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February 2014

in Australia

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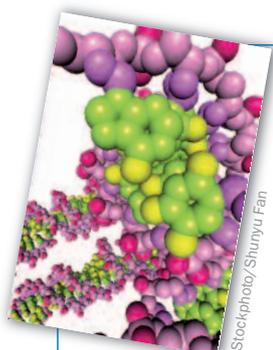
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cover story

Getting to know big molecules. 2013 Nobel Prize in Chemistry I

Chemistry's most recent Nobel Laureates have developed methods to 'see' how large molecules such as enzymes move, interact and react. Stanford University's Michael Levitt is among them.

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16 Closing the loop: industries as ecosystems

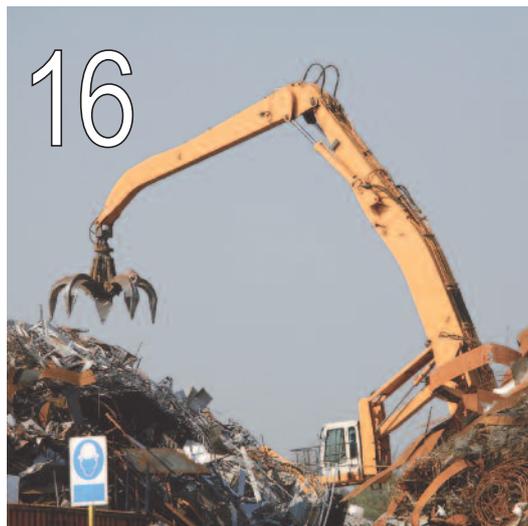
'Waste' can be an opportunity for value recovery or improved practice, rather than just a red mark on the bottom line.

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New year, new ideas

Welcome to the first edition of *Chemistry in Australia* for 2014; I hope you've had a chance to enjoy some well-earned R&R. On the subject of welcomes, I'd like to introduce two of our more recent writers, whose contributions will be ongoing and a great asset to the magazine.

You may have noticed a recurring name in our features section in the second half of 2013, writing on such topics as Direct Nickel and the R&D Tax Incentive. Dave Sammut has recently joined the RACI and generously offered his time as a regular feature writer.

Dave Sammut has degrees in both science and business, and has worked for 20 years in active R&D, R&D corporate management and commercialisation, and in professional communications to government and investor audiences.

After gaining his undergraduate degree in Industrial Chemistry at the University of New South Wales, Dave spent the first years of his career in a series of roles with Intec Ltd, a small minerals processing technology company, participating in and eventually running its laboratory and demonstration plant R&D programs. During a two-year stint living and working in Canada, Dave started DCS Technical (Canada) as a specialist 'think tank', mostly performing research and solving problems for the Australian minerals industry, as well as conducting business development for Canadian entrepreneurship programs.

Upon returning to Australia, Dave spent some time as a commodities analyst before returning to Intec Ltd to manage both technical projects and most

of the company's business development and investor relations. He set out on his own in early 2013 with the Australian version of DCS Technical Pty Ltd. His business now

divides its time between consulting to a broad range of clients on the Federal R&D Tax Incentive (as an associate of Access RnD Tax Solutions) and consulting to the domestic and international minerals processing industry as an expert in chloride hydrometallurgy. Dave also performs boutique consulting to the Australian waste industry.

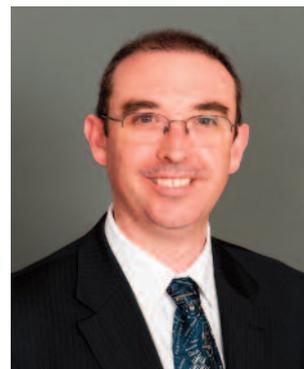
Dave also mentors young scientists as they make the transition from university into their first career roles, and sponsors a prize for excellence in undergraduate inorganic chemistry at the University of New South Wales.

Stephen Boyd wrote for us about molten salts in the October 2013 edition. You will see more of his columns this year. CEO of Havelide Systems, Inc. in Blue Point, New York, he graduated from Michigan State University in 1991 with a degree in International Finance. His PhD related to chemical physics and intimately involved magic-angle spinning nuclear magnetic resonance (MAS NMR) and X-ray diffractometry.

At Aufbau Laboratories, which Stephen founded, he began developing several prototypes involving novel energy



Stephen Boyd



Dave Sammut

scavenging methodologies, ranging from dramatic thermodynamic improvements in existing heating equipment to novel applications of electricity production from several different potential-energy sources, including aliovalent doped, fluoridated and non-fluoridated piezoelectric crystals.

Stephen has worked extensively on international projects, allowing him to hone his speaking, reading and writing proficiency in four languages and translational capability in eight. His current work as CEO of Havelide involves the development and commercialisation of a novel, proprietary, non-Fischer-Tropsch method of converting low-molecular-weight alkanes (C₁-C₄) from natural gas at the wellhead to high-quality naphtha.

As the year progresses, we'll be bringing you special opinion pieces from the chemical sciences and beyond, so stay tuned!



Sally Woollett

(wools@westnet.com.au) Thanks to Dave and Stephen for providing biographical information for this editorial.

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EDITOR

Sally Woollett
Ph (03) 5623 3971
wools@westnet.com.au

PRODUCTION EDITOR
Catherine Greenwood

ADVERTISING SALES

Gypsy Media & Marketing Services
Marc Wilson, ph 0419 107 143
marc@gypsymedia.com.au



PRODUCTION

Control Publications Pty Ltd
Ph/fax (03) 9500 0015/0255
science@control.com.au

BOOK REVIEWS

Helmut Hügel
helmut.hugel@rmit.edu.au

GENERAL ENQUIRIES

Robyn Taylor
RACI National Office, 21 Vale Street
North Melbourne VIC 3051
Ph/fax (03) 9328 2033/2670
chemaust@raci.org.au

PRESIDENT

Mark Buntine FRACI CChem

MANAGEMENT COMMITTEE

Sam Adeloju (Chair) Sam.Adeloju@monash.edu.au
Tatiana Anesbury, Anna-Maria Arabia, Helmut Hügel, Alan Jones,
Amanda Saunders, Colin Scholes, Curt Wentrup

CONTRIBUTIONS

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

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From the President

I trust that all members enjoyed a safe, relaxing and refreshing break over the summer holiday period. Late last year, the RACI hosted a round of meetings and activities. These included several successful divisional conferences that showcased some of the fantastic advances being made by Australian chemistry researchers, as well as providing an opportunity for Australians to learn about advances being made by colleagues from across the globe. I had the pleasure of presenting at the Physical Chemistry Division's PhysChem2013 meeting in Hobart in early December. The conference included plenary lectures from leading experimental and theoretical chemists from overseas, and demonstrated the achievements of an exciting mix of established and up-and-coming Australian physical chemists through an extensive keynote lecture platform. A comprehensive program of contributed oral and poster presentations celebrated what one colleague heartily described as the 'broad church' of Australian physical chemistry. I was particularly impressed with the quality of the science being undertaken by the enthusiastic early career researchers at the conference, including our PhD students. Reports that have come through to me indicate the other Division meetings held across the country were equally successful. I am optimistic about the future of the Australian chemistry research capability, and am reassured that our profession is making significant contributions to advancing our economy and society.

On 22 November last year I hosted a celebration of the very best of Australian chemistry at the annual RACI Awards presentation in Melbourne. At this event, recipients of the RACI national awards were recognised in front of an audience of almost 100 RACI members. The evening featured an Occasional Address delivered by Professor Jane den Hollander, Vice-Chancellor at Deakin University. Professor den Hollander delivered a lively, entertaining and thought-provoking lecture around the broad theme of opportunities and challenges facing the Australian higher-education sector in an environment of increasing student demands for flexibility and an age of rapidly evolving technological advances. Professor den Hollander spent considerable time discussing the possible threats and opportunities for Australian universities with the emergence of Massive Open Online Courses (MOOCs) and similar advances. Feedback from RACI members at the event was overwhelmingly positive, and several members told me how inspired and motivated they were by Professor den Hollander's address.

Saturday 23 November saw the RACI Annual General Meeting held in Melbourne, followed by the Assembly. At the AGM, the new Board took office and the names of all Branch Presidents and Division Chairs were recorded. The Assembly provided an opportunity for a range of important policy matters to be discussed by the broad RACI leadership team, with several recommendations from the Assembly sent to the Board for consideration at the Board meeting held on Sunday 24 November. At the Assembly, Professor Paul Mulvaney, incoming Chair of the Australian Academy of Science's National Committee for Chemistry

(NCC), delivered an outline of preliminary work being undertaken by the NCC (the RACI President serves ex officio as a member of the NCC) in the development of a Decadal Plan for Australian Chemistry. The Assembly agreed that the RACI should collaborate with the NCC in developing the Decadal Plan. The Board formally approved the RACI's involvement the following day.

Professor Scott Kable, the RACI Hon. Gen. Secretary, delivered a presentation to the Assembly on a proposal to provide formal professional management education opportunities to RACI members in collaboration with a registered training provider. The proposal involves providing RACI members with education and training opportunities at significant discounts and the concept received positive feedback from the Assembly delegates. Work is underway to run a trial of the program during 2014. I encourage members, particularly those from industry, to consider participating in the trial. Details can be found by contacting RACI CEO Mr Roger Stapleford at the National Office.

I reported to the Assembly on an approach made to the RACI from the Turkish Chemical Society (TCS) for RACI members to join their Turkish counterparts at the 2015 Annual Congress of the TCS to be held in the city of Gallipoli in mid-2015. Members will recall that 2015 will be the 100th anniversary of the ANZAC landings on the Gallipoli Peninsula, and our Turkish colleagues are eager to have an Australian element at their meeting to recognise this significant historical event. Assembly delegates were very enthusiastic in their support for the concept of an RACI involvement at the TCS Congress. I encourage those members potentially interested in travelling to Gallipoli in mid-2015 to 'watch this space' for details as they emerge.

Finally, the Assembly discussed the suggestions I outlined in my column in the October 2013 issue (p. 5) about possible changes to the structure of the RACI Board. These ideas were widely regarded as being a positive evolution of the RACI corporate governance model, with several variations of the concept suggested for consideration. At the Assembly, I also articulated some additional ideas not discussed in the aforementioned column. These ideas involve the possibility of opening up one or two Board positions for non-RACI members who have not-for-profit organisational expertise in accounting, commerce, corporate governance and the like – in essence, expertise that the RACI needs beyond the technical capabilities of chemists. As a result of the Assembly discussions, the Board has formed a small Constitutional Working Party to further explore the ideas canvassed and to develop a more detailed proposal to be presented to the RACI membership later this year. I urge all members to carefully consider and comment upon the proposals that emerge from the Constitutional Working Party.



Mark Buntine FRACI CChem (president@raci.org.au) is RACI President.

The attraction of railway lamps

I found your November 2013 editorial on the railway lamp very interesting. I clearly remember that during my childhood in wartime England, we used paraffin (kero) oil lamps in the bomb shelter (Anderson shelter) in our outer London garden. It was knocked over several times when the bombs rained down, but it survived the war, even when we had a direct hit in our garden, and I used it when I went on scout camps. It was a great light and gave out plenty of lumens although I am sure that the CO breathed in was somewhat unpleasant. I would love to have it now but, as with most things, my parents cast it aside when they retired. I can also remember that we had a Tilley lamp in the 1940s, which was a pressurised kero lamp, and we used this when we went to bed at my grandparents' place as they had no upstairs electricity.

David Wood FRACI CChem

I refer to your interesting editorial in the November 2013 issue about the old railway lamp you have at home. I too have a somewhat similar lamp kept from my parents' dairy farm. It was designed to be fitted to a horse and buggy, early automobile or push-bike. However, rather than have an oil-burning lamp, it has chambers for water and calcium carbide with a drip-feed valve, so that a controlled amount of acetylene is evolved for the burner (giving a bright white light when limited air is entrained). It has a concave mirror behind the burner and a convex lens for focusing the light emitted forward plus small coloured windows for rearward and side illumination.

As mentioned in my recent articles in *Chemistry in Australia*, I have long been interested in developing low-cost instrumental chemical analysis, mainly for schools, which typically have low budgets for science. One of the inhibiting ongoing costs is the rent charged for gas cylinders, such as acetylene for flame atomic absorption (AA) and argon (or nitrogen) for furnace AA. For the small amount of use involved in teaching, these ongoing rental costs are considerable.

When working at university, one ongoing service to the local industry had been wear metal in used engine oil samples. This involved analysis typically for Fe, Cr, Cu, Ni, Al and Si. By ICP, these were all straightforward but now that I have retired, I continue to offer the service from home by AA. However, Al and Si are not suitable for air-acetylene flame AA and I too find rent for acetylene uneconomic for the small number of samples involved. Nevertheless, I can do Fe, Cu and Ni using air-propane flame AA, but Cr has low sensitivity. By using propene (in throwaway MAP gas bottles costing \$30 at Bunnings) with the propane slot burner (it has almost the same flame propagation speed), the sensitivity for Cr was more than doubled. I had toyed with the idea of using the old lamp to generate the acetylene but this is still fairly limited and I hesitate to use nitrous oxide as the oxidant (cost and safety not justifiable). It would be possible for me to use furnace AA for Cr as well as for Al and Si but this needs Ar or N₂ as carrier gas. I notice one can now buy small throwaway bottles of Ar for

welding for \$60 (Gippsland Bearings) plus flow regulators (\$35). Each analysis would be slow but may be worth investigating.

Ray Hodges FRACI CChem

Anyone for chemology?

As always, I enjoy the Letter from Melbourne by Ian Rae. I particularly was amused, or should I say bemused, by his letter in the October edition about terminology relating to chemists and pharmacists.

As a person with a 'foot in both camps', or, perhaps better, both feet in both camps, I think it is most unfortunate that pharmacists of years gone by insisted on the name 'chemist'. Why insist on keeping the name 'chemist' when the name 'pharmacist' provides a clear indication of what the profession is about.

My understanding is that the name 'chemist' as used by pharmacists came about because the name 'pharmaceutical chemist' was commonly used in the 19th century. That is not surprising, as a major part of a pharmacist's training from then up to recent times had a lot of chemistry taught during the old apprenticeship days and the early days of the Bachelor of Pharmacy degree. It is not surprising that most people would prefer to have their prescriptions filled out by visiting a 'chemist'. The alternative was too much of a mouthful to say: 'I am going to visit the pharmaceutical chemist'.

It is a great pity that pharmacists during the last century did not take the opportunity to call themselves 'pharmacists' and not refer to themselves as 'chemists'. If they had, using the term 'chemist', meaning a person or a place where medicines are purchased or prescriptions are filled, would have died out long ago. Hence, we would not have been continuing the silly situation we have today. There is an increasing number of pharmacists who prefer to be called just that, but there continue to be community businesses (retail pharmacies) that incorporate the word 'chemist' as part of their trade names, so we are stuck with this situation for some time to come. Presumably, this is because of the fear of losing business if they do not continue in the same manner as competing businesses.

Even though my day-to-day job is centred predominantly on chemistry and pharmacology, I still maintain my registration as a pharmacist. In some social environments, depending on the conversation, I am occasionally asked if I am a chemist. I have great delight by responding: 'Yes, and I am a pharmacist too'. Occasionally, I am asked if I am a pharmacist, and I like to respond: 'Yes, and I am also a chemist'. Not surprisingly, I sometimes receive blank looks of bewilderment. Some individuals like to ask what I mean. This occasionally can and does lead to explanations of what chemists and the RACI are all about.

Desmond Williams FRACI CChem

New nanoparticle delivers and tracks cancer drugs

University of New South Wales chemical engineers have synthesised a new iron oxide nanoparticle that delivers cancer drugs to cells while simultaneously monitoring the drug release in real time.

The result, published online in *ACS Nano* (<http://pubs.acs.org/doi/abs/10.1021/nn404407g?prevSearch=boyer&searchHistoryKey=>) represents an important development for the emerging field of theranostic nanomedicine – the use of nanoparticles to treat and diagnose disease.

'Iron oxide nanoparticles that can track drug delivery will provide the possibility to adapt treatments for individual patients,' said Associate Professor Cyrille Boyer from the University of New South Wales School of Chemical Engineering.

By understanding how the cancer drug is released and its effect on the cells and surrounding tissue, doctors can adjust doses to achieve the best result. Importantly, Boyer and his team demonstrated for the first time the use of the technique fluorescence lifetime imaging to monitor the drug release inside a line of lung cancer cells.

'Usually, the drug release is determined using model experiments on the lab bench, but not in the cells,' said Boyer. 'This is significant as it allows us to determine the kinetic movement of drug release in a true biological environment.'

Magnetic iron oxide nanoparticles have been studied widely because of their applications as contrast agents in magnetic resonance imaging. Several recent studies have explored the possibility of equipping these contrast agents with drugs. However, there are limited studies

describing how to load chemotherapy drugs onto the surface of magnetic iron oxide nanoparticles, and no studies that have effectively proven that these drugs can be delivered inside the cell. This has only been inferred.

With this latest study, the researchers engineered a new way of loading the drugs onto the nanoparticle's polymer surface, and demonstrated for the first time that the particles are delivering their drug inside the cells.

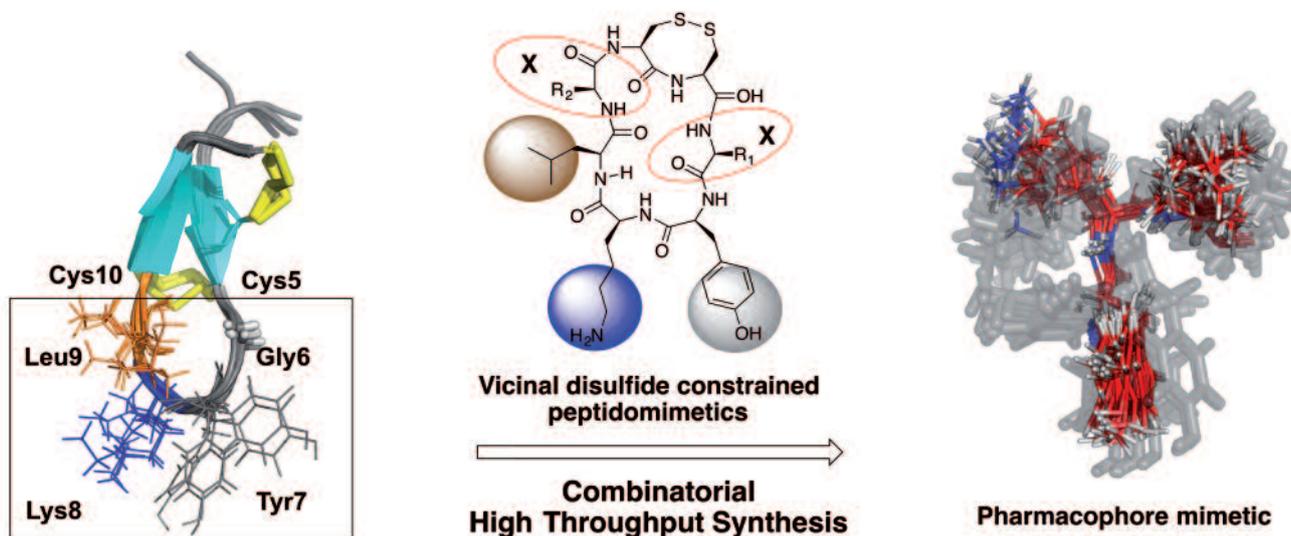
'This is very important because it shows that bench chemistry is working inside the cells,' said Boyer. 'The next step in the research is to move to in-vivo applications.'

UNIVERSITY OF NEW SOUTH WALES



Associate Professor Cyrille Boyer

Turning off the norepinephrine transporter

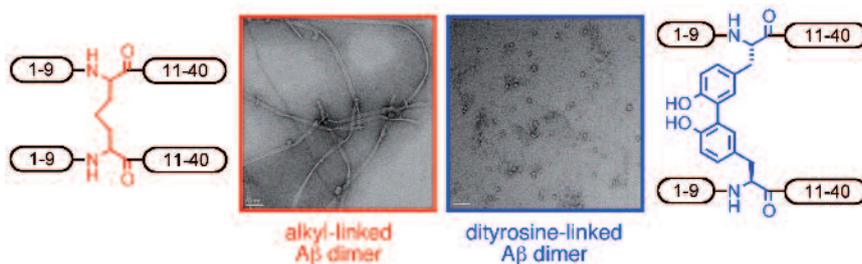


Peptide turn mimetics have promised much but delivered little over the past two decades. It has been anticipated that they would have significantly improved properties over their parent peptides and deliver drug leads with exceptional stability, low molecular weight and improved biophysical properties, but this promise is yet to be realised. An all-Australian team centred at the Institute of Molecular Bioscience, University of Queensland, has described a general approach to developing peptidomimetics of β,γ -turns that may well turn the field around (Brust A., Wang C.-I.A., Daly N.L., Kennerly J., Sadeghi M., Christie M.J., Lewis R.J., Mobli M., Alewood P.F. *Angew. Chem. Int. Ed.* 2013, **52**, 12020–23, hot paper). The team

describes a vicinal disulfide-constrained cyclic peptidomimetic that targets the norepinephrine transporter. The designed reuptake inhibitor is a structural and functional mimetic of the parent peptide and is exceptionally stable in plasma. The authors used the first high-throughput synthetic approach towards peptide thioesters and cyclopeptides via Boc-chemistry. Using a safety catch linker in combination with a compartmentalised resin, it was possible to overcome the throughput-limiting bottleneck of HF cleavage. This development will also have impact in the field of protein synthesis where peptide thioesters are core building blocks.

Dityrosine-linked amyloid- β peptides in Alzheimer's disease

Alzheimer's disease is characterised by the formation of amyloid deposits primarily comprising amyloid- β (A β) peptide. Substantial evidence suggests that soluble oligomers of A β are the neurotoxic species related to progression of Alzheimer's disease. Recent collaborative studies performed at the Bio21 Molecular Science and Biotechnology Institute, University of Melbourne, have culminated in the synthesis of dityrosine cross-linked A β peptides, which has enabled investigation of the biophysical properties of these species (Kok W.M., Cottam J.M., Ciccotosto G.D., Miles L.A.,



Karas J.A., Scanlon D.B., Roberts B.R., Parker M.W., Cappai R., Barnham K.J., Hutton C.A. *Chem. Sci.* 2013, **4**, 4449–54). The dityrosine cross-linked A β peptides display increased neurotoxicity, despite exhibiting a decreased propensity toward fibrilisation. These results suggest

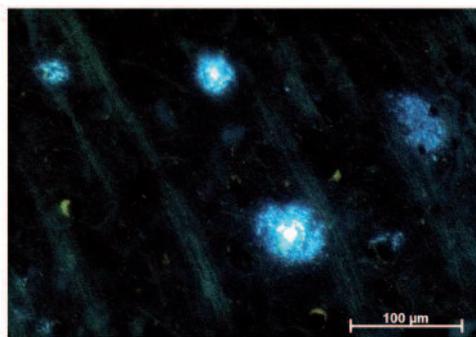
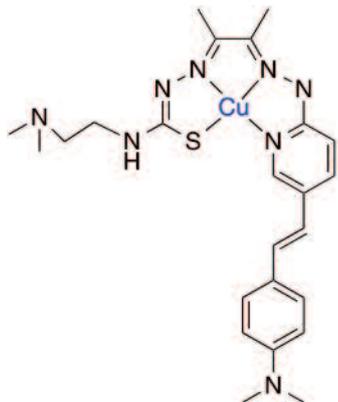
that this specific form of A β exists for longer in the toxic 'soluble oligomer' state and its formation in vivo may therefore contribute to the progression of Alzheimer's disease.

New imaging agents for Alzheimer's

The most common neurodegenerative dementia is Alzheimer's disease, which is associated with insoluble aggregates called amyloid plaques. The major constituent of these plaques is the protein amyloid- β . Diagnostic imaging by positron emission tomography (PET) is a powerful technique to study the molecular nature of disease in living

patients. PET relies on a tracer radiolabelled with a positron-emitting isotope that is administered to the patient and detected by a PET camera. Imaging of A β plaque burden in living patients is possible using radiolabelled compounds that cross the blood-brain barrier and selectively bind A β plaques. Drs James Hickey and Paul Donnelly, and

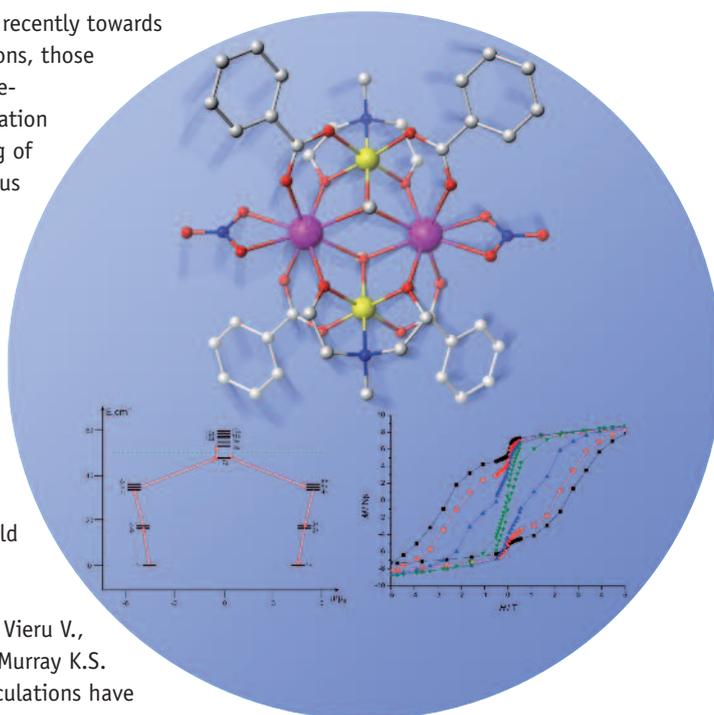
their colleagues at the School of Chemistry, University of Melbourne, have discovered new imaging agents to aid the clinical diagnosis of Alzheimer's disease (Hickey J.L., Lim S.C., Hayne D.J., Paterson B.M., White J.M., Villemagne V.L., Roselt P., Binns D., Cullinane C., Jeffery C.M., Price R.I., Barnham K.J., Donnelly P.S. *J. Am. Chem. Soc.* 2013, **135**, 16120–32). The team synthesised new thiosemicarbazone-pyridylhydrazine-based ligands that incorporate amyloid- β plaque-binding moieties. The new ligands form stable four-coordinate complexes with a positron-emitting radioactive $^{64}\text{Cu}^{\text{II}}$. Two of the new Cu^{II} complexes include a functionalised styrylpyridine group which causes the complex to bind to A β plaques in post-mortem human brain tissue. Strategies to increase brain uptake by functional group manipulation have led to a complex that effectively crosses the blood-brain barrier in mice.



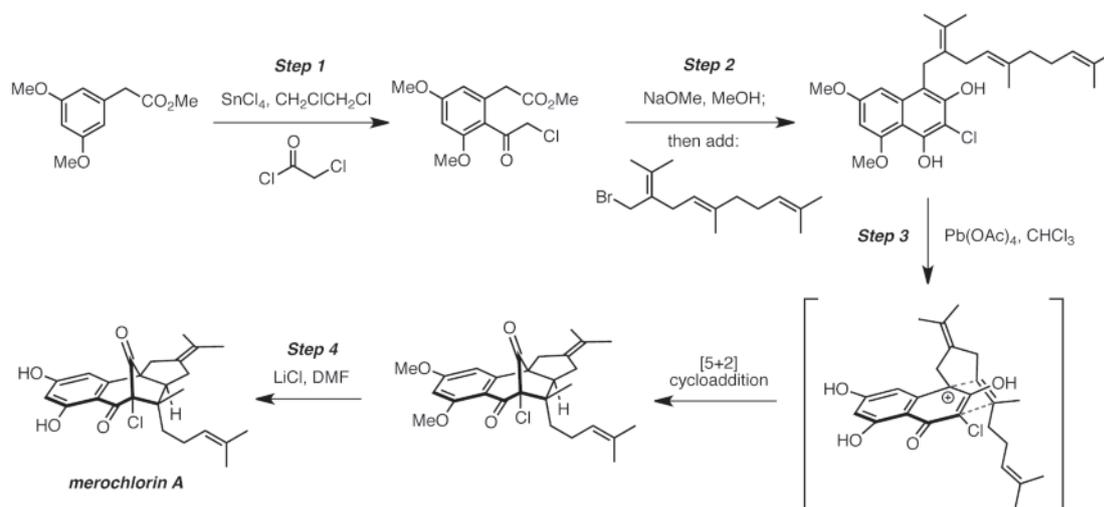
The copper complex (left) binds to A β plaques in human brain samples from subjects with diagnosed Alzheimer's disease. Samples of human frontal cortex are treated with the copper complex and the binding to A β plaques is detected using epi-fluorescent microscopy (bright blue spots, right).

Improved molecular magnets

Research on single-molecule magnets has moved its focus recently towards clusters and monomers of anisotropic f-block lanthanoid ions, those containing dysprosium(III) proving to yield the best single-molecule magnet features. Such features include magnetisation reversal, the barrier height to reversal, quantum tunnelling of magnetisation, and the blocking temperature. One notorious property of Dy^{III} is its weak exchange coupling to neighbouring Dy^{III} or other ions. A US group has recently used radical bridging N_2^{3-} ligands in dinuclear Dy^{III} complexes to enhance exchange and single-molecule magnet features. In a different approach, researchers at Monash University and their collaborators from the Universities of Melbourne and Manchester and the Catholic University of Leuven have used paramagnetic Cr^{III} centres, in 'butterfly'-shaped tetranuclear $\{\text{Cr}^{\text{III}}_2\text{Dy}^{\text{III}}_2\}$ species, not only to enhance Dy–Dy exchange but to increase the blocking temperature and, importantly, to yield 'stepped' hysteresis at normal Squid temperatures, up to 3.5 K, rather than requiring micro-Squid methods and temperatures below 1 K. (Langley S.K., Wielechowski D.P., Vieru V., Chilton N.F., Moubaraki B., Abrahams B.F., Chibotaru L.F., Murray K.S. *Angew. Chem. Int. Ed.* 2013, **52**, 12014–18). Ab initio calculations have yielded the spin-phonon mechanism of magnetisation relaxation.



Taking nature's lead in the synthesis of new antibiotics



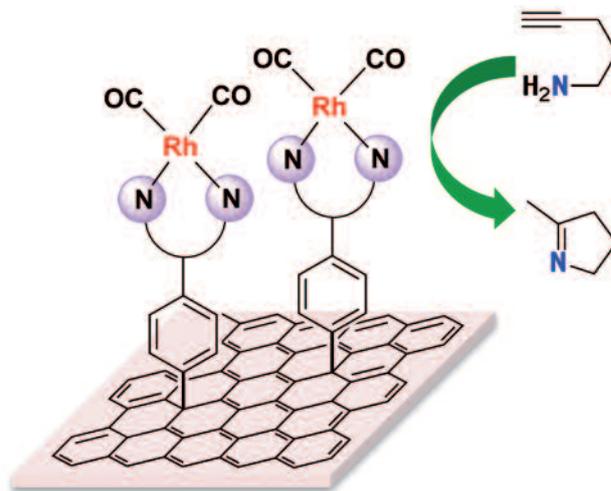
Marine microorganisms have proved to be a rich source of unusual natural products with potentially useful biological activities. A good example is merochlorin A, a chlorinated meroterpenoid isolated from a marine strain of *Streptomyces* bacteria, which possesses potent antibiotic activity against methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*, two species

associated with potentially devastating hospital-acquired infections. Organic chemists at the University of Adelaide have recently reported a short synthesis of merochlorin A, using a strategy that is closely based on their proposed biosynthesis of the natural product (Pepper H.P., George J.H. *Angew. Chem. Int. Ed.* 2013, **52**, 12170–3). The four-step synthesis consists of a Friedel-Crafts

acylation, a one-pot aromatisation-alkylation sequence, a [5+2] cycloaddition initiated by oxidative dearomatation, and then demethylation of aryl methyl ethers under Krapcho-type conditions. The efficiency of the synthetic approach has allowed more than a gram of merochlorin A to be prepared, as well as several analogues for testing as antimicrobial agents.

Immobilising homogeneous catalysts

Homogeneous metal catalysts are widely used for the production of both bulk and high-value chemicals. The molecular nature of the catalysts allows for a high degree of control over the reaction mechanism, which can be tuned to afford products efficiently and with the desired selectivity. However, the separation of the catalyst from the reaction products and subsequent reuse are very challenging, which significantly decreases the overall sustainability of the process. The separation problem can be solved by attaching a homogeneous catalyst onto an insoluble solid support, creating a hybrid catalyst that retains the high efficiency of the parent homogeneous catalyst and can be easily separated from the reaction products. The Messerle research group (School of Chemistry, University of New South Wales) has immobilised Rh^I catalysts onto solid glassy carbon supports via robust C–C bonds between the surface and ligands (Tregubov A.A., Vuong K.Q., Luais E., Gooding J.J., Messerle B.A. *J. Am. Chem. Soc.* 2013, **135**, 16429–37). The immobilised complexes were shown to be very efficient model catalysts for the hydroamination reaction,



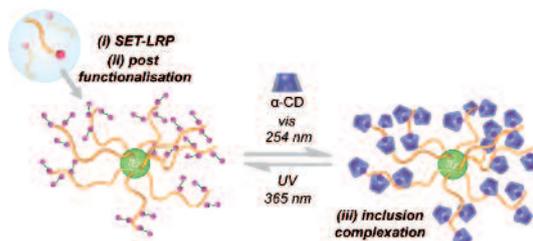
with the linkage between the surface and a ligand remaining intact during catalysis. These results can be used as a starting point for the development of industry-applicable immobilised catalysts.

Compiled by **Matthew Piggott** MRACI CChem (piggott@cyllene.uwa.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 Matthew.

Aust J Chem

The January issue features a selection of papers authored by the participants in the newly formed Sino-Australian Polymer Chemistry Mission, organised by Greg Qiao (University of Melbourne) and Meifang Zhu (Donghua University, Shanghai), which involved the visit of an Australian delegation to China last northern winter.

The Qiao group reports the one-pot synthesis of water-soluble poly(2-hydroxyethyl acrylate) (PHEA)-based core cross-linked star (CCS) polymers via single-electron transfer-living radical polymerisation (SET-LRP). The star polymers display excellent water solubility and the pendent hydroxyl groups provide a platform for facile post-

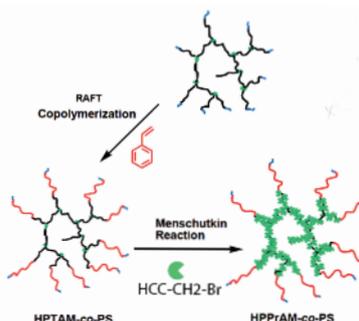


functionalisation with various molecules. Thus, a photoisomerable molecule, 4-(phenylazo)benzoic acid, was conjugated onto the preformed stars

through partial esterification of the available hydroxyl groups (5–20%). The azobenzene-functionalised stars were subsequently employed to form inclusion complexes with α -cyclodextrin. Due to the photo-responsive behaviour and the *cis-trans* nature of azobenzenes, the functionalised PHEA CCS polymers exhibit selective and reversible complexation and decomplexation. Such materials may find application in self-healing materials and sustained drug delivery systems.

Meifang Zhu et al. describe novel 3D magnetic hydrogels based on pomegranate-like functional magnetic nanospheres (FMNs) as photoactive cross-linkers and polyacrylamide as polymer matrix by photoinitiated free radical polymerisation. These novel super-structured FMNs were prepared by embedding Fe_3O_4 nanoparticles into polystyrene (PS) through mini-emulsion polymerisation. Due to a large fraction of magnetite, the monodispersed FMNs exhibit a much higher saturation magnetisation than previously achieved. This facile realisation of magnetic hydrogels expands opportunities for application in the field of smart magnetic switches, targeted drug release, biomimetic sensors and chemical machines.

Chao Gao et al. (Zhejiang University) report on a novel kind of amphiphilic hyperbranched polymer (AHP), poly(2-(dimethylamino)ethyl methacrylate)-co-polystyrene (HPTAM-co-PS), synthesised via the combination of reversible addition-fragmentation chain transfer polymerisation and self-condensing vinyl polymerisation. The HPTAM-co-PS polymer so obtained was then functionalised via a highly efficient Menschutkin 'click' reaction with propargyl bromide ($\text{HC}\equiv\text{C}-\text{CH}_2\text{Br}$), which afforded hyperbranched poly(propargyl quaternary ammonium methacrylate)-co-polystyrene (HPPrAM-co-PS) featuring a hydrophilic quaternary ammonium salt core and a hydrophobic PS shell. The core-shell amphiphilic materials encapsulate guests of water-soluble dyes. The colouring is very stable and uniform. This work opens an avenue for efficient dye-colouring via hyperbranched polymers.



Many more papers in diverse areas of polymer and materials chemistry complete the issue.

Curt Wentrup FAA, FRACI CChem (wentrup@uq.edu.au),
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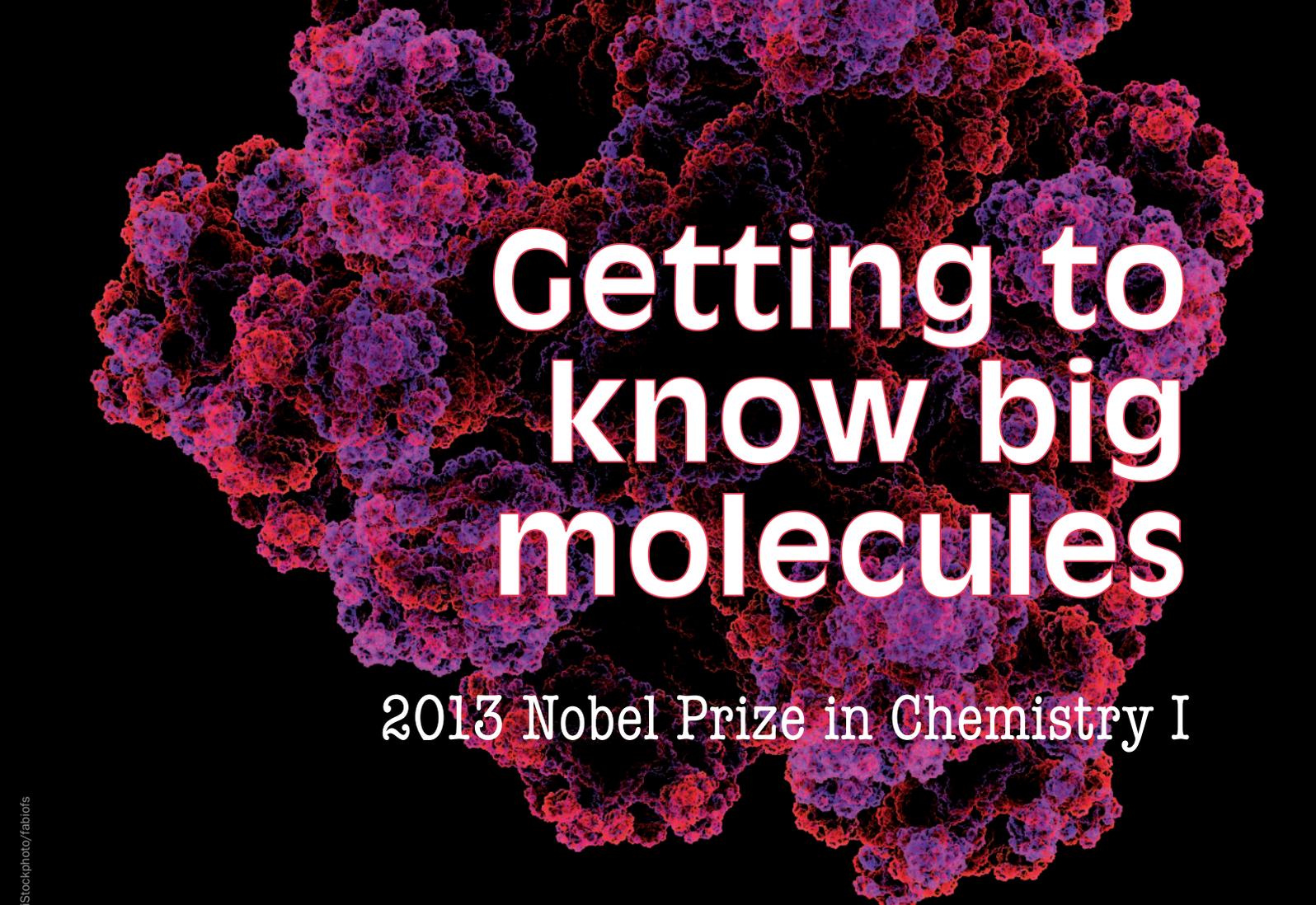
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Getting to know big molecules

2013 Nobel Prize in Chemistry I

BY **PETER KARUSO**

Chemistry's most recent Nobel Laureates have developed methods to 'see' how large molecules such as enzymes move, interact and react. Stanford University's Michael Levitt is among them.

Chemical reactions happen so fast that they are generally not observable. Even if reactions were not so fast, individual molecules are so small, they cannot be seen, except in bulk.

The Schrödinger equation is the quantum mechanical description of chemistry, but it cannot be solved exactly for anything interesting. Newtonian mechanics can describe the motion of huge molecules with ease, but cannot say anything about reactivity. Put them together, and these two approaches allow the study of interactions, reactions and movements of large molecules.

Until recently, simulating molecules on computers required software based on either molecular mechanics or quantum mechanics, two fundamentally different approaches. Both had their strengths and weaknesses (see box).

To fully appreciate the development of these two worlds, we need to go back to 1926. Werner Heisenberg (Nobel Prize in Physics, 1932) had just developed matrix mechanics; Erwin Schrödinger (Nobel Prize in Physics, 1933) had proposed the basic non-relativistic wave equation governing the precise motion of nuclei and electrons in any molecule:

$$E\Psi = H\Psi$$

This differential eigenvalue equation cannot be derived, but just sprang forth from the mind of Schrödinger for the energy E and wavefunction Ψ of a particular state. H is the Hamiltonian operator and Ψ depends on Cartesian and spin coordinates of the component particles. The apparent simplicity of this equation caused Paul Dirac (who shared the 1933 Nobel Prize in Physics with Schrödinger) to exclaim: 'Chemistry has come to an end'.

The Schrödinger equation is exactly solvable for the hydrogen atom, which has only one proton and one electron. However, anything more complicated runs into the so-called 'three body problem', which has no exact solution for molecules. This arises because the Hamiltonian contains coulombic components of pairwise interactions between all three bodies that depend on two sets of coordinates that cannot be separated.

Dirac later tempered his jubilation:

*The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known ... the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble. (Proceedings of the Royal Society of London, 1929, **123**, 714)*

Thus the Schrödinger equation can be thought of as the border between physics and chemistry. On one side, the equation can be solved; on the other side, not so much.

To come close to a solution to this impossible equation, a number of compromises can be made. The first is to recognise that protons are 1800 times heavier than electrons so their kinetic energy can be neglected (Born approximation) and they can be treated as fixed, point charges. A long series of ingenious approximations, shortcuts and alternative approaches culminated in the Nobel Prize in 1998 for John Pople (ab initio methods) and Walter Kohn (DFT theory) for two different methods of dealing with the Schrödinger equation. Ab initio methods seek approximate solutions to the Schrödinger equation while DFT theory avoids the computational costs of solving the Schrödinger equation, substituting the n -electron wave equations for just three coordinates – optimising the electron density of the molecule.

Before modern advances in methods and super computers, in the 1940s there were no computers at all so even the crudest approximations of the Schrödinger

equation for even the smallest molecules were well out of reach. Three groups proposed an alternative independently. Terrell Hill was a monumental figure in statistical mechanics, a product of the Lewis school of thermodynamics at Berkeley, completing his BA (1939) and PhD (1942) in Chemistry, working on the Manhattan Project, then getting a faculty position at the University of Rochester after the war. Teaching undergraduates was not his forte, but he was a great research mentor, preparing his students to be free-thinking critics of the literature. He encouraged students to develop their ideas first and then consult the literature, since the literature (especially in theoretical biology) is often full of preconceptions and misleading lines of reasoning. He was a deep thinker and his papers were always concise.

One example, a single author note of less than a printed page, was the first to suggest a mechanical approach to measuring the steric effects in small molecules (Hill T.L. *J. Chem. Phys.* 1946, **14**, 465):

$$E^s = \mu_0 \left(\frac{r_0}{r}\right)^{12} - 2\mu_0 \left(\frac{r_0}{r}\right)^6 + \frac{1}{2}k_a(l - l_0)^2 + \frac{1}{2}k_b(\theta - \theta_0)^2$$

This equation looks qualitatively similar to every molecular mechanics equation in use today, containing parabolic functions for bond lengths (l) and angles (θ) and Lennard-Jones 6-12 component for estimating van der Waals interactions (r). The only things missing are dihedral and electrostatic terms (and cross terms).

In the same year, Frank Westheimer, citing Hill's paper, published a similar formula for estimating the energy required to racemise hindered biphenyls (*J. Chem. Phys.* 1946, **14**, 733). At the same time, Ingold was considering the energy required for nucleophilic substitution and wrote a paper outlining the five components that add to the steric hindrance associated with attack of the nucleophile (*J. Chem. Soc.* 1946, 173). Notably, he used a Morse function to describe the bond lengths instead of a simple parabola. This was required of course because in nucleophilic substitution the leaving group bond must eventually break. Westheimer's group quickly became the leading researchers in this area, but it was not until the advent of computers that calculating the energy of different conformations of small molecules became possible.

One of the first examples was in 1961 from James B. Hendrickson (University of California, Los Angeles), who

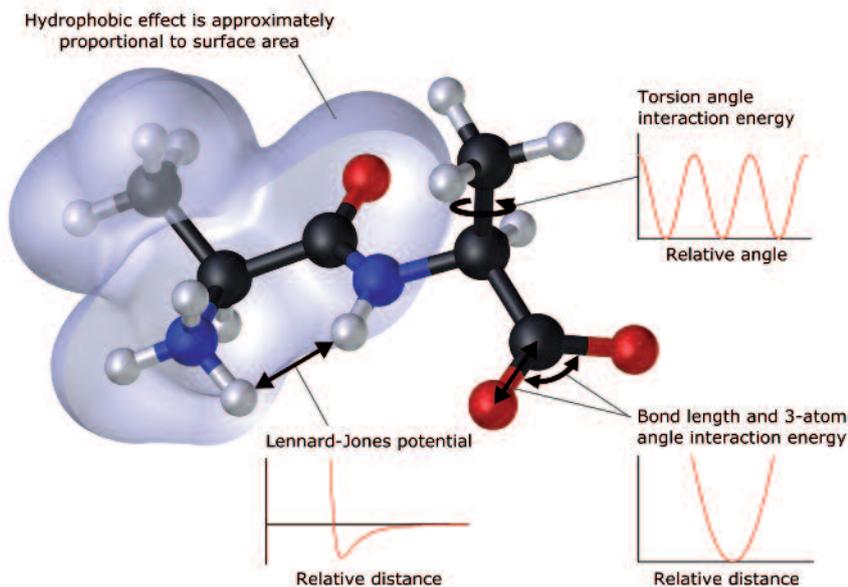
Rival views of molecular reality

Molecular mechanics

- Based on Newton's laws of motion
- Treats atoms as perfect spheres and bonds as springs
- Handles large systems, such as proteins; displays the positions of the atoms in a molecule
- Does not say anything about reactivity or reaction mechanisms

Quantum mechanics

- Based on approximate solutions of the Schrödinger equation
- Relatively unbiased; can be used to model not only ground state but excited states and transition states of molecules
- Requires enormous computing power to process electron occupancy of every single molecular orbital and nucleus of every atom; calculations thus limited to quite small molecules in a vacuum and solvent interactions are ignored



The atoms in a molecule can be modelled using Newton's laws as inelastic charged spheres connected by springs that try to maintain bond lengths and angles. The charged atoms interact with each other (via Coulomb's law) and with the solvent. The model shown is the basis of every molecular mechanics potential energy function to simulate how molecules move and behave. The molecule shown is an alanine dipeptide.

Wikimedia/Edboas. Published in Boas F.E., Harbury P.B. *Curr. Opin. Struct. Biol.* 2007, 17, 199–204.

used the latest million-dollar IBM 709 computer (capable of ~5000 FLOPS compared to a Sony PlayStation 4, which is capable of 1.84 teraFLOPS today and costs \$400) to calculate the conformational energy of a number of cyclic hydrocarbons (*J. Am. Chem. Soc.* 1961, **83**, 4537). The next major advance came in 1965 when Kenneth Wiberg (Yale) wrote an algorithm to find the lowest energy conformation of a molecule. Until then, computer programs could only calculate the energy of a structure given but now with the 'steepest descent' algorithm it was possible to find the local minimum, starting from a random structure. In 1967, Shneior Lifson (Weizmann Institute) was attempting to draw all these strings together and develop a general program that could simulate the structure of any molecule from a simple potential energy function (*Tetrahedron* 1967, **23**, 769).

... the Schrödinger equation can be thought of as the border between physics and chemistry. On one side, the equation can be solved; on the other side, not so much.

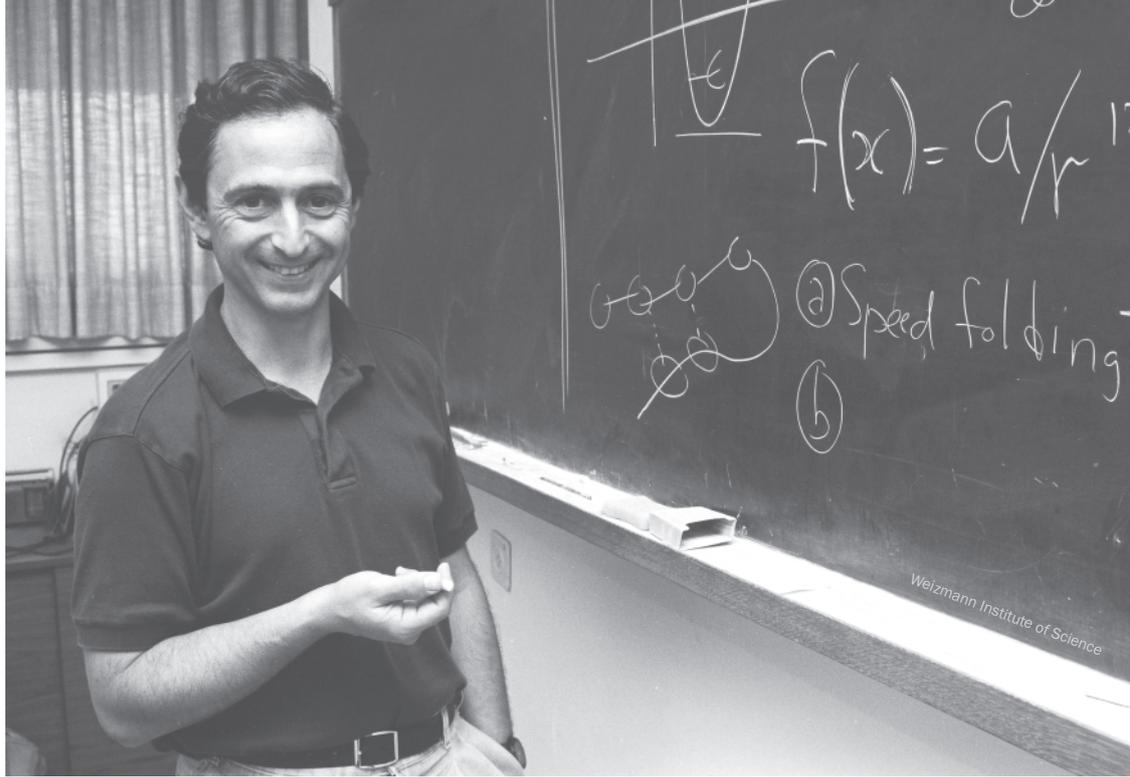
As is customary each year, in 2013 the Nobel Committee telephoned the Nobel Prize recipients just before the public announcements were made – the middle of the night in California. After the delight of the news washed over Michael Levitt, his first thought was to pull down the photos from the 2013 Burning Man festival in Nevada that he had recently posted on Facebook. There were a few pictures of Levitt just in underpants, of which he says, 'At least I wasn't naked'.

Michael Levitt is from a Jewish family that originated from the western town of Plunge, in Lithuania, but emigrated to South Africa because of World War II. Michael was born in Pretoria on 9 May 1947. He attended school in Pretoria but was bored by school. With private tutoring, he passed his matriculation exams at the age of 14. His mother (Gertrud Levitt) wanted her son to attend an English university but none was prepared to take such a young student, so she contacted the University of Pretoria. Professor Wolfgang Schilz (the Head of Chemistry) agreed to take Michael and he completed first year (Maths, Physics and Chemistry) with Distinction, but the family moved to England in 1963 at the end of his first year.

In 1964, he was so strongly influenced by the BBC TV series *The thread of life* narrated by Sir John Kendrew that after finishing his BSc at Kings College in Physics (1967) he went immediately to Kendrew and asked to be admitted as a PhD student, but was rejected by the MRC (the Medical

$$E = \sum \varepsilon \left[\left(\frac{r_0}{r} \right)^{12} - 2 \left(\frac{r_0}{r} \right)^6 \right] + \sum \frac{1}{2} K_b (b - b_0)^2 + \sum \frac{1}{2} K_\theta (\theta - \theta_0)^2 + \sum K_\phi [1 - \cos(n\phi + \delta)] + 332 q_i q_j / r$$

The functional form of CFF as envisaged by Lifson in 1967. Lifson was the first to realise that hydrogen bonding could be simulated as an electrostatic interaction of partial charges (last term).



Michael Levitt at the Weizmann Institute, 1983

Research Council Laboratory of Molecular Biology in Cambridge).

Kendrew received the 1962 Nobel Prize in Chemistry with Marx Perutz (his PhD advisor) for the X-ray structure of myoglobin. At the time, structures were mapped onto sticks terminated with balls indicating the location of atoms in space from electron density maps. In 1967, Kendrew was aware of Lifson's paper in *Tetrahedron* and thought that a computer program would be much better for refinement of protein crystal structures than trying to match up shadows manually from balls on sticks. He suggested this prospective student (Michael Levitt) go to the Weizmann Institute in Israel to visit Shneior Lifson, who was developing the consistent force field (CFF). Levitt arrived in October 1967 and under Lifson's and a PhD student's (Arieh Warshel) supervision managed to program CFF in just a few months. This was the first program that could calculate the energy, first derivative (force) and second derivative (curvature) with respect to atomic positions for any molecule.

Warshel went on to use this program to predict the ground state conformation of small molecules (*Chem. Phys.* 1968, **49**, 5116) while Levitt, recalling Kendrew's advice, applied the program to proteins. Lifson and Levitt published the first energy minimisation of an entire protein (myoglobin – based on Kendrew's crystal structure) in 1969 (*J. Molec. Biol.* 1969, **46**, 269). At about the same time, Norman Allinger extended the work of Hill, Westheimer and Wiberg, applying classical mechanics to the conformational analysis of small molecules to unprecedented accuracy. This led to the development of the MM1 force field that aimed to reproduce the experimental conformations of small molecules to a high degree of accuracy based purely on classical mechanics. In the area of proteins, Némethy and Scheraga were using a very simplified approach to tackle

the conformation of proteins. Their model did not use a force field (so did not calculate an energy), but simply listed possible conformations based on a set of predetermined rules.

Levitt went back to the UK and was admitted to the MRC under Kendrew's supervision in 1968. The heady atmosphere at the MRC with teams headed by Sydney Brenner, Francis Crick, Fred Sanger and John Kendrew was distracting for Levitt, who got side-tracked on the structure of the molecule of the year (tRNA), which had just been discovered but had been predicted to exist by Crick a decade earlier. He did settle down and in 1971 submitted his thesis ('Conformation analysis of proteins'). Because his interest was in the application of classical mechanics (e.g. CFF) to proteins, he returned to Lifson's group at the Weizmann in 1972 and started working on the problem of protein folding, a problem that still occupies his time today at Stanford University and one that, at present, has no good solution.

Levitt was interested primarily in structure and using computational methods to predict protein structure, but Arieh Warshel was more interested in how enzymes work. It is enzymes that make life possible but it is not possible to model reactions, which proceed through an unstable transition state, using molecular mechanics. Quantum mechanics is required to determine the activation energy of reactions and plot reaction potential energy surfaces.

Michael Levitt is one of three people to receive the 2013 Nobel Prize in Chemistry. Part II will look at how co-laureates Arieh Warshel and Martin Karplus contributed to the development of methods to incorporate quantum mechanics into molecular mechanics.

Peter Karuso FRACI CChem is Professor of Chemistry at Macquarie University, Sydney. Part II will be published in the March issue.

Closing the loop

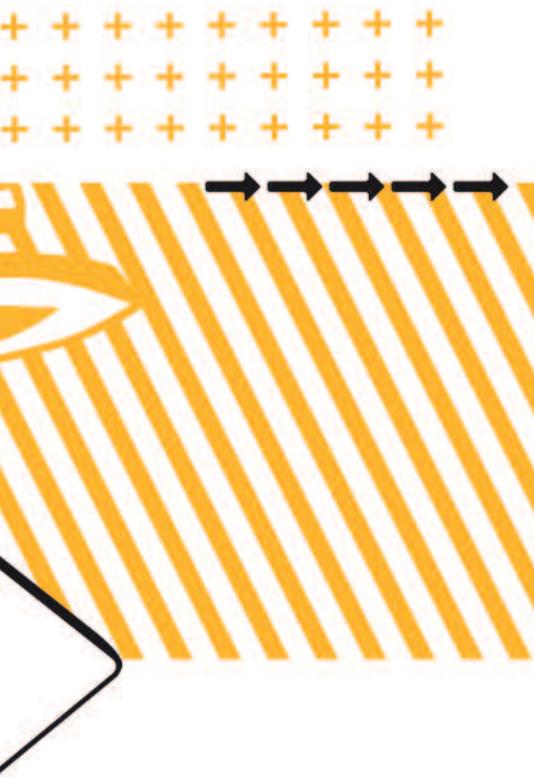
Industries as ecosystems



iStockphoto/Alex_Bond

BY **DAVE SAMMUT**

'Waste' can be an opportunity for value recovery or improved practice, rather than just a red mark on the bottom line.



Australia has a problem. The decline of Australian industry, and with it the symbiotic relationships of industries sharing intermediate or 'waste' materials, has been noted more than once in *Chemistry in Australia* (June and July 2013 editions, p. 40). Along the way, local and global industries have been squandering millions of tonnes of materials potentially useful as intermediates and reusable feedstocks.

The trend has been exacerbated, unintentionally, by government regulation. Some legislative restrictions on the movement and processing of waste create enough red tape, delay and expense to deter all but the most dedicated recycler.

Consider the problem created by a difference in the landfill levy between New South Wales, at \$108 per tonne, and Queensland, where there is no levy. Thousands of tonnes of waste are sent across the border each week at a transport cost significantly less than the landfill levy in New South Wales. Systems that create such situations are the enemy of good environmental practice. However, the protocols intended to redress this hinder environmentally sensible trans-boundary movements (controlled by the National Environment Protection Measure, NEPM), even before the substantial economic, environmental

and social costs of long-distance transport are taken into account.

Very similar problems occur internationally. The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal is an essential impediment to dumping in developing countries, but it is also a major obstacle to sensible reuse or recycling of certain Australian wastes overseas. Australia has limited standing recycling pathways for selected industrial wastes, including metals (predominantly steel, copper, brass and lead), some clean and uncontaminated plastics, paper and cardboard, and construction and demolition wastes (notably concrete and bricks). Many other materials, due to low volume and resulting high unit costs, would be more sensibly recycled or reused internationally, where economies of scale could transform their value.

The volume and tonnage of industrial and consumer waste that ends up in landfill each year is both astonishing and abhorrent. Many old landfills are now considered so rich in resources that proposals have been put forward to mine them.

Businesses have improved to some extent in accordance with the 'reduce, reuse, recycle' mantra. Encouraging evidence from businesses in New South Wales shows recycling rates are

increasing. However, tonnages are also up: ABS data (2013, cat. no. 4602.0.55.005) shows that the total amount of waste generated per capita has more than doubled over the past 15 years alone.

Many of the waste issues that organisations face can be addressed through applied industrial ecology. While some academics have described industrial ecology as the 'science of sustainability', there is no consensus, and definitions will probably be debated for many years to come. Notwithstanding any controversy, a particularly significant strategy developed by industrial ecologists and others describes this developing science as:

... the shifting of industrial process from linear (open loop) systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes can become inputs for new processes.
(Wikipedia)

One of the key barriers to practical industrial ecology is the lack of access to useful information. Our industries have become so compartmentalised, the sites so physically remote from each other, that identifying potential users of waste or sources of usable material is extremely problematic. Some state governments (such as New

South Wales and Victoria) have introduced programs intended to overcome this limitation. As the regulatory authorities, the state environmental protection authorities hold considerable amounts of potentially useful information about the wastes being generated in their jurisdiction.

Networking is a principal way of overcoming information 'silos'. In the late 2000s, the Victorian EPA hosted HazWaste Expo events, which brought together those with waste problems and people with the means to address them. The Sustainability Advantage program run by the Office of Environment and Heritage in New South Wales has many similarities with this approach. Both state governments run vital grants programs funded, notionally, from punitive landfill levies.

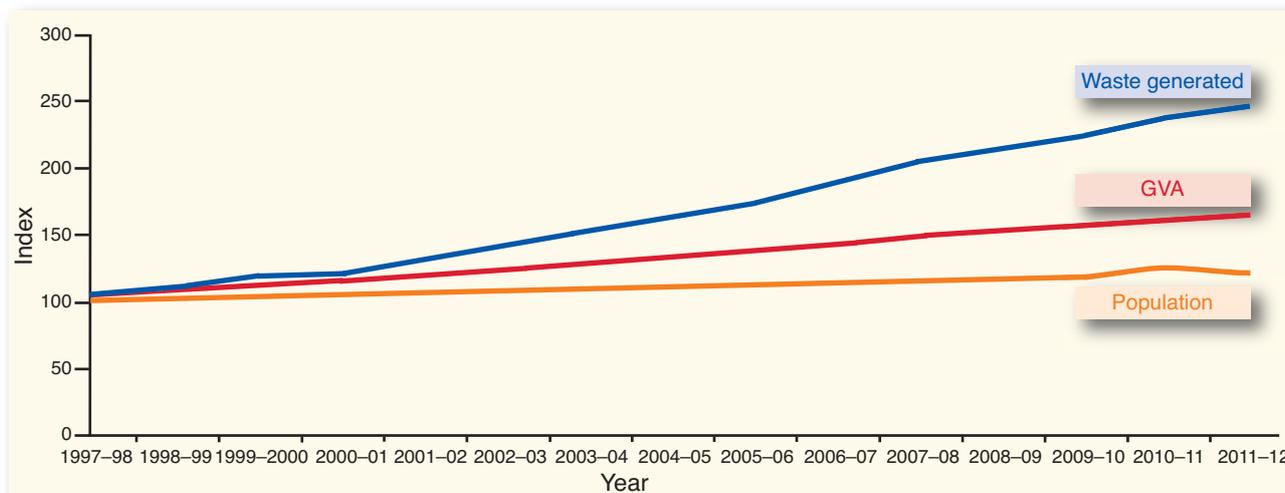
The Australian Industrial Ecology Network (AIEN), established in 2009 under the auspices of the Waste Management Association of Australia, has the aims of industrial symbiosis. I am involved with this group, and together we foster affiliations between industry, government and academia. One of our main objectives is to eliminate unnecessary disposal of materials in landfill.

AIEN organised the fourth Australasian Industrial Ecology Conference, held in Sydney during

October 2013. Over two days, the breadth of opportunity discussed across both the formal presentations and the many informal meetings (some examples follow) was truly encouraging.

Several resource-intensive industries are particularly suited to the principles of industrial ecology. The cement industry can reuse siliceous and thermal materials, and there are substantial additional opportunities in civil construction. A broad range of organics can be used in agriculture, as well as certain beneficial inorganics such as nitrates and phosphates. The minerals industry offers excellent reuse opportunities for metalliferous wastes.

The calorific value of carbon-based waste is low-hanging fruit. The modern approach is more sophisticated, but regulatory (and community) attention remains against memories of older models of incineration. Other interesting approaches include the preparation of biochar from forestry residues and municipal solid waste streams, of which biomass represents 50–60% of total tonnage. Mark Glover of Renewed Carbon Pty Ltd talked engagingly of the opportunities for biochar use in the petrochemical sector, manufacturing/smelting, agriculture and soil productivity, and even in liquid transport fuels.



Rate of waste generation in Australia compared to gross value added (GVA) and population growth 1998–2012

Data source: Australian Bureau of Statistics



Barriers to industrial ecology in Australia

- Inadequate integration of high-level resource recovery policies and strategies government portfolios (e.g. industry policy and environmental planning)
- Regulations that inhibit the search for industrial waste reuse
- Costs of licensing and approvals
- Lack of markets to absorb recyclables
- Contamination and quality issues
- Lack of communication between manufacturers and recyclers
- Site planning issues and NIMBYism

Adapted from conference presentation by Grant Musgrove, CEO, Australian Council of Recyclers

Many tonnes of materials such as old concrete, fly ash and coal washery rejects have been used in roadbase and concrete aggregate. In each case, the reuse of existing material offers several advantages, including elimination of the environmental effects of disposal and displacement of fresh materials, with substantive environmental and cost savings.

Efforts to recycle old mattresses is an excellent case study from the conference. Although the total tonnage arising from the 1.2 million mattresses disposed annually across Australia is modest (19 000 tonnes), the landfill volume is considerable: 900 000 cubic metres on average. A presenter at the conference showed a video of the operation of a prototype high-pressure disintegrator to shred mattress material and foam off the steel frame, each mattress taking approximately 40 seconds to process (if received dry and flat, which is a major problem in municipal collection). The resulting foam may be reused, if only for its calorific value, and the steel and wood recycled.

The downside is that mattresses are manufactured by many small facilities throughout Australia, using differing

designs and materials. The lack of standardisation, the move to non-recyclable 'body' foams, and the lack of design attention to end-of-life issues are all major impediments to economic reprocessing. The same is true in the automotive industry, consumer packaging and portable electronics, where combination materials are increasingly being chosen for their appearance or other consumer-oriented factors, with little or no attention to end-of-life issues.

Industrial ecology is making headway at the end of industry's pipeline, but it should do so very much more than that. It should be in the design of industrial processes and their products with end-of-life reuse and recycling in mind. In every step from product design to industrial waste, scientists should be taking the lead, paying particular attention to the separability of materials in the end-of-use streams, the recyclability of those materials and their economic value.

The solution needs to be seen as part of daily working practices, reducing unnecessary complexity in waste streams. We need clear and consistent definitions of waste and resource recovery to reflect better

reuse and recycling. Most importantly, we need to break down the barriers of communication, and to drive long-term legislative trends towards sensible outcomes.

Ultimately, legislating good practice is not possible. Market factors have to drive industrial ecology, and while governments can influence crude economic drivers such as landfill costs, the New South Wales–Queensland experience clearly shows that even local variations in regulation can seriously distort markets. As scientists driving innovation, we should always bear in mind the economics of our work, with a plan for waste as something more than a red item at the bottom of the list.

Dave Sammut MRACI CChem is Principal at DCS Technical Pty Ltd. He is a member of the Waste Management Association of Australia, and is on the committee of the Australian Industrial Ecology Network. A small fraction of annual revenue is derived from waste industry clients. None of the companies mentioned in this article is a current or former client of DCS Technical.

Q&A: Picric acid

BY **ROGER READ**

Incidents and forced evacuations related to unsafe picric acid are becoming less common, but they remain a cause for concern.

On 24 October last year, police and emergency services responded to a triple 0 call in Sydney just before 11 am. They evacuated about 5000 students and staff from a site in and around the University of Technology Sydney (UTS), Ultimo, while members of the Bomb Disposal Unit extracted two bottles of picric acid from a basement storage area for later controlled, explosive disposal.

What is picric acid?

Picric acid (2,4,6-trinitrophenol) is a homogeneous, pale yellow, intensely bitter, crystalline substance, melting point 122–123°C. Picric acid is toxic, soluble in hot water, and readily soluble in a wide range of organic solvents, including ethanol, diethyl ether, benzene and acetone.

How is picric acid used?

Picric acid has presumably accumulated in the storerooms of wet chemical laboratories because of its relative low cost and varied applications. As a relatively strong acid (pK_a 0.25), picric acid was favoured to form crystalline salts of otherwise low

melting, or even liquid, primary, secondary and tertiary amines for characterisation. As a phenolic nitro aromatic, it forms salts with intensely coloured anionic components in solution, which has also led it to being used for quantitative, colorimetric methods of analyses.

Relevant to the UTS incident, where analytical and forensic science is emphasised, picric acid is frequently found in forensic laboratories where it is used as a component of the Christmas tree stain for semen and in the Jaffe reaction for creatinine determination in blood and urine. In histology, it is used in stains for connective tissue, cytoplasmic features, fungal hyphae in wood, and as a fixative agent, and it has also found use as an antiseptic, as a treatment of burns, and in formulations for the treatment of ailments such as malaria, herpes and smallpox.

Picric acid was first prepared by alchemist Johann Glauber in 1742 by treating wool or animal horn with nitric acid to give lead or potassium picrates. In 1771, it was manufactured by a British chemist, Peter Woulfe, from indigo for use in the European dyestuff industry, where it was first used to dye silk, and later wool, yellow. Amusingly,

or perhaps alarmingly, its properties as a dyestuff were noted in workers making picric acid as recently as 1914. These men became known as 'canaries' because of the yellow discoloration of their skin.

When does picric acid become explosive?

The possibility of using picric acid as an explosive was first explored by Welter in 1830. In 1873, Sprengel demonstrated that picric acid would detonate, and following experiments at Lydd, England, the English adopted it in 1888 as a relatively insensitive (compared with known powders at the time) explosive material called 'Lyddite'. Russia adopted picric acid as an explosive after their own tests in 1894, and it soon replaced gunpowder in munitions and was used extensively as the main filling in bombs and grenades during the early years of World War I.

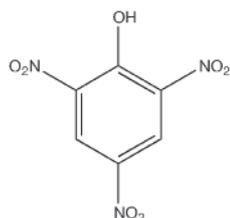
In its dry state, picric acid is slightly more powerful than trinitrotoluene (TNT), as measured by strength (specific energy: 987 versus 870 kJ/kg; Trauzl lead block test: 315 versus 300 m³/10 g) and detonation velocity (confined: 7350 m/s at ρ 1.7 g/cm³

versus 6900 m/s at ρ 1.60 g/cm³). It is also more sensitive to impact (fall energy = 7.4 Nm, relative to TNT = 15 Nm). However, none of these criteria is of significant concern where quantities of up to a few hundred grams are considered. More relevant to the incidents at UTS and elsewhere, picric acid is chemically much more reactive than TNT and has a tendency to react with metals, except tin and aluminium, to form highly impact-, friction- and heat-sensitive picrate salts. When generated and used under controlled conditions, these salts can be valuable for initiating explosives within explosive trains. As impurities, they can lead to accidental initiation and the explosion of nearby, much less sensitive, materials, including, in large enough quantity, picric acid itself. The material is therefore dispensed with wooden or non-metallic spatulas.

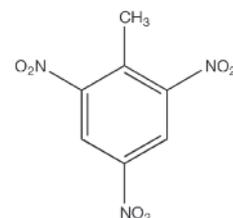
Safe storage and transport of picric acid requires it to be packed with 10–30% water. Safe Work Australia classifies quantities equal to or greater than 500 grams of picric acid with less than 30% water by mass as a Class 1.1D explosive. Equal quantities with greater than 30% water by volume or lesser amounts with at least 10% water are classified as Class 4.1 flammable solids. The quantities involved mean that it is unlikely that wetted picric acid in a research situation will be an explosive hazard. There have been no documented occurrences of spontaneous detonation of picric acid in a laboratory.

What are the laboratory hazards?

The main hazard with picric acid in a laboratory or research facility storeroom lies in the discovery of dry picric acid, particularly if it is aged and closed with a metal seal. In these circumstances, shock- and friction-sensitive metal picrate salts might have formed and any attempt to remove the cap, or even move the container, could cause an explosion that could severely injure or



Picric acid (2,4,6-trinitrophenol)



TNT (2,4,6-trinitrotoluene)

maintain an adult. It is best to contact explosives experts in this situation. Knowledgeable explosives disposal experts will use robotic devices to handle the container and immerse it in water to rewet the picric acid or remove it safely for disposal elsewhere.

If the container cap is plastic and the picric acid contents have dried, there might be crystals on the threads between the container and the cap. Friction can be sufficient to cause the crystals to detonate and the contents to explode. In these cases, it is usually safe to immerse the container and lid in water and allow water to seep into the seal. It can also be helpful to add ice to the water so that negative pressure is created in the container and water is drawn into the seals. Leave the container immersed for several days until water is seen to have penetrated. At this stage, it is safe to remove the lid and fully rehydrate the solid.

How can labs improve safety around picric acid?

- Make sure any stored picric acid is kept wet. Do not open new bottles until they are needed. Label containers to show the date when they are first opened. Check the hydration of picric acid as part of the regular lab inspections and add distilled water if necessary.
- Do not use metal spatulas to remove material from containers of picric acid; wooden or plastic spatulas are safe to use.
- Ensure that the neck of containers, caps and any threads are cleaned with a damp cloth before resealing.
- Dispose of old bottles with metal

caps. Use extreme caution with such containers that still contain picric acid, even if it remains wet. For those that appear dry, *do not touch* the container but contact explosives experts.

- Do not store large amounts of picric acid. Dispose of stocks that are more than two years old.
- Wherever possible, eliminate picric acid from the inventory of stored chemicals. In forensic and biological laboratories, purchase premixed stains or highly dilute (1% solution) picric acid for use in stain preparation.

Picric acid can be disposed of by one of two reductive methods to convert it into a non-explosive form by treatment with sodium hydroxide and sodium sulfide or with hydrochloric acid and granulated tin. These methods will generate toxic material that will then have to be disposed of as hazardous waste. Alternatively, picric acid can be submitted for disposal as hazardous waste as a flammable solid for incineration. *Do not* pour picric acid down a sink, where it might encounter copper or other metal fittings to form explosive salts.

The UTS evacuation is unlikely to be the last of its kind, but such incidents can be avoided to a large extent by regular inspections and careful monitoring of stocks of picric acid and other useful but hazardous materials.

Dr Roger Read FRACI CChem is Honorary Associate Professor, School of Chemistry, University of New South Wales, and RACI NSW Branch President. Picric acid, its uses, hazards and suggestions for safe storage are described in a highly readable briefing document published by Canadian industrial hygienist Mark Cameron (2007) <http://oag.ca.gov/sites/all/files/pdfs/cci/safety/picric.pdf>. This document deserves more formal recognition and many aspects of it have been reiterated in this article.

MOOCs

and the 'efficiency' dividend



BY **RICHARD THWAITES**

In the face of government cuts and student interest in massive open online courses, how can universities secure their future?

The concept of an 'efficiency' or 'productivity' dividend is not new. Former Deputy Prime Minister Tim Fischer in his book *Holy See, unholy me* (ABC Books, 2013) describes productivity dividends as a lazy way for departments of finance to bring about cutbacks. He was writing about cutbacks in the Department of Foreign Affairs and Trade (DFAT), but cutbacks in other departments are also not uncommon. In response to the Gonski Report on improved schooling, the then government suggested the imposition of an 'efficiency' dividend on the university sector to pay the cost of implementing Gonski – amid justified howls of protest from the universities.

Given that the bulk of university funding is supplied by government in one form or another, universities are seeking to better insulate themselves from the threat of future 'efficiency' dividends by finding other sources of income, or cutting expenditure, or both.

Non-government sources of income include full-fee-paying students. Increasing the number of students enrolled could increase revenue from this source, but other factors such as maintaining standards and having to increase costs to provide a quality education could counter any income gains.

In the US, major universities keep in regular contact with their alumni. The culture of philanthropy is strong (helped by a favourable tax regime). Philanthropic donations from wealthy alumni make up a key source of income for many institutions. In the UK, long-established universities and colleges have substantial endowment funds, and continue to ask alumni for support. In Australia, acts of philanthropy seem rare, with a few notable exceptions. I found it surprising, in my experience as Chair of the RACI Qualifications and Accreditation Committee (QAC), that university chemistry departments rarely seemed to know what happened to their graduates after leaving: the



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QAC sought this information to help assess the relevance of courses. Universities ought to be putting more emphasis on keeping track of alumni as potential future sources of income.

The other side of the ledger is to reduce costs. In chemistry, one popular way among administrators to reduce costs is to reduce laboratory contact hours. This has happened in other parts of the world, not just in Australia. In Scotland, for example, Norman Reid (University of Glasgow) and Iqbal Shah (Open University, Islamabad, Pakistan) in their paper 'The role of laboratory work in university chemistry' (*Chem. Educ. Res. Pract.* 2007, **8**(2), 172–85) provided data that showed that over the first three years of a Scottish chemistry degree program, laboratory hours virtually halved between the 1960s and the 2000s.

For a number of years, the QAC regularly carried out surveys of laboratory hours in Australian chemistry degree programs. The results of these surveys indicated that over the period 1995 to 2004 (when the surveys stopped), the number of hours undergraduates spent in the laboratory during a typical three-year chemistry major degree program declined by some 12%. Anecdotal evidence in more recent years suggests further declines have occurred. Several academics have indicated that the desirability of maintaining RACI accreditation for their chemistry degrees was an important factor in preventing further reductions in laboratory hours.

Measuring the number of laboratory hours in a degree program is a rather blunt instrument for determining whether a student has acquired the necessary competence, confidence and understanding of what practical chemistry is all about. On the other hand, without an adequate grounding in laboratory procedures and practices, including the design of experiments to test hypotheses, assessing the feasibility, reliability and

reproducibility of different methods, taking measurements and interpreting results, and appreciating the risks and hazards of carrying out different procedures, chemistry graduates will be ill equipped to embark on a career in chemistry in industry, academia or teaching. The QAC regularly used to interview students about what they liked most about their courses, and the overwhelming response was the practical content. Chemistry students in Australia like practical work! It is dangerous to consider cutting laboratory hours just to reduce costs. This is not to say that lab programs should not be re-designed to put more focus on testing hypotheses and solving problems and less on simple manipulation of equipment – but that is another subject.

It has been said that the next major revolution in university education is the creation of massive open online courses (MOOCs). Will these help to insulate universities from further government cutbacks (or 'efficiency' dividends) and help them balance the books?

Many articles have been written about the rise of MOOCs (e.g. Cooper S. 'MOOCs: disrupting the university or business as usual?', *Arena J.* **39/40**, 2013, 182). The *Australian Financial Review* regularly publishes items on MOOCs in its Monday Education section.

Several Australian universities offer degree courses by distance education. The University of New England and Charles Sturt University, for example, both offer RACI-accredited chemistry degree programs that can be undertaken largely by distance education. These universities overcome the problem of having enough practical work in the program by holding compulsory residential intensives on campus in which a semester's lab program is condensed into a few days' work. For mature-age students with significant laboratory experience who are upgrading their qualifications, this works very well. For

Measuring the number of laboratory hours in a degree program is a rather blunt instrument for determining whether a student has acquired the necessary competence, confidence and understanding of what practical chemistry is all about.

others, it is perhaps less than ideal. (Many students prefer their practical work to have a close link with what they have learnt in lectures and tutorials, which may not be possible using this model. But it is better than nothing.)

The concept behind MOOCs is fundamentally different from learning online by distance education, although there are some basic similarities. Enrolling in a distance education program requires payment of upfront fees, 'class' sizes are usually quite small, and at some time during the course, student work is assessed and graded, and counts towards a final degree. On the other hand, students are not charged to enrol in MOOCs, 'class' sizes are often enormous, students work at their own pace and are not necessarily constrained by timetables and schedules, and satisfactory completion of a MOOC does not necessarily lead to any accredited qualification. Professor Jim Barber, University of New England Vice Chancellor, speaking on Radio

Large MOOCs providers such as Coursera and Udacity have links to around 80 major universities, including Stanford and MIT, and the attraction from a student's perspective is access to top teachers in their chosen field.

National's *Ockham's razor* (13 October 2013) noted that although enrolling in a MOOC is free, universities could make money from MOOCs by charging students for any qualification achieved on the satisfactory completion of a course.

Large MOOCs providers such as Coursera and Udacity have links to around 80 major universities, including Stanford and MIT, and the attraction from a student's perspective is access to top teachers in their chosen field. MOOCs allow students to work at their own pace. Although millions of students have enrolled to start a MOOC program, the completion rate is apparently very small. To date, no links have been established between completing a course and obtaining a qualification such as a diploma or a degree, although this situation could well change.

Presumably after coursework material has been prepared and lectures videoed, MOOCs could be offered to any number of students who decide to enrol at any location at any time. The obvious extension of this is that lecturers and professors would no longer be needed and vast numbers of teaching staff would be made redundant once the coursework had been prepared. (Maybe student queries could be handled by a call centre located in a country where salaries are much lower than in Australia?) But although universities might see substantial cost savings, they would not make any money out of MOOCs unless they charged students in some way, possibly as suggested by Barber, on the successful completion

of the programs they are enrolled in.

This leads to the problem of assessing the knowledge students have acquired. One suggestion is that students' work could be assessed online by their peers with little intervention by university staff, which might work in some subjects, but possibly not in chemistry. Recent work by the Chemistry Discipline Network on assessing Learning Outcomes has shown that it is not necessarily all that easy to find ways to demonstrate Learning Outcomes. Students need to show that they can not only reproduce what they have learnt, but also that they understand and can apply it to solve problems. In other words, it is important that students know not just what to think, but also how to think.

A strong argument against substituting traditional methods of teaching and learning with MOOCs is that students would be deprived of other interpersonal on-campus interactions: they would be deprived of stimulating conversations with other students in their own and other disciplines. People of my generation would subscribe to this argument; younger generations would probably argue that interpersonal on-campus interactions are a poor substitute for modern online social media.

Maybe a way forward is to look again at the potential for MOOCs or modified MOOCs in selected areas such as first-year chemistry programs normally delivered by lectures. The Chemistry Discipline Network has found that there is a lot of similarity in first-year chemistry across a wide range of university offerings. First-year



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chemistry is a drain on the teaching resources of many chemistry departments due to the large numbers of students enrolled, particularly where first-year chemistry is offered as a service for other degrees. Maybe an Australian First Year Chemistry MOOC, to be completed by all Australian undergraduates studying science in general and chemistry in particular could be developed to free up university teaching resources. Fees would be collected by the university on successful completion of the course, but the costs to the universities would be small once the coursework had been prepared. This might then free up funds to allow universities to provide more comprehensive practical subjects in chemistry degree programs. Maybe a first-year chemistry MOOC would enable only the best Australian teachers to present material. Maybe the RACI could be involved in its development.

Is this a possibility, or would a common Australian first-year chemistry MOOC be too much of a revolution?

Richard Thwaites FRACI CChem retired in 2008 after more than 40 years in the chemical industry. He was for several years Chair of the RACI Qualifications and Accreditation Committee and is currently President of the Victorian Branch.

New Fellow

Dr Jack Ryan is an organic chemist and a CSIRO senior principal research scientist. He leads the Small Molecules Stream of projects for the Australian Biotechnology Growth Partnerships Theme, part of CSIRO's Future Manufacturing Flagship.

Ryan grew up in the small farming community of Colbinabbin in northern Victoria and achieved dux of Assumption College Kilmore, a school more famous for producing AFL footballers than chemists. Venturing to the University of Melbourne, he gained a BSc(Hons) (first class) in chemistry and a PhD on cyclopropane chemistry, supervised by Martin Banwell. He undertook postdoctoral appointments researching iodonium chemistry with Peter Stang (University of Utah), and supramolecular chemistry with George Meehan and Len Lindoy (James Cook University). He gained academic experience lecturing at the University of Tasmania (Launceston) and industry experience as a process research and development chemist at the Institute of Drug Technology Australia (Boronia – Melbourne).

Ryan was appointed to CSIRO as a research scientist in 2001, and was promoted to senior research scientist in 2003, principal research scientist in 2007 and senior principal research scientist in 2013. His current research interests involve a combination of fundamental (reactive intermediates, reaction mechanisms, heterocyclic chemistry) and applied chemistry (medicinal chemistry, peptide mimetics, fragment-based drug discovery, chemical process development and scale-up and flow chemistry) and span the fields of human health, insecticides, photoprotection and chemical manufacture.



Ryan has worked on projects with 17 Australian and global industry collaborators, with work being captured in 58 reports to industry, resulting in patents and substantial revenue to sustain CSIRO's organic chemistry group. His industry-focused work has been recognised through CSIRO awards for project management in 2003, 2004 and 2007 and supported by Australian Enterprise Connect Researcher-in-Business Awards in 2010, 2011 and 2012.

Ryan has (co)supervised undergraduate, honours and PhD students and has published 33 peer-reviewed journal articles and book chapters. He is currently a member of the Arkivoc Board of Referees, Victorian Representative on the RACI's Organic Division Committee and a member on the advisory board of Deakin University School of Life Sciences. He is married to Helen; they have daughters Niamh, Ada and Lucy and reside in the Melbourne suburb of Northcote.

More keynote speakers for National Congress

In addition to the nine international plenary speakers that have been secured, I'm delighted to announce that at time of print, an additional 13 keynote speakers have been confirmed for the 2014 National Congress:

- Luisa De Cola, Université de Strasbourg
- Peter Schreiner, University of Giessen
- Paul Mulvaney, University of Melbourne
- Michael Sailor, University of California, San Diego
- Steve Armes, Sheffield University
- Shu-Hong Yu, University of Science and Technology of China
- Annabella Selloni, Princeton University
- Annette Beck-Sickinger, Universität Leipzig
- Craig Lindsley, Vanderbilt University
- Joachim Heberle, Freie Universität Berlin
- Neil Vasdev, Massachusetts General Hospital, Harvard Medical School
- Graham Cooks, Purdue University
- Kazuma Mawatari, University of Tokyo

The call for abstracts opened on 2 December 2013 and we welcome your submissions via the Congress website.



Please visit the Congress website, register your interest to receive electronic updates, and, even more importantly, submit your abstract before 9 May 2014.

If you would like to become more engaged in the planning of the Congress, get in touch with either your Division Chairs, who are already participating in the developments relating to this Congress, or a member of the Congress organising committee. Full speaker and committee details are at www.racicongress.com.

Joe Shapter FRACI CChem, Congress Chair

Trevor Appleton

Teacher and mentor



Trevor George Appleton FRACI CChem (8 November 1944 – 13 June 2013) made an invaluable contribution to the profession of chemistry – through the RACI and during his career as an academic and researcher at the University of Queensland. Trevor's career at the University of Queensland spanned from 1963, when he commenced as an undergraduate, through to 2009, when he retired as a senior academic staff member, with breaks for overseas study.

Trevor's service to the RACI was at Branch and Group level and at a National level as the National Coordinator of the Titration Competition for over 30 years. This competition continues to grow throughout Australia, and will be a fitting legacy to Trevor. It is estimated that in excess of 60 000 students have participated in the competition since Trevor introduced it, first in Queensland in 1980, then nationally in 1984. In recognition of his outstanding service, the Board unanimously awarded Trevor Honorary Life Membership in 2013, despite not achieving the normal milestone of 50 years' service. And in 2008, the Queensland Branch renamed the two RACI Academic Prizes offered at the University of Queensland School of Chemistry and Molecular Biosciences as the RACI Trevor Appleton Awards for Level 1 & Level 3 chemistry.

Trevor was nearly lost to science. At the completion of his Queensland Senior year (as the final years of school were called in the 1960s), Trevor was ranked sixth in the state, and had the opportunity to study medicine. He chose science instead; medicine's loss, science's gain. Trevor's early academic promise showed itself fully at university, where he was awarded the Edward Taylor Prize in 1964, the CSR Prize in 1966 and a University Medal for academic achievement. Trevor completed his Honours and PhD with the late Dr John Hall, in 1966 and 1970.

A PhD is an opening to the world of academia. In Trevor's case, it took him to the University of Western Ontario in Canada to work with Howard Clark. Among the postdoctoral fellows there with Trevor was Malcolm Chisholm and Leo Manzer. The group was working on aspects of organometallic chemistry of platinum and this led Trevor to the area of platinum complexes. In one of those fortuitous circumstances, Trevor and Leo Manzer were asked to write a review on a little understood area of platinum chemistry called the 'trans influence'. This review, published in 1973, became a seminal article in the area, and its importance can be viewed by the number of citations it has received – to date, 1417.

After leaving Canada, Trevor went to the Research School of Chemistry at ANU in Canberra to work with Professor Martin Bennett. At that time the Research School was the principal chemistry research institution in the country and a position there was much sought after.

In 1974, Trevor moved to the University of Queensland. He progressed through the academic ranks from senior tutor to

associate professor, each successive rank being achieved through recognition of his scholarship and teaching excellence, and service to the university body and to the profession. While at the university, Trevor demonstrated many strengths, and for many years he filled the role of Assistant Director of Studies in the Faculty of Science.

In teaching and mentoring, Trevor fostered 12 PhD students (many of whom now hold academic positions in Australia) in a long and extremely fruitful collaboration with Associate Professor John Hall, as well as 20 Honours students. Trevor taught at all levels in the chemistry undergraduate program and in a number of areas, many not deemed to be his area of 'speciality'. Trevor was academically broad in his skills, and he was recognised as a thoughtful, thorough and good teacher who was interested in students learning chemistry, and also learning the broader skills of being a good scientist. Moreover and importantly, Trevor cared about all his students. Trevor was also a driver of significant innovation, and was the major instigator of the computer-managed testing system for students, which still lives on today in a newer form.

Over a period spanning 40 years, his research and subsequently that of his group was published in national and international journals and his group at the University of Queensland became internationally recognised for its work on the synthesis and nuclear magnetic resonance studies of platinum-containing complexes. This work has had a lasting impact and, by all the criteria used these days to quantitate research, has stood the test of time. Trevor was a quiet achiever who had a huge influence on the work of others, work that has led to the development of a new generation of platinum anticancer drugs. Trevor published more than 100 publications, which have been cited more than 5000 times.

Trevor always had interesting stories to tell when meeting up with friends and colleagues at some international conference, as he had usually travelled to wherever it was by a rail journey of some sort. During childhood, Trevor developed a passion for shell collecting and his extensive shell collection is truly something of beauty.

Trevor was a fearless defender of what was right; he was not afraid to speak his mind if he felt that something needed to be said. Trevor once said that he followed the dictum of the Chinese general Sun Tzu – pick your battles – but when he did pick them they were fought with skill and logic.

Tributes have been received from many friends and colleagues throughout the world.

Professor Lawrence Gahan FRACI CChem, Professor Sue Berners-Price FRACI CChem and Ruth Meaney

Roger Brown

A life in synthesis and pyrolysis

Roger Frederick Challis Brown FRACI CChem (30 June 1931 – 1 September 2013) was the eldest son of Herbert and Ruth Brown. Herbert graduated from the University of Sydney in 1921 and studied history at Oxford in 1923; he brought to the family a love of learning. Ruth Brown (née Carver) was strong willed and ambitious for her three sons. Roger had two younger brothers, Julian (b. 1936), who became a physical chemist, and Michael (1938–97), who was a rebellious artist whose work is found in many Australian galleries.

Roger was educated at Chatswood Primary School, Artarmon Opportunity School and North Sydney Church of England Grammar School (Shore). At the age of 14, he came across an old chemistry text and was entranced by the organic structural formulas therein, and began, as a hobby, the study of chemistry and the development of his own laboratory. He was well read and good at English but failed to get the Honours he hoped for in his final examinations, but was recompensed by coming second in Chemistry in New South Wales.

He entered the University of Sydney in 1949 to study science, and in his third year did double chemistry. Laboratories were open for long periods in the higher years and enthusiasts such as Brown got a strong grounding in practical chemistry. In his third and honours years, he lived in College and made lifelong friendships. For his honours year in 1953, he studied natural products chemistry with G.K. Hughes and E. Ritchie, gaining first class honours and the University Medal. For his MSc degree, he pursued a problem, flindersine, an alkaloid, and through a reinterpretation of the known data and a few experiments defined the structure. Brown achieved outstanding results and in 1955 was awarded an 1851 Exhibition Scholarship and took passage to England in August that year.

At Cambridge, his doctoral studies with Sir Alexander Todd, under the direct supervision of Malcolm Clark, involved initiating a synthesis of corrin, the central ring system of vitamin B12. New pyrroline *N*-oxide chemistry was developed and these molecules were coupled to two-ring systems that could possibly be carried forward in a synthesis. In 1958, Roger Brown met and married Mary Glasscock and the newlyweds travelled to Boston in the US.

Roger Brown's contributions to chemistry can be considered in three categories: structure determination, synthesis and pyrolysis. His training in structure determination and his doctoral work came together and were applied in his postdoctoral studies with George Buchi at MIT in 1959. The alkaloid aconitine, known then for 100 years, was oxidised to the *N*-oxide and thermally decomposed to a derivative, which finally led to the correct structure.

When in 1960 Roger was appointed to a position at the School of General Studies in Canberra, he began his studies in

synthesis with work on thiolutin and mycelianamide and in his later career at Monash attempted syntheses of mycorrhizin and tridentoquinone.



Roger was introduced to preparative pyrolysis when working with Buchi and was made aware of the large number of reactions then known. His initial contribution was to extend the technique to flash vacuum pyrolysis where the chemical is volatilised through a hot silica tube and the products collected on a cold surface. At this time, mass spectrometry was exhibiting the extraordinary fragmentations of the radical cations formed from complex organic compounds and he examined the possibilities of like processes in these different techniques. His first flash vacuum pyrolysis experiments showed that ninhydrin and phthalic anhydride fragmented to benzyne.

In 1968, Roger was appointed to a readership at Monash University and in 1992 to a personal chair. His initial pyrolysis work was on heterocyclic compounds, but in 1972 research on cumulenones began. Derivatives of Meldrum's acid on flash vacuum pyrolysis gave cumulenones, which decarbonylated to carbenes and acetylenes. These findings together with the formation of benzyne allowed the study of numerous cyclisations and rearrangements.

In retirement, he kept active and from 1993 contributed considerably to the running of the Victorian Branch of the RACI in the difficult times of its reorganisation. He also studied at and taught at the U3A and extended his artistic abilities.

Periods of depression marred Roger's life and were difficult times for family, friends and colleagues. Each time, he recovered his clarity of thought and could assess his own abilities; in his *Chemobiography* (RACI, 2001), he describes his limitations and love-hate relationship towards synthesis. Mary Brown died in the year he retired (1996), his youngest brother followed and, tragically, his son Andrew (1960–2002). He is survived by his daughter Alison, grandson Sam and the partner of his last happy years Neddy (Mary) Campbell.

Frank Eastwood FRACI CChem

Obituary guidelines

Obituaries for publication in *Chemistry in Australia* should have an approximate length of 450 or 800 words or less and can be submitted with an image to the Editor at wools@westnet.com.au.

Shaping our science future



Young scientists share ideas about their career issues at the Australian Early/Mid Career Researcher Forum's national Science Pathways meeting.

Australia's future scientific leaders engaged with industry and innovation at the Australian Early/Mid Career Researcher Forum's 2013 Science Pathways meeting in Melbourne.

Young scientists around the globe kick-start their scientific research careers by enrolling in a PhD. Full of enthusiasm, they are often unaware of the hurdles they have yet to face in what has become a 'marathon pursuit' of an academic research career. Some will clear the bars with ease, while many (for a variety of reasons) will leave the track before finishing the race. Most of those walking away will be women.

The Royal Society in the UK found that most PhD graduates will establish their careers outside of scientific research. In fact, fewer than 5% of these best and brightest remain in academic research and only 0.45% became full professors. Scientific careers in Australia are not so carefully tracked; but with funding success rates at an all-time low and thousands of new science-related PhD graduates every year, there are accumulating indicators of a similar situation. While there is a national call for more PhD graduates (see 'Meeting Australia's research workforce needs', DIISR), there are also concerns about over-supply of this cohort at a global level and the need for balance was emphasised in 'The changing PhD – demand and supply' (see December 2013/January 2014 issue, p. 16).

Getting science on the national agenda

Recognising the challenges emerging researchers face, the Australian Academy of Science established the Australian Early/Mid Career Researcher Forum. Since 2011, the Forum has engaged with early and mid-career researchers (EMCRs) and advised the Academy on key issues facing younger researchers, to inform their policy recommendations to government.

The Forum's inaugural national meeting Science Pathways: Getting Science on the National Agenda in 2012 saw over 100 EMCRs in the scientific disciplines identify the challenges they face and brainstorm possible solutions. Highlights included the candid Q&A session with Australia's Chief Scientist, Professor

Ian Chubb, and the Ben Chuwen Keynote Address by Nobel Laureate Professor Brian Schmidt. Schmidt took delegates from the beginnings of Australian science, through the challenges of the present, into an exciting, collaborative vision for the future. Professional development sessions introduced 'best practices' in PhD training and gender equity, and a range of scientific careers. An education session on science policy from the perspectives of scientists and government was thought-provoking and informative.

The issues

Young scientists embraced the opportunity to have their voices heard. In a series of focus groups, EMCRs exchanged ideas with their peers, Fellows of the Academy, policy-makers and professionals from some of Australia's top public and private organisations. Critical issues included poorly defined career structures, the high degree of competition for funding, a lack of job security, 'uneven playing fields', the metrics defining a 'successful scientist', inconsistent professional skills development, mentoring, limited mobility between different sectors, and gender equity. The 'unforgiving' nature of science (where a career interruption or change of research field can mean 'career suicide') was of particular concern to young researchers.

Finding solutions

Science cannot be turned on and off like a tap – scientists and research both need to be supported long term. EMCRs proposed a number of simple yet creative solutions at the level of individuals, institutions and government.

Researchers called for longer grants earlier in their research career to facilitate the transition from postdoctoral fellow to established investigator. Reflecting the situation in the US and

elsewhere, postdoctoral fellows are considerably older than 10–20 years ago. Typically, postdocs juggle the demands of a young family, a first home and establishing nascent research careers. Most have 12-month contracts that prohibit long-term planning and offer little job security. Longer grants and contracts would extend the capacity of research projects, increase job stability and enhance productivity. Establishing staff scientist positions for senior postdocs was also loudly applauded.

Gender equity and family-friendly policies were also high on the agenda. Groundbreaking initiatives (see www.wehi.edu.au/about_us/gender_equity) at the Walter and Eliza Hall Institute impressed many. These include competitive funds to hire a research assistant while on maternity leave, and childcare assistance. The Suzanne Cory Fellowship also provides five years of funding to promote highly qualified women to laboratory head. Delegates agreed a broad cultural shift towards greater acceptance of career disruptions, changes in research field and mobility between sectors was critical.

Diversified PhD training to ensure graduates possess transferable skills for today's corporatised world, such as the Balanced Scientist PhD Program (www.invasiveanimals.com/research/goals/goal-11/11e1), was considered essential. There was also strong consensus for internships and secondments for researchers in education, industry and government, to increase their exposure to these sectors and enhance their professional mobility. Notably, Melbourne's Bio21 Cluster launched a successful Political Internship that placed a young researcher with a Federal Member of Parliament (MP) part-time for three months. These types of internships could be offered nationally at the state and federal levels. The US has had such fellowships in place for the past 40 years.

The report card

Based on the avalanche of constructive ideas that emerged from this meeting, the Forum prioritised clear goals – and is achieving them! EMCRs have connected, with state EMCR

networks now in Victoria, Queensland and New South Wales. The release of the Forum's position statement 'Gender equity: current issues, best practices and new ideas'

(science.org.au/policy/documents/GenderEquityEMCRForum.pdf) on International Women's Day in 2013, sparked not only interest but action, with new gender equity committees established in several research organisations around Australia.

The second national meeting, Science Pathways: Engaging with Industry and Innovation was held in Melbourne this year and was extremely popular, with registration closing early due to space limitations. Over 150 delegates valued the Q&A with the Chief Scientist and had the opportunity to network with industry professionals, learn about industry careers and gain entrepreneurial 'savvy'. Importantly, the Forum met with key ministerial leaders to share evidence-based policy recommendations and also engaged with federal MPs who champion science through two parliamentary friendship groups: Science and Women in Science, Maths and Engineering.

The Forum has become a clear, impassioned and respected national voice for Australia's future scientific leaders. Science Pathways demonstrates the energy and passion that young scientists feel for how science is done in Australia and how they can contribute. With support from all political parties and across all sectors, we can position Australia at the leading edge of the wave to become a scientifically literate nation, with a responsive, innovative culture that is to be revered world-wide. Our vision is for young scientists to receive the best training possible to ready them for the track, equipped with the knowledge, skills and support they need to navigate the hurdles and take the bends with ease – so that they can enter any professional career in science with the wind at their heels.

Marguerite V. Evans-Galea is the Founding Chair of the Early/Mid Career Researcher Forum with the Australian Academy of Science, Canberra. She is also an investigator in the Bruce Lefroy Centre for Genetic Health Research at the Murdoch Childrens Research Institute, Melbourne. The author acknowledges and thanks all members of the Australian Early/Mid Career Researcher Forum and Science Pathways delegates for their contributions.

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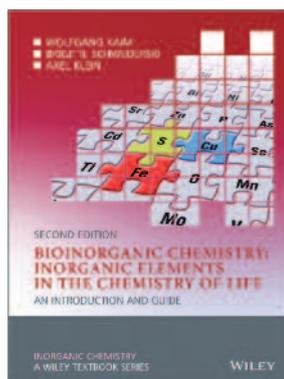
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Bioinorganic chemistry: inorganic elements in the chemistry of life – an introduction and guide

Kaim W., Schwederski B., Klein A., Wiley,
2nd edition, 2013, soft cover, 426 pp.,
ISBN 9780470975237, \$87.95

Bioinorganic chemistry considers the role of the metal ions and the non-

metals in biological systems – putting the inorganic into biochemistry. One can regard it as a branch of coordination chemistry in that around 40% of known enzymes contain one or more metal ions, and the principles of coordination chemistry apply even in complex macromolecules. Given this, the field becomes enormous as it encompasses all living species. Although the importance of metal ions in living systems has been known for a long time, only in the past few decades has there been intense research into the specific modes of action. Thus, many aspects remain poorly understood, if at all.

Although there are several excellent advanced books, the problem that I encountered some time ago when I was putting together a one-semester course on bioinorganic chemistry was trying to find a suitable text, i.e. one pitched at a level appropriate for undergraduate students. As this was an inorganic chemistry course, the prerequisites were primarily an understanding of the principles of coordination chemistry coupled with some basic organic chemistry.

My approach was to discuss the questions: first, which elements are biologically essential (toxic) and then, what are their functions in biological systems? I took a holistic approach, looking at both the macro nutrients with structural (Ca) and regulatory functions (Na, K, Mg, Ca) and the microelements located within proteins, metalloenzymes etc.

Kaim and co-authors' book, which is a translation of the German edition, treats all of these topics. As it was written for

a two-semester course, it has both breadth and depth of coverage. The arrangement of topics is: general principles, transition metals, s-block metals, p-block elements, toxic metals, applications. The book starts with an overview of which elements are biologically active/toxic, applications and their occurrence and availability.

Four chapters are devoted to the manifold roles of iron – oxygen transport, catalysis, iron–sulfur proteins, transport and storage. There are chapters on the biological roles of cobalt, copper, nickel, zinc, the early transition metals and photosynthesis (Mn and Mg). This is followed by a treatment of the role of the electrolyte ions (Na, K, Mg, Ca), biomineralisation and the functions of the non-metallic elements. To complete the picture, the toxic metals are discussed.

The book finishes with medical applications – radionucleotides and medical imaging, and chemotherapy.

The book is amply illustrated with many full-colour figures of the active sites of enzymes and the structures of proteins, as well as structures of molecules, figures, schemes and mechanisms. Boxes are inserted throughout the text, explaining a theoretical point or a spectroscopic technique with which the reader may not be familiar. Each chapter finishes with a list of literature references.

A small point: as proteins feature heavily in biochemistry, and not being a biochemist, I would have liked to see a discussion of polypeptides and protein structures and especially the different ways they are represented. Figures with protein structures and cartoons appear regularly throughout the book and this would aid their interpretation, particularly by a readership with an inorganic background. Section 2.3.1 discusses the coordination by proteins; thus the only amino acids mentioned are those with side chains that can bind a metal ion. Perhaps the other amino acids merit a section for the sake of completeness.

In my opinion, this book has all that you would want for a course textbook and I wish that I'd had it earlier.

Franz Wimmer MRACI CChem

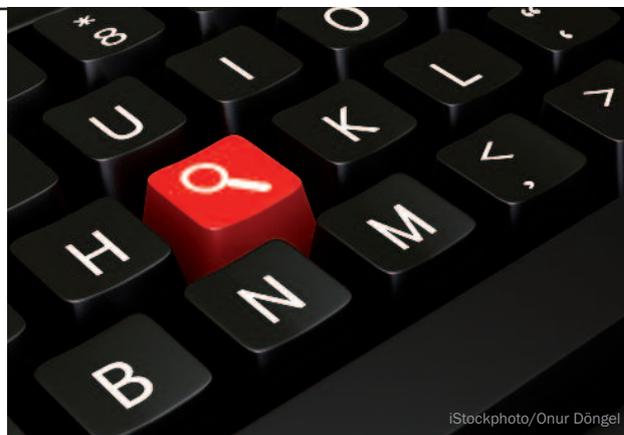
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Global trends and patterns in carbon mitigation

Jones C., Bookboon, 2013, ebook, 146 pp., ISBN 9788740304657, free

Dr Jones is a regular contributor to *Chemistry in Australia* and to other journals. His motivation in writing this book was to provide a global up-to-date coverage of the topical subject of carbon emissions and

mitigation strategies. He largely succeeds. An extensive list of countries and regions are profiled in 14 chapters including the UK, other EU countries, China, North America, the Far East, OPEC countries, the Indian subcontinent, Australia, New Zealand and the South Pacific, South America, Former Soviet Union states and selected African countries. The scope is very comprehensive as a catalogue of activities, but no major intercountry comparisons of energy profiles are made.

The source and trend of the carbon footprint since 1990 in various countries, using a range of fossil and renewable fuels, is presented. The focus is mainly, but not exclusively, on electricity generation with the impact on CO₂ emissions of replacing fossil fuels (coal, oil and gas) by renewable energy sources such as wind, solar, biomass and nuclear. There are many quantitative calculations of emissions from the fuel sources relevant to each country. The calculations and data are useful in gaining an understanding of the amount of CO₂ emitted annually by countries and their per capita performance. There are also good illustrations for selective countries of the reductions in transport emissions to be achieved by the replacement of natural crude oil-derived gasoline and diesel fuels by plant and animal waste-derived bioethanol and biodiesel.

The book is well researched, relying predominantly on web-based sources, and providing a very useful profile of the energy production and use situation in many countries up to 2012. The emission reductions that can be achieved by changing the fuel mix for electricity generation, transport and household use in a given country are well illustrated, but CO₂ reduction is only one element in the complex energy security profile for a particular country.

Some more fundamental matters that must be addressed by each country to achieve a balanced energy policy are not considered in this work. Central issues are the quantitative resource constraints associated with non-fossil fuel energy sources impacting on energy security issues, the cost of energy production from renewables, the impost on the economy of incentives and subsidies, energy storage and transmission

issues. Grid management is a complex and challenging problem for dealing with intermittent generation in a distributed grid system. While dealing with these issues in detail is beyond the scope of the present book, the book would have been improved if the focus on emissions reduction achievements by countries had been placed in the broader policy context. The drawing together of the key findings into a concluding chapter would have enhanced this work.

This is a free ebook that can be downloaded at bookboon.com. It represents a growing trend by authors to have their books published free of charge in return for advertisement liberally interspersed throughout the text. The publisher states that there is an advertising limit of 15% of the space per book. In this book of 145 pages, there are advertisements on some 50 pages. The publisher targets advertisers who are potential employers of the students who read the books. The business model does seem to be working for the publishers, with over 1000 ebooks published globally since 2008. Bookboon is the largest online publisher of ebooks in the world. The authors benefit because of the potential wide circulation of the work at no personal publication cost. There does not seem to be a general policy to referee works prior to publication.

Dr Jones has produced a valuable compendium reference work that will be of considerable benefit to scientists interested in quantitative aspects of CO₂ emissions from various energy sources in many countries, linked to the climate change policy debate. The fact that the book can be obtained online at no cost should enhance its use.

Frank Larkins FRACI CChem

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Butanol and biosynthesis

We have reached a major crossroads in developing new technologies that meet our energy and chemical feedstock needs. Many researchers are wondering in which direction we should take our future research and development efforts.

One path being taken is bio-butanol synthesis using *Clostridium* or *Escherichia coli* bacteria. This is done by modifying and/or developing the classic anaerobic conversion of lactic acid and calcium lactate developed by Louis Pasteur in 1862 or the ABE (acetone, butanol, ethanol) fermentation process pioneered by Chaim Weizmann during World War I, to produce cordite (a family of smokeless propellants). Start-ups and joint ventures include Gevo, Optinol and Cobalt Technologies from North America, GranBio from Brazil, UK's Green Biologics Limited, Swiss-Butalco and Cathay Industrial Biotech in China.

Despite numerous attempts at the biosynthesis of butanol, the concentrations of butanol in the fermentation broth are not satisfactory. A number of strategies have been pursued

to reduce the apparent toxicity of butanol to cells, including overexpression of heat shock proteins, modification of the cell membrane, and alteration of the cellular stress response. In principle, butanol could be produced via biomass to liquid (BtL) processes or from petroleum feedstocks, but fermentation seems to be the method of choice adapted by industry, for reasons of sustainability. Most of the aforementioned start-ups have targeted isobutanol over n-butanol. The primary difference between the two isomers is that n-butanol is used in a larger set of chemical markets, for paints, and lacquers, for example, where a linear molecular chain is needed. Applications for isobutanol involve more niche markets, such as the production of synthetic rubber.

The blend stock opportunity for n-butanol exceeds \$80 billion per year. Despite this, the synthesis of n-butanol from the more accessible bio-ethanol has remained elusive to commercialisation. Despite being ranked eighth in the world for ethanol production, none of these

processes has become commercial in Australia. Major ethanol producers within Australia include Dalby Bio-Refinery and Sarina Distillery in Queensland and Manildra Ethanol Plant in New South Wales, with a combined total installed capacity of 440 ML. Ethanol works pretty well as a 'drop-in' fuel, when blended with traditional petroleum-based fuels. Most oil companies or car manufacturers recommend 5% ethanol as a fuel additive, usually referred to as E5. More recent lobbying has resulted in E10 or E15, or an extreme of E85 has been endorsed through the new flex-fuel VE Series II Holden Commodore. But what if you used neat ethanol? Nikolaus August Otto (inventor of the combustion engine) and Henry Ford demonstrated in the late 1800s that their engines could be run on pure ethanol. But the same can't be said of today's cars. Even recent makes (pre-2007) can handle only up to E15 with modifications.

Before biofuels became a buzzword, David Ramey, founder of butylfuel™ LLC, endorsed big-brother butanol as a fuel

over ethanol by driving an unmodified 13-year-old Buick Park Avenue in 2005 across the United States, using n-butanol instead of petrol. The consumption was approximately 9% higher; however, emissions of CO, hydrocarbons and NO_x were much lower. Researchers from the University of Bristol in collaboration with Butamax™ Advanced Biofuels (a joint venture between BP and DuPont) reported on their approach towards the large-scale conversion of bio-ethanol using a ruthenium-based catalyst system, obtaining 94% selectivity towards n-butanol at 22% ethanol conversion (doi: 10.1002/anie.201303723). This was a significant improvement (67% selectivity towards n-butanol at 12% conversion) over the preceding studies by Ishii and co-workers from Kansai University with a homogeneous iridium catalyst. This technology has not yet been deployed; however, this giant leap by researchers at Bristol gives plenty of bang for the buck until further developments occur.

The design of any catalyst systems that upgrade existing biofuels (such as ethanol to n-butanol) must be relatively inexpensive to keep investments and thus end-product prices low. Butanol is rather expensive at present – about US\$1250–1350 per tonne versus about US\$650–750

per tonne for ethanol (as of September 2013). A simple back-of-the-envelope calculation would suggest the following: with 100% conversion of ethanol to n-butanol, the mass yield would be 80%. So potentially US\$700 of ethanol feedstock could be converted to US\$1050 worth of n-butanol. This gives a limited scope for capital investments on improving the conversion while still reducing the product-selling price. A high single-pass conversion is desirable as it reduces the size of the plant required and the consumption of utilities.

The research laboratory that develops the chemistry to selectively valorise biomass or biomass components to high-value commodity chemicals will revolutionise both the petrochemical industry and the energy sector. Australia is among the few nations with the culture and well-integrated research laboratories, such as at CSIRO and the University of Sydney, to help bring about the next paradigm in catalysis. While endorsements and lobbying for ethanol continues, it is imperative for researchers at national labs and the nation's top universities to collaborate with existing companies who have the infrastructure to develop fuels for the future. Although production of next-generation biofuels is

an important endpoint, it will be critical to first tap into ethanol from the Australian viewpoint to strategically make these new fuels economically viable. Taking advantage of the existing Australian sugarcane industry seems the most realistic short-term goal. This will strengthen both the nascent biofuels industry and the agriculture industry.

Reflecting on one of the largest-scale commodity processes, the Haber–Bosch process, why did we choose to follow an entirely synthetic route and not use millions of years of biological evolution to produce ammonia? Why should our research and development efforts remain focused on human-engineered chemical processes and not biological ones? Admittedly, nature has not developed the ability to handle high temperatures; molecular complexity and high temperatures do not work together (think poaching an egg). Instead of using high-energy conditions, nature uses high-energy species. These are important questions to ponder as we pursue sustainable systems.

Dr Kapil Shyam Lokare (lokarek@gmail.com). He is indebted to Geoff Covey (Covey Consulting Pty Ltd) for many helpful discussions.



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China isn't creative enough to win a science Nobel

'China is at the forefront of medicine and hi-tech and computing.' So said UK Chancellor George Osborne, who recently visited the country. Global tests for 15-year-olds show the youth of Shanghai are comfortably outperforming the rest of the world in science, as well as in reading and maths. Breathless media reports routinely refer to China as a 'new scientific superpower'.

Headlines and sound bites would have you believe that China has already succeeded in transforming itself into an innovation-powered economy. Yet serious questions persist over China's true capacity to create. And no one is more aware of its limitations than Chinese people themselves.

Triumph in the Nobel science category has become entwined in China's resurgent nationalism, a national priority on par with the hosting of a successful Olympics or landing a spacecraft on the moon. That Mo Yan, a mainland Chinese writer, won the Nobel Prize in literature in 2012 in many ways magnified the government's frustration. After all, Chinese writers develop their craft in a constrained, illiberal environment, while leading scientists have access to limitless financial resources.

Acute insecurity in China reached fever pitch during last year's Nobel Prize award ceremonies. The Communist Party has long craved a homegrown Nobel science prize, as evidence of a technological power to match its economic might and a vindication of the astonishing £243 billion [AU\$440 billion] China has poured into the development of science and technology in the last seven years. Another year passes, another unsuccessful bid. The reality is that no Nobel science winner has been a product of China's education system.

There are many reasons for China's failure to win the prestigious award. An education system enslaved to rote learning and test scores is one. Zheng Yefu, a sociologist at Beijing's Peking University, insists that no matter what university you study at – Oxford, Cambridge, Harvard or Yale – you have no chance of winning a Nobel Prize for science if you have spent your first 12 years in a Chinese school. An exaggeration perhaps but the premise of his argument is sound: individuality, curiosity, imagination and creativity are simply expunged by the Chinese education system.

Down the wrong pipe

There is a paucity of excellent Chinese scientists. Confucian doctrine teaches that 'a good scholar will make an official' and some of the best scientists are more than willing to leave their labs for respected administrative roles that are probably tied to enormous resources.

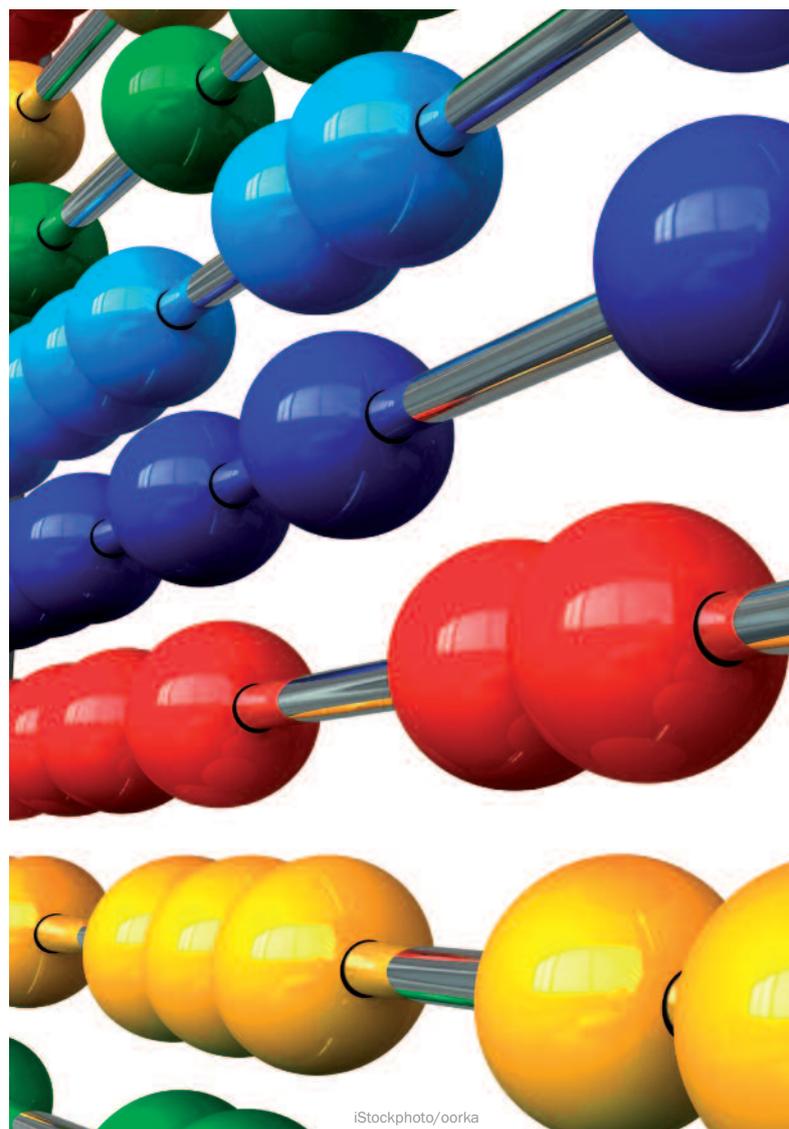
Entrenched political and social barriers hinder progress. The Chinese academic system binds students to their mentors. Mentors are authority figures as formidable as strict parents, and to challenge them is unacceptable. This blind loyalty discourages criticism of senior academics and the science they advocate.

Chinese scientists complain the allocation of research funding is not meritocratic. There is little encouragement for scepticism towards existing theories, especially when those theories are propounded by senior academics who hold the departmental purse strings.

Equally, there are few incentives for researchers to risk exploring the unknown, as the system does not tolerate 'failure' in research terms. Consequently, Chinese scientists are more likely to conduct research that yields quick and achievable outcomes, rather than fostering grander aspirations for the advancement of knowledge.

All these factors converge to create one fundamental obstacle to China's pursuit of a Nobel science prize: it is simply unable to embrace the values that underpin it.

In rewarding those who confer the 'greatest benefit on mankind', the Nobel Prize in science embodies an appreciation



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and celebration of not merely breakthroughs, discoveries and creativity but a universal set of values that are shared and practised by scientists regardless of nationality or culture. It is recognition of the latter that can achieve the former.

Revolutions happen for a reason

China's embrace of science only dates back to the May Fourth Demonstrations in 1919 when scholars, disillusioned with the direction of the new Chinese republic following the fall of the Qing Dynasty, called for a move away from traditional Chinese culture to Western ideals – or, as they termed it, 'a rejection of Mr Confucius and the acceptance of Mr Science and Mr Democracy'.

But these concepts of science and democracy differed markedly from those advocated in the West and were used primarily as vehicles to attack Confucianism. The science championed during the May Fourth movement was celebrated

... Chinese scientists are more likely to conduct research that yields quick and achievable outcomes, rather than fostering grander aspirations for the advancement of knowledge.

not for its Enlightenment values but for its pragmatism, its usefulness.

Francis Bacon's maxim 'knowledge is power' ran right through Mao Zedong's view of science following the founding of the People's Republic in 1949. Science and technology were considered as integral components of nation-building: leading academics contributed their knowledge for the sole purpose of modernising industry, agriculture and national defence.

The notion of saving the nation through science during the nationalist regime in the 1920s and 1930s has translated into current communist government policies of 'revitalising the nation with science, technology and education' and 'strengthening the nation through talent'. A report by Nesta in October argued that China should be regarded as 'an absorptive state', adding practical value to existing foreign technologies rather than creating novel technologies of its own.

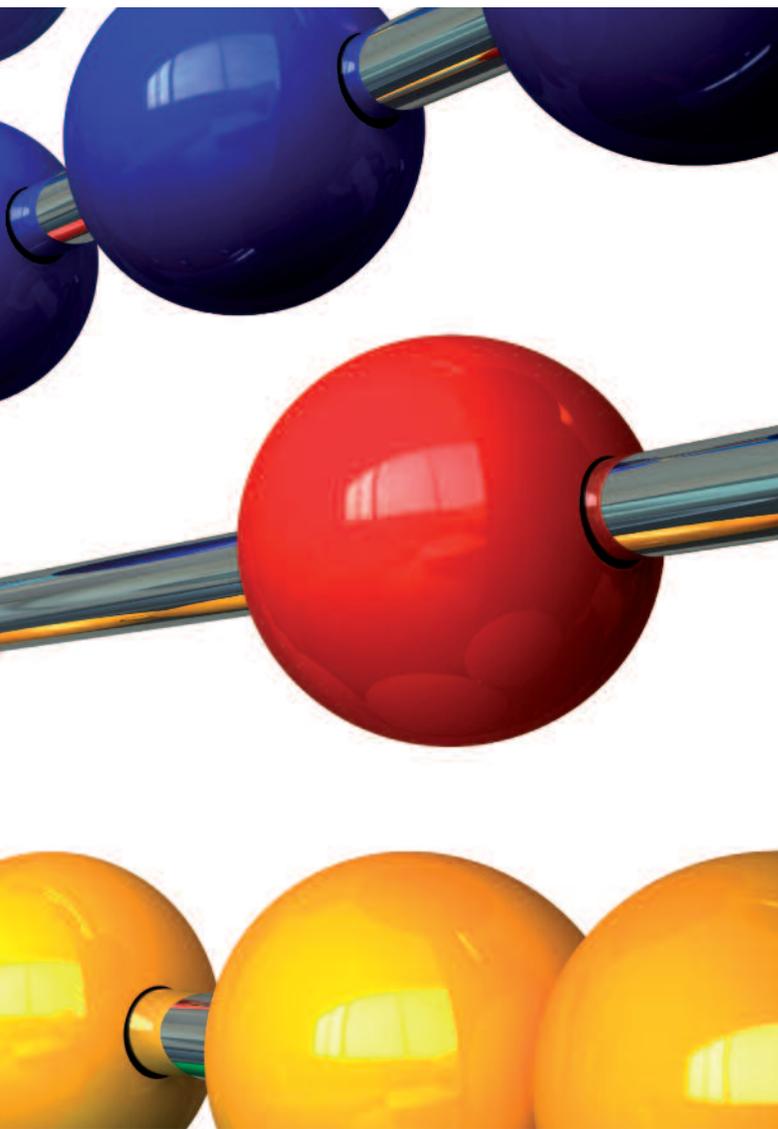
This materialistic emphasis reflects the use of science as a means to a political end to make China powerful and prosperous. However, a series of high-profile fraud scandals involving leading scientists at China's top academic institutions has raised concerns over this highly utilitarian view of science. They have led to calls for China to truly embrace the universal values of science as a means to take the country forward.

These core values of truth-seeking, integrity, intellectual curiosity, the challenging of authority and, above all, freedom of inquiry are shared by scientists all over the world. In this sense there is no such thing as 'Chinese' science or 'British science', or science 'with Chinese characteristics'.

On his latest visit to Beijing, US vice president Joe Biden told a group of young Chinese that 'innovation can only occur when you breathe free' and that 'children in America are rewarded – not punished – for challenging the status quo'.

The Chinese leadership would do well to apply these principles to the nurturing of its next generation of scientists. Only when it abandons cold-blooded pragmatism for a value-driven approach to science can it hope to win a coveted Nobel prize and ascend to real superpower status.

Cong Cao, Associate Professor at the University of Nottingham. First published at The Conversation (www.theconversation.com).



Illegal tree felling and carbon sequestration



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Trees have a critical role in carbon sequestration (see December 2011 issue, p. 35). The ratio of trees to persons on the planet has sharply decreased over the last century, from about 1000:1 to 60:1, figures that give much cause to ponder. The illegal felling of trees for timber goes well beyond theft of goods and the market value of the timber: the destruction of trees causes a reduction in the carbon sequestration capacity of the Earth, working against the attainment of targets for carbon dioxide reduction.

The world needs timber for building, furniture manufacture and numerous other purposes. Since internationally coordinated responses to high carbon dioxide levels began, timber producers have had the additional responsibility of replacing felled trees, although in some ecosystems the replanting can be left to nature. After growth, such replacements – by human agency or naturally – will restore the carbon sequestration capacity of the trees felled. If such practices prevailed internationally, then the total sequestration capacity due to trees would remain steady, if not increase. This is not just a local or regional issue – carbon dioxide is no respecter of international boundaries and the entire Earth's atmosphere needs protecting from high carbon dioxide levels. Trees have a major role in this protection; hence, the importance of introducing and maintaining practices for the replacement of legally felled trees. For example, in Thailand, there has recently been a planting program to reverse the depletion of teak trees. Misappropriation of timber by illegal felling of trees is obviously not accompanied by such measures and, in some parts of the world, is on a large scale.

Of the order of four billion trees are felled annually to make

wood products, and a UN report states that 15–30% of these are felled illegally. Using a percentage value around the middle of this range and allowing for a significant plus-or-minus on the number of trees felled, the annual number of illegally felled trees is about one billion. If we assume that a tree takes up 25 kg of carbon dioxide per year, then this represents a loss of 25 million tonnes from the carbon sequestration capability of the planet. An equivalent amount of carbon dioxide therefore enters the atmosphere as an indirect result of the illegal felling.

By way of comparison, a modern car releases about 125 grams of carbon dioxide per kilometre travelled so the figure above is equivalent to the release from:

$$(25 \times 10^{12}/125) \approx 2 \times 10^{11} \text{ car kilometres}$$

Assigning an average value of 20 000 kilometres to the annual distance travelled per car, this is equivalent to the carbon footprint of:

$$(2 \times 10^{11}/20\,000) \approx 10 \text{ million cars}$$

and this is 75% of the number of cars (as distinguished from trucks and buses) in Australia (www.abs.gov.au/ausstats/abs@.nsf/cat/9309.0).

Jeopardy to world campaigns to reduce carbon dioxide emissions by illegal felling of trees is evident from this comparison. The use of carbon-neutral fuels and wind turbines, for example, might need to be accompanied by closer surveillance of timber trading if they are to have full effect.



Clifford Jones FRACI CChem (j.c.jones@abdn.ac.uk), who worked in Australia over the period 1978–95, is now a reader in the School of Engineering at the University of Aberdeen.

The mHealth revolution

The social contract between patients and doctors is changing at an unprecedented rate. We don't see doctors and the rarefied world of medicine in the same light as we once did. We are witnessing and participating in a radical redistribution of responsibility and decision-making between doctors and patients. One of the reasons for this shift is the emergence of digital medical technologies and the consumer's ability to access technology without a medical gatekeeper in charge.

In some areas of medicine, consumers are clearly demonstrating their willingness to co-manage their wellness and, increasingly, critical aspects of chronic care. Most interestingly, patients are prepared to fund it from their own pocket. We are buying medical technologies from app stores at an astonishing rate largely on the basis of recommendations from family and friends.

A PricewaterhouseCoopers report from June 2012 sums up the situation, explaining that mobile health (mHealth) offers patients greater control over their medical care and patients are increasingly taking up the opportunity to manage their own wellness.

A closer look at some of the report's survey results is revealing. About half of the patients surveyed believe mHealth initiatives will improve the convenience, cost and quality of their health care, even though it is funded by them and not reimbursed.

Australia is very well placed to take advantage of the mHealth development opportunity and we are already well and truly in the game. Melbourne is the biotech capital of Australia as well as having one of the largest IT and games technology hubs in the southern hemisphere. Victoria is also the headquarters for advanced manufacturing, with infrastructure and technical support from facilities such as the Melbourne Centre for Nanofabrication and the National Manufacturing Innovation Precinct.

Late last year, the Small Technology Cluster, south-east of Melbourne's CBD hosted a statewide MedTech's Got Talent competition for small, pre-seed start-ups. The winners took home cash, mentoring and connections to some of the biggest names in the Australian medtech sector. Supported by the Victorian government, this dragon-den style of competitive technology development was a smashing success.

The medtech ideas presented by the 12 finalists were inspiring, demonstrating a wealth of talent in Victoria. A number were mHealth solutions utilising robotics, smart surfaces, polymer technologies and imaging technologies, to name a few. Most of the teams incorporated IT expertise and engineering ability with medical know-how. Many of them were practising physicians and almost all of the collaborators were locally sourced. Some of these mHealth technologies will rely on health practitioners as prescribers, but just as many will not.

The commercialisation opportunity with mHealth technologies is equally targeted towards doctors as it is towards patients.

A 2011 survey of US doctors by Manhattan Research discovered that 30% of doctors have iPads and used them in clinical practice and a further 28% expected to buy one in the next six months. Uptake in emerging markets with healthcare practitioners is even stronger. Doctors and health service providers are buying into mHealth technologies because it helps to meet some of their unmet needs, such as monitoring patient compliance, assessing records, improving diagnostics and communicating and collaborating with colleagues on patient-care strategies.

The investment community is moving fast to take advantage of this evolving technology market with a vast number of venture capitalists turning from high-risk, expensive biotech projects to mHealth.

Venture capital investment in mHealth technology is on the rise around the world. A recent US report by RockHealth calculated that the only rising investment market for venture capital was in medtech, up by 12% on the previous year, with biotech continuing to fall.

In his blog, Shyam Jha, Cayenne Consulting (<http://bit.ly/1diYr52>), writes 'During the first 8 months of 2013, the top three recipients of VC funds in mobile health segment were Proteus Digital – a smart-pill maker, Fitbit and Withings, both makers of popular fitness bands.'

'Whereas Proteus's product – a tiny silicon chip embedded in a pill that is activated by stomach acids upon swallowing and communicates with a smartphone – is a regulated device, Fitbit and Withings are consumer devices that do not require FDA approval.'

The next big conversation in mHealth will be regulation. This is a moving feast but right now the window of opportunity is wide open.



Michelle Gallaher (mgallaher@biomelbourne.org) is CEO of BioMelbourne Network, having had 20 years in research and listed biotech companies. She is one of the most prolific social media commentators on science and biotech in the Asia-Pacific.

Ethics – an important part of chemistry education

The Nobel Peace Prize 2013 was awarded to the Organisation for the Prohibition of Chemical Weapons 'for its extensive efforts to eliminate chemical weapons'; disarmament is featured in Alfred Nobel's will. Other Nobel Peace Prizes directly associated with disarmament include the International Atomic Energy Agency and Mohamed El Baradei (2005), the International Campaign to Ban Landmines and Jody Williams (1997), Joseph Rotblat and the Pugwash Conferences on Science and World Affairs (1995), the International Physicians for the Prevention of Nuclear War (1985), and Linus Pauling (1962). A common theme is that these organisations and individuals worked towards the responsible and peaceful use of science and technology.

A distinctive feature of any profession is that members profess a code of practice, usually including a formal code of ethics. For example, the RACI, the American Chemical Society and the Royal Society of Chemistry all have a code of ethics or equivalent. These codes deal with more than just knowledge or skills, but state, for example, that 'the responsibility for the welfare, health and safety of the community shall at all times take precedence' (RACI By-Law 13.1.1).

An important part of chemistry education, and science education in general, regardless of future career paths, is to develop scientifically literate citizens by fostering an awareness of the ethical implications of our discipline. At school level, this is embedded in the National Curriculum, but not so at tertiary level. Formal mapping exercises and informal discussions indicate that most Australian universities have little or no systematic ethics education in chemistry degrees, even though personal and social responsibility is an integral part of the Science Academic Standards.

*Chemistry graduates will have an awareness of the ethical requirements that are appropriate for the discipline. These may include the importance of accurate data recording and storage, proper referencing (and the need to avoid plagiarism), intellectual integrity, having an awareness of the impact on the environment of their activities, and an appreciation that chemistry can generate new knowledge with benefits and risks to society. It is important that chemistry graduates have some understanding of their social and cultural responsibilities as they investigate the natural world. (Chemistry TLO 5.3, October 2013)**

Traditionally, professional practices, responsibilities and ethics have been learned in a master-apprentice model in the laboratory, while curricula focused on content knowledge. However, with the explosion in chemistry and scientific advances in knowledge, no school or university curriculum can hope to include all topics in all sub-disciplines of chemistry. Furthermore, as Australia aspires to have 80% of its young

people complete year 12, an appreciation and understanding of science is more important than content knowledge and preparation for university. The same is also true of university, where only one in ten chemistry PhD graduates continue to a career in research. A 21st-century chemistry education focuses on the broad understanding of fundamental or threshold concepts, with deep understanding and knowledge in one or two areas, coupled with an appreciation and understanding of the nature of science and the practice of chemistry, including ethics.

... most Australian universities have little or no systematic ethics education in chemistry degrees, even though personal and social responsibility is an integral part of the Science Academic Standards.

An awareness of ethics is also relevant for understanding privacy provisions, the difference between leadership and bullying, natural justice and fair dealing with colleagues, conflicts of interest, the concept of a fair test and the avoidance of bias. Social and cultural responsibilities and responsibility for the welfare of the community can include initiatives such as Earth Hour, in which the primary message of switching to renewable energy has unfortunately been swamped by images of switching from electricity to candles and other non-electric lighting. Economic cost means that a resource that is used for one purpose is unavailable to be used for other purposes; green chemistry is about maximising the sustainable use limited resources and minimising detrimental consequences.

It is an easy temptation for chemistry educators to put ethics in the too-hard basket. However, the intrinsic 'testable and contestable nature of the principles of chemistry', and the fact that 'chemistry plays an essential role in society' (Chemistry TLO 1) are obvious vehicles for discussions of objectivity, responsible choices and other ethics-related issues. The preparation of our students to be better citizens must include a deliberate approach to the teaching and learning of scientific ethics.

*The Chemistry Academic Standards Statement was first published in: Jones J., Yates B., Kelder J.-A. *Science: Learning and Teaching Academic Standards Statement*, Australian Learning and Teaching Council, Strawberry Hills, NSW (www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011).



Kieran F. Lim (林百君) FRACI CChem (kieran.lim@deakin.edu.au) is an associate professor in the School of Life and Environmental Sciences at Deakin University.

Sweet wine for an aperitif?

Recently, I attended a dinner that celebrated the life and times of Henri IV, king of France from 1589 to 1610. Henri was born in Pau, in the south-west of France, close to the Pyrenees. This is the Jurançon wine region and tradition has it that the sweet wine of Jurançon was rubbed on Henri's lips at his baptism. And so began a great tradition for the wine region.

The Jurançon region is best known for its white wines made from Petit Manseng and Gros Manseng, varieties that are not known here. The wines are made in a dry (*sec*) or sweet (*moelleux*) style. Petit Manseng is perhaps the better variety for production of the sweet wines. The vines are trained high (see image) and the bunches contain a large number of tiny berries with very thick skin, which allows prolonged ripening and sugar accumulation without berry splitting.

The dry wines are a great accompaniment to food, especially fish and white meats. It is the *moelleux* wines that I wish to discuss here. This may seem a little strange, given that some of my previous columns have focused on the pleasures of dry, high acid wines. However, some years ago when working in the Anjou region of France, I was introduced to the sweet Coteaux du Layon wines as an aperitif and this brought me to the *moelleux* wines of the Jurançon. They are delicious wines and an ideal way to relax on a warm summer's evening with *foie gras* or *pâté*. All the world's problems can be solved very easily while enjoying the wine. The locals will drink the sweet wine with strong meat dishes such as *confit d'oie* (goose), the sweetness blending with the strong meat flavours. And, of course, they make great dessert wines.

The wines are concentrated, perhaps almost honey-like. I use 'viscous' to describe the palate, viscosity in wine sensory terminology referring to the force required by the tongue to move the wine around in the mouth. The sweet wines will age from five to 20 years with 'ripe peaches' and 'cinnamon toast' aromas. And, importantly for me, there is also plenty of acid that carries the flavour right through the palate. The reputation of the sweet *moelleux* wine of the Jurançon was really established by Colette, who described the wine as *séduction du vert gallant*, a term applied to Henri IV, a well-known womaniser. This link with Henri IV and the lifestyle of Colette created a marketer's dream for the region's wines.

There are several ways to prepare a sweet wine. One is simply to stop the ferment before it finishes, by cooling and the addition of sulfur dioxide to kill the yeast. It would be fair to say that great sweet wines are not made this way. Concentration of sugars in the grape berry while the bunches are still on the vine is a better way to produce a sweet wine. This can be achieved when *Botrytis cinerea* (noble rot) infects the vine, causing desiccation and consequent concentration of the sugars or by allowing the grapes to freeze on the vine as in Icewine (*Eiswein*).

In the Jurançon, climatic conditions allow long, slow ripening, with the harvest taking place in November and



A Jurançon vineyard in the foothills of the Pyrenees

Discovervin

What to try

The Jurançon wines are not widely available in Australia. Recently, I tried the 2009 Domaine Bellegarde Jurançon Moelleux Cuvée Thibault and the 2010 Chateau Jolys Cuvée Jean, accessed through Discovervin. Both have a lovely gold colour with a sweetness matched by acid. They are not cloying and show a delicacy that opens in the mouth for a long, lingering finish.

December, at least two months after the regular harvest period. During this long period on the vine, the berries start to shrivel, concentrating the sugar and acidity. This is sometimes referred to as *passerillagé*. The juice is difficult to extract during pressing as it is a highly viscous solution. Fermentation is slow, maybe taking 2–3 months, before barrel ageing of 12–18 months. Patience and care is needed to produce a wine with 12.5–13% alcohol and 30 or more grams per litre of residual sugar. Hygiene is also important as the residual sugar is a great food source for microbial activity. And the residual sugar, being an aldehyde, can bind sulfur dioxide, reducing its availability for antimicrobial activity. Production costs are high and this pushes up the bottle price considerably. But maybe one has to pay a price for pleasure.



Geoffrey R. Scollary FRACI CChem (scollary@unimelb.edu.au) was the foundation professor of oenology at Charles Sturt University and foundation director of the National Wine and Grape Industry Centre. He continues his wine research at the University of Melbourne and Charles Sturt University.

Is it all in the architecture?

2013 was the centenary of the founding of Canberra, the best-known legacy of Walter Burley Griffin's time in Australia. However, in his time here, Griffin did more than design Canberra. It might be a bit late, but a look at the environmental aspects of his legacy is worthwhile.

Griffin's plan for Canberra was influenced by the local topography and geographical features. The Molonglo River, which was dammed to form the lake that is named for him, formed one axis of his design, with the perpendicular axis being based on the line between Mt Ainslie, Kurrajong Hill (now Capital Hill) and features in the Brindabella Ranges. These days, the sustainability of an artificial lake in Canberra's hot, dry climate might be questioned, but Griffin did note that future residents might appreciate its tempering influence during the hot summer. In any case, the design envisaged by Griffin would score more highly on sustainability grounds than some of the other entries. The second prizewinning design resembles the canals of Amsterdam. The 'minority prize' winner, favoured by the dissenting chairman of the selection panel, was remarkably like Budapest on the Danube, complete with chain suspension bridges.

Other aspects of the original design for Canberra, today, seem quite enlightened. The design of the core of Canberra, for which Griffin was largely responsible, is well suited to cycling and walking, and probably contributes to Canberra being the capital city with the highest proportion of commuting by bicycle. The more far-flung suburban centres that are without rail connections for high-capacity public transport, were more a product of the 1950's National Capital Development Commission, so their high rates of car usage can't be laid at Griffin's feet.

After some time battling with Commonwealth politicians and bureaucrats over the implementation of his plan for Canberra, Griffin sought commissions for major buildings and urban developments in other cities. Within the new urban developments he designed and promoted, Griffin's environmental credentials were evident. At Castlecrag, on Sydney's north shore, he saw the potential in former dairy farming land from which the native blue gums had been denuded, and set about re-vegetating the estate as part of his masterplan, and incorporated community parks (a theme prominent in the Canberra design). Also, he promoted the use of the local sandstone in buildings, to allow the structures to blend with the natural landscape. This had the added effect of increasing the thermal mass of houses, assisting winter heating and summer cooling. At the Glenaird Estate in Melbourne, in the area made famous by the landscape painters of the Heidelberg School, the challenge was to preserve the natural environment. Griffin did this with some effect, and many of the red gums, which would have been mature trees in 1916 when the estate was designed, are still there.

Finally, Griffin played a role in the waste management industry, through his designs for municipal incinerators. In the



Walter Burley Griffin incinerator, Ipswich, Queensland, built in 1936 and now a theatre

Cybergothic/Wikimedia Commons

1920s, one of his clients, Nisson Leonard-Kanevsky, acquired the rights to reverberatory incinerator technology, and formed the Reverberatory Incinerator and Engineering Company. In Sydney, in particular, ocean disposal of household waste had been prevalent, but community disquiet about waste being washed back onto the city's beaches forced local authorities to look for other solutions. In Melbourne, where disused clay pits from the brick industry were ready-made landfill sites, the scarcity of more pits as the depression slowed brick production also drove the search for alternative waste management. The reverberatory furnaces operated with a high thermal efficiency, and lower fuel consumption, using the hot exhaust gases to heat the waste being fed to the furnace (as in metal smelting). Griffin's designs also featured gravity feed of the waste through upper level chutes into which trucks were directly unloaded, reducing labour costs. Both features were attractive to cost-conscious councils. Griffin's designs were ornate and pleasing to the eye, but even a Walter Burley Griffin design could not completely assuage the mood of a hostile local community, and Griffin was instrumental in having the proposed Sydney City Council facility located in industrial Pymont rather than the more genteel Moore Park.

In all, 13 incinerators were built, in New South Wales, Queensland, South Australia, Victoria and, fittingly, Canberra, although the later versions were designed by Griffin's partner, Eric Nicholls, after Griffin's departure for India in the mid-1930s. Five still remain, preserved and heritage-listed. One of those, at Thebarton in South Australia, is quite near my former high school. In the 1980s, it was converted to a clubroom for a local ham radio group. The combustion chambers and ash-handling areas provided large open rooms, and the chimney provided a convenient support for the radio antennae. This is a good example of how re-use of a building preserved heritage and conserved materials.

So, it's pretty clear, that a range of professionals can have a positive impact on the environment, and their work can influence communities and organisations long after they are gone.



Paul Moritz MRACI CChem (Paul.Moritz@douglaspartners.com.au) is a Principal with Douglas Partners, and an EPA-appointed Environmental Auditor in Victoria. He is not a ham radio enthusiast, but some primary school friends were.

Credit where credit's due

With the present emphasis on science communication to a lay public, one might think that it was something new that had not been tried before. In fact, library catalogues are littered with publications of this ilk. A local one that caught my eye was *Science made simple*, published in 1939 by The Leisure Age Book Company in Sydney. The author was C. Barclay-Smith (1893–1957), a journalist who had earlier published a good deal of advice to those with time to spare, in *The Art of Life Series*, which included titles such as *Get more out of life!*, *The art of being happy* and *Your guide to music*.

His science book drew on the work of popularisers who still had at least one foot in the relevant scientific field. The topics covered included cosmology, astronomy, geology, physics – electricity and X-rays – atmospheric science, the chemical elements and the origins of life. Barclay-Smith took an establishment line in reminding readers that matter is always conserved, 'its form only is changed'. Some things changed, though, since while 92 elements were known to science so far, 'science occasionally discovers another one'. In a chapter about *The Incredible Story of Nitrogen*, he emphasises the biological importance of the element and moves from Chilean nitrate to various ways to achieve nitrogen fixation. Although German work is mentioned as the apotheosis of such industrial chemistry, he doesn't mention Haber or Bosch. In this chapter he draws on the work of American professor of industrial chemistry Robert Kennedy Duncan (1868–1914) and later, writing about cellulose, on that of Charles Frederick Cross (1855–1935), whose 1890s patents on viscose and cellulose acetate had laid the foundation for the artificial silk industry. Neither source was really up to date, but Barclay Smith didn't say that.

There is more to Colin Barclay-Smith than his advice on how to fill the leisure hours with uplifting knowledge. In 1932, he founded a weekly newspaper called *The New Era*, which was sponsored by the Douglas Social Credit Association of New South Wales, and he continued to edit this publication until his death in 1957. The paper survived him but only by a couple of years. In 1932, he also published *The ABC of Douglas Social Credit explained in simple dialogue form* and the following year he debated the concept with D.R. Hall, Labor member of federal parliament who had been Attorney-General for New South Wales during World War 1. According to the manuscript held by the National Library of Australia, Hall complained that he had 'listened tonight to the fulminations of Mr Smith and his friends against the banks and learned from their lips what an extraordinary lot of robbers these bankers are.' However, he went on, 'the bank manager of the biggest bank in Australia does not get nearly as good a salary as "Mo" gets to tell dirty jokes down at the Tivoli Theatre'. Those who cannot remember Roy Rene ('Mo') can probably not remember times when bankers had modest salaries, either. Still on his conspiracy theory, Barclay-Smith published *It's time they knew*, a tract endorsed by

Monetary Research (said to be a group of Australian monetary authorities), in which members of the public are warned that they are being cheated.

Social Credit was the creation of Major C.H. Douglas (1879–1952), a British engineer. The details of his theory changed over time as its precepts were challenged by orthodox economists, but in its simplest form it consisted of a government allocating credit to purchasers so that they could close the gap between the wages they got for producing goods and the price that their employer charged consumers for those goods. I can never figure out where the money was to come from but Douglas had many adherents who believed in such economics. Social Credit political parties were formed, and the Canadian province of Alberta had a Social Credit government for some years. Douglas made a lecture tour of Australia in 1934 and spawned the formation of a Social Credit Party here, but it had little effect on local politics.

In *Use your leisure time!* (1939), Barclay-Smith wrote about the 'wonders we can work' by systematic use of our time. In a week of 168 hours, he allocated 56 hours for sleep, 40 for employment, 12 for meals, and seven for dressing etc. This leaves 53 hours and if we allow 21 for recreation, then there are still 32 hours a week for 'study, cultural reading or hobbies'. Over a year, this time would allow any normal man or woman to read 150 biographies, become familiar with all of English poetry, become well-versed in the theory and history of music, read 50 great works of fiction, or become reasonably skilled in pottery work, clay modelling, wood carving, drawing, painting, tapestry work, rug weaving or cabinet making.

He concluded by revealing that he had spent some years taking evening courses in science at a technical college, although this was interrupted by war service. Based on his experience, he recommended the study of chemistry because it is the basis of several other sciences. A home laboratory 'in the woodshed or on a bench of the garage' was recommended as a way to get beyond book learning.



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 dispenses advice on chemical hazards and pollution.



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MELBOURNE
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www.flogen.org/ShechtmanSymposium

18th International Microscopy Congress (IMC 2014)

7–12 September 2014, Prague, Czech Republic
www.imc2014.com

Biosensors 2014

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www.biosensors-congress.elsevier.com

2014 International Biophysics Congress (IUPAB 2014)

3–7 August 2014, Brisbane, Qld
www.iupab2014.org

RACI National Congress

7–12 December 2014, Adelaide, SA
www.raci.org.au/events-awards/raci-national-congress-2014

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RACI events are shown in blue.

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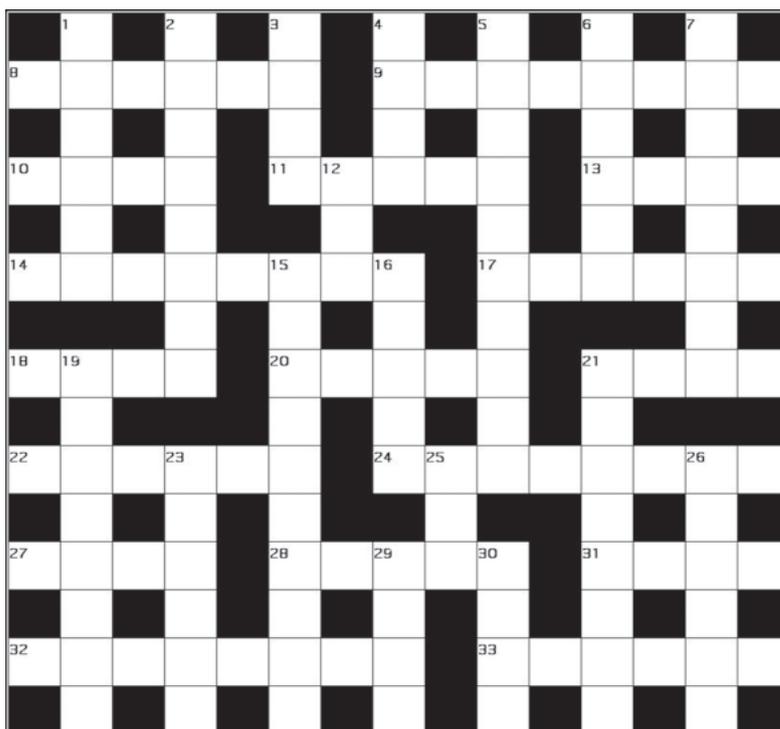


Coming up

PETER KARUSO continues the story of the 2013 Nobel Prize in Chemistry, profiling laureates Arieh Warshel and Martin Karplus.

GREGG SMITH describes one of the key pathways for a novel drug compound: the clinical trial.

Metabolomics may be relatively new, but it has a lot to offer neuroscience research, says **OLIVER JONES**.



Across

- 8 One iodine spill with no IO_2 or C_9H_8 . (6)
- 9 Foil cleaned up pipe soot. (8)
- 10 Leave tungsten under the weather. (4)
- 11 Lithium and hydrogen in plant. (5)
- 13 Detect purines, pyrimidines and other heterocyclics for inclusion. (4)
- 14 Lots left charges. (8)
- 17 Again falls for viscous liquids. (6)
- 18 Questions argininosuccinate synthase inclusion of potassium. (4)
- 20 N^{5+} ? Negative. (5)
- 21 Cover dial. (4)
- 22 Basic talk a little accommodating. (6)
- 24 One's travel cooking with no tin has ups and down. (8)
- 27 Opening retreat. (4)
- 28 Headed new media. (5)
- 31 Fashioned iodine spill from 28 Across radical. (4)
- 32 Alter NI_2 formation after disinclination to act. (8)
- 33 Spooner's double figures, my man. Bulls-eye! (6)

Down

- 1 Colour in like nothing. (6)
- 2 Seize lot strangely used as catalysts in the petrochemical industry. (8)
- 3 Abandoned port. (4)
- 4 Be in favour of storing uranium. (4)
- 5 Image presentation. (10)
- 6 Steers around compounds. (6)
- 7 This acid (2,4,6-trinitro-1,3-benzenediol) is suggestive of a frozen chip! (8)
- 12 Penultimate alpha effect experiment yields prussic acid. (3)
- 15 $(\text{CO}_2\text{H})_2$ formed in coaxial transformation followed by investigators. (6,4)
- 16 Phosphorus in old man's address: a big building. (5)
- 19 Is backing liquid oxygen and a rare gas characterised by alternating silicon and oxygen atoms. (8)
- 21 8747 guys time incomplete piece. (8)
- 23 Erbium salt makes amends. (6)
- 25 22 Across came down and told a fib. (3)
- 26 Controls or up comes sulfur (red). (6)
- 29 Animal of great interest to us. (4)
- 30 Avoid the animal. (4)

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

Never too young to experiment

2013 University of Wollongong Illawarra Coal Science Fair

More than 700 primary and high school students presented their experiments at the University of Wollongong (UOW) Illawarra Coal Science Fair in the UOW Sports Hub on 6 November 2013.

The UOW Illawarra Coal Science Fair is an innovative program aimed at inspiring school students to study science. The eighth annual Science Fair was a great success, with 720 students from 57 schools presenting the results of their scientific investigations to 200 expert judges.

Trophies, medals and cash prizes were awarded for winners in each age category. Prizes were also awarded for the best projects in Biology, Chemistry Earth & Environmental Sciences, Engineering, Mathematics, Medicine and Health, Physics and Technology. Kirsten Martinoski from St Mary Star of the Sea College, Wollongong, won the Best Chemistry Project award for her project titled *BUSTED – BPA*. Kirsten of Year 10 investigated whether different plastic water bottles released Bisphenol A when subjected to heat treatments. Her experiment demonstrated that some commonly available plastic water bottles did release BPA when heated. Kirsten won a trophy and a cash prize recognising her outstanding efforts in Chemistry.

UOW's Executive Dean of Science, Medicine and Health Professor Don Iverson said: 'The UOW Illawarra Coal Science Fair is a significant win for everybody involved with it – the community, the schools and its science teachers, the parents of participating students, and most importantly the students whose projects are on display. Each year the number of student research projects in the Fair increases, and their



Kim Morgan, Illawarra and Southern Region Manager, Hatch, presents the Best Chemistry Project award to Kirsten Martinoski, St Mary Star of the Sea College, for her project titled *BUSTED – BPA*.

scientific creativity and quality improves. I have no doubt that many of the students presenting at the Fair will be future leaders in science.'

A team of science mentors, enthusiastic science students from the University of Wollongong, visits schools throughout the year to inspire students and provide practical advice on completing research projects. This is a highlight of the Science Fair for many students. Mentor Kaitlyn Lieschke said she was thrilled to visit her old school Woonona High to share her passion for science with younger students. 'The projects they came up with were fascinating; it's inspiring how excited about science the students are,' she said. Mentor Jacob Byrnes said 'The students from Ambarvale High School were particularly inspiring. I was amazed at

how ambitious the students were with the scope of their projects, and how eager they were to tackle their big ideas.'

Another highlight of the Science Fair for participants was the entertaining and informative key note address presented by Dr Neeraj Sharma titled 'Energy for the Future', part of RACI's Nyholm Youth Lecture series.

The UOW Illawarra Coal Science Fair is hosted by the UOW Faculty of Science, Medicine and Health and generously sponsored by Illawarra Coal, Hatch, UOW Faculty of Engineering and Information Sciences and ANSTO. For more information, visit <https://smah.uow.edu.au/sciencefair>.

Dr Melissa Thompson is Schools Liaison Manager, Faculty of Science, Medicine and Health, University of Wollongong.

Royal Australian Chemical Institute National Congress

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Harvard University



Professor Phil Baran,
The Scripps
Research Institute



Dr Stacie Canan,
Global Health Division,
Celgene Corporation



Professor Makoto Fujita,
The University of Tokyo,
Japan



Professor Hubert Girault,
Ecole Polytechnique Fédérale
de Lausanne



**Professor Katharina
Landfester,**
Max Planck Institute



Professor David Leigh,
University of Manchester



Professor Daniel Nocera,
Harvard University



Professor Greg Scholes,
University of Toronto

For the full biographies of confirmed speakers to the RACI 2014 National Congress please visit the Congress website at www.racicongress.com

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- Biomolecular Chemistry Division
- Carbon Division
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- Colloid and Surface Chemistry Division
- Electrochemistry Division
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- Materials Chemistry Division
- Organic Chemistry Division
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Key Dates

Call for Abstracts Opens 2 December 2013

Registration Opens 2 December 2013

Abstract Submission Deadline 9 May 2014

Notification of Acceptance of Abstract June 2014

Early Bird Registration Closes 1 August 2014

Accommodation Booking Deadline 30 September 2014

Congress Dates 7-12 December 2014

Scientific Program Themes

- Synthetic Chemistry
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Contact Us

RACI2014 Congress Secretariat
ICMS Australasia
GPO Box 3270, Sydney NSW 2001
Ph: +61 2 9254 5000 • Fax: +61 2 9251 3552
info@racicongress.com

