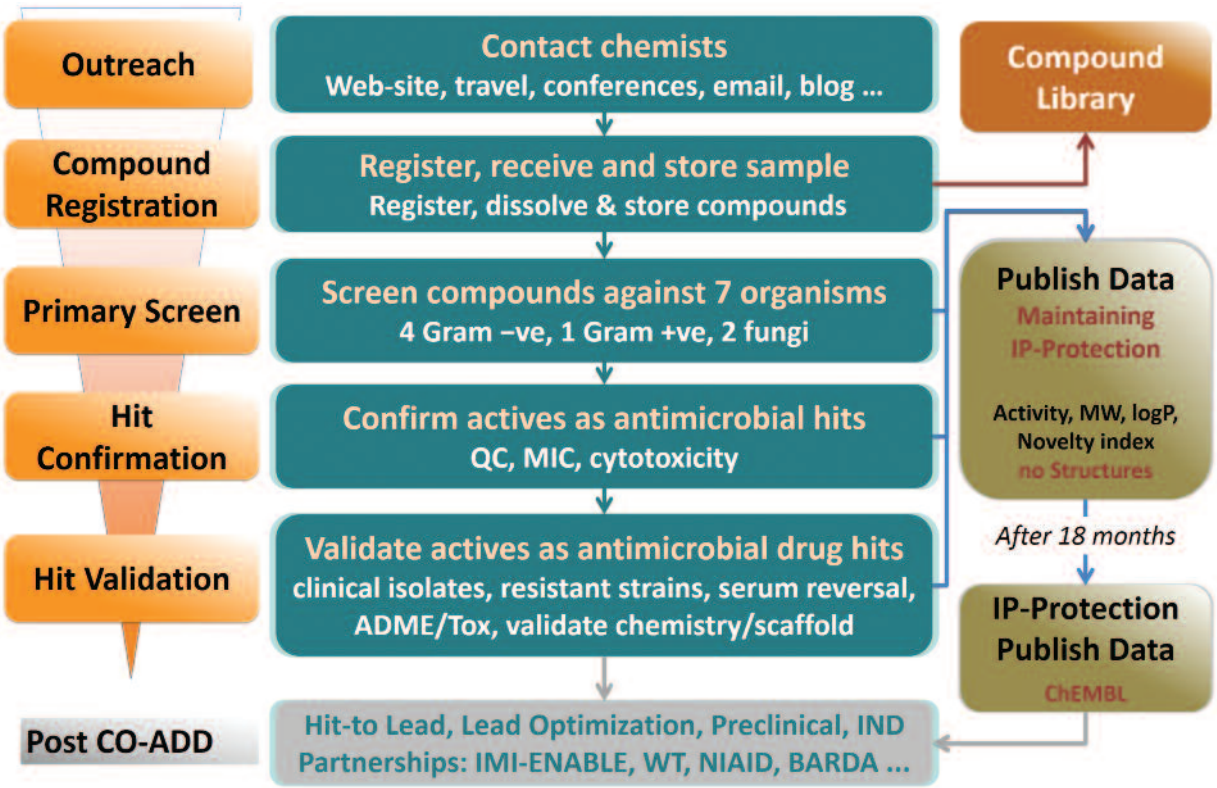
Gram staining and antibiotic resistance

Bacteria can be broadly divided into two classes on the basis of how they react to staining with crystal violet stain, a test devised by Danish physician Hans Christian Gram in 1884. Gram-negative bacteria cannot retain violet stain because the peptidoglycan layer between the two membranes of their cells is relatively thin.

The extra membrane of Gram-negative bacteria makes these microbes more resistant to antibiotic penetration than their Gram-positive counterparts.



Cell wall structure of Gram-positive and Gram-negative bacteria.



Workflow of CO-ADD antimicrobial screening.

Just 1 mg of compound is required for testing, or 50 μL of a 10 mM solution. Once received, compounds undergo an initial single concentration screen at 32 μg/mL to test their ability to inhibit the growth of any of five bacteria (one Gram-positive, MRSA, and four Gram-negative, *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*) or two fungi (*Candida albicans*, *Cryptococcus neoformans*) (see flowchart). Any 'hits' undergo a 'hit confirmation' assay, with dose ranging measurement of the minimum inhibitory concentration against the pathogens, counter-screening for cytotoxicity against mammalian cells, and quality control to confirm identity and purity. Compounds that pass these criteria are progressed to a more comprehensive evaluation in the 'hit validation' stage. All the data is returned to the submitting scientist, for them to publish, patent or develop.

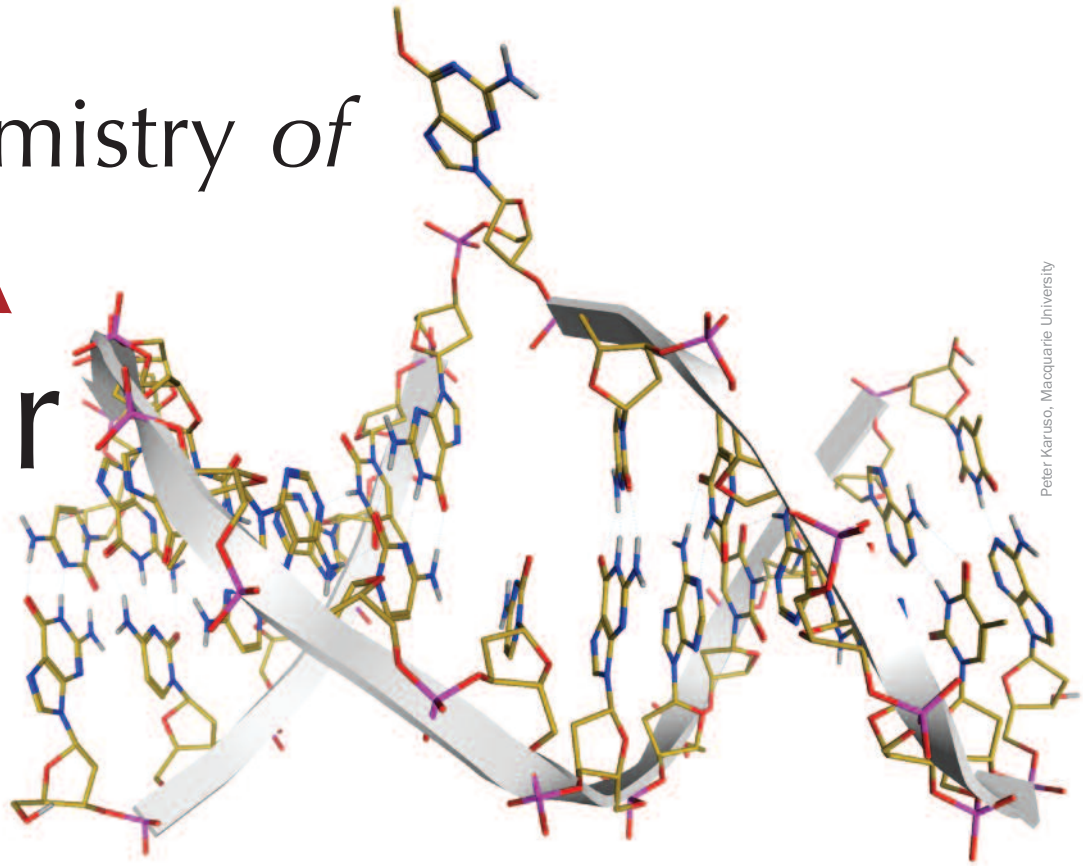
CO-ADD has had a great reception from the scientific community, with more than 80 participating groups from 26 countries sending nearly 20 000 compounds in our first eight months, and over 300 000 additional compounds promised. We have run a 'Thinkable' competition (http://thinkable.org/competition/30) to award novel ideas for submissions. It's still too early to see whether we'll discover the next antibiotic, but we've already identified nearly 500 compounds with promising activity, which require further testing.

To foster the collaborative effort, CO-ADD has established contacts with a range of other organisations, including Compounds Australia, IMI-ENABLE (the European Union Innovative Medicines Initiative – European Gram-negative Antibacterial Engine), ChEMBL, ANTRUK (Antibiotic Resistance UK), NPS MedicineWise, the RACI, Royal Society for Chemistry and American Chemical Society. Notably, the output of CO-ADD (validated antimicrobial activity under standardised conditions, coupled with additional characterisation) is exactly the data package that IMI-ENABLE is asking for in submissions for hit-to-IND (investigational new drug) development. Looking to the future, CO-ADD is actively seeking additional funding to expand screening of this unique collection of compounds to include other neglected diseases such as tuberculosis, malaria, dengue and parasitic diseases such as leishmaniasis and Chagas disease.

CO-ADD relies on your help to be successful, so please dig into those dusty boxes of vials and send us your compounds! Students, set aside a sample of every compound you make, and send them in every few months. You could quite easily gain an additional publication for relatively little effort and, more importantly, contribute towards a solution that will save lives.

Mark Blaskovich MRACI (m.blaskovich@imb.uq.edu.au) is Program Coordinator, Hit Validation & Chemistry, Community for Open Antimicrobial Drug Discovery, Institute for Molecular Bioscience at the University of Queensland.

The chemistry *of* DNA repair



Peter Karuso, Macquarie University

2015 Nobel Prize in Chemistry II

The 2015 Nobel Prize in Chemistry was awarded for discoveries in the enzymatic mechanisms of DNA repair. Here, we consider the roles of Tomas Lindahl and Paul Modrich in this fundamental and groundbreaking work.

BY **PETER KARUSO**

Image: **O6-methylguanine DNA methyltransferase, based on the crystal structure of Maria Ciaramella (*Nucleic Acids Research* 2015, vol. 43, p. 8801).**

In Part I (February issue, pp. 14–17), we looked at nucleotide excision repair (NER), photoreactivation and Aziz Sancar's contribution to DNA repair. In this issue, we will look at base excision repair (BER), mismatch repair (MR) and the roles of Tomas Lindahl and Paul Modrich in elucidating the mechanism of BER and MR.

So, how stable is DNA anyway?

Tomas Lindahl was certainly thinking about the stability of DNA in 1961, when he started his PhD in biochemistry at the University of Stockholm (thesis title: 'On the structure and stability of nucleic acids in solution'). Originally trained as a medic, Lindahl was lured into research by **Einar Hammarsten**, Emeritus Professor of Biochemistry at the Karolinska Institute. He completed his PhD in 1965 and later went back to finish his medical training (MD, 1970). However, in between he landed a postdoctoral appointment at Princeton with **Jacques Fresco**. He worked on heat-induced unfolding of transfer RNA (tRNAs are the molecules that bring amino acids to the ribosome where they get built into proteins, see March 2010 issue, pp. 24–7).

In contrast to DNA, RNA is a nightmare to work with because it is extremely prone to degradation by ribonuclease enzymes that seem to be lurking in every corner of every lab. So, when the Fresco lab's new postdoc failed to get his RNA folding experiments to work it was taken as a sure sign of incompetence. After all, Lindahl had two handicaps: he was both a medico and Swedish. However, Lindahl had other ideas. He noticed that the RNA degraded at the same rate every time, regardless of how it was prepared and purified, which didn't make sense if the RNA was contaminated with random ribonucleases. He even wrote up a small paper on the instability of RNA (Lindahl, *J. Biol. Chem.* 1967, vol. 242, pp. 970–3) that Fresco politely declined to co-author. Lindahl wondered 'how stable is DNA

anyway?' Surely if RNA can completely degrade in 10 hours at 90°C, then DNA can't be that much more stable? Chemically, after all, the only difference is a single hydroxyl group on the ribose.

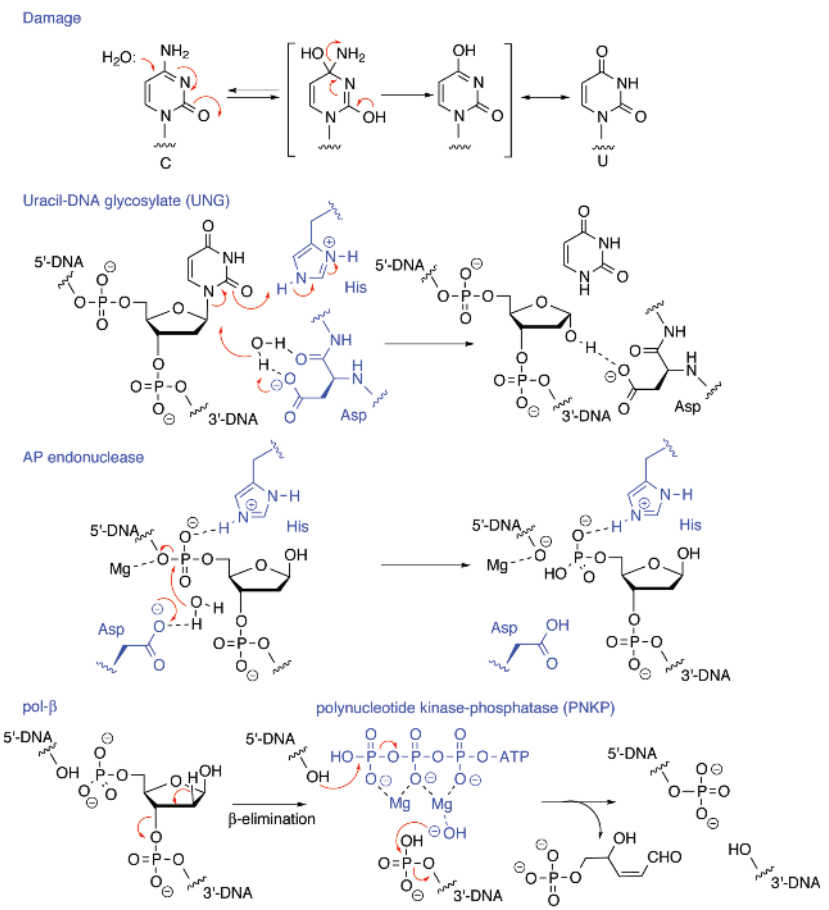
Lindahl promptly forgot about these questions and moved onto another postdoc at Rockefeller University (**Gerald Edelman**, Nobel Prize 1972) and then back to Sweden to finish his medical degree in 1970. In 1971, he took a position in the department of chemistry at the Karolinska Institute where he returned to the question of how stable DNA really is. This led to a landmark paper (Lindahl and Nyberg, *Biochemistry* 1972, vol. 11, pp. 3610–18) where he showed that the rate of DNA depurination is $4 \times 10^{-9}\,s^{-1}$ at 70°C, pH 7.4, and that the activation energy for the reaction is 31 ± 2 kcal/mol. These data suggested that DNA should spontaneously degrade at room temperature, albeit slowly. Lindahl's grounding in chemistry meant that he was the first to understand that the necessity for DNA repair existed, not because of exogenous insults, but because of the inherent lability of specific bonds in DNA. By 1972, he had characterised several spontaneous degradation pathways, including deamination, oxidation and methylation.

The first chemical weakness he investigated involves the conversion of cytosine (C) to uracil (U). C pairs with G (guanine) but U pairs with A (adenine). If this conversion is not corrected the next time the DNA is replicated, then the U (was originally a C) will pair with a T (thymine) instead of the correct G. This would spell certain disaster for the cell so there had to be a way of rapidly repairing this sort of damage. In tracking down how the C-to-U error was fixed, Lindahl discovered an entirely new class of repair mechanism: base excision repair (BER).

The damage is caused by spontaneous hydrolysis (deamination) of C to U (see figure). The U is detected and chopped out of the DNA chain by uracil–DNA glycosylase (UNG), an enzyme able to cleave the bond between the base and the backbone, leaving the double-stranded backbone intact. endonuclease then cuts the 5′-phosphodiester and DNA polymerase β (pol β) cuts the 3′-phosphodiester, leaving a gap. Polynucleotide kinase-phosphatase (PNKP) then removes the 3′-phosphate and adds on a 5′-phosphate, utilising its dual phosphatase and kinase activity and pol-β comes back again to replace the gap with a C. A final ligation repairs the damage so that the DNA can now be faithfully copied or transcribed.

By 1974, Lindahl had characterised the first repair protein in BER from *E. coli* (UNG). At about the same time, Tomas was persuaded by the head of department (Peter Reichard) to work on Epstein-Barr virus (EBV) because 'no one else is working on DNA repair in Sweden and you need someone to talk to'. Reichard suggested a collaboration with Georg Klein (also at the Karolinska), which quickly bore fruit with Lindahl discovering that the EBV replicated in cells as a discrete circle of DNA (plasmid).

In 1978, Lindahl moved to Gothenburg where he took up a professorship in medicinal chemistry and continued to work on EBV and DNA repair. Despite both projects going well, he only lasted in Gothenburg for three years and moved to the UK for someone much more important than science (Beverly Griffin), who he met at an EBV conference and was working at the Imperial Cancer Research Fund (ICRF) also on EBV. Lindahl got a job at the ICRF in 1981, in the same building that Beverly worked and continued to



The base excision repair mechanism.

work on EBV and DNA repair. However, because **Walter Verly** (Montreal) and others were hot on his heels, having identified similar activity, and Verly had also proposed that this was part of a new DNA repair system, and to avoid getting ulcers trying to keep two projects going, Lindahl dumped the EBV project to concentrate entirely on DNA repair. By 1982, he discovered another repair mechanism where *O*-6-methylguanine-DNA methyltransferase, restores mutant *O*-6-methylguanine bases by taking one for the team. Thus *O*-6-methylguanine-DNA methyltransferase is not a true enzyme because once the aberrant methyl is transferred from the DNA to the enzyme, the 'enzyme' is permanently inactivated – the enzymatic equivalent of falling on a live grenade.

In 1986, Lindahl became the first director of the ICRF's Clare Hall research institute in Hertfordshire, which became part of the Francis Crick Institute in 2015. At the new location, by 1994 he had reconstituted the entire BER system for *E. coli* in a test tube … and it repaired DNA! By 1996, the entire human BER system was reconstituted (it worked too). This allowed a clear picture of how the whole system works and raised many philosophical questions as to when such mechanisms first evolved and when to repair … or not repair to evolve.

DNA may not be stable but replication is perfect, right?

We have about 6.0×10^9 base pairs in our DNA (the human genome of about 19 000 genes) in one cell, which would stretch to about two metres if it were all one strand. In the original fertilised egg, there is just one copy of this precious blueprint but an adult has about 3.7×10^{13} cells. An adult has enough DNA that if it were strung into one strand it would reach to the sun and back over 250 times (7.4×10^{10} km). The original template from single cell to adult human has to be copied at least 3.7×10^{13} times, probably much more ... with no mistakes. Can anything really be that perfect?

Certainly in 1959 when **Arthur Kornberg** and **Severo Ochoa** won the Nobel Prize in Physiology or Medicine for their discovery of the mechanism in the biological replication of DNA, and when **James Watson** and **Francis Crick** received their Nobel Prize (1962) for the structure of DNA, it was thought that:

> … specific base pairing underpinned the *perfect copying of the molecule* [author's emphasis], which is essential for heredity. During cell division, the DNA molecule is able to 'unzip' into two pieces. One new molecule is formed from each half-ladder, and due to the specific pairing this gives rise to two *identical daughter copies* from each parent molecule.
>
> www.nobelprize.org/educational/medicine

However, today we know that about 50 000–100 000 mistakes/changes occur in your DNA per cell every single day. Most of these are caused by radiation, oxidation, alkylation and hydrolysis but some are just mistakes in copying the DNA. It turns out that about 1 in 500 000 errors are made every time a genome is copied. That is at least 2×10^{19} errors in a lifetime. Luckily DNA polymerase has built-in error checking (exonuclease activity), but even so there are 1 in 10 000 000 errors encoded per cell division. That is, a wrong nucleotide ('mismatch') is put into the copied DNA strand. This means in copying a genome (6.0×10^9 base pairs (12 billion bases)), 1200 errors would be encoded in each replication!

There must be a way to fix this. Herein lies one of molecular biology's biggest mysteries: when single-stranded DNA is copied, how does the cell know which of the two resulting strands is the correct copy?

In the mid-1970s, **Matthew Meselson** (Harvard), who did his PhD for **Linus Pauling** in CalTech on equilibrium density gradient centrifugation, proposed that the DNA methylation is used to identify the correct strand, at least in bacteria. Some years earlier, Meselson and

Duke University Photography

Paul Modrich

Franklin Stahl (as part of the 'phage group') proved that DNA is replicated semiconservatively. That is, by growing *E. coli* on media that contains only nitrogen-15 and then switching to nitrogen-14 media and then using equilibrium density gradient centrifugation to separate out the DNA, they showed that the newly synthesised DNA was half ^{15}N and half ^{14}N. **Paul Modrich** was a postdoc at Harvard at the time, working for **Charles Richardson** on DNA polymerase from bacteriophage T7 and knew of Meselson's work. In 1976, Modrich was offered a job at Duke University and proposed to work on the newly discovered restriction enzymes (e.g. EcoR*I*).

Paul Modrich was born in a small town in New Mexico (13 June 1946) and was always interested in nature. His father was a biology teacher and when it was announced in 1962 that Watson and Crick had won the Nobel Prize for the structure of DNA he said to Paul 'you should learn about this DNA stuff'. Modrich was Junior at High School at the time in Raton, New Mexico, and went on to study Chemistry and Biology at MIT (BSc, 1968) and then Stanford for a PhD ('Structure, mechanism, and biological role of *Escherichia coli* DNA ligase') in 1973, where he did learn lots about

DNA. His advisor was **I. Robert Lehman** who worked on DNA enzymes and the two of them published a series of eight papers from his PhD work on *E. coli* ligase – the enzyme that repairs breaks in a DNA strand. After Harvard, Modrich set up his own lab at Duke University in rural North Carolina. He soon discovered (1977) that DNA methylation was critical to the functioning of restriction enzymes such as EcoR*I* and so turned his attention to dam (deoxyadenosine) methylase, which Meselson had just suggested was involved in DNA mismatch repair (MR). This started Mordich on the road to discover the exact mechanism of MR. The first major result was the discovery that elevated expression of dam methylase in *E. coli* led to bacteria that were hypermutable. This was consistent with Meselson's theory that dam methylase was involved in MR.

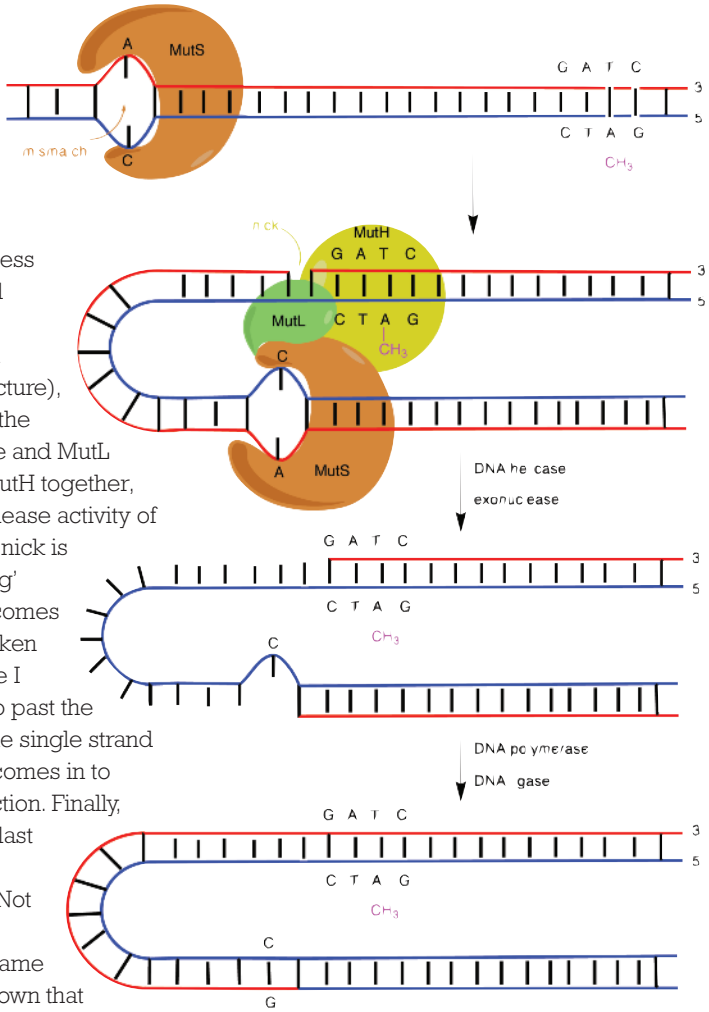
Working with Meselson, they designed and performed one of those definitive experiments that was both profound and simple (*Genetics* 1983, vol. 104, pp. 571–82). They created a λ phage virus that intentionally had DNA mismatches and infected *E. coli* with this mutant virus. They found that when DNA was methylated on only one of the two strands (λ phage virus is a double-stranded DNA virus), MR occurred only on the unmethylated strand, and when neither DNA strand was methylated, repair occurred on either strand.

This was the first direct evidence that methylation directs repair of mismatches and kick-started a decade of research from the Modrich lab, isolating and characterising every enzyme in the MR machinery, and resulted in a molecular understanding of the process. By 1993, Modrich had reconstituted the entire *E. coli* MR system, consisting of the proteins MutS, MutH, MutL, DNA helicase II, DNA polymerase III, single strand binding protein (SSB) and DNA ligase. With the addition of ATP and the four deoxynucleoside triphosphates (dNTPs), the system effectively repaired mismatched DNA.

In vivo, methylation of DNA occurs slowly so that the new DNA strand in semiconservative replication always has less methylation that the old strand. Once the MutS recognises a mismatch (bulge in the DNA structure), it recruits MutH to find the nearest methylation site and MutL then glues MutS and MutH together, activating the endonuclease activity of MutS and ensuring the nick is made next to the 'wrong' base. DNA helicase II comes in and unwinds the broken strand and exonuclease I cuts out all the strand to past the mismatch. SSB holds the single strand and DNA polymerase comes in to rebuild the missing section. Finally, DNA ligase makes the last phosphodiester bond.

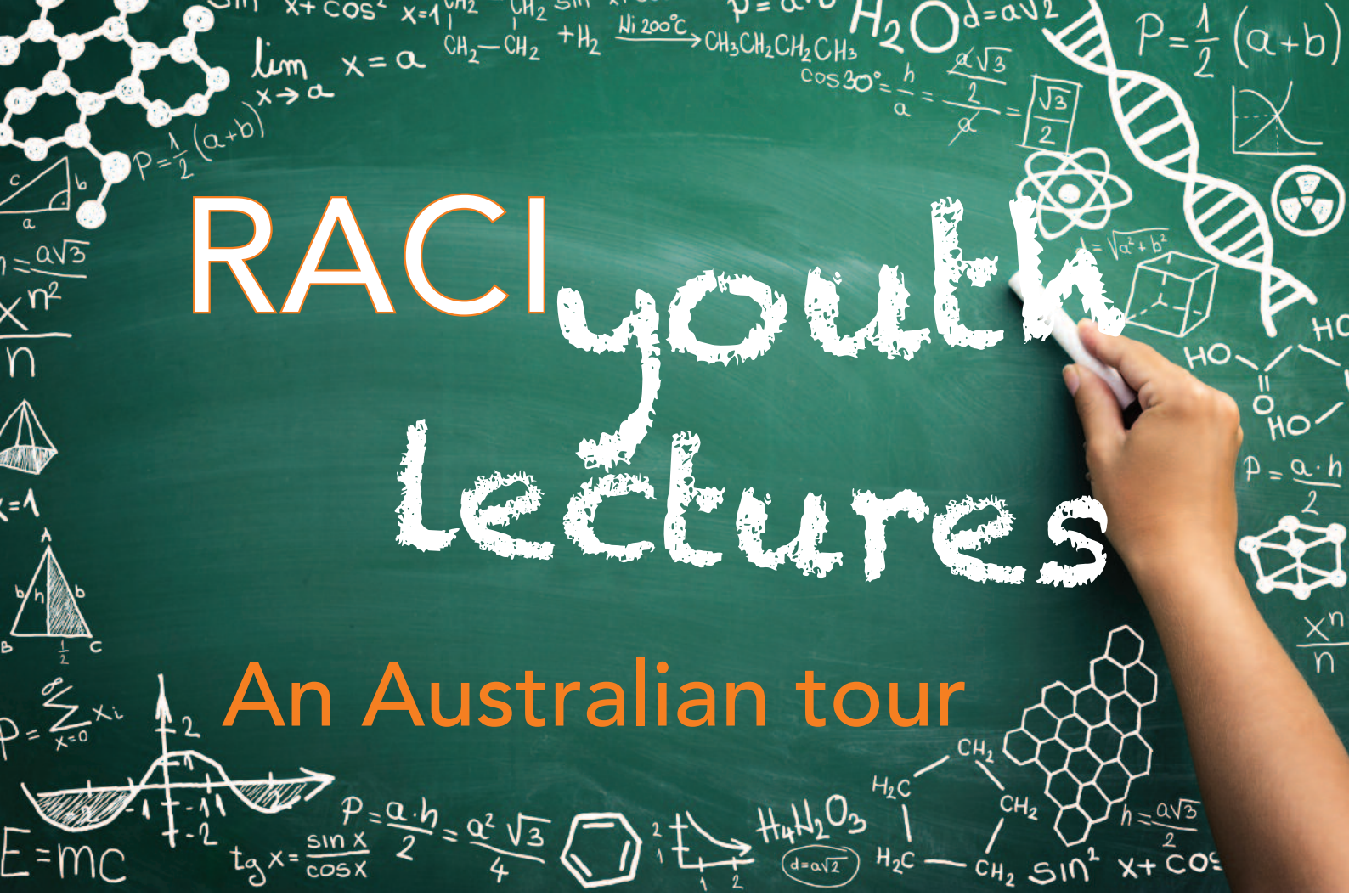
So mystery solved! Not quite: humans do not methylate DNA in the same way and it has been shown that methylation does not direct MR in humans. So MR remains one of molecular biology's biggest mysteries. Several theories exist on how mammals recognise the 'wrong' strand. These include nicks apparently present in the newly formed strands or the occasional presence of ribonucleotide bases transiently present in the newly formed strand. In other aspects, human MR and bacterial MR are surprisingly similar. By 2004, the Modrich lab had successfully reconstituted the entire human MR repair system in a test tube and showed that it worked too.

Defective MR is responsible for hereditary colon cancer and possibly many other types of cancer. Knowledge of DNA repair has also allowed the design of better anticancer drugs that cause damage that cannot be repaired or take advantage of cancer cells' drug resistance. Knowledge of which repair mechanism is defective can be used to target the remaining mechanisms to selectively kill the cancer cells. The recently introduced drug olaparib is a PARP inhibitor and an effective anticancer drug for cells that are overly reliant of nucleotide excision repair, which relies on PARP to fix single-stranded DNA breaks. Also, the patterns of DNA damage discovered by Lindahl are now used to give the stamp of authenticity to ancient DNA. A recurring theme for the 2015 Laureates is that they came upon their life's work while trying to study something completely different. 'That is why curiosity-based research is so important: you never know where it is going to lead…' Paul Modrich, 2015.



Bacterial mismatch repair.

Peter Karuso FRSN, FRACI CChem is the Professor of Chemistry at Macquarie University, Sydney. Part I appeared in the February issue.



RACI youth lectures

An Australian tour

iStockphoto/CherriesJD

Many RACI members know about the youth lectures in their own state. Here's what's happening elsewhere across the country.

Bayliss Lecture Series (WA)

The Western Australian Branch of the RACI established the Bayliss Youth Lecture Series in 1971 to pay tribute to the late Emeritus Professor Sir Noel Bayliss, Kt, CBE, FAA, FRACI for his contributions to chemistry and education, and to encourage in young people an interest in chemistry. These lectures given by inspirational chemistry speakers from academe and industry are aimed at high school students from year 9 and the general public. Recent topics have included forensic science, conservation and medicinal chemistry.

The Bayliss Youth Lecture is organised by the Chemical Education Group of the Western Australian Branch of the RACI with support from ChemCentre, Rowe Scientific, Kwinana Industries Council and the Northern Territory Branch of the RACI. Over the last few years it was presented in a number of metropolitan and country locations in Western Australia as well as in Darwin in the Northern Territory.

Speakers selected for the last few years have been chosen to specifically address the year 11 and 12 chemistry curriculum. For example, in 2015 and 2016, this has meant more of a focus on analytical chemistry, as this has recently had a higher profile in the Western Australian Curriculum. The lectures also take into account subjects of broad interest to the general public, such as conservation science, medicine, environmental science and forensic science.

D.R. Stranks Memorial Lecture (SA)

The Chem Education group in South Australia runs the D.R. Stranks Memorial Lecture every year. It is targeted at year 11 and 12 chemistry students and is usually given in the Rennie Lecture Theatre at the University of Adelaide. The lecture is unsponsored and entry is by gold coin donation.

The lecture is held in honour of Professor Donald Stranks, a former Professor of Inorganic Chemistry and Vice Chancellor at the University of Adelaide, and Professor of Inorganic Chemistry at the University of Melbourne.

The Chemical Education Group discusses possible presenters. In the last two years they have tried to fit the lecture to the International Year theme for that year. Last year, the theme was light and the speaker was Professor Greg Metha, Head of Chemistry at University of Adelaide.

The Chemical Education Group discusses possible presenters. In the last two years they have tried to fit the lecture to the International Year theme. In 2014, it was the International Year of Crystallography and Professor Jenny Martin, Laboratory Head in the Chemistry and Structural Biology Division, University of Queensland, gave a talk entitled 'Why should we know about crystallography?'. Last year, the theme was light and Professor Greg Metha, Head of Chemistry at the University of Adelaide, spoke on 'Light, life and the universe – a chemistry perspective'.

> Brilliant personal connection – knowing the people and research behind the discovery makes it come alive.

Teacher
2014 D.R. Stranks Memorial Lecture

Hartung Youth Lectures (Vic.)

The Hartung Youth Lectures aim to inspire students in years 9–12 and promise an engaging and educational experience, in the tradition of the lectures given by Professor Hartung over 50 years ago.

Ernst Johannes Hartung (1893–1979) was Professor of Chemistry at the University of Melbourne, an outstanding lecturer who made a point of carrying out experiments and demonstrations during his lectures, and a renowned astronomer. He was President of the RACI on three separate occasions.

The Hartung lectures are open to school students, usually years 9–12, and are free. The Victorian Branch picks up the cost of the lecturer's travel and accommodation and there is a small honorarium associated with the lecture.

For the past few years, the Branch has arranged for universities around the state to host the lectures – last year, they were planned for La Trobe University campuses in Wodonga, Bendigo and Bundoora, and Federation University campuses in Ballarat and Churchill. In 2014, the lecture in the city was held at RMIT University. In 2015, the lecture was held at University High School and at the John Monash Science School (which is located on the Monash University Campus). The lecture is presented several times at some locations, so the Hartung lecturer has to work quite hard!

The RACI and the universities promote the event to schools via established mailing lists and also through the CEA (Chemical Education Association). Schools respond, register the number of students attending and organise to get their students to the relevant venue.

The lecturer is chosen by the Branch Committee. Usually, they seek expressions of interest via the *Reporter* and form a subcommittee to review applications in order to make a selection, although the Branch does from time to time approach someone they feel would make a good Hartung lecturer and make the appointment. They try and ensure that the lecture is given at least once during Science Week.

> What I really took from the experience was learning how to present and phrase my research in a manner that was both engaging and intellectually stimulating to students, while avoiding the terminology and assumptions that I take for granted.

Dr Colin Scholes (University of Melbourne)
2015 Hartung youth lecturer, 'Chemistry of the atmosphere and climate change'

Nyholm Lecture Series (NSW)

The Nyholm Lecture Series commemorates Sir Ronald Nyholm (1917–71), an outstanding Australian researcher and passionate chemical educator. The Nyholm lectures began in 1979 and have run more or less annually since then in various formats.

These popular lectures are aimed at year 9 and 10 students. They are loosely linked to the year 7–10 Science syllabus, although others will find their material inspiring. A feature of the lectures is their practical content and interactive presentation style. The lectures generally run in term 2, although in 2015 they also ran in term 3. In 2016, the aim is to run the lectures exclusively in term 2 (May–June).

The 2015 lectures were presented at a range of venues in metropolitan Sydney and country New South Wales by two outstanding chemical educators. Lecturers deliver their lectures over two years, visiting different venues in each year. Each lecturer gives lectures at 6–8 school and university venues, sometimes multiple times, each year.

Prospective lecturers are sought for the following year from term 2 (July) onwards. Lectures must be relevant to the year 7–10 Science syllabus. The vacancy is advertised in the New South Wales monthly branch newsletter. The lecture series is then advertised from term 4 onwards to encourage schools to request to host a lecture or to enquire about attending a different venue. The lecturer for the current year is advertised at this time.

> I am now very proud of the contribution to science that an Adelaide-born scientist had.
>
> Student
> 2014 D.R. Stranks Memorial Lecture

O'Donnell Schools Lecture (Qld)

The RACI Schools Lecture series was introduced in 1980 by the Chemical Education Group of the Queensland Branch. The Group was headed by Professor Jim O'Donnell, the resident Professor of Physical Chemistry at the University of Queensland. Jim passed away in 1995, and the series has been subsequently renamed in his honour. The lecture is open to students in years 11 and 12 studying chemistry/science. Students in Junior Secondary interested in studying chemistry/science to grade 12 may also attend.

The location and number of lectures varies from year to year. Owing to their own lecture and research commitments, and geographical distances in Queensland, the lecturers are unable to visit all regions every year. Sponsorship is received by the Cairns Business Liaison Association to ensure that the tour visits the Far North Queensland schools district every year. Other regional areas are on a rotational basis – usually biannually.

In the mid-2000s, the lecture was not held every year. Historically, the lecturer took about three months off their lecturing and research jobs and drove around the state. This was becoming increasingly costly, and increasingly difficult for the lecturers to take this amount of time away from their jobs. The tour is now divided into regions, with the lecturer doing a fly-in, fly-out option for a few days or up to a week. For the local schools in the lecturer's own area, they fit the school visit around their daily university schedule.

All the Queensland universities are represented on the Chemical Education Group. Each year all the members look among their own colleagues and networks and suggest names for lecturers. Then the group decides.

Consideration is given to the academic institution and the field of research of the lecturers. The field of research is to be relevant to the curriculum, and the lecture to be age appropriate – and there should be a diversity of fields of chemistry presented from year to year, as well as a fair representation across the universities.

> I learned that high school students were engaged when they saw that chemistry is not just about complex calculations and reaction mechanisms – it underpins exciting current and future applications.
>
> Dr George Vamvounis (James Cook University)
> 2015 O'Donnell Schools lecturer,
> 'Semiconducting polymers: shining new light on plastics'

The universities are very supportive of the RACI lecture series, and the lecturers can accept the honour of being the lecturer without any financial loss of pay or leave entitlements from their academic roles.

It is extremely difficult to find an individual in industry in Queensland who can take the time away from their jobs (and have the employer support them during that time). Costs prevent bringing in an interstate or international speaker to Queensland.

Tasmanian Branch (RACI) Youth Lecture

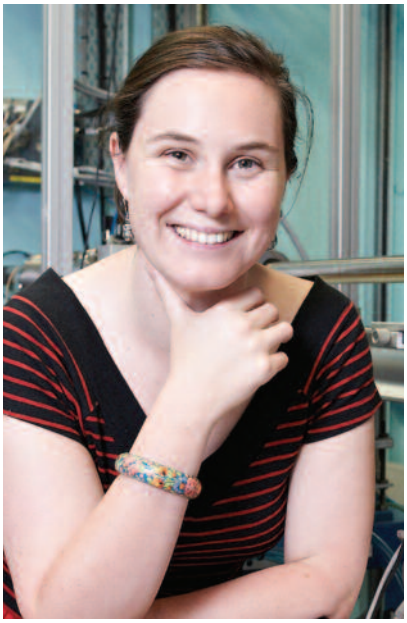
The Tasmanian Branch has organised and hosted the Tasmanian Branch (RACI) Youth Lecture since the late 1970s. The lectures are for primary and secondary school children, and one lecture (in Hobart) is open to the public.

The Tasmanian Branch committee canvases committee members and associates for potential lecture candidates. Usually at least two possible candidates are identified. The committee uses recommendations from other Branches and its own network to help identify and select candidates. The committee attempts to obtain as much information about the candidates as possible (testimonials, previous presentations) during its selection process. The search for a lecturer usually occurs in the same year as the lecture. There are no formal selection criteria.

Up to six lectures (including the public event) are delivered, spread between Hobart and Launceston and several regional centres (e.g. Ulverstone, Devonport, Burnie). The lectures usually occur in September, occasionally October.

The Youth Lecture is usually sponsored by the local Branch, rather than a third party. Last year was a little different because the Australian Institute of Physics helped support the Hobart Youth Lecture (public event). However, sponsorship is rare. The Branch may look to change that in future.

There is usually no honorarium but the Branch pays for the lecturer's reasonable expenses (flights, accommodation). The lecturer is usually happy not to ask for a 'fee for service'.



I was fortunate enough to get a really great variety of questions, some that I had to write down as they may be a good course of action for further research!

Dr Helen Maynard-Casely (ANSTO)
2015 Tasmanian Branch (RACI) youth lecturer, 'Exploring the solar system with the bright lights of Australia'

Compiled by Sally Woollett. Thanks to the RACI National Office, Branch presidents and coordinators and youth lecturers for their assistance with this article.

RACI youth lectures at a glance

Lecture	When and where	Suitable for	Forthcoming lectures
Bayliss Lecture Series	Seven or eight lectures between March and June Metropolitan and country locations in WA as well as in Darwin in the NT	Year 10 upwards, and the general public	Zombies, cars and shoes: case studies in physical 'evidence': Dr Kari Pitts, ChemCentre Contact: Simon Lewis, s.lewis@curtin.edu.au
D.R. Stranks Memorial Lecture	One lecture per year. Usually runs in June at Rennie Lecture Theatre at the University of Adelaide	Year 11 and 12 chemistry students and their teachers	2016 lecturer to be decided Contact: Robyn Pillans, robynp@saceboard.sa.gov.au
Hartung Youth Lectures	About 10 lectures. Universities around Victoria, at least once during Science Week, with other lectures in September	Year 9–12 students	Kitchen chemistry: Dr Christopher Thompson, Monash University Contact: Richard Thwaites, richard.thwaites@bigpond.com
Nyholm Lecture Series	Around 14 lectures during school term 2; a range of venues in metropolitan Sydney and country NSW	Year 9 and 10 students	Sugars, drugs and rock and roll: Dr Michela Simone, University of Newcastle Fundamentals of radioactivity and its interesting applications: Dr Lidia Matesic Contact: Pam Chantrell, raci-nsw@raci.org.au
O'Donnell Schools Lecture	Lectures in school term 3 and the first part of school term 4; various regions in Queensland depending on lecturer	Year 11 and 12 students and students in years 8 and 9 who are interested in continuing to study chemistry/science	2016 lecturer to be decided Contact: Ruth Meaney, qld-raci@raci.org.au
Tasmanian Branch (RACI) Youth Lecture	Up to six lectures, between Hobart and Launceston, and in several regional Tasmanian centres, during September or October	Primary and secondary school students, and one public lecture	2016 lecturer to be decided Contact: Nathan Kilah, nathan.kilah@utas.edu.au

Mentoring – an open invitation

I first joined the RACI in 1994 with vague notions of furthering my career. I guess I just expected that if I joined up, I would come to know people, and career opportunities would flow. But of course, I had very few networking skills, and found it very difficult to make connections at the events I attended.

Over a few short years of membership, I was able to discern relatively few tangible benefits, and my ties to the RACI weakened. I let it lapse, and moved on with my commercial career.

The membership statistics say that this is a common story. As an organisation, we are getting pretty good initial interest from young chemists (it could be better), but we are then losing many of these during the first years of their career.

Given that the membership fees are not very high, my interpretation is that these early career losses must come down to *perceived* value – in loose terms 'what's in it for me?' – and our struggle as an organisation to answer that question really well. Possibly the best answer to that question is 'you get from membership what you put in', but that is much easier later in your career than earlier.

I rejoined RACI in 2013, with the express intention of giving back to the profession that I love. One focus has been to trial various initiatives to create direct value for young chemists via networking and advice.

Via the New South Wales Analytical and Environmental Group (NAG), we created a two-hour lecture series on understanding the job market (bit.ly/1Nou93Z) as part of a wider initiative to create educational webcast content for the RACI. And I invite any universities or groups to contact me if you would like me to give some version of the talk to your students.

Last year, together with the NSW Young Chemists Group, the NAG organised a 'speed dating' event (October 2014 issue, p. 40), and we followed this up with a short flyer for young chemists on how to network at events – techniques for walking into a room full of people you don't already know and making good connections.

There is one more initiative that I want to raise – and I do so with an open invitation to our RACI members (both established members and young chemists) to contact me if you are interested in participating.

For the last year or so, the NSW Branch has trialled a mentoring program for young chemists. Following an application and matching process, two student members, Melissa Neskoski and Tom Frith, were selected to work with me to help prepare them for the workplace, grow their networks, and generally support them through their Honours year and into their chosen career paths.

As their mentor, I spent time getting to know the young chemists, talking with them about their university experience and aspirations. I offered them guidance on *how* to select their Honours project topics (but not *what* to choose). I invited them to RACI events and paid for their tickets to make their attendance easier (which would of course be entirely optional for other mentors, and we might in future be able to fund this from sponsorship if the program grows).

At the RACI events, I introduced them to other members, and generally kept an eye on their movement in the room to

Melissa Neskoski (BForSc(Hons)), University of Technology Sydney

As an individual who was unsure of my future career path, and who lacked confidence in the area of networking and communicating with 'new' people, I found this program to be quite beneficial.

This program has allowed me to find out more about myself, and made me realise that I am a valuable and capable individual who has something to offer the science industry. It has allowed me to develop many friendships, including with my mentor as well as with the other mentee, and has improved my self-confidence significantly, which has resulted in me being able to take more from each networking opportunity and connect with new people in the science industry. This has resulted in me being able to determine the career path that I want to follow, allowing me to focus my attention on my optimal career objective.

This has all been achieved by the meaningful advice, attention, guidance and assistance that was provided to me by my mentor. My greatest achievement while being in the program has been earning an interview with my dream job, which may not have been offered to me if I had not received the support and assistance that I did with structuring my job application. I highly recommend this program for individuals who require guidance for that smooth transition from university to the workforce – especially if they are unsure of the path they want to follow.

I have had the opportunity to play a small part in helping two intelligent, capable young chemists during an important phase in their life.

make sure that they didn't become isolated. More widely, I also facilitated introductions through my own network to people of interest in the mentees' chosen careers, either as general contacts or for specific guidance.

We met semi-regularly, to catch up and to plan their job preparation and application process. I reviewed their resumés and some of their applications, and discussed the specifics of individual applications and interviews to try to increase their chances of success.

These last paragraphs have contained a lot of 'I'. So it is important that I add that I got a lot out of this too. This has been an immensely enjoyable experience. I have had the opportunity to play a small part in helping two intelligent, capable young chemists during an important phase in their life. I have watched them grow in confidence and preparedness (noting that their innate qualities were already there). And I believe that I have made two new friends.

As you can see from the two boxes, the experience has been mutually positive and beneficial. Based on the success of the trial, the NSW Branch would now like to extend the pilot. We'd like to establish up to five mentor/mentee pairings, on the same sort of principles as above, and support the relationships as we establish some structure to the program. We invite anyone who is interested to contact me at dave@dcstechnical.com.au.

Dave Sammut FRACI CChem is principal of DCS Technical, a boutique scientific consultancy, providing services to the Australian and international minerals, waste recycling and general scientific industries.

Tom Frith (BAdvSci(Hons)/BMus), University of New South Wales

I began working with my mentor about 18 months ago, as I was starting to prepare for my honours year. At that stage, I wasn't exactly sure whether I wanted to take on a career in research or industry or diverge from chemistry completely. I applied to the mentoring program, looking for guidance on how best to make this decision, for which my mentor offered an experienced point of view.

The mentoring program helped me to begin to understand the nature of developing professional relationships through networking, as well as more generally begin to tune my thinking to how the professional world operates. The program was very relaxed, which worked well for me, as I felt comfortable to chat openly with my mentor.

Through working with my mentor, I was able to develop my resumé and cover letter preparation skills, and as a result have been able to secure a full-time graduate job starting in 2016. I would highly recommend the mentoring program to all students coming to the end of their studies, as I found the experience incredibly rewarding. I would also hope that more mentors could be available to allow for more students to get the same experience I was allowed.

Centenary Book – volunteer helpers required

In 2017, the RACI will be 100 years old and to celebrate this mega RACI milestone, the Centenary Committee is working to write a coffee-table-style book covering the Centennial RACI history. Obviously this is an enormous project and we are looking for interested parties to research and write relevant pieces on important events and people over the years.

We also wish to make contact with anyone in possession of past RACI-related documentation, letters, records and, in particular, photos that can be incorporated into the project.

If you are interested, please contact Roger Stapleford (roger.stapleford@raci.org.au).

New Fellow

Paul Moritz obtained a BSc with Honours (1980, awarded the CSR Chemicals Prize) and a PhD (1987) in inorganic chemistry from the University of Adelaide. He worked with Australian Synthetic Rubber, as a process development chemist, from 1981 to 1983. Membership of the RACI was strongly encouraged, and attendance at the monthly Victorian Polymer Group almost mandatory, to which Moritz took with gusto.

In 1987, Moritz joined the Advanced Technical Development group of CRA (now Rio Tinto), working in hydrometallurgical R&D. His projects covered the Port Pirie lead smelter, the Port Kembla copper smelter and numerous new ventures and exploration deposits such as the Century zinc deposit, Wimmera mineral sands, WA nickel sulfides and environmental simulations for gold deposits in PNG. Much of this work involved continuous mini pilot plant operations. Moritz left industrial R&D behind in 1997. He subsequently noted that, of the innovations and resource developments he had worked on over 12 years, all but one had either progressed no further than the R&D stage, or had been divested or shut down. To him, this showed that the power of research can sometimes be in what is disproved, as much as what is proved and demonstrated.

He joined EPA Victoria in 1998 as Manager of the Environmental Chemistry unit and then, from 2002, the Land and Groundwater unit. In addition to managing the laboratory and air monitoring functions, he oversaw the laboratory's move to a new facility in a recycled building at Mont Park in Melbourne. He also initiated the NATA accreditation of the laboratory in the field of Environmental Forensics, the first such accreditation to be granted. He later managed the Victorian environmental audit system. As part of these roles, he was a member of the assessment panels for individuals seeking statutory appointment as Analysts, and as Environmental Auditors, under the provisions of the Victorian *Environment Protection Act*. He was also a member of national bodies, including the NATA Council, the National Dioxins Project steering committee and the review team for the contaminated sites National Environment Protection Measure.

Since 2006, Paul has been a contaminated-land consultant based in Melbourne, and with Douglas Partners since 2012. In 2009, he was appointed as an environmental auditor under the Victorian *Environment Protection Act*, and in 2015 as a contaminated site auditor under the NSW *Contaminated Land Management Act*. He is currently a member of the analytical chemistry focus group of the Australian Contaminated Land Consultants Association's Victorian branch. His involvement with RACI activities includes membership of the Newcastle Section committee between 1988 and 1991 and, since 2012, a regular columnist on environmental topics for *Chemistry in Australia*.

Moritz's other interests include athletics, Australian history and politics, travel, and the comedy works of the Marx Brothers and Ronnie Barker. He was formerly a member of the Australian Democrats and twice stood as a parliamentary candidate, without success (although he retained his nomination deposit on both occasions).

Mander Best PhD Thesis in Organic Chemistry Award

The Mander Best PhD Thesis in Organic Chemistry Award recognises the best PhD thesis submitted in the previous two years in the field of organic chemistry. This award is for outstanding achievement and communication in organic chemistry. The recipient will receive a cash prize of $1000, generously provided by Davies Collison Cave.

The recipient of the inaugural Mander Best PhD Thesis Award for 2015 is Dr Christopher Newton.

Dr Newton conducted his PhD studies under the supervision of Professor Michael Sherburn at the Australian National University. His thesis describes research on the synthesis of fundamental hydrocarbons and their application to the efficient total synthesis of natural products. The work has been described by thesis examiners as 'outstanding', 'truly original' and 'of the highest standard'. The selection committee were impressed by the depth and scope of the work contained in the thesis and the publications that have arisen from it in the highest quality chemistry journals.

John Tsanaktsidis FRACI CChem, Chair – Organic Chemistry Division

The *STEM Programme Index* (SPI2016)

The first national *STEM Programme Index* (SPI2016) was released by the Office of the Chief Scientist, Canberra, just before the start of the 2016 school year. The *Index* provides a snapshot of over 250 possible incursions, excursions and other science, technology, engineering and mathematics (STEM) programs.

The guide was compiled by the Australian Industry Group, with funding by the Office of the Chief Scientist. Ten chapters list programs under the broad divisions of general science, biology/agriculture, chemistry, earth/climate science, physics/astronomy, digital technology and ICT, engineering and technology, mathematics integrated STEM and multidisciplinary, and entrepreneurial skills. Each chapter is further divided by school level (primary, primary and secondary, and secondary), reach (international, national and state), and program type (in-school program, excursion, competition, resource, mentoring, school visit, careers etc.).

The entries in the *Index* are very helpful. A typical entry includes information about each program, as well as contact details and a web address.

CSIRO Indigenous STEM education programme: Inquiry for Indigenous Science Students

CSIRO Education

Targeting middle-school students in mainstream metropolitan and regional schools, the Inquiry for Indigenous Science Students (I2S2) programme uses hands-on inquiry-based projects to increase student engagement and achievement in science.

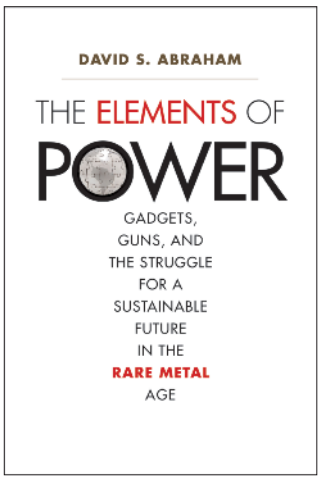
Type: In-school programme
Location: National
Target Audience: Middle school, metropolitan and regional, Indigenous students
Dates: Ongoing
Sponsors/Partners: BHP Billiton Foundation
Contact: CSIRO Education and Outreach, education@csiro.au
Website: www.csiro.au/en/Education/Programs/Indigenous-STEM

However, the *Index* is very incomplete: 'we know there are more great programs out there'. For example, 21 engineering/technology programs are listed, but only three chemistry programs, with none of the RACI's programs. Programs at Canberra's Questacon, the Earth Science Museum in Perth, Western Australia's Scitech and the Newcastle Museum are mentioned, but programs at Sydney's PowerHouse Museum, Melbourne's Scienceworks and many others are omitted.

While the *Index* includes much useful information, its patchiness severely limits its usefulness. Hopefully, the implied promise of more complete *STEM Programme Indices* in the future will be realised: 'and there'll be more to come in the critical years ahead'.

The *Index* can be downloaded from www.chiefscientist.gov.au.

Kieran F. Lim FRACI CChem



The elements of power: gadgets, guns, and the struggle for a sustainable future in the rare metal age

Abraham D.S., Yale University Press, 2015, hardback, ISBN 9780300194795, 319 pp., $74 approx.; ebook, ISBN 9780300216714, $46 approx.

The elements of power: gadgets, guns, and the struggle for a sustainable future in the rare metal age has a very long and descriptive title. However, don't let this deter you, because David Abraham has written a most worthy and fascinating book. His account highlights our seemingly insatiable demand for high-tech gadgetry, for our amusement, communications, commerce and warfare. All of these areas are highly dependent on a supply of rare metals for incorporation into manufacture and many of the products can be almost guaranteed to fail or become obsolete shortly after expiration of the warranty.

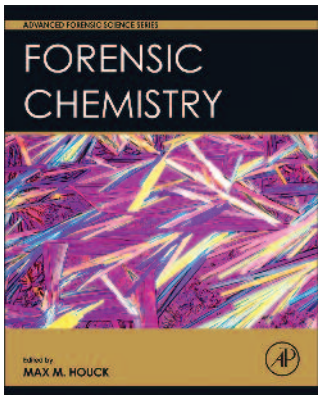
Your smartphone is reckoned to contain about half the naturally occurring elements. If you were to try to come up with the list of 45 or so elements, you will get into pretty exotic territory inhabited by intriguingly unusual atomic beasties. All of this is in a very neat little package, and the battery is most probably 'built in', which is a shorthand way of saying you can't replace it, as well as a prompt after a couple of years for you to either return it to the manufacturer for an expensive and access-interrupting repair, or to simply replace the whole shebang. From my observation, many of my fellow beings see their mobile telephones as an integral element of their very existence, something that defines their status and (self-adjudged) importance in the world. Where *would* they be without it! So this high-tech marvel, if it is lucky, finds its way into a recycling stream, whence it is (most frequently, illegally) exported to China. Here the appliance is broken down, the plastic burnt (fouling the air), the circuit components unsoldered (poisoning the workers), the printed circuit boards burnt to recover their metal components (again polluting the air), and metal components dissolved in acids prior to recovery (contaminating waterways). All in all, a very unsavoury business, but certainly not in our backyard! That's programmed failure and obsolescence folks!

So, what makes a metal 'rare'? Roughly, two-thirds of the elements in the periodic table are metals or metalloids. There are large-tonnage base metals, such as iron, aluminium, lead, copper and zinc, which are relatively widely distributed, consumed in vast amounts and traded on the international metals markets. Then there are the precious metals, which have high aesthetic value as well as their utility value. Most of the remaining metals, namely most of the first and second transition metal series and the lanthanoids (rare earths) fall into the category of minor metals. Rarity occurs when there is a shortage of sources of the metal, or when geopolitical factors insert criticality, like quotas or export embargos on supplies. For example, most of the world's cobalt comes from the Democratic Republic of Congo, not exactly a haven of peace and light. Even more critical is the reliance on China as the principal supplier of the rare earths. Having undersold the American rare earth industry to bankruptcy, China hiked the price and imposed export restrictions on its virtual monopoly of the rare earths supply chain. There is currently a World Trade Organization truce of sorts, but imagine, if you will, the pressure China could bring to bear on Japan by denying its electronics industry access to rare earths. So, rare metals can be rare because they simply are rare (there aren't a lot of them about) or because the supply lines are rare, or 'shaky'. Rare metals can be traded on minor metal exchanges, but they are also traded in underhand, illicit cash transactions, frequently from smuggled or stolen supplies, which may or may not have undergone some crude refining in backyard or kitchen laboratories, and in amounts down to the odd kilogram. It can be a pretty murky business.

Hiccups in rare metal supply chains can cause serious indigestion to companies. Imagine if you will, for example, Tesla, the company manufacturing world-beating electric cars. These cars are utterly reliant on their battery technology and electric motors, which, in turn, rely on strong magnet technology. Once a model is designed, the company would ideally want to sit with that technology for a few years to amortise R&D costs, and, in any case the technology cannot be changed willy nilly because the price of the rare earth element incorporated into the magnets doubles in price or supply becomes difficult. That's a major redesign. So, supply chains are very important and hence black markets thrive, although I'm certainly not suggesting Tesla is part of any such activity. There are going to be wildly fluctuating prices in rare metals, depending on technology tweaking versus the needs for steady production lines for a few years to amortise costs.

Everybody ought to read this book. It will give you a well-rounded picture of an area of economic and strategic importance. The author, who is not a chemist but a rare metals trader, is passionate about the subject and writes with real authority. The guided missiles we cause to be dropped in Syria rely on rare metals for their guidance systems, and while I am not advocating a resurrection of Burris Skinner's pecking pigeons as a way to steer missiles (the RSPCA would never stand for it!), sooner or later we will find ourselves constrained to walk a little more gently on our Earth. Recycling of missiles is ultimately unproductive, but I came away from this book with a renewed sense of concern both about our national predilection for possessing the latest gizmos and trinkets, and our failure to really embrace a womb-to-tomb global strategy to exploit and recycle rare metals. And I learnt a lot about rare metals too.

R. John Casey FRACI CChem



Forensic chemistry

Houck M.M. (Ed.), Academic Press, 2015, hardback, ISBN 9780128006061, 492 pp., $117.95

Forensic chemistry examines the role of chemistry in the forensic sciences, and this title attempts to act as a reference source for the field, as part of a series on forensic science.

First off, this is no text version of a 'CSI' television show, with many of the roles chemistry has in forensic investigation discussed in depth and detail, with some prior chemistry knowledge assumed. It is clear there is more to forensics than just comparing DNA samples, and the first fact you learn is that anything (and they mean anything!) can become evidence in a criminal investigation and be presented into court. Fascinatingly, this means the field of forensic chemistry alone is incredibly broad; the authors could have easily doubled the 471 pages and still not provided enough depth.

The title is separated into eight sections, with the most interesting sections focusing on Drugs as well as Fire and Arson. The Drugs section goes into details on the classes of natural and synthetic drugs, the analytical procedures to identify them, spot testing for drugs in the field, and clandestine laboratory set-up and detection. The Fire and Arson section details the thermodynamics and types of fire, degradation of various materials in the presence of fire (including human remains) as well as fire patterns and how to inspect a fire scene. It is a real triumph of science that significant amounts of information can be recovered from fire, and the fire residual itself is almost a fingerprint of what existed before.

A section is also dedicated to Explosives, which had a strong military/terrorism tone differing from the rest of the text. The final section on Professional issues has two chapters unrelated to chemistry, in that it deals with forensic science from a more legal perspective, in terms of managing the evidence and reporting. I would strongly recommend these two chapters to general chemists, because the points raised have implications in broader fields where science meets the humanities.

The major issue with this reference is the repetitive discussion of analytical instrumentation used to identify chemical compounds. Much of this information is pitched at the same level as an undergraduate analytical chemistry text and overlaps between chapters. This repetition is clearly the product of multiple authors. Ideally, the editor should have exercised greater control of the final text to limit instrumentation discussion to each specific section, then let the other topic areas focus more on individual procedures and case studies.

Overall, *Forensic chemistry* is a good solid reference source on chemistry in the forensic field; it provides detailed insight supported with interesting case studies. I would recommend it to any chemist entering or in the field of forensics, as well as any aspiring criminal, because it becomes clear how much information can be gathered from otherwise insignificant details.

Colin Scholes FRACI CChem

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From student to startup – how a PhD can boost budding businesses

What should an undergraduate student who's inspired to change the world do? Should they continue their education in a PhD or found a startup? I have recently done both – at the same time – and my experience suggests the combination is better than you might expect.

I have just submitted my thesis in computational linguistics (the sub-field of artificial intelligence devoted to automatically understanding human language) at the University of Sydney. I am also a co-founder of Grok Learning, an education technology startup that aims to teach the world's kids to code.

At first glance, there isn't much in common between a PhD and a startup.

A Doctor of Philosophy, from the Greek *philosophia* – love of knowledge and pursuit of wisdom – is awarded for conducting independent research, demonstrated through a significant contribution to knowledge in a specific field. The stereotype is deep, rigorous thought carried out over many years in a narrow field that few people in the world understand.

A startup is an organisation searching for a business model. It's a business that isn't yet viable. The stereotype is brash, fast-moving organisations that are looking to reshape, or disrupt, our lives within a few years. Think AirBnB, Freelancer and Uber.

So what do a PhD and a startup have in common? It turns out, quite a bit.

- Both start with an idea, the vision of which often sustains and inspires student and founder, and unites their team in a common purpose.
- Both require financial (and social) sacrifices to achieve that vision.
- Both are risky with uncertain rewards. The path is littered with failed startups and unfinished PhDs.
- Both involve the search for answers in unknown conditions, where supervisors and mentors can guide, but only your exploration can (hopefully) uncover the solution.

This last point profoundly shapes PhDs and startups, and determines who excels in them. According to US author and entrepreneur Eric Ries, a startup is an organisation trying to deliver a new product or service under conditions of extreme uncertainty.

This sounds a lot like my own PhD experience and that of my peers. The very popular Lean Startup methodology that Ries champions applies the research methods familiar to students in empirical disciplines, such as science and engineering, to growing a business.

The focus of the lean methodology is learning which ideas work and which don't through efficient, rapid experimentation that iteratively improve the startup's product–market fit, finding a product that people want to buy at a price the startup can sustain.

A/B, or split testing, involves experimenting on your customers by changing one thing at a time and keeping a control group, and recording the impact of the change. That's the scientific method!

A minimum viable product involves developing just enough of the product to enable these experiments, sometimes with almost no other functionality at all. This reminds me of every experimental setup I've seen, held together with spit and string as the student races for a publication (or thesis) submission deadline.

And if the experiments continue to produce negative results, knowing when to pivot – a major course correction to a (hopefully) more fruitful line of exploration – is one of the most painful decisions for a student or founder (and their advisors) to make, especially when substantial time, energy and often money has been spent exploring a particular direction.

Finally, students and founders are both all too familiar with the idea of a runway – the length of time before funding (from savings, investors or a PhD scholarship) or enrolment runs out and the student or startup is no longer achievable.

While everyone asserts that written and spoken communication skills are critical, students are often surprised that we must promote and position our work in the competition of ideas and actively develop our own academic profile, but marketing is literally life and death for entrepreneurs.

Of course, not everything is parallel in research and startups. A key difference is the timeframe and the urgency it demands. Many startups are born and die in the time it takes to finish a masters (18 months), let alone a PhD.

In a startup, the goal is to learn fast, doing experiments on a daily basis that could substantially improve your product. In research, you might take months to set up a single experiment.

So, while PhD students are well suited to the challenges of exploring the unknown, we may need to work on being more dynamic and responsive (their supervisors might agree too, but industry might say that of many academics).

Universities could encourage a flourishing startup ecosystem and energise their PhD programs by intermingling PhDs and startups, and providing founders with APA-like seed funding (during or after their degree) and considerable enrolment flexibility.

Partnerships that integrate researchers and entrepreneurs in residence could create dynamic hybrid accelerators and postgraduate programs. In-house financial, legal and administrative support would help startups begin, and a lower-friction approach to protecting IP would allow students (and academics) to turn ideas into ventures more often.

Finally, universities need to recognise the value of startup creation as an academic output.

There is much to do, but for now I'm taking my PhD experience and leaping into the unknown.

Nicky Ringland is a PhD student (Computer Science) at the University of Sydney. She is a co-founder of Grok Learning, an EdTech start-up dedicated to teaching the world's kids to code. First published at www.theconversation.com.

Is my 'invention' an invention? An overview of what is patent eligible

Dr Jess Gledhill, Registered Patent Attorney, FB Rice

A patent provides the owner with exclusive rights to commercially exploit their invention for the life of the patent. In most countries, to obtain a patent, the invention must be:

- for subject matter that is patent eligible;
- novel;
- useful; and
- non-obvious.

It is therefore possible to have an 'invention' that is novel, useful and non-obvious but it cannot be patented as the subject matter is not patent eligible. Although exactly what constitutes patent eligible subject matter varies from country to country, what is consistent between countries is that a patent cannot protect a mere idea. Instead, the idea must be embodied in something tangible.

Distinguishing a mere idea from a potentially patent eligible invention starts with considering whether the 'invention' lies in the intellectual realm or the technical or practical realm. Technical or practical matters are potentially patent eligible in contrast to entirely intellectual matters.

In general terms, exclusions from patent-eligible subject matter include:

- discoveries with no means of putting them into effect;
- mere ideas, schemes or plans;
- scientific theories;
- mathematical algorithms;
- human beings or the biological processes for their generation; and
- fine arts.

Under Australian and most foreign laws, a patent may be obtained for 'traditional' inventions such as machines or devices and manufactured articles (e.g. tools). It is also possible to patent:

- new substances (e.g. non-naturally occurring chemical compounds);
- new compositions (e.g. pharmaceutical formulations and personal products formulations);
- methods or processes (e.g. methods for making naturally and non-naturally occurring chemical compounds, analytical methods, mining processes and industrial methods for the production of materials);
- methods of medical treatment (e.g. a method of treating a disease with a new drug);
- biological inventions (e.g. isolated bacteria, cell lines, genetic vectors, expression systems, genetically manipulated organisms and processes using enzymes or microorganisms); and
- computer-related inventions (e.g. software with industrial application and hardware of improved construction).

For 'traditional' inventions, the scope of patentability is comparable throughout most of the world. For other inventions, including new substances and compositions, methods of medical treatment and biological inventions, the scope of patentability is far less homogeneous and generally more complex.

In Europe, methods of medical treatment are not patent eligible. By contrast, biological material (including natural chemical products and DNA encoding for genes) isolated from its natural environment or produced by a technical process may be patent eligible.

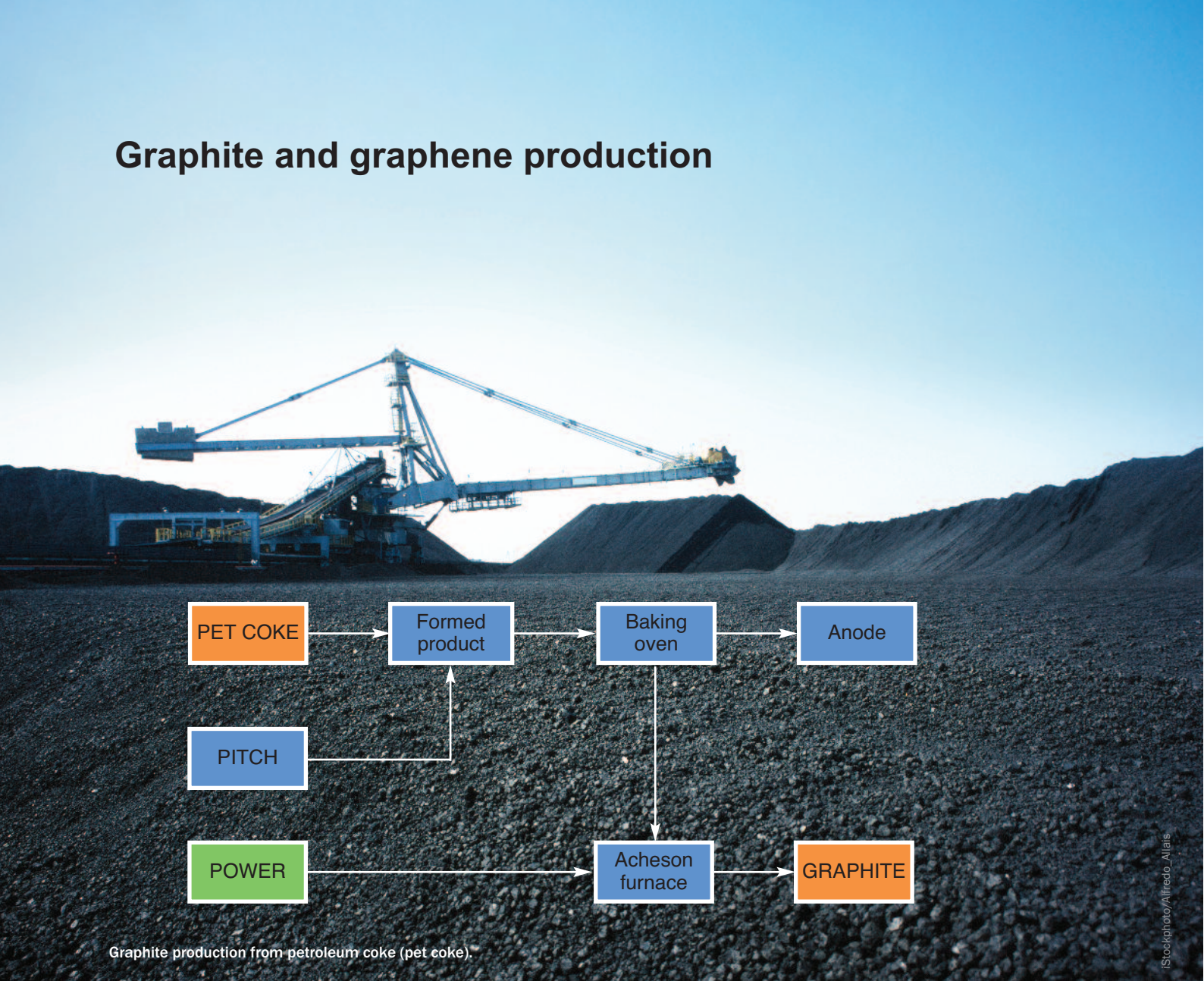
In the US, methods of medical treatment may be patent eligible. However, isolated biological material (including natural chemical products and DNA encoding for genes) that is the same as it existed in nature is generally not patent eligible.

In Australia, a recent High Court decision has created uncertainty around what biological material constitutes patent-eligible subject matter.

Before commercialising your invention, it is important to consider the differences in patent-eligible subject matter and the effects of this in relevant countries. This is a difficult and complex consideration and to ensure appropriate patent protection is obtained, advice from a patent attorney should be sought.

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

Graphite and graphene production



Graphite production from petroleum coke (pet coke).

Previously I have discussed pending developments in rechargeable batteries based on lithium, and particularly the lithium–air battery, which uses lithium metal as the anode (March issue, p. 34). The cathode of the optimum battery is based on graphite.

The role of the cathode is to absorb oxygen from air and facilitate electron transfer:

$O_2 + 4e^- \rightarrow 2O^{2-}$

with the anode reaction being:

$Li \rightarrow Li^+ + e^-$

For maximum capacity, the absorbed oxygen should be held within interstitial planes in the graphite structure, so theoretically monolayers of graphene should be the optimum form of graphite. Lithium reacts irreversibly (and violently) with water and carbon dioxide so the air in contact with the graphite anode should be free from these materials or be impervious to them.

There are two forms of graphite, mined as a mineral or produced synthetically from carbon sources. Graphite is an allotrope of carbon stable at high temperatures and low pressures, and for synthetic graphite any carbon source could be used. In practice, the preferred starting materials are carbon sources where the carbon is highly graphitised in the first instance, such as anthracite coal or petroleum coke, and which have a low quantity of impurities. A preferred binding material is coal tar pitch, which readily transforms to graphite when heated.

The production of synthetic graphite follows several steps as shown in the flowchart.

The required article is first formed by a combination of the petroleum coke (pet coke) and coal tar pitch. This is then transferred to a baking oven where the article is baked at typically 1000°C. This process produces electrically conducting products such as anodes for aluminium or lithium smelting,

which do not require the intense treatment to produce pure graphite.

Pure graphite is produced by heating the baked article to over 3000°C such as in an electrically heated furnace invented by Acheson in 1895 or an induction furnace to the same temperature. This is possibly the highest temperature used in an industrial process of commercial significance. Slowly heating from ambient to 3000°C accomplishes almost total graphitisation and purification of the graphite. The sublimation point of graphite is over 3600°C and because all of the impurities (including mineral matter) sublime well below 3000°C, the major portion of impurities are expelled from the formed article.

For high-purity graphite (used, for example, in nuclear reactors), volatile halogen compounds are added during the furnace heating. These can be as sodium fluoride or gases such as sulfur hexafluoride. (Note the very high greenhouse potential ($23\,900 \times CO_2$) of the latter.) These additives convert impurities to more volatile halides and reduce the impurity level to very low levels (e.g. total ash <100 ppm for nuclear uses of graphite).

Graphite electrodes are produced by machining the formed graphite articles to the dimensions required.

The natural mineral graphite occurs in various forms depending on how formed. Most current interest is in the flake type of mineral and especially the so-called jumbo-flake. The structure of natural graphite is in two forms – hexagonal and rhombohedral. Natural graphite has some properties that distinguish it from synthetic graphite, for instance higher density. Natural graphite is favoured over synthetic for some uses, such as bushes for DC motors. It is not clear if natural graphite is preferred over synthetic for the production of lithium battery carbon cathodes.

Of course, natural graphite will contain mineral matter. Most of this can be removed by flotation at the mine site. For high-purity uses and total graphitisation of the carbon present, high-temperature furnace treatment, as for synthetic, would be required.

Since its discovery in 2004, graphene has become the subject of major study and development across a broad range of fields; there are currently over 1000 US patents and over 2600 US patent applications containing the word 'graphene' in the abstract. Theoretically, graphene could offer the optimum capacity for holding oxygen in a lithium–air battery cathode.

There are two forms of graphene currently being widely used that are produced from graphite – non-oxidised and oxidised. In the non-oxidised version, graphite sheets are exfoliated by mechanical means or intense untrasonication to produce a graphene slurry, which is subsequently processed. In the oxidised version, the edges of the graphite are oxidised by strong, usually acidic, oxidising agents (sulfuric/nitric acid, chromic acid etc.), which after untrasonication produces

... there are currently over 1000 US patents and over 2600 US patent applications containing the word 'graphene' in the abstract. Theoretically, graphene could offer the optimum capacity for holding oxygen in a lithium–air battery cathode.

graphene in which the edges have pendent oxygen or hydroxyl groups. If necessary, the oxidised form can be reduced or the oxygen groups used beneficially to synthesise larger sheets or attach the graphene as a ligand onto another substrate such as a carbon fibre.

From the present state-of-the-art, it is not clear whether natural graphite offers significant advantages over synthetic form. However, of note is the very high value of jumbo-flake graphite, which can command prices over three times that of other flake graphite. However, this may be because this form can produce very large graphene sheets, which have uses in other fields (micro-electrical components) rather than being used for battery cathodes.

Compared to lithium side of the battery, the optimum technology for the graphite/graphene cathode and its manner of production, from the basic starting materials to the final product, is poorly defined. This offers many opportunities for Australian researchers to make their mark in this rapidly developing field.

Although the optimum technology for graphite use in lithium batteries remains unclear, what is evident is the high energy intensity of producing graphite of high purity and the likely high cost (relative to other commodity chemicals) of producing graphene if that is required. Again like lithium, we are likely to see Australia producing only relatively low-valued mineral graphite to be exported to manufacturing intensive countries – Australia does not produce either petroleum coke or anthracite, which are the preferred feedstock for synthetic graphite.

The high energy intensity of producing both lithium and graphite/graphene supports the argument advanced by John Morgan (August 2014 issue, p. 22) that battery storage for solar is, in the long term, an unsustainable option for powering a country such as Australia.

Duncan Seddon FRACI CChem is a consultant to coal, oil, gas and chemicals industries specialising in adding value to natural resources.

Scientific ethics

Scientific ethics is and should be part of a science education (see February 2014 issue, page 38). The Australian Curriculum implies ethical practice as early as year 2 when collecting and recording observations, and explicitly discussing ethical considerations from as early as year 3, in which students are expected to learn that science knowledge helps people to understand the effect of their actions, and in particular, considering how materials, including solids and liquids, affect the environment in different ways, and deciding what characteristics make a material a pollutant. As students progress through the year levels, this becomes more involved; for example, at year 7, they learn that solutions to contemporary issues that are found using science and technology may impact on other areas of society and may involve ethical considerations. At tertiary level, students are also expected to have an awareness of the ethical requirements that are appropriate for the discipline. Professional organisations, such as the RACI, have long had a Code of Ethics (By-Law 13), and more employers are also introducing formal or informal codes; for example, the Victorian Government requires that all public sector employees uphold the following values: responsiveness, integrity, impartiality, accountability, respect, leadership and human rights.

As discussed at the recent Pacifichem 2016 conference (Symposium on Chemistry Education: International and Multicultural Perspectives), scientific ethics is much more than just using literature citations correctly. There are at least five broad aspects relating to research and commercial ethics, safety, scientific writing and publishing, the environment, and security, in addition to the usual general ethical considerations that could arise in any workplace, for example interpersonal relationships and dynamics. Having knowledge about ethics permits decisions about ethical issues to be made consistently, provide reasons for what we do and to critically examine opinions.

So what is ethics? First, ethics is not religion, or following the law, or following societal norms. Ethics refers to standards of right and wrong that guide what we should do. Ethics also refers to the study and development of one's ethical standards. There are many sources of information about ethics. One good source is the Markkula Center for Applied Ethics at Santa Clara University, California, (www.scu.edu/ethics). The BBC also has a good Ethics Guide (www.bbc.co.uk/ethics/guide), but this guide has been archived and is not being updated. The following is a brief sample of some ethics approaches.

Virtue ethics is based on the moral character of an individual, such as honesty, integrity, courage, justice and wisdom. Virtue ethics make no distinction between decisions and actions in a work-related situation and the rest of a person's life, but its main difficulties are that there is general agreement on what the virtues are and lack of clear guidance on what to do in moral dilemmas. Consequentialism is based on maximising the good consequences of decisions and actions; it is often associated with utilitarianism, the greatest good for the greatest number, but in extreme cases is the basis of the saying the end justifies the means. In contrast, deontologism is concerned with people's decisions and actions, not with the consequences. For example, since lying is morally wrong, the philosopher Immanuel Kant thought that it would be wrong to lie in order to save a friend from a murderer. Our difficulty is that we have to consider both the consequences and the means; we need to find a balance between the extremes of consequentialism and deontologism.

Ethics education is not just learning concepts, but also about how to apply those to real situations.

Ethics education is not just learning concepts, but also about how to apply those to real situations. Most ethics education is based on case studies and scenarios: what would a person do in this situation? Is that different from what a person should do? There are no unique correct answers as different people may make different choices in the same situation. Analyses of the content and learning outcomes of Australian and overseas degrees indicate that we need to improve the learning outcomes associated with ethics. Teaching scientific ethics may be difficult, but it is essential because being ethical is at the core of being a professional chemist. We, as professional chemists, profess our values, publically declare and uphold them.

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Wine labels


iStockphoto/williammpark

Recently, while strolling along the aisles in a bottle shop, I was surprised to see a bottle labelled as 'AC/DC Rock or Bust'. Sure enough, the 2015 Shiraz was released to celebrate the 40th anniversary of this 'legendary rock n roll' band. Normally, I am not taken by flashy labels, but in this case, I could not resist the purchase and to savour the wine 'with the speakers thumping', as the label recommended.

When I first started seriously purchasing wine, label information was minimal. There was only one label showing the name, the producer, the vintage and sometimes the variety or varieties. This is still the case in many parts of the 'Old World' wine industry. The argument seems to be that 'we make the wine and if you do not know what it is, then it is up to you to find out'. There are some labels with so much information, they can be difficult to read. Some imported wines have the text in the language of the country of origin as well as an English translation and a third label may be needed to include the mandatory information before the wine can be offered here for sale.

In Australia, we now almost always have two labels on the main body of the bottle and occasionally an extra one on the neck for good measure. While the terms 'front label' and 'back label' are sometimes used, the reality is that a significant amount of information is required under the Australian Grape and Wine Authority Act and the Food Standards Code as well as export requirements for wine that is sent off-shore. Thus, producers need to be aware that statements on any label, whether front or back, must meet what is specified by these legal requirements.

Mandatory information includes the volume statement in 3.3 millimetre print height, the alcohol concentration as say 14.1% alc/vol and the number of standard drinks, which can be either text or an image with the number of standard drinks shown on a glass. Allergens must also be declared including sulfur dioxide above 10 mg/L (Australian regulators insist on using 'sulphites') as well as milk and egg products, if these were used in processing. Commonly, one finds a statement such as 'contains sulphites' or 'preservative 220 added' and 'produced with the aid of egg and milk products and traces may remain'.

The word 'wine' must be shown on the label to 'convey the true nature of the food'. In Australia, wine is defined as the product that results from the complete or partial fermentation of fresh grapes with a minimum alcohol concentration of 4.5%. Additives and processing aids are regulated. Inclusion of the country of origin, as 'wine of Australia' or similar phrase is also mandatory. The name and street address of the 'responsible entity' (the company, in reality) as well as the lot number must be included to allow the wine to be traced, if necessary. Audits are carried out for good reason – some years ago, there was a case where the registered address was actually a vacant paddock in central New South Wales!

A brand name for a wine may be included on the label, provided that is does not 'mislead as to the origin, age or identity of the wine'. There are several other optional inclusions on the label, each of which, if stated, is subject to regulation and justification when audited. The harvest year (vintage) may be included, with the requirement that 85% of the wine in the container must come from the declared year. Similarly, the region or geographic indication (GI) can be listed, subject to 85% of the wine coming from the declared GI. Finally, the variety, provided it is 85% or more, can be declared. Multiple varieties can be listed but must be in descending order. More details of the Label Integrity Program (LIP) can be found at bit.ly/23rPbHH.

The remaining label space is then open for the marketers to write (in the name of the winemaker, of course) whatever information is considered vital to convince the consumer to buy a particular wine. Perception psychology becomes important in the design of the label as the aim is to attract the customer's attention in crowded display shelves – my AC/DC purchase is a good example here. One of the reasons for the initial success of the [yellow tail] brand was the name all in lower case, resembling an SMS and consequently attractive to frequent users of mobile phones.

In a detailed study entitled 'Message on a bottle: colours and shapes in wine labels', de Mello and Gonçalves de Borobia showed that consumers exhibit a strong preference for specific colour-shape combinations in label design (see bit.ly/1SIRKkY). Label colour alone is not as important as colour-shape combinations. The authors did note that their results may have been influenced in part by the demographics of their consumer sample and that age, location and socioeconomic status may influence choice.

In addition to label design, price, availability and previous knowledge remain important drivers in determining purchase. The ability to pronounce the name of the wine variety correctly is an important issue also, as self-image when presenting wine to friends can be shattered if the name is mistakenly pronounced. You may recall the Yalumba advertisements with the phonetic spelling of Viognier when this variety first appeared in the market place.

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Risky business

I did something rash a few months ago. I quit my well-paid, holiday-laden job in the semi-utopian city of Lausanne in Switzerland to move to a rainy little city in the north-east of the US. So here I am in the unenviable position of being an unemployed scientist, wondering if I have made the correct decision. And the thing is, despite some niggling doubts, I think I have.

You see, I didn't move here on a whim. This is something that my family and I have thought long and hard about and planned for meticulously. So why leave a well-paying job for uncertainty in a foreign country? The truth is, we took the risk because I wanted to change career paths. I've often mused, in these columns, about the pros and cons of being an academic. So now, I've finally taken the plunge and decided to test the temperature of the water in the other pool of industrial employment; I have decided to go corporate.

Andrew Parodi/Wikimedia Commons

Bridges of Portland, Oregon, US.

It has not been easy leaving the security of a job (and the potential long-term security of a career) for the uncertainty of a new life. My days are consumed with trawling job boards, finding jobs suited to my particular expertise and putting in earnest, time-consuming applications. But, this is exactly what we expected. For a highly specialised scientist like myself, a course change doesn't come without teething pains and I am not taking to unemployment well. I miss the sense of purpose and of achievement that accompanies a salaried position.

But in the midst of my despair at never finding my feet again, I keep reminding myself that this is the type of risk people all over the world are taking. And to be even more specific, the type of risks that seemed ingrained in my immediate family's DNA. Of the four children my paternal grandparents had, none stayed in their country of birth, instead choosing to seek their fortunes in the US, Japan, Brazil and New Zealand.

My parents both left well-respected positions in multinational companies to take their three (!) kids to New Zealand. Landing there in 1994 was an eye-opener for me. Our lives changed instantaneously with a single international flight. We went from being a middle class family, surrounded by friends and family, to unemployed strangers in a strange land. I could only imagine what my highly skilled and well-established parents went through in those first few months of relentless job-seeking. I remember the thrill when my dad (an electrical engineer who specialised in industrial high-voltage applications) finally landed a job in Wellington and my mum, the research chemist, followed suit.

Now, I can finally grasp a little of what they went through. I understand the sense of futility as application after application is met with a negative response. (Or, as is more prevalent these days, total radio silence from the employer). I understand the second-guessing that they might have indulged in. But more than anything, I can understand how grateful they would have been to find a job.

And here is the true 'take-home' message of this column: I think that a relatively recent immigrant who has been unemployed for a while might make the best employee anyone could ask for. My dad stayed in his job for 20 years and my mum for 18, both rising through the ranks and being grateful employees. They were both well respected by their bosses and peers and worked really hard for their companies.

I am sure it will be the same for me. I chose Portland, Oregon, with a specific aim in mind. I wanted to work for a multinational company (Nike and Intel are headquartered here). I wanted to grow within it and make valued contributions through the years. I want to repeat what so many of my family have done and what so many people do every day in countries around the world. It is a risky business being an immigrant and I'm sure it may seem risky to some to hire immigrants, but I am sure these risks are worth it and there are tremendous rewards to be had by both sides. I encourage you all to give it a try some time.

The author has been an immigrant in New Zealand, Japan, Australia, Switzerland and now the US. He swears that this time will be his last.

The wild colonial chemist/mountaineer

George Ingle Finch (1888–1970) was the subject of a biography published last year with the title *Maverick mountaineer*. While the mountaineering occupies most of the book, it is George's career in science and technology that interested me more. He was born in Orange, New South Wales, and grew up there, with occasional visits to the big smoke in Sydney. The family travelled to England in 1902 and then on to Paris. After a year away, the family broke up, his father returning to live in Australia, while George with his mother, Laura, younger brother Max, and sister Dorothy stayed in Paris where the children went to school. Laura became interested in Theosophy and through this movement she met a number of prominent scientists.

While still in their teens, George and Max began their mountaineering careers and climbed many of Europe's toughest peaks. Later, George was part of a failed British expedition to climb Mount Everest in 1922 but as a brash colonial upstart, and moreover a technophile, he clashed often with the senior members of the British Alpine Club. Against their opposition, he introduced oxygen as an aid to high-altitude climbing, designed the valves and containers and maintained them under trying conditions on the mountains.

George studied medicine at the Sorbonne for a couple of years but a growing interest in chemistry caused him to seek the advice of his mother's Theosophist friend Sir Oliver Lodge about further study in this field. Should be go to Oxford? No, said Lodge, go to Zurich and study at the Eidgenössische Technische Hochschule (ETH). Finch took Lodge's advice and prospered at the Swiss academy. He graduated at the head of his class and was hired by senior ETH staff member Georg Bredig, who had earlier worked with Fritz Haber on catalysis of chemical reactions. Bredig involved Finch in his collaboration with Haber and their commercial partner, the Badische Anilin- und Soda-Fabrik (BASF), in the synthetic ammonia project that is one of the icons of 20th-century science. Before long, Finch was employed by BASF and worked alongside Carl Bosch who was responsible for the chemical engineering that transformed Haber's laboratory discovery into an industrial process.

As an outsider in a German company, Finch was never comfortable and so after a short period at the University of Geneva, and with signs that the Balkan wars could soon spread to involve other countries, he moved in late 1912 to the safe haven of London where technically trained men were in demand. His first job was at the Woolwich Arsenal, but after a few months he joined the staff of Imperial College, in the fuel technology department newly founded by Professor William Arthur Bone FRS (1871–1938). Although his appointment was interrupted by war service and peripatetic mountaineering, Finch was active at Imperial College until 1952 when he was granted Emeritus status.

At the College, he worked on fuels, catalysis of gas-phase reactions, surface science and electrochemistry, probably best described as applied physical chemistry. Although the Alpine Club shunned him for many years, the scientific establishment admired him and he was elected to Fellowship of the Royal Society in 1938. His biographical memoir, published in 1972, makes interesting reading. His introduction to surface chemistry came though the technique of electron diffraction. In the early 1930s, he constructed a diffractometer, one of the first to use magnetic coils to focus the electron beam and used in transmission and reflectance mode. The specimen holder was a novel design that enabled the specimen to be moved laterally and rotated. The high-tension voltage could be varied in the range 30–110 kV but the instrument was normally operated at about 70 kV. Precise measurement of the voltage was a problem that Finch solved by alternating measurements of the unknown specimen and a reference substance for which the crystal spacings were known, and from which the voltage could be calculated.

Using electron diffraction, Finch made important contributions to the study of Beilby layers that form on polished surfaces of crystalline materials. These layers, as thin as 0.5 nm, and others formed by electrodeposition, are amorphous and much harder than the bulk material. The work was extended to the study of friction in internal combustion engines and the action of lubricants. George Thomas Beilby (1850–1924) was a Scottish industrial chemist whose studies of metal surfaces, around the turn of the 20th century, gave rise to a new field of materials science.

His family and colleagues remembered Finch as a practical man, given to tinkering with technical equipment. He built high-speed photography equipment, an electron diffraction imaging apparatus and an experimental car engine. In World War II, he was involved in developing the incendiary weapon known as the J Bomb. Initially, it was a canister filled with butane but the low-boiling hydrocarbon proved too difficult for munitions manufacturers to handle and the final accelerant was petrol, ignited by a metallic oxide catalyst. On impact, the J Bomb burst and generated an expanding cloud of burning gas that destroyed the interiors of buildings.

In the early 1950s, Finch accepted the invitation of Prime Minister Jawaharlal Nehru to lead the research division of India's recently established National Laboratory in Poona and he spent several years there before returning to Britain. Work on surfaces and electron diffraction was established, and a tracer laboratory was staffed with specialists who came under the Colombo Plan. A new division dealing with essential oils and a much-expanded workshop – a characteristic Finch touch – rounded out the new facility.

Fortuitously, Finch was in India to greet Edmond Hilary as he travelled through Delhi on his way home after conquering Everest in 1953 – using oxygen.

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.

events

IChemE Fundamentals of Process Safety
11–15 April 2016, Perth, WA
www.icheme.org/fpsperth

ISE Satellite Student Regional Symposium on Electrochemistry & 20th Australasian and Electrochemistry Symposium
17 April 2016, University of Auckland, Auckland, NZ
www.raci.org.au/events/event/20th-australasian-electrochemistry-symposium

Fire Australia & Hazmat 2016
4 and 5 May 2016, Melbourne Convention and Exhibition Centre, Melbourne, Vic.
www.fpaa.com.au/events/fire-australia.aspx

7th Heron Island Conference on Reactive Intermediates and Unusual Molecules
9–15 July 2016, Heron Island, Qld
www.Heron7.org

27th International Conference on Organometallic Chemistry (incorporating the RACI Inorganic Chemistry Division Conference)
17–22 July 2016, Melbourne Convention and Exhibition Centre, Melbourne, Vic.
http://icomc2016.com

International Conference and Exhibition on Marine Drugs and Natural Products
25 July 2016, Rydges, Melbourne, Vic.
http://naturalproducts.pharmaceuticalconferences.com

2nd Energy Future Conference and Exhibition
4–6 July, University of NSW, Sydney, NSW
http://energystoragealliance.com.au/event/energy-future-conference-exhibition

NZIC-16
21–24 August 2016, Millennium Hotel, Queenstown, New Zealand
www.nzic16.org

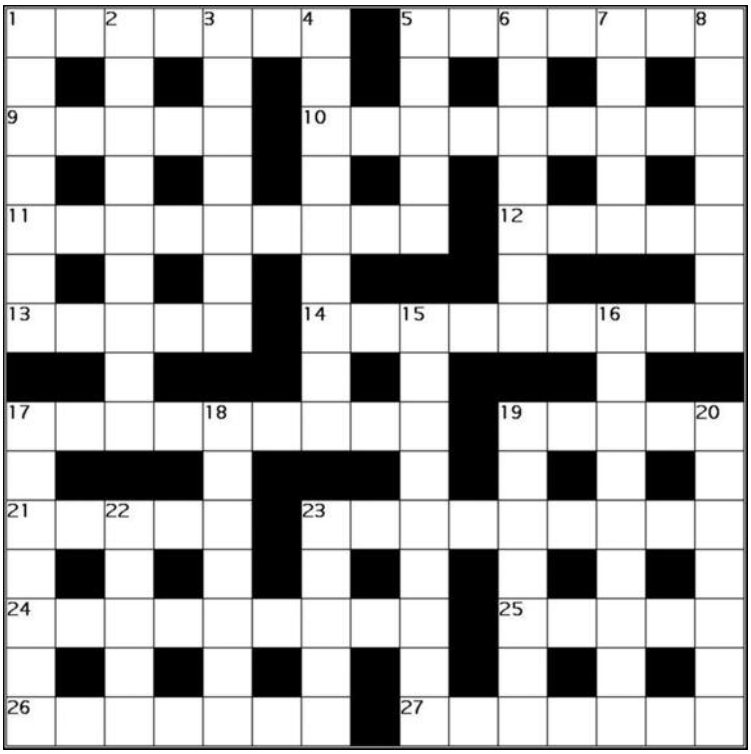
European Symposium of Biochemical Engineering Sciences (ESBES)
11–14 September 2016, Dublin, Ireland
www.esbes2016.org

Chemeca 2016
25–28 September 2016, Adelaide Convention Centre, Adelaide, SA
www.chemeca2016.org

6th International Conference and Exhibition on Pharmaceutical Regulatory Affairs and IPR
29 September – 1 October 2016, Orlando, Florida, US
http://regulatoryaffairs.pharmaceuticalconferences.com

RACI events are shown in blue.

cryptic chemistry



Across

1 Used smartphone software that was deceptive. (7)
5 Necessary cover. (7)
9 Skids around flat cylinders. (5)
10 1,3-Diphenyl-2-propen-1-one and derivatives (6113271016). (9)
11 Getting ore out without iodine leaves H_2S odour. (6,3)
12 Ground in to near the bone. (5)
13 Carbon with noisy condensed water. (5)
14 Round special HR treatment. (9)
17 Mischievous Reds spied and spread out. (9)
19 Radioactivity unit uses iodine in therapy. (5)
21 A component by itself. (5)
23 See 6 Down.
24 Came to aid resolution of CH_3CONH– group. (9)
25 Attracted by the positive to get a 28 on. (5)
26 Dropped radical out. Forced out. (7)
27 Mark Twain in a miracle mensurable experiment. (7)

Down

1 Polyhydroxy dicarboxylic acid real reaction when electron is lost. (7)
2 Spots suppose charges. (9)
3 In place as a substitute. (7)
4 Presses cutbacks?! (9)
5 Crystallographer makes crow sounds. (5)
6 and 23 Across Use of importins and exportins changing natural process return? Not sure. (7,9)
7 Central hostel 68. (5)
8 E10 logo has a problem. (7)
15 Chair dozy about something pertaining to HN_3. (9)
16 $[CO_2]^{2-}$ used to freeze Han Solo. (9)
17 In a daze about H_2NNH_2. (7)
18 Separate quotation. (7)
19 Calcium sulfide aced over torrent. (7)
20 Ranges made from canvas. (7)
22 A 7510 hydrocarbon. (5)
23 Lithium even at their ride. (5)

Graham Mulroney FRACI CChem is Emeritus Professor of Industry Education at RMIT University.
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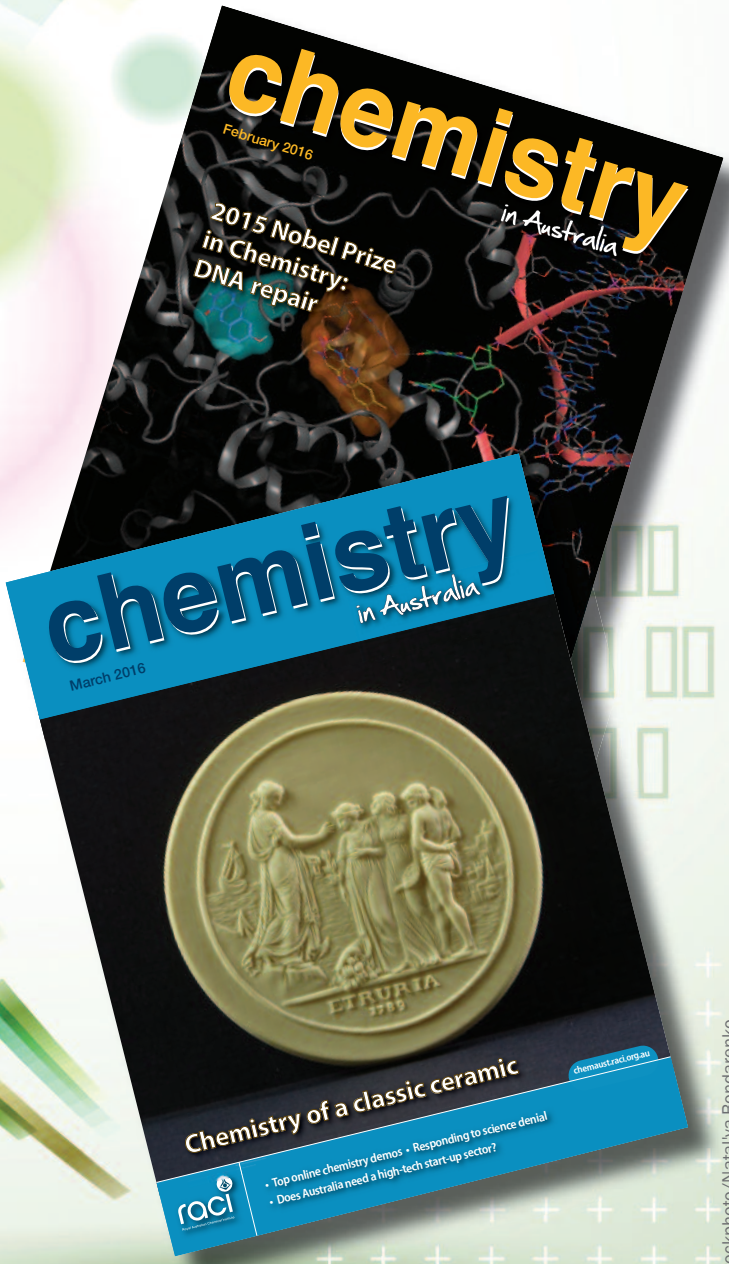

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