

chemistry

February 2017

in Australia

Celebrating RACI's centenary

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Happy centenary, RACI!

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14 Rise of the machines. The 2016 Nobel Prize in Chemistry. I

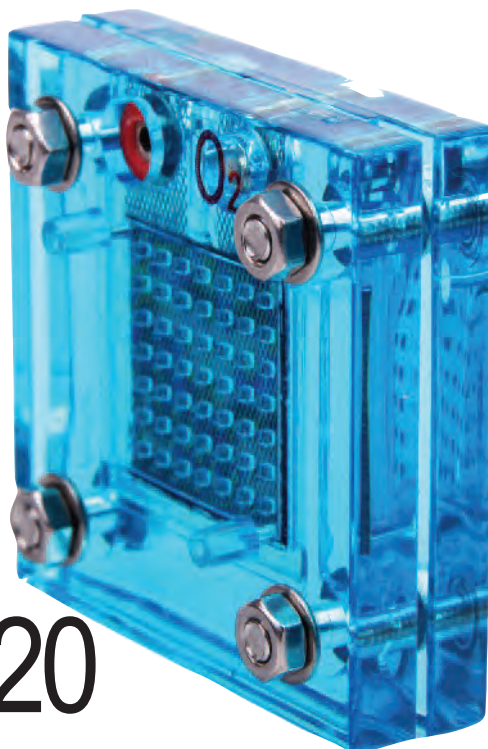
The 2016 Nobel Prize in Chemistry recognised three scientists for pioneering work towards building molecular machines. Jean-Pierre Sauvage and Fraser Stoddart developed synthetic methodologies for making mechanical bonds, including catenanes and rotaxanes. Bernard L. Feringa, using these components and light-driven double-bond isomerisation, created the first molecular motor.

20 From thin air: seeking the next source of transport energy

Dave Sammut explores current and emerging technologies aiming to meet future transport fuel needs.

24 RACI national awards: celebrating contributions in chemistry

Getting involved in the national awards is a great way to celebrate RACI's centenary year.



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Celebrating RACI's rich history

Regular readers of this magazine will be aware that this year, 2017, marks a momentous occasion for the RACI – we celebrate our 100th anniversary. The Australian Chemical Institute, as we were originally known, was founded in 1917. Throughout this year, there will be a number of activities and events across the breadth (both geographically and technically) of the RACI to mark our first century of promoting the chemistry profession in Australia. Some activities will celebrate our history. Others will be looking forward to explore the role of the RACI over the next 100 years. This year, *Chemistry in Australia* will feature articles to mark our anniversary.

One particular highlight of our centenary year of celebrations is the Centenary Congress to be held in Melbourne on 23–28 July. Much has been written about the Centenary Congress over the past couple of years, and we encourage readers to visit the Congress website (racicongress.com; or via the front page of the RACI's own website raci.org.au) to see up-to-the-minute information regarding speakers as well as the technical and social programs. The Congress has been designed to cater to all RACI members, whether you work in the industrial, education, government or academic contexts. Abstracts to present at the Congress are still being accepted (the closing date is 23 March), so we encourage you to consider making a submission to be part of this exciting event. You may wish to consider requesting an oral presentation, or perhaps a poster session is more to your liking. The Congress is catering for all styles and tastes. The 'early bird' registration deadline is 23 April, and all delegates who submit an abstract to present will be informed of the acceptance of their submission(s) prior to this date.

The Centenary Congress will be, by far, the largest meeting ever organised by the RACI. The Congress is expected to have over 3000 delegates participating across the six days. The Congress involves the concurrent involvement of nine partner conferences that span a broad range of the chemical sciences.

Delegates are free to participate in all aspects of the Congress program. That is, unhindered delegate exchange and participation across the conferences is strongly encouraged. Congress plenary speakers include captains of industry and two Nobel laureates. A significant trade and exhibition program is being organised, and numerous social activities are on offer.

The RACI Centenary is more than the Congress in July. A highlight satellite event organised by the Victorian Branch is the Centenary Ball in Melbourne on Saturday 22 July at the Plaza Ballroom on Collins Street. We encourage Congress delegates to consider coming to Melbourne a day early to attend the ball. This will be a great opportunity to dress up and celebrate in style.

Another key centenary activity is the production of a 1917–2017 RACI Centenary Book. This initiative is being led by RACI stalwart Helmut Hügel and will see the production of a publication that celebrates the RACI's past, present and future. We are grateful for the tremendous effort that Helmut and his team have devoted to this task and look forward to the book's launch later this year.

Finally, we remind readers that 2017 involves a year-long series of celebrations marking the RACI's centenary milestone. Keep an eye on each month's issue of *Chemistry in Australia* where key events and activities will be showcased. Also, the RACI website contains a great deal of information regarding centenary celebrations across the country.

This year will see us celebrate our rich history and reflect upon the role of the RACI over the next 100 years – a period many refer to as the Asian Century. Based upon our heritage of excellence, it is exciting to consider how the Australian chemistry profession can contribute on the global stage over the coming century.

Professor Peter Junk FRACI CChem, RACI President, and **Professor Mark Buntine** FRACI CChem, Centenary Congress Chair

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Supply and demand

Mervyn Crawford's delightful story (November 2016, p. 5) of the group who attempted to obtain a chemical from a supplier, whose supply was required to be generated by the group, reminds me of my own twisted tale.

At a small university town in South Africa, I asked a student to purchase some log-log graph paper from the local stationer, since I recollected having seen it there. The student returned to say that the stationer had none. Being sure of my ground, I asked the departmental storeman to get the paper, but he returned with the same story. Determined to get the offending graph paper, I went to the stationer's myself and asked for the item. The assistant said: 'You know, there has been such a run of requests, we should get some in!'

Leslie Glasser MRACI CChem

Science employment prospects

I was waiting for someone with more knowledge and insight than me to comment on the disturbing article 'Science graduate numbers are growing but the jobs are not' in the October 2016 issue (p. 12). I believe that this is a very serious issue and needs to be pursued with vigour by the RACI.

Under the CSIRO Scientists and Mathematicians in Schools (SMiS) program, I am partnered with a senior science teacher at a local high school. He is heavily involved with the full-scale implementation of the STEM program in his school. When I showed him this article, he responded: 'It seems to contradict the massive STEM push by government'. I agree. I am appealing to readers of *Chemistry in Australia*: what do I tell a student if she or he asks me about the prospects of a career in science? Do I say forget about it unless you have the ambition, talent and grit to push through to a PhD and join the swelling ranks of short-term contractors and academic hopefuls (as a young PhD related her experiences to me)?

Education imposes considerable financial burdens, firstly on the student who has to repay a not inconsiderable partial cost of tuition through HECS, and secondly, on the taxpayer at large, who supports the education system. It is important that graduates obtain knowledge and skills that put them in the best position to be employed and contribute to the maximum extent to the common weal. There is an urgent need for students to be given the best possible information clearly and honestly as to employment prospects for STEM graduates. Giving out this information should start at high school, be heavily emphasised at the time of university enrolment and be extended to, say, the end of first year. This is one area where governments, universities and employers can help.

In the accompanying article from the Professional Scientists Australia (which I understand is essentially a trade union) a typically bureaucratic 'top down' approach is advocated, seeming to argue that the employment of STEM graduates is hampered by a lack of 'soft skills', making them less attractive to prospective employers, but is something that may be rectified by government

intervention. I am willing to be contradicted, but it would seem to me that the principal barrier to STEM graduate employment is lack of jobs. With the retreat of the extractive industries and collapse of the manufacturing sector, there aren't that many new jobs being offered in industry. The burgeoning public sector offers some hope, although I suspect that those with postgraduate qualifications are squeezing out those with undergraduate degrees in the competition for jobs.

In industry, the traditional sink for new science graduates has been in process and quality control and in product development. Initially, employers are looking for plug-and-play employees who can do the scientific and technological grunt work. Obviously, employers will avoid the technically less competent, the semiliterate and those with obvious personality problems. The first job in industry is a two-way street for both employee and employer. Employers know that many new graduates use their first job to gain experience and build their CV, and may be on their way in a couple of years. Employers are also on the lookout for hard workers who make the effort to adapt quickly, and are eager to acquire knowledge and learn new skills over and above their job description, rapidly becoming essential members of the corporate team.

The PSA argument that STEM graduates have the capacity to enhance their business is exactly the same one that university arts faculties have made for years: that eventually their graduates can do all sorts of good things for a company. This is no doubt true, but employers must have the financial capacity and confidence in the future of their company before they commit to creating new positions. Business confidence is a critical factor. The rising costs of employment, as well as the cost for energy and the costs associated with dealing with increasingly onerous government regulations do little to aid business confidence and much to dissuade expansion of existing businesses and creation of new ones.

The PSA would also seek to increase the financial burden on both the student and the taxpayer by adding teaching of soft skills and prolonging STEM courses. I could be convinced that a person with entrepreneurial fire in the belly may improve the chance of success with business training or mentoring, but I'm not sure that entrepreneurship itself can be taught. I would leave it to readers to judge. Budding entrepreneurs want to be their own boss, make money and perhaps even create new organisations. For new graduates seeking to learn leadership and people management skills, I'd say join the Army Reserve. It will also look good on your CV, and you'll make money instead of it costing you. As to the other soft skills mentioned, these can be acquired on the job or by postgraduate study should career advancement depend on it.

Clearly, the best way to increase the number of jobs is to improve the business environment so that businesses are encouraged to invest in and develop new technology, not to mention an environment where people are encouraged to strike out on their own. The dead hands of government and the unions should be kept well away.

Thomas K. Smith FRACI CChem

Going bush for *Scaevola spinescens*

I was fascinated to read Geoff Taylor's article on *Scaevola spinescens* in the November 2016 issue (p. 22). It took me back to a former role with the Materials Science Section of the ChemCentre in the late eighties. At the time, I had thought I was probably one of scores of staff members who had been involved with this work. Having now read the history, I suspect the number is more likely to be in the hundreds!

I can recall the periodic brewing days when large-scale batches of the extract were boiled up, its aroma percolating through the building in East Perth, the batches then being packed off for patients to collect. This was warm work in summer but nothing to compare with the field trips to collect the plant material required to make the extract. These involved an annual trek to the Goldfields region of Western Australia, some 600 kilometres east of Perth. Announcement of the need for a field trip elicited a range of responses from staff. For some, it evoked feelings of trepidation or dread, for others a matter-of-fact resignation to just get it done. And then there were the enthusiasts. I remember one staff member from another section who couldn't wait to get out into the bush again each year. In the Materials Science Section, it was lore that you were not a fully fledged member of staff until you had participated in a field trip. So new starters were generally pushed to the top of the list of participants.

Despite what colleagues could tell you about the field trips, it hardly prepared you for the actual experience, particularly if the weather was unkind. Harvesting and milling the plants followed by bagging up the chipped material in the bush north of Kalgoorlie was hot, dusty, physically demanding work. The job was even hotter because of the heavy protective clothing we needed to provide some protection from the spiny plants. And despite our best preparations, we inevitably ended up with a decent array of cuts and scratches each day. I remember we did our best to avoid the worst of the heat each day, setting off before sunrise to start work very early. We were so relieved in the early afternoon when the team leader finally announced we had our day's quota. Then we invariably sought refuge from the heat in the Ora Banda Hotel before taking the day's harvest to the rail head in Kalgoorlie for freighting back to Perth. Then we did it all again the next day. After a stocktake towards the end of the week, we rang the section head back in East Perth hoping that the quantity would be enough and we could head home.

Jeff Stewart MRACI

'Your say' guidelines

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

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Send letters to editor@raci.org.au.

Busting myths about women in STEM

A new paper from the Office of the Chief Scientist highlights the need for ongoing action to encourage and support women to pursue careers in science, technology, engineering and mathematics (STEM).

'Busting the Myths about Women in STEM' dispels four damaging and persistent myths facing women in STEM. It is accompanied by an illustrated datasheet that shows Australia's gender STEM imbalance persisting from the classroom through to the workplace.

Australia's Chief Scientist Dr Alan Finkel said the nation needed to build a culture that further encourages girls and women to enter and excel in STEM fields.

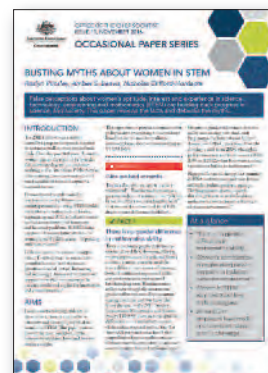
'Australia is already a global leader in science. Imagine what we could achieve if women and men felt equally welcomed and appreciated in STEM professions,' Finkel said.

'This paper will help equip Australians with the facts about gender inequality in STEM, and help us to continue the progress already being made in this area.'

The paper highlights that women are just as talented and capable as men in STEM fields, but the gender pay gap, workplace discrimination and a belief that STEM professions are 'male' roles discourage girls and women from pursuing these careers.

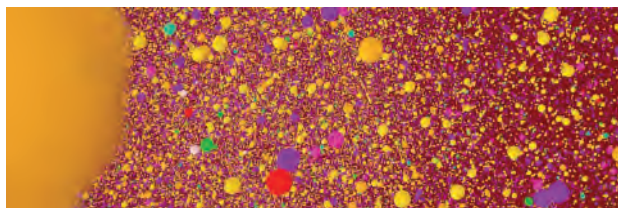
The paper and the datasheet can be downloaded at www.chiefscientist.gov.au/2016/11/occasional-paper-busting-myths-about-women-in-stem.

Office of the Chief Scientist



Tooth decay – drilling down to the nanoscale

Tom Hartley



With one in two Australian children reported to have tooth decay in their permanent teeth by age 12, researchers from the University of Sydney believe they have identified some nanoscale elements that govern the behaviour of our teeth.

Material and structures engineers worked with dentists and bioengineers to map the exact composition and structure of tooth enamel at the atomic scale.

Using a relatively new microscopy technique called atom probe tomography, their work produced the first three-dimensional maps showing the positions of atoms critical in the decay process.

The new knowledge on atom composition at the nanolevel has the potential to aid oral health hygiene and caries prevention, and has been published in *Science Advances* (doi: 10.1126/sciadv.1601145).

Professor Julie Cairney, Material and Structures Engineer in the Faculty of Engineering and Information Technologies, said 'The dental professionals have known that certain trace ions are important in the tough structure of tooth enamel but until now it had been impossible to map the ions in detail.

'The structure of human tooth enamel is extremely intricate and while we have known that magnesium, carbonate and fluoride ions influence enamel properties, scientists have never been able to capture its structure at a high enough resolution or definition.

'What we have found are the magnesium-rich regions between the hydroxyapatite nanorods that make up the enamel.

'This means we have the first direct evidence of the existence of a proposed amorphous magnesium-rich calcium phosphate phase that plays an essential role in governing the behaviour of teeth.'

Co-lead researcher on the study, Dr Alexandre La Fontaine from the university's Australian Centre for Microscopy and Microanalysis, said: 'We were also able to see nanoscale "clumps" of organic material, which indicates that proteins and peptides are heterogeneously distributed within the enamel rather than present along all the nanorod interfaces, which was what was previously suggested.

'The mapping has the potential for new treatments designed around protecting against the dissolution of this specific amorphous phase.'

University of Sydney

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Prospecting for PhDs?

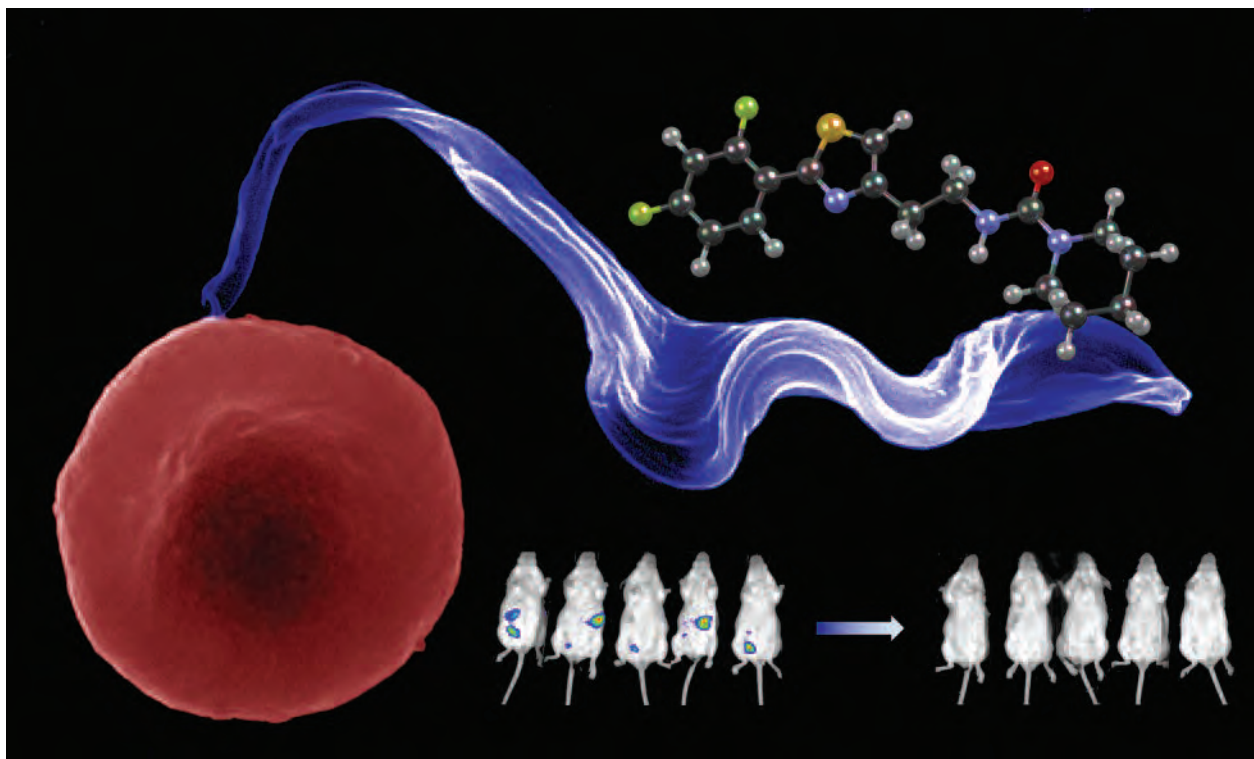
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New drug leads tryp parasites



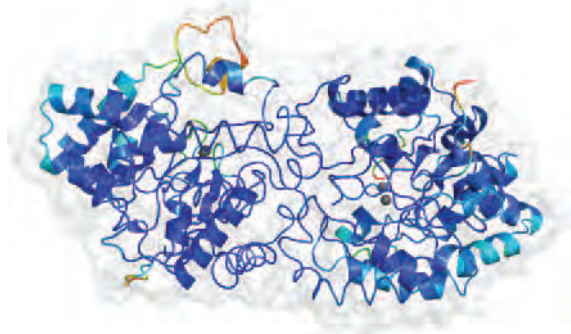
The parasitic protists *Trypanosoma brucei* and *T. cruzi* are responsible for significant human suffering in the form of African sleeping sickness and Chagas disease. Existing drugs for these diseases have severe side-effects and inconvenient administration regimes, and are limited in their efficacy; alternative drugs are sorely needed. A team of researchers from the University of Western Australia, Monash Institute of Pharmaceutical Sciences, Griffith University and GlaxoSmithKline, along with other international collaborators, has discovered a new class of *N*-(2-(2-phenylthiazol-4-yl)ethyl)amides, carbamates and ureas that rapidly and potently kill both species of trypanosome (Russell S., Rahmani R., Jones A.J., Newson H.L., Neilde K., Cotillo I.,

Rahmani Khajouei M., Ferrins L., Qureishi S., Nguyen N., Martínez-Martínez M.S., Weaver D.F., Kaiser M., Riley J., Thomas J., De Rycker M., Read K.D., Flematti G.R., Ryan E., Tanghe S., Rodriguez A., Charman S.A., Kessler A., Avery V.M., Baell J.B., Piggott M.J. *J. Med. Chem.* 2016, **59**, 9686–720 + cover). The compounds are non-toxic to mammalian cell lines and have favourable physicochemical parameters for penetrating the central nervous system, which is critical for treating African sleeping sickness. However, as a class, they are rapidly metabolised. One of the optimised leads (pictured) cleared all signs of *T. cruzi* infection in mice when cytochrome P450 metabolism was inhibited. This family of compounds thus shows significant promise for trypanosomiasis drug discovery.

 	<p>ROWE SCIENTIFIC <small>PTY LTD ABN 63 009 437 750</small></p> <p>www.rowe.com.au</p> <p>Pledge to Chemists</p> <p>If chemists in Australia are experiencing difficulty in obtaining supply, please send me an email, peter.sommers@rowe.com.au and I promise to help you.</p> <p>This is not a 'subtle' attempt to obtain more business, but a sincere pledge to help fellow scientists source the items they need to do their work, and thereby help Australia grow. This is the raison d'être for Rowe Scientific Pty. Ltd.</p> <p>Peter Sommers (FRACI)</p>	<p>ADELAIDE 08 8186 0523 rowesa@rowe.com.au</p> <p>BRISBANE 07 3376 9411 roweqld@rowe.com.au</p> <p>HOBART 03 6272 0661 rowetas@rowe.com.au</p> <p>MELBOURNE 03 9701 7077 rowevic@rowe.com.au</p> <p>PERTH 08 9302 1911 rowewa@rowe.com.au</p> <p>SYDNEY 02 9603 1205 rowensw@rowe.com.au</p>
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Elucidating enzyme evolution

The continued improvement and application of biological catalysts requires a strong fundamental understanding of the factors that underpin the function of nature's most efficient enzymes. The laboratories of Colin Jackson at the Australian National University and Nobuhiko Tokuriki at the University of British Columbia, Canada, have analysed an artificial (laboratory-generated) evolutionary trajectory to identify the effects of protein dynamics on the evolution of new function (Campbell E., Kaltenbach M., Correy G.J., Carr P.D., Porebski B.T., Livingstone E.K., Afriat-Jurnou L., Buckle A.M., Weik M., Hollfelder F., Tokuriki N., Jackson C.J. *Nat. Chem. Biol.* 2016, **12**, 944–50). The evolution of a bacterial phosphotriesterase into an arylesterase produced 22 different intermediates, with varying functional trade-offs between the two activities. Analysis of X-ray crystal structures of several variants along the trajectory revealed that minimal change to



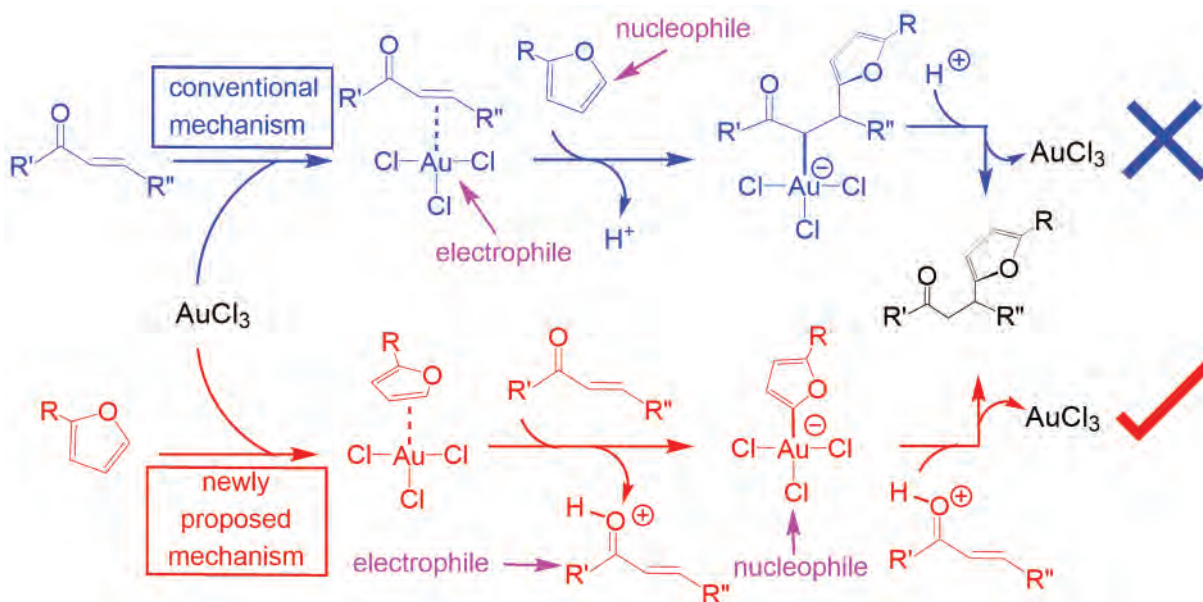
protein structure occurred during the evolution of the new function. Instead, new function was obtained through the enrichment of pre-existing conformational substates, and through the 'freezing out' of non-productive substates. This link between protein dynamics and the acquisition of new activity will provide protein engineers with a new approach for improving or altering enzyme function.

New mechanism for gold catalysis

Gold complexes have attracted broad attention from the research community as efficient catalysts for the synthesis of many pharmaceutical drugs and natural products. A well-accepted role for the gold centres in catalysis is to activate unsaturated bonds as electrophiles, facilitating the attack of nucleophiles (Nu-H) on the gold-activated unsaturated bonds. Now, researchers at the University of Tasmania, University of Heidelberg, Germany, and Islamic Azad University, Iran, have used density functional theory

to show that this picture is not always true and the gold centres sometimes play a different role, serving as a proton producer via coordination to Nu-H to give Nu-Au and H⁺. The in-situ-generated proton then serves as a strong electrophile and accelerates nucleophilic attack of Nu-Au on the unsaturated bonds by activating these bonds (Bagi A.H., Khaledi Y., Ghari H., Arndt S., Hashmi A.S.K., Yates B.F., Ariafard A. *J. Am. Chem. Soc.* 2016, **138**, 14 599–608). In this unprecedented mechanism,

the nucleophile consists of the gold centre, whereas in the traditional one the gold centre plays a reverse role. The researchers investigated hydrofurylation of allenyl ketone, vinyl ketone, ketone and alcohol substrates catalysed by AuCl₃ and found that the corresponding functionalisations are best rationalised in terms of this novel mechanism. This variant reaction pathway is expected to receive greater consideration in other reactions catalysed by gold in future work.



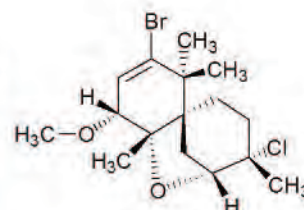
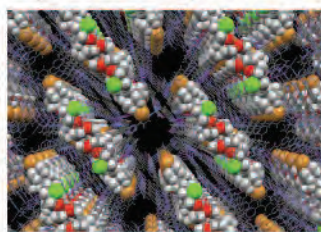
Express approach to absolute structures

The research teams of Dr Sylvia Urban at RMIT University and Professor Makoto Fujita at the University of Tokyo, Japan, have unveiled the versatility of the crystalline sponge method in securing the absolute structure of natural products (Lee S., Hoshino M., Fujita M., Urban S. *Chem. Sci.* 2017, doi: 10.1039/c6sc04288k). Cycloelatanene A and B are marine natural products first reported from a southern Australian marine red alga. Their relative structures had been elucidated by an extensive NMR study and they were found to be epimers. However, their absolute configurations had not been established because they were isolated in only minute quantities as oily compounds. In this study, the complete structures of cycloelatanene A and B, including absolute configurations, were determined by the crystalline sponge method. The structure analysis confirmed the unique tricyclic structure involving a spiro[5.5]undecene skeleton. One stereogenic centre at C4 was revised as a result of this analysis. Since it only took 1–2 weeks to complete the experiments using the crystalline sponge method (guest-soaking followed by crystallographic analysis), this method is now highly recommended as a first port of call to achieve complete natural product structure elucidation.

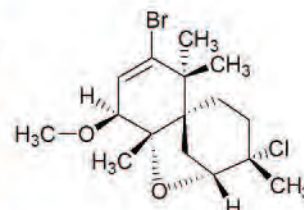


Natural Product Isolation

Crystalline Sponge Method



cycloelatanene A



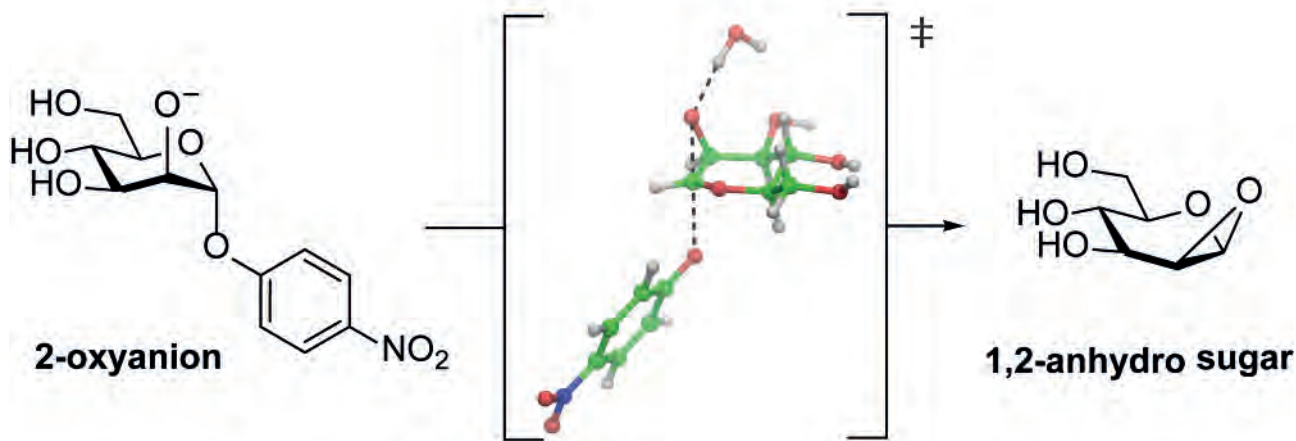
cycloelatanene B

Basis of basic glycoside breakdown

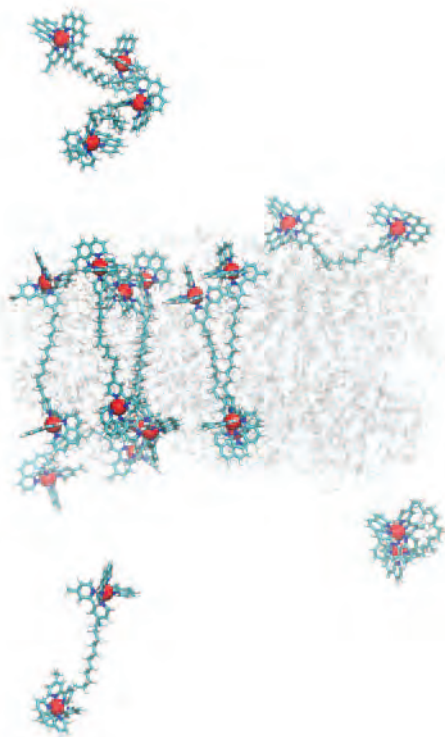
Glycosides are most commonly hydrolysed through acid-catalysed processes. However, for over 100 years it has been recognised that certain naturally occurring glycosides, such as salicin (an anti-inflammatory agent from willow bark), undergo rapid cleavage under basic conditions. The mechanism involves a 'back-biting' neighbouring group participation in which an oxyanion of the 2-hydroxy group performs a nucleophilic attack, substituting the glycosidic linkage, to make a sugar epoxide (a

1,2-anhydro sugar), which is subsequently hydrolysed. In collaboration with researchers at Simon Fraser University, Canada, the group of Professor Spencer Williams at the University of Melbourne has used kinetic isotope effect analysis to probe the nature of the transition state of the alkaline solvolysis of 4-nitrophenyl alpha-mannoside (Speciale G., Farren-Dai M., Shidmoosavee F.S., Williams S.J., Bennet A.J. *J. Am. Chem. Soc.* 2016, **138**, 14 012–9). This analysis requires

accurate measurement of the effect upon the rate of the reaction when extra neutrons are added to various atoms within the substrate to form isotopic isomers. The measured kinetic isotope effects were modelled computationally, providing a picture of the shape and charge distribution of the transition state. The kinetic signatures have the potential to provide insight into the mechanism of action of enzymes that cleave glycosides through an equivalent process.



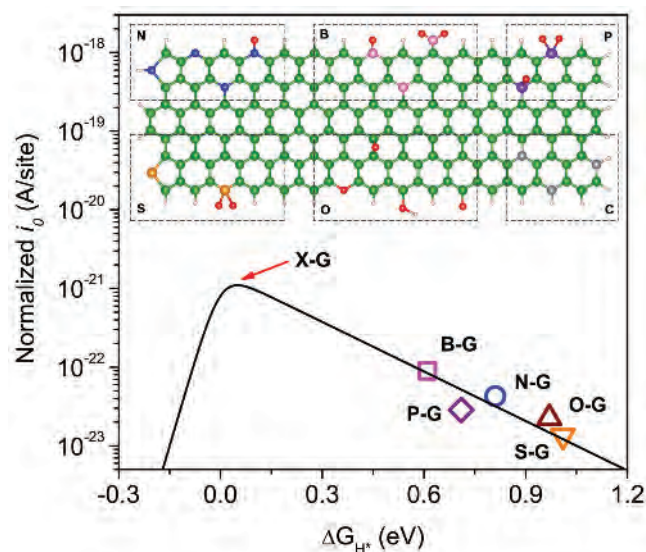
Membrane-active mechanisms for ruthenium-based antibacterial agents



The emergence of antibiotic resistance has become a serious health concern as the pipeline of new therapeutic agents continues to decline. Dinuclear polypyridylruthenium(II) complexes bridged by a flexible methylene linker have been found to have antibacterial potency rivaling that of conventional antibiotics, while also maintaining activity against drug-resistant strains. A collaborative effort involving researchers from the University of Melbourne, the University of Adelaide, James Cook University, the University of New South Wales and IBM Research Australia, which combined solid-state NMR and molecular dynamics simulations, found that selective antibacterial activity of the potent $[\{\text{Ru}(\text{phen})_2(\mu\text{-bb}_{12})\}]^{4+}$ complex (Rubb_{12}), where phen = 1,10-phenanthroline and bb_{12} = bis[4(4'-methyl-2,2'-bipyridyl)-1,12-dodecane], depends on its insertion into anionic bacterial membranes (Weber D.K., Sani M.-A., Downton M.T., Separovic F., Keene F.R., Collins J.G. *J. Am. Chem. Soc.* 2016, **138**, 15 267–77). This contrasts with the highly charged, but biologically inactive, iridium analogue $[\{\text{Ir}(\text{phen})_2(\mu\text{-bb}_{12})\}]^{6+}$ (Irbb_{12}), which was not capable of insertion. Incorporation of these biconically shaped complexes in extended conformation induced a significant degree of membrane thinning, which may be either a membrane-disruptive mechanism in itself or perhaps a helpful intermediate in the process of uptake to reach intracellular targets (i.e. nucleic acids).

Climbing the hydrogen production volcano

The hydrogen evolution reaction (HER) is a fundamental process in electrocatalysis and plays an important role in energy conversion via water splitting to produce hydrogen. Effective candidates for HER are often based on noble metals, while carbon-based metal-free electrocatalysts generally demonstrate poorer activity. Professor Shizhang Qiao and co-workers at the University of Adelaide have systematically evaluated a series of heteroatom-doped graphene materials as efficient HER electrocatalysts by combining spectroscopic characterisation, electrochemical measurements and density functional theory calculations (Jiao Y., Zheng Y., Davey K., Qiao S. *Nat. Energy* 2016, **1**, 16 130). The voltammogram-measured HER exchange current (i_0) on each chemically synthesised sample was found to be correlated with the hydrogen adsorption strength (ΔG_{H^*}) from judiciously constructed molecular models. This correlation explains the variations in catalytic reactivity in terms of the electronic structure of the materials. On the basis of these results, the team has proposed an experimentally achievable two-step strategy to improve the performance of graphene-based materials to be competitive with benchmark metal catalysts. The resulting design principle considers both the intrinsic electronic structure and extrinsic physicochemical properties of graphene, and paves the way for atom-level design of efficient carbon-based electrocatalysts for future energy-conversion applications.



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

Australasian peptide chemistry Research Front

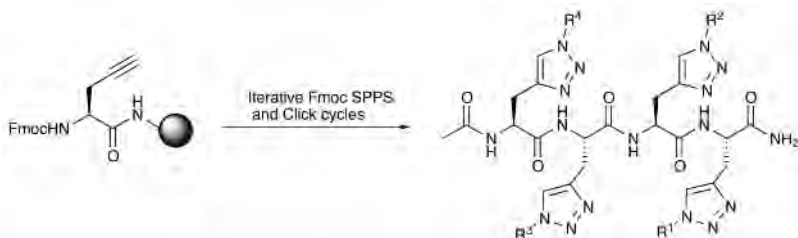
The February 2017 issue of the *Australian Journal of Chemistry* is a special Research Front guest co-edited by Professor Paul F. Alewood, Institute for Molecular Bioscience, University of Queensland, and Professor John D. Wade of the Florey Institute of Neuroscience and Mental Health, University of Melbourne. It is devoted to highlighting the international excellence of peptide chemistry in Australasia by a selected cohort of current elite peptide researchers.

The issue also commemorates the 70th anniversary of the establishment of Australia's first dedicated peptide research laboratory at CSIRO when E.O.P. Thompson returned from the UK where he undertook PhD studies with Frederick Sanger in Cambridge on the sequencing and primary structure determination of ovine insulin. Sanger was awarded the Nobel Prize in Chemistry in 1958 for this work. Thompson was soon joined by the Australian chemist John Swan, who had been awarded a Fulbright Fellowship to undertake a postdoctoral year with Vincent du Vigneaud at Cornell University, USA, where he was part of the team that synthesised the nonapeptide oxytocin. This was the first chemical synthesis of a biologically active peptide and led to the award to du Vigneaud of the 1955 Nobel Prize in Chemistry. Swan later became the Foundation Chair of Organic Chemistry at Monash University.

From these origins at CSIRO in 1956, peptide chemistry soon also expanded into academia and has both grown and matured greatly where today it is at the forefront of a wide diversity of outstanding research fields led by many Australasian world-leading practitioners with expertise ranging from peptide discovery, medicinal chemistry, chemical synthesis, chemical biology, structure determination and drug development.

Each of the 13 contributions in this special issue is by a well-established, highly respected peptide chemist with an international reputation in his or her respective areas of study. The diverse range of topics includes peptide dendrimers, antimicrobial peptides, peptide natural products, macrocyclic peptidomimetics, cyclotides and beta-amino acid oligomers.

An article by Jolliffe and colleagues reports the introduction of an iterative 'click' step into solid-phase peptide synthesis protocols to provide a method for rapid functionalisation of peptide side chains with a range of diverse moieties (see figure). Another article by Norton and colleagues describes the use of surface plasmon resonance and NMR spectroscopy to gain insights into the binding of iNOS-derived peptides to SPSB2. The complex interplay of peptide sequence and protein binding will inform efforts to design peptide therapeutics to disrupt the iNOS-SPSB interaction. Collectively, these contributions provide the reader with an appreciation of the sustained excellence of Australasian peptide research.



George Koutsantonis FRACI CChem and John D. Wade FRACI CChem, Co-Editors-in-Chief, *Australian Journal of Chemistry*



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Rise of the machines

The 2016 Nobel Prize
in Chemistry. Part I

BY **PETER KARUSO**

The 2016 Nobel Prize in Chemistry recognised three scientists for pioneering work towards building molecular machines. Jean-Pierre Sauvage and Fraser Stoddart developed synthetic methodologies for making mechanical bonds, including catenanes and rotaxanes. Bernard L. Feringa, using these components and light-driven double-bond isomerisation, created the first molecular motor.

On the night of 10 December 2016 in Stockholm, Sweden, the Nobel Prize in Chemistry was given to Jean-Pierre Sauvage (University of Strasbourg, France), Sir J. Fraser Stoddart (Northwestern University, Evanston, Illinois, USA) and Bernard L. Feringa (University of Groningen, Groningen, the

Netherlands) 'for the design and synthesis of molecular machines'. Sauvage was the first to efficiently make a molecule held together by a mechanical bond and a variety of molecular knots. Stoddart was the first to thread a molecular ring onto an axis and Feringa put it all together to make the first molecular motor.

Molecular topology

I have always been attracted to knots. For example, the monkey's fist (pictured) is a three-dimensional Borromean ring of exquisite topological beauty but also has utility. Hard to tie, but with a symmetry that is easy to appreciate and utility in sailing at the end of a heaving line, rescue rope and as a weight for throwing mooring lines. So too this year's Nobel Prize in Chemistry. On one level, it is a very

traditional prize for synthetic chemistry, but on another level it is a prize for the artistic expression of chemists for creating objects of beauty and utility on the smallest possible scale.

What differentiates chemistry from every other discipline is that chemistry *creates* its own objects of desire as Berthelot noted in 1860. This science of *creation* is based on analogies that relate molecules with macroscopic objects, such as switches, cars and knots, because such analogies promote transduction (inferring invisible events from familiar macroscopic observables has been habitual with chemists since atomism arose in the 19th century) and make it possible to see molecules as objects of manipulation. The essence of this year's Nobel Prize is the precise manipulation of matter, at a molecular level, into exquisite topological objects. It so happens that these objects also have the potential to change the world we live in through the synthesis of molecular machines and systems and perhaps even the creation of actual artificial life, not just tinkering with existing life as in current 'synthetic biology'.

The first step towards a molecular machine was taken some time between 1906 and 1912 when Richard Willstätter (Nobel Prize, 1915), while giving a series of seminars in Zürich, postulated the existence of mechanical bonds – the results of interlocked molecular architecture not held together by covalent bands. In 1953, Frisch, Martin and Mark postulated that the unusual mechanical properties of high molecular weight polysiloxanes were due to the existence of interlocking rings, but there was no direct evidence for this.

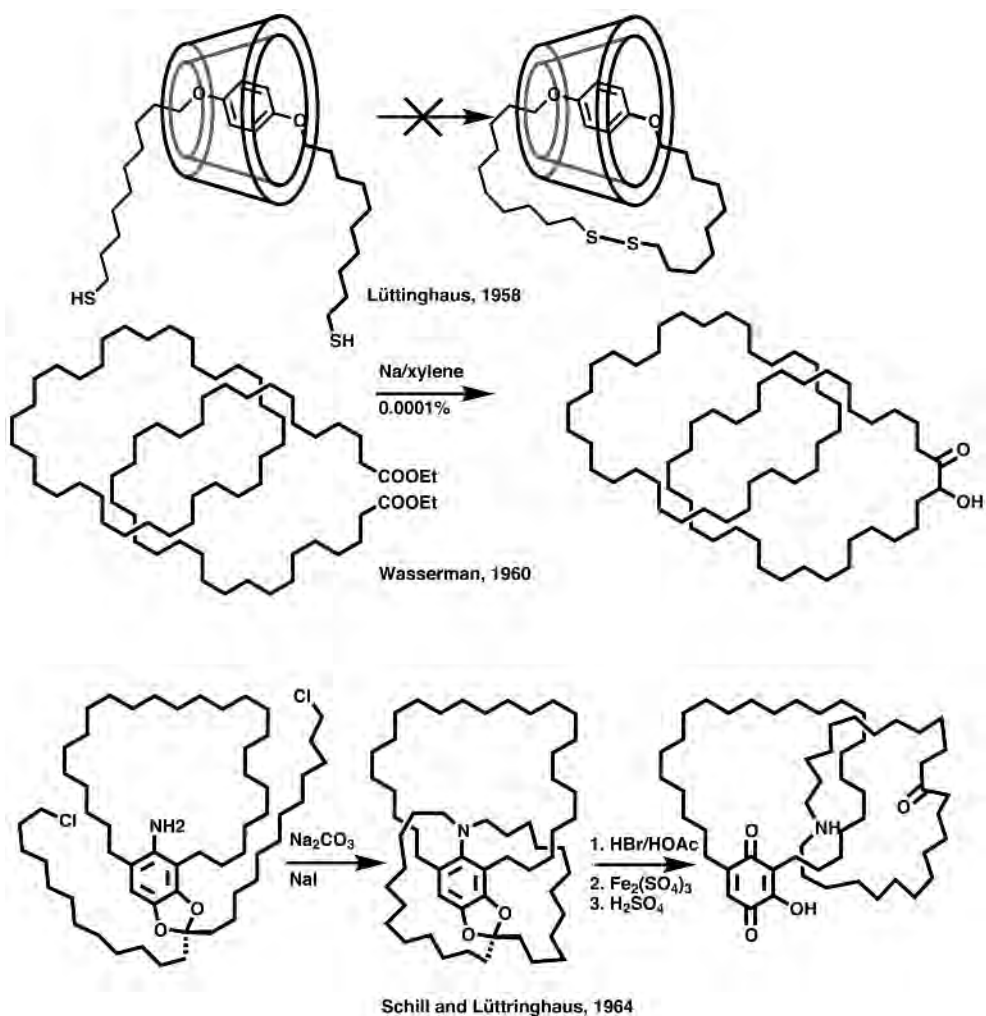
A few years later (1958), Lüttringhaus and Cramer attempted (unsuccessfully) the first synthesis of a catenane (from the Latin *catena* – chain) by threading a long-chain sulfide through the middle of cyclodextrin and then closing the

second ring by oxidising the dithiol to a disulfide. The idea was good, in that the dihydroquinone is about the right size to fit into the cavity of cyclodextrin and should form a stable adduct. It is likely that the expected product was formed but that the analytical methods available in the 1950s were not good enough for isolation of the miniscule amount.

The first [2]catenane was synthesised by Wasserman in 1960 through the acyloin condensation of a dilute solution of a long-chain diester in the presence of a high concentration of a C_{34} cyclic hydrocarbon. Because this and Lüttringhaus' synthesis relied on a statistical approach, the yield would be very low (0.0001% in the case of Wasserman) and of no real interest to the chemistry community

because the product had no physical or chemical properties of value. However, it is worth noting that this was the first, and remains the only, example of a fully saturated catenane, but more importantly it led to a seminal paper by Frisch and Wasserman (*JACS* 1961, vol. 83, p. 3789) that discussed 'molecular topology' for the first time and ways to directly synthesise mechanically interlocked systems and molecular knots.

The experimental realisation followed shortly (1964) from Schill and Lüttringhaus, who placed an amino group in a C_{28} macrocycle and did a double intramolecular cyclisation to two alkyl halides to yield a threaded structure, which after oxidative cleavage of the aryl–nitrogen bond led to a [2]catenane in 15 steps. Schill went





Jean-Marie Lehn giving the opening lecture at the 65th birthday/retirement party of Jean-Pierre Sauvage, December 2009, showing the young Jean-Pierre Sauvage at the bench in Lehn's lab in 1969. Jean Weiss

on to make [3]catenanes, [2]rotaxanes and several molecular knots. Unfortunately, the reaction schemes were often long (20+ steps), low yielding and daunting to carry out. By the early 1980s, fatigue was starting to set in amongst the small number of research groups still interested in mechanically interlocked systems.

It seemed as though there was no solution to the practical synthesis of catenanes when out of the blue a revolutionary solution was published in 1983 in French (*Tetrahedron Lett.* 1983, vol. 24, p. 5095). Jean-Pierre Sauvage proposed a novel strategy for making catenanes based on the templating effect of copper(I).

This strategy (metal templating) lifted the field from theoretical to real and has been generalised and used by many others to produce new families of topological molecules such as higher catenanes and complex knots.

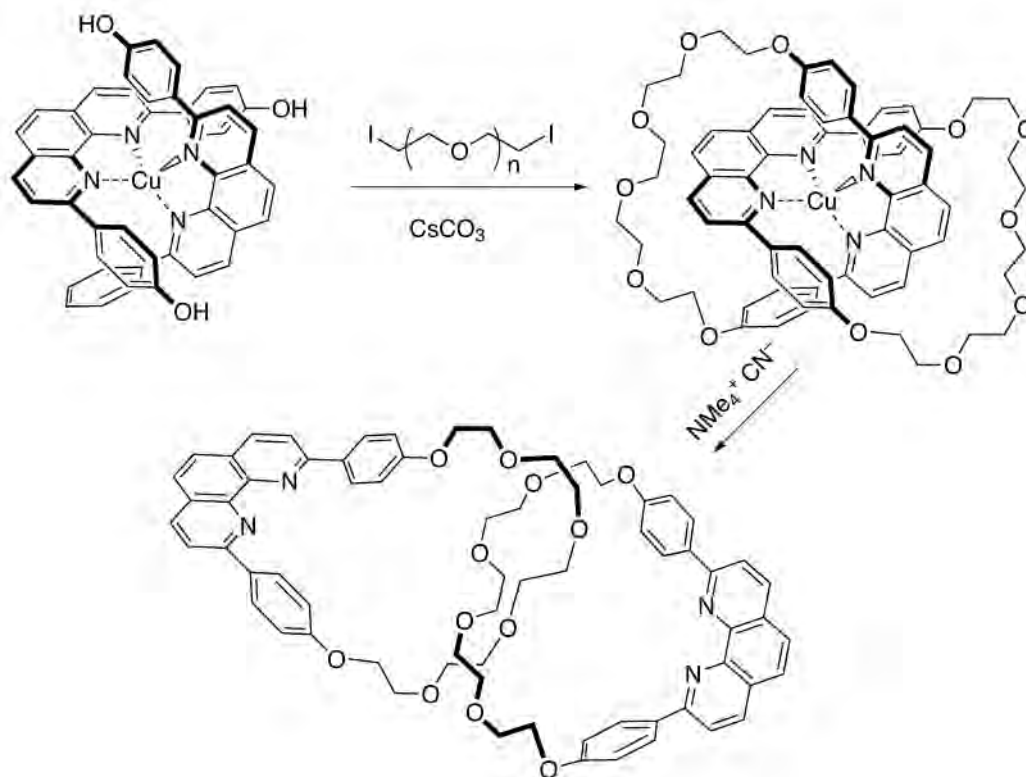
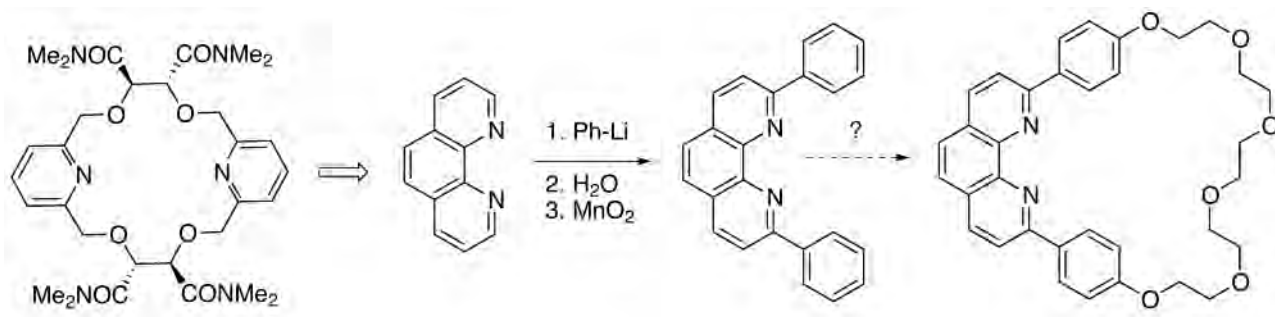
Jean-Pierre Sauvage

Jean-Pierre Sauvage was born in Paris, France, on 21 October 1944. He studied chemistry at the Ecole Nationale Supérieure de Chimie de Strasbourg and obtained his PhD from the Université Louis Pasteur de Strasbourg (now the University of Strasbourg) under the supervision of Jean-Marie Lehn (1971). Little did he know, but at the time he was already doing Nobel Prize research during his PhD ('Les cryptates', *Tetrahedron Lett.* 1969, vol. 10, p. 2889). This paper led directly to the Nobel Prize for Jean-Marie Lehn, which he shared with Charles J. Pedersen and Donald J. Cram in 1987 for their development of supramolecular chemistry and molecules with structure-specific interactions of high selectivity. Lehn studied chemistry at the University of Strasbourg and did his PhD under Guy Ourisson, did a

postdoc for R.B. Woodward (Nobel Prize, 1965) and returned to Strasbourg as a lecturer in 1966. Pedersen had first developed crown ethers to capture alkali metals and Cram extended this to more general host-guest chemistry and Lehn, with his first PhD student (Sauvage), developed the cryptands.

Sauvage managed to publish 10 papers from his PhD, many of them very highly cited. He followed this with a somewhat less successful foray into organometallic chemistry as a postdoc at Oxford with Malcolm L.H. Green (1973–4), from which arose only one minor paper on the synthesis of a half-sandwich ferrocene complex.

Sauvage returned to Strasbourg in 1974 and continued to work with Lehn until 1982 on the photochemical generation of hydrogen and oxygen (artificial photosynthesis) using noble metal catalysts. In 1980, he also started



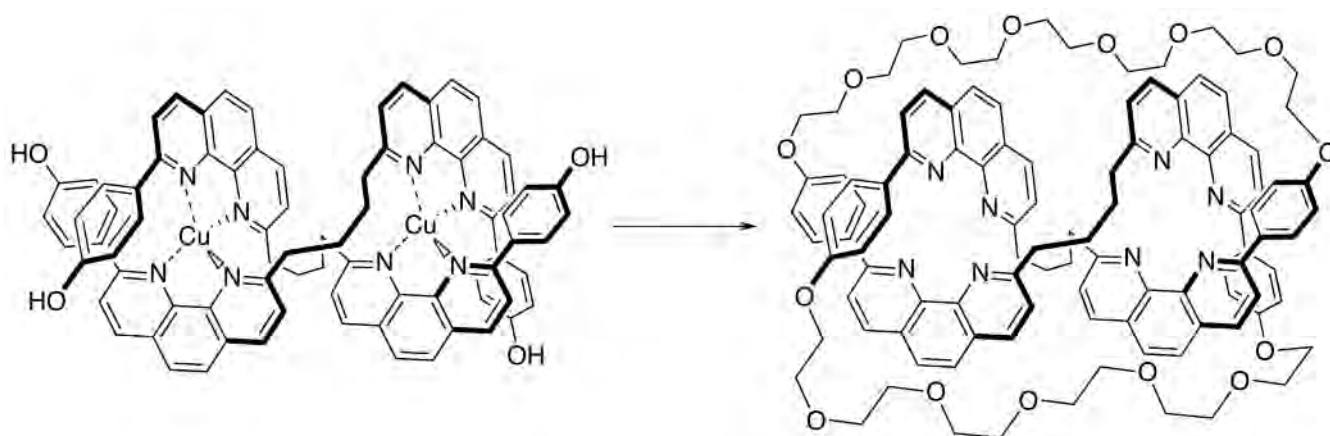
to work on something he had begun as a PhD student – making polyfunctional crown ethers that could complex transition metals by virtue of incorporation of pyridine rings and tartaric acid. A student, Christiane Dietrich-Buchecker, then discovered the direct arylation of phenanthroline (*Tetrahedron Lett.* 1982, vol. 23, p. 5291) that opened the door to easy access to 2,9-disubstituted phenanthrolines and now it is not so far to the revolutionary paper of 1983 describing the efficient metal-templated synthesis of catenanes.

The idea was simple: use tetrahedral copper(I) to complex two phenanthroline units that were 2,9-disubstituted with phenols.

Addition of a base (caesium carbonate) and a diiodopolyethylene-glycol rapidly led to an interlocked structure. Removal of the copper proved harder than expected due to the 'catenane effect' – the first emergent property to be identified in the field of mechanical bonds – but once it was removed very high yields of a functionalised [2]catenane resulted. The structure was proved beyond a doubt in 1985 with an X-ray crystal structure. By removing the copper atom, the phenanthrolines had moved 11 Å – the first example of *translational isomerisation*.

Sauvage went on to use metal templating to make [3]catenates (*Angew. Chem.* 1987, vol. 26, p. 661), a

prototype for the synthesis of high molecular weight polycatenanes, and the first molecule knot – a trefoil, the simplest non-trivial knot being reported in 1989 by Sauvage (*Angew. Chem.* 1989, vol. 28, p. 189) and a doubly interlocked [2]catenane, the so-called Solomon's link (*J. Am. Chem. Soc.* 1994, vol. 116, p. 375). The synthesis of a trefoil effectively crossed the boundary between art and science. Like Eaton's 1964 synthesis of cubane, Sauvage's synthesis of a trefoil knot is clearly a result of logic; in the construction of a synthetic strategy, it is also art, not only the simple beauty of the product, but also in the cleverness of the approach. To quote a master of synthesis, E.J. Corey:



[2]catenane



trefoil



Solomon's link

The synthetic chemist is more than a logician and strategist; he is an explorer strongly influenced to speculate, to imagine, and even to create. These added elements provide the touch of artistry, which can hardly be included in a cataloguing of the basic principles of Synthesis, but they are very real and extremely important ...

During the 1990s, Sauvage and his research group designed and synthesised a large series of multicomponent transition metal complexes. For example, in collaboration with the Fujita group (University of Tokyo), Sauvage was able to get quantitative yields of [2]catenanes and Solomon's links using palladium (Fujita) and copper (Sauvage).

The challenge now was to instil utility into these molecules and the first step would require the interlocked systems to move in a controllable way. This was the focus of Fraser Stoddart's research at Sheffield but also became a focus of Jean-Pierre Sauvage's group

in the late 1990s and 2000s. Sauvage had already demonstrated the movement of [2]catenanes when uncomplexed (see above), and in 1996 he was able to demonstrate an electrochemically controlled translation in [2]catenanes by incorporation of phenanthroline and terpyridine in the macrocycles. Copper(I) tends to complex the two phenanthroline residues in a tetrahedral complex, but when oxidised to copper(II) it tends to an octahedral configuration, switching to the terpyridine ligands, thus creating a controllable motion.

Catenanes, rotaxanes and knots opened the door to new areas of chemistry as well as structurally more complicated motors, machines and nanotechnology. Along with catenanes and rotaxanes, knotted molecules are now commonplace components of integrated molecular machines, often displaying emergent properties that are more than just the sum of their parts.

In common with other great scientists, Sauvage identified a big problem and brought a solution. To do this, he ventured into a chemical wasteland that had been largely forsaken by other chemists since the 1960s and created a niche for himself through the application of transition-metal-templated macrocyclisation to make topological molecules. He was soon joined by hundreds of other research groups that elaborated his original ideas and made beautiful interconnected molecules and even machines.

In the next issue, we will look at the contributions of Fraser Stoddart and Ben Feringa, who took topological molecules, translational isomerisation and photochemical isomerisation and turned them into switches, motors and nanomachines.

Peter Karuso FRACI CChem FRSN is Professor of Chemistry at Macquarie University, Sydney. Part II will appear in the next issue.

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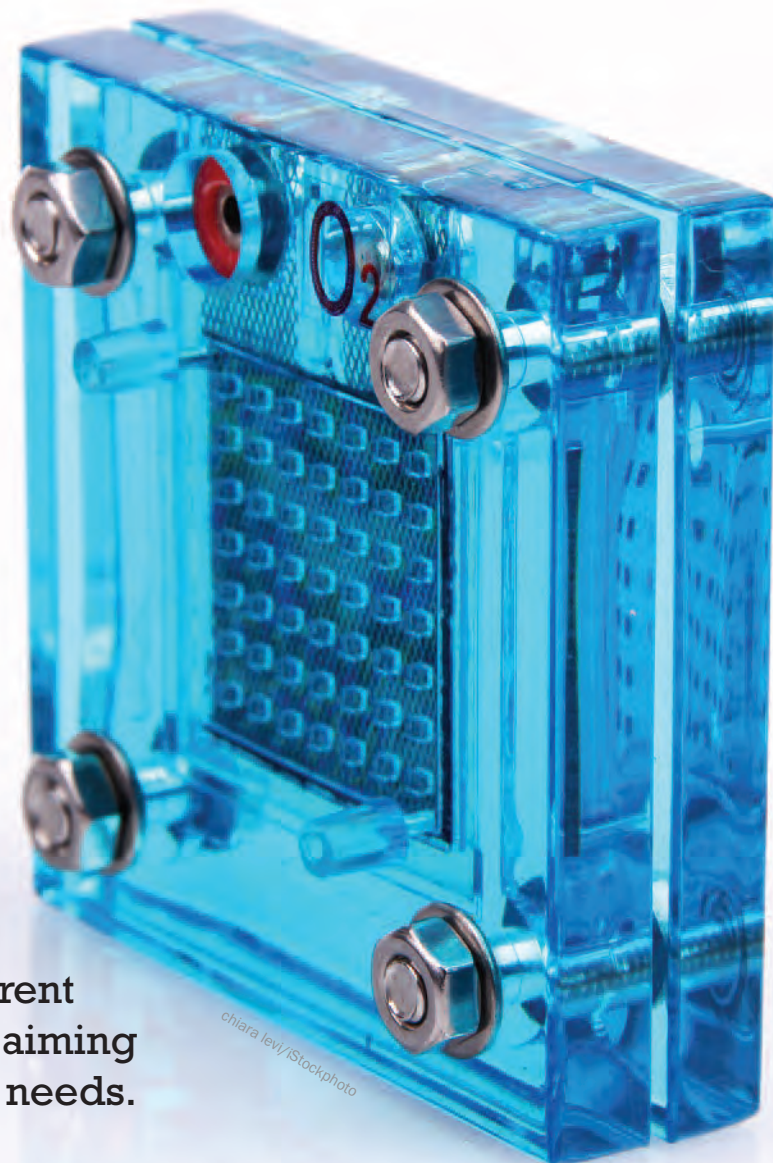


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From thin air

Seeking the next source of transport energy

Dave Sammut explores current and emerging technologies aiming to meet future transport fuel needs.



More than ever before, society is turning to the scientific community to offer the solutions by which people can have their cake and eat it too. We're being asked to bring forth viable alternatives to a fossil fuel economy, without compromising on standards of living or consumer culture.

Like my hero, Scotty of the Starship Enterprise, we might grumble that 'ya cannae change the laws of physics', but the fact is that every day science is making strides towards the better future demanded of us.

The current problem is the issue of energy for transport. Starting in the 1800s, but most particularly over the past century, cheap, readily available transport has transformed society across the globe. This has become a critical vulnerability because, even with a ten-year horizon, there is no transformative technology to step into the looming fossil fuel shortfall.

Transport, effectively, is an issue of chemical energy density. The internal combustion engine converts chemical energy to thermal energy, then in turn to mechanical energy. Ignoring the losses to extract the fossils fuels from

the earth and transport them to the point of use, the efficiency of the conversion is only around 20%. So the energy contained per unit mass of fuel is critical to the performance.

There are really only two alternatives to fossil fuels for transport, again both relying on chemical energy density: batteries and fuel cells. In both cases, chemical energy is converted to electrical energy, and then in turn to mechanical energy. The efficiency of these engines is much higher (potentially >80%), but to date the issue has been in achieving practical energy density at practical prices.

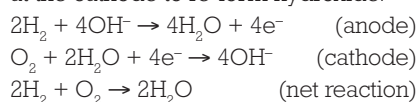
... the key difference with both batteries and fuel cells is that the chemical energy might – in theory at least – be restored in a cyclic process, albeit one that in turn requires further energy, most commonly from non-renewable sources.

Unlike fossil fuels, the key difference with both batteries and fuel cells is that the chemical energy might – in theory at least – be restored in a cyclic process, albeit one that in turn requires further energy, most commonly from non-renewable sources.

Fundamentally, batteries and fuel cells are very similar. The difference is that in batteries the chemical mass is contained and static, while in fuel cells the reagent mass can flow through the cell, and may be partially sourced from atmospheric gases (just as in combustion engines).

And just like the myriad battery technologies, there are quite a few fuel cell technologies. I'm going to discuss just three, due to their comparatively advanced development.

First, there's the alkaline fuel cell. This is pretty much the original practical version, developed for the US space program in the 1950s. It uses hydrogen and oxygen, with a potassium hydroxide electrolyte. In simple terms, hydrogen gas is oxidised with hydroxide at the anode to form water, while oxygen is reduced at the cathode to re-form hydroxide.

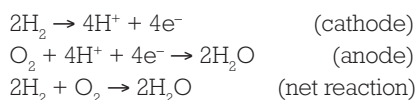


The chemistry is virtually ideal in concept. It is based on readily available, abundant elements, with completely safe wastes. With the exception of the oxygen cylinder explosion on the famous Apollo 13 mission, it was particularly ideal for space missions because both the reagent gases and wastes had dual purposes in the vessel's environmental systems.

However, alkali fuel cells aren't practical for terrestrial use because carbon dioxide can't be effectively removed from either of the reagent gases. Neither hydrogen nor oxygen can be readily produced at sufficient purity.

This problem is avoided in the fuel cell being most commonly considered for transport purposes: the proton exchange membrane fuel cell (PEMFC). Here, the KOH electrolyte is replaced with a 'polymer electrolyte' that will only permit the passage of the protons.

Hydrogen is catalytically split into protons and electrons at the anode. These protons can permeate the membrane to the cathode (to react with oxygen), while the electrons are forced to 'make the loop' through the electrical circuit.



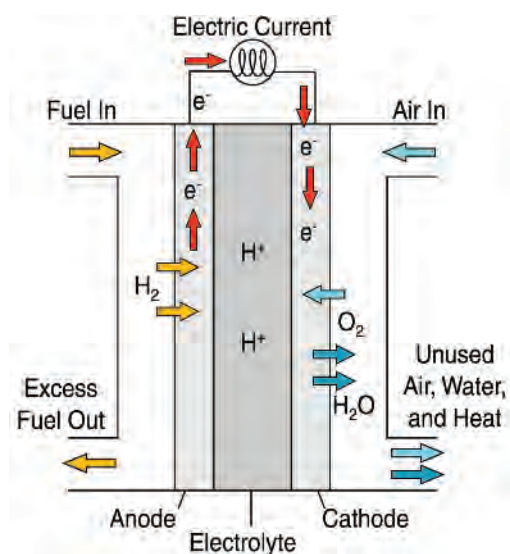
Each couple generates approximately 0.7 V of potential, requiring stacked cells. These operate at comparatively low temperatures (typically 60–80°C), and can potentially be developed into engines that are compact and light enough to be used for transport purposes.

By contrast, solid oxide fuel cells (SOFCs) use a solid electrolyte, most commonly yttria-stabilised zirconia (YSZ). Oxygen is oxidised at the anode to anions, which are transported through the electrolyte to the cathode:

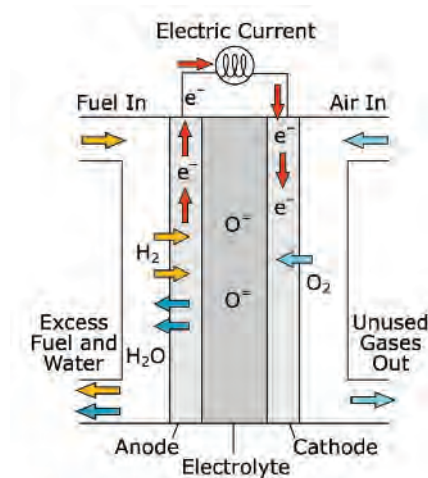


SOFCs require high operating temperatures (typically 800–1000°C)

and can use a variety of fuels. They offer significant potential for large-scale continuous base-load operation, possibly as an adjunct to industrial wind and solar power generation.



A proton exchange membrane fuel cell.
Mattuci [CC0], via Wikimedia Commons



A solid oxide fuel cell.
Sakurambo, via Wikimedia Commons

Both PEMFCs and SOFCs face major technological challenges in materials and cost, but both appear to offer significant potential benefits as part of the solution to the looming energy crisis. So how close are these fuels cells to commercial application?

In his State of the Nation address in 2003, US President Bush announced a Hydrogen Fuel Initiative, inclusive of a planned US\$1.7 billion investment over five years 'to develop hydrogen-powered fuel cells, hydrogen infrastructure and advanced automotive technologies'.

This announcement followed closely on the heels of a report by the US Department of Energy that analysed the state of hydrogen fuel cell technology, and identified six key areas for detailed investigation (including basic research):

- catalysis
- nanostructured materials
- membranes and separations
- characterisation and measurement techniques
- theory, modelling and simulation
- safety and environmental issues.

While considerable advances have been noted in all of these areas in the intervening decade, we have yet to see the fundamental breakthroughs that would bring fuel cell technology to widespread commercial use. And in that same time, considerable advances in battery technology have seen electric vehicles take the lead in the race to market.

At least part of the issue has been politics. Many observers interpreted Bush's Hydrogen Fuel Initiative announcement as a means of staying wedded to traditional fuel paradigms, and history showed that the majority of the money earmarked for fuel cell research was ultimately diverted into research into incremental improvements in conventional combustion engine technologies. *Issues in Science and Technology* notes that of US\$1.6 billion spent under the related programs in the decade to 2012, only US\$500 million was spent on

fuel cell research, and often not on critically needed basic research (bit.ly/2eT9PvW).

For many observers, electric vehicle and fuel cell technologies do not seem at all incompatible. There is a range of hybrid vehicles on the market that use combustion engines to top up electrical storage, and a similar suggestion has been very sensibly made to use fuel cells in place of the combustion engine to do exactly the same.

While inventor Elon Musk has been famously dismissive of fuel cell technology – at one point referring to it as 'incredibly silly' – his primary objections appear to be hydrogen storage and infrastructure, which are widely accepted as two of the major drawbacks to commercial PEMFC take-up.

In this respect, recent news from RACI Fellow Professor Richard O'Hair might represent another incremental step. In a recent article in *Nature Communications* (doi: 10.1038/ncomms11746), O'Hair and colleagues used silver catalysts to produce hydrogen from formic acid at PEMFC operating temperatures (70°C), producing CO₂ as waste.

The ability to store hydrogen and the infrastructure for refuelling are both important commercial considerations for PEMFC technology. Transferring hydrogen under pressure requires dedicated infrastructure, and is potentially too slow for general transport purposes. O'Hair's approach would have the advantage of potentially being able to use existing technology and infrastructure to transport, store and deliver the formic acid. Vehicles could potentially continue to use existing fuel tank technology, and the fuel would be potentially both safer and more palatable to the public.

However, the large-scale production of formic acid would sacrifice many of the greenhouse gas advantages of hydrogen fuel cells. In the associated press release, O'Hair noted that

While the safety of hydrogen has been given significant consideration, as well as the need to change public perception of a gas that has been demonised since the *Hindenburg*, there appears to have been little subsequent research on environmental issues.

'... there are still many barriers to overcome, such as the production of carbon dioxide and how it could potentially be recycled to regenerate formic acid.'

Another issue that has been raised is the potential environmental issues of a hydrogen economy. While the safety of hydrogen has been given significant consideration, as well as the need to change public perception of a gas that has been demonised since the *Hindenburg*, there appears to have been little subsequent research on environmental issues. One obvious question would be what effect, if any, would the inevitable leakages of hydrogen gas have on the atmosphere, and particularly the ozone layer?

While PEMFC technology currently requires considerable platinum for the catalyst (which, in turn, contributes to the current high cost), progress is being made in both reduction (to date, from about 80 grams to about 30 grams) (*Nature*, doi: 10.1038/

SOFC multifuel automotive system under development



Nissan's SOFC system test bench. The system generates electricity from ethanol and air to charge the battery.

Nissan Motor Co. Ltd. is researching and developing an SOFC-powered system that runs on bio-ethanol electric power. The new system – a world first for automotive use – features an e-Bio Fuel-Cell with an SOFC power generator. The SOFC fuel cell uses the reaction of multiple fuels, including ethanol and natural gas, with oxygen to produce electricity with high efficiency.

The e-Bio Fuel Cell generates electricity through the SOFC (power generator) from bio-ethanol stored in the vehicle. The fuel cell uses hydrogen transformed from fuel via a reformer and atmospheric oxygen, with the subsequent electrochemical reaction producing electricity to power the vehicle.

The fuel cell affords greater power efficiency to give the vehicle cruising ranges similar to petrol-powered cars (more than 600 kilometres). The car has distinct electric-drive features, including silent drive, linear start-up and brisk acceleration.

Nissan Motor Corporation

4641262a) and substitution – such as with gold nanoparticles (bit.ly/2fASHyL) – another aspect of science that is advancing rapidly.

Faced with a seemingly insuperable challenge, scientists across the globe are incrementally advancing towards solutions. The large manufacturers are backing these efforts. Toyota and Honda both have significant vested interests in hybrid and electric vehicle technologies, yet both also have fuel cell concept vehicles and significant R&D programs in the field.

I don't know how the technologies will shape up over the decade and more to come, but I predict that we won't see just one become reality. Material science, electrochemistry, nanotechnology and much more will combine and diverge, and multiple solutions will emerge to address the problems that we see.

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



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Getting involved in the national awards is a great way to celebrate RACI's centenary year.

One of the most important roles of the RACI is recognition and promotion of the contributions and achievements of members. Applying or nominating others for an award is a significant way to be involved in the Institute, particularly in its centenary year. It's an opportunity to reflect on and be recognised for contributions to and achievements in chemical science by colleagues and other RACI members,

particularly in the centenary year. For early-career chemists, it's the chance to be supported to travel for professional development. It's an impressive addition to your resumé, too.

Read about this year's national award winners on page 28 and find out more about the awards below. After that, apply or nominate someone for a 2017 award!

As a researcher, my hope is that my work will make a contribution to our general knowledge and scholarship. I feel receiving an award from RACI is a measure of acknowledgement of this aspiration, as RACI represents the body of researchers whom I hold in highest regard.

Professor Eric Kennedy, 2016 Applied Research Award recipient



Applied Research Award

The Medal shall be awarded annually to a full member (MRACI and above) of the RACI who, in the opinion of the Board of the RACI, has contributed significantly towards the development of, or innovation through, applied research, or in industrial fields. This contribution shall be judged on evidence submitted to the adjudicating panel.

Citations

There are a considerable number of chemists – members of the RACI – who make substantial contributions to chemistry, and, especially to the progress of the profession over a period of many years. To provide recognition of these contributions, the RACI has initiated an award entitled The RACI Citation.



Cornforth Medal

The Board of the RACI awards the Cornforth Medal, a bronze relief medal bearing the words 'For a Thesis on Chemical Research' commemorating the work of Sir John Cornforth AC, CBE, FRS. The medal is designed to give recognition of outstanding achievement in chemistry and to promote chemical communication.



Distinguished Contribution to Economic Advancement – Weickhardt Medal

This Award shall be made every year to a full member (MRACI and above) of the RACI who, in the opinion of the judging committee, has contributed significantly towards the economic advancement of the Australian economy through work in the chemistry area. The Award shall consist of a medal, named the Weickhardt Medal.

Distinguished Fellowship

Inaugurated in 1996, a Distinguished Fellowship is the recognition of highly distinguished contributions to the profession in academia, government or industry and the RACI and is awarded on, or very close to, retirement from the candidate's principal professional role. Distinguished Fellowships do not carry financial or postnominal implications. Rarely would there be more than three Distinguished Fellowships awarded per year.

Fensham Medal for Outstanding Contribution to Chemical Education

The RACI introduced the Fensham Medal for Outstanding Contribution to Chemical Education to recognise outstanding contributions to the teaching of chemistry and science in general over an extended period. It is intended that the Fensham Medal be the most senior award for education in the Institute.



H.G. Smith Memorial Award

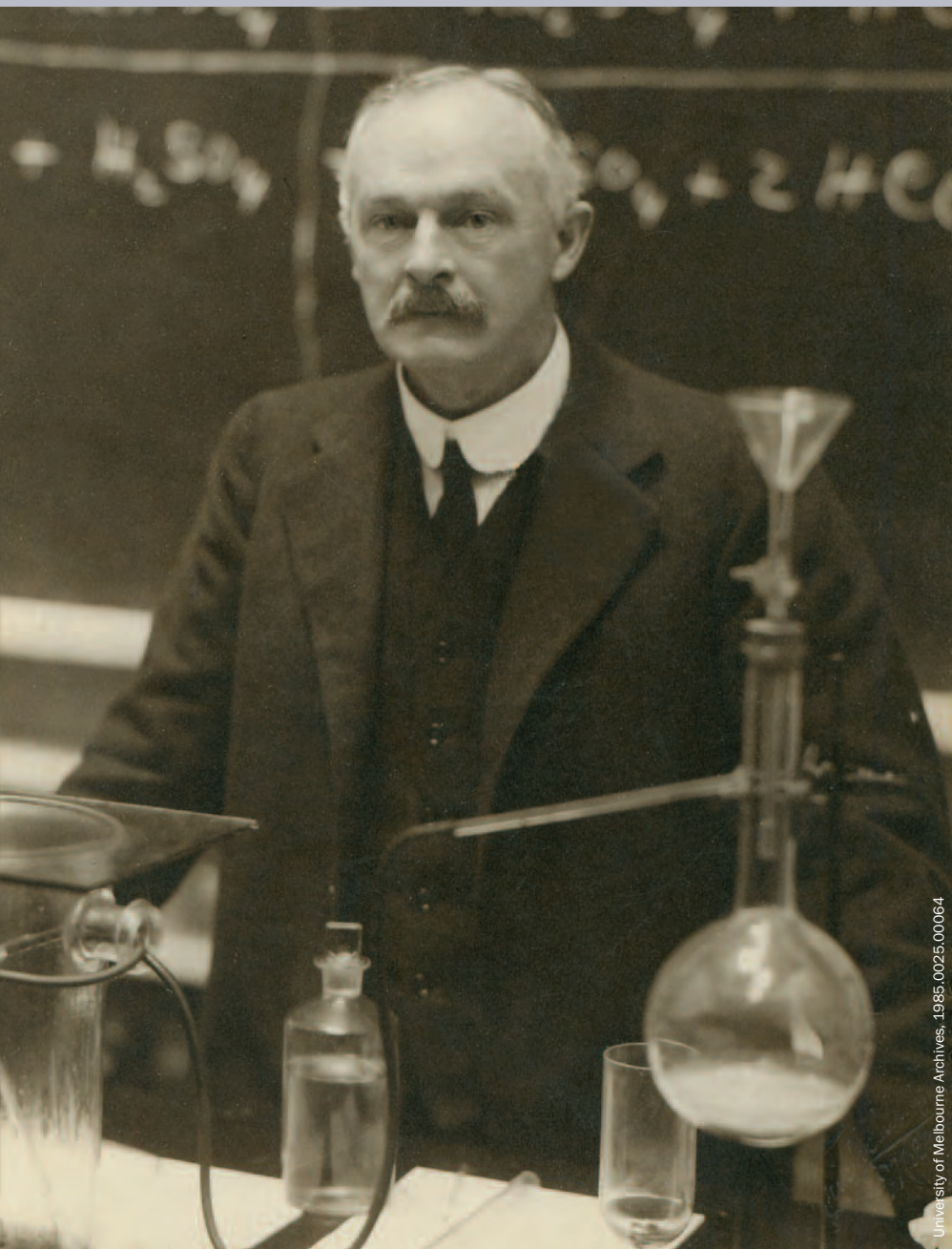
The H.G. Smith Medal shall be awarded annually to a member of the RACI who, in the opinion of the RACI Board, has contributed most to the development of some branch of chemical science; this contribution will be judged by research work published or accepted for publication during the ten years, or equivalent relative to opportunity, immediately preceding the award.

I am surprised and honoured to receive this award and particularly pleased to be the first woman to receive it – I hope it will encourage many more young female chemists to continue in chemistry.

Professor Michelle Coote, 2016 H.G. Smith Memorial Award recipient

Award names: remembering distinguished chemists

Many RACI awards and medals have been named after distinguished Australian chemists, including founding member of the Institute Sir David Orme Masson (pictured). Find out more about their contributions to chemistry in the *Encyclopedia of Australian Science* (www.eoas.info) and in the biographical memoirs of the Australian Academy of Science (www.science.org.au/fellowship/fellows/biographical-memoirs).



University of Melbourne Archives, 1985.0025.00064

Professor David Orme Masson, standing in the chemistry theatre at the University of Melbourne. Professor Masson was Professor of Chemistry and founder of the Melbourne University Chemical Society and its first President, 1904–24. (Colin Sach collection; photo by Kricheldorf, 1913)

Leighton Memorial Medal

The Leighton Memorial Medal commemorates the distinguished career of A.E. Leighton. The Award was established in 1965 through the generosity of his daughter, Miss Anne Leighton. It is the RACI's most prestigious medal. A.E. Leighton CMG, FRIC, FRACI MICHemE, died in 1961 after a distinguished career as a chemist, technologist and administrator, in which he had served Australia's interests in both war and peace.



Masson Memorial Award

This Award has been established as a memorial to the late Sir David Orme Masson, Founder of the RACI. The award is open to any financial member of the RACI or to any financial student of the RACI, who has attained the academic qualification of BSc or its equivalent, and who is eligible to proceed for a further year's study of chemistry at BSc Honours level, at either a university or other approved institution in Australia.

The process of applying for this award was really helpful – it gave me a chance to think about all the teaching I'd been involved in, and the impact that it had on my students. It is great that this award places value on teaching activities.

Dr Elizabeth New, 2016 RACI Chemistry Educator of the Year Award recipient

MRACI Post Graduate Student Travel Bursary

The RACI has introduced the Graduate Student Travel Bursary to assist Post Graduate Student members of the Institute to travel professionally from their home institution.

2017 is the RACI centenary year and to emphasise the importance of our 100 years, the award will be modified. For the 2017 Bursary criteria, check the RACI website www.raci.org.au/events-awards/awards.

RACI Chemistry Educator of the Year Award

This award has been established by the RACI for academics whose primary activity is teaching in the chemistry discipline. The award is designed to encourage developing teachers, and is open to tutors, lecturers and senior lecturers (academic levels A, B and C) teaching in undergraduate or postgraduate university courses.

Rennie Memorial Medal

This medal is awarded by the RACI for excellence in research in Chemical Science.

How and where to nominate

You can apply for some of these awards yourself; others require nomination.

See www.raci.org/awards or email awards@raci.org.au for more information about the requirements for nominations for each award. **All national awards except the Post Graduate Student Travel Bursary (closing date 30 April) close on 31 August.** Winners are notified by 30 September. Visit www.raci.org.au/events-awards/division-awards for Division-based awards, and Branch websites (listed at www.raci.org.au/branches/list) for Branch awards.



2016 RACI National Award winners

Applied Research Award



Eric Kennedy FRACI CChem obtained his BSc (Pure and Applied Chemistry) with 1st Class Honours from the University of New South Wales in 1985, and a PhD in Physical Chemistry from the same institution in 1989.

Following a year as a research fellow at Macquarie University, he moved to the US, where he was research fellow at Texas A&M and then Yale University. Eric joined the Department of Chemical Engineering at the University of Newcastle in 1994 and was promoted to professor in 2006.

Since arriving in Newcastle, he has built an active group, undertaking research in the areas of environment protection and energy-related projects. His current interests include the large-scale storage of CO₂ using the process of mineral carbonation, a non-destructive process to treat fluorine-containing synthetic greenhouse and ozone-depleting gases, exploring technologies to convert waste glycerol into useful products, developing catalysts for conversion of ventilation air methane as well as exploring the use of a solid oxide fuel cell (SOFC) for conversion of waste or low-grade fuels for power generation.

Citation: Contributions to Chemistry and the Chemical Profession



Clifford Jones FRACI CChem is a graduate of the University of Leeds (BSc 1974, PhD 1977, DSc 2005). He worked in Australia during 1978–95. His thesis supervisor at Leeds was B.F. Gray, whom he followed to Macquarie University. Clifford went from there to the R&D Department of the then State Electricity Commission of Victoria, where his interest in low-rank coals was implanted. After four years there, he went to the University of New South Wales, School of Chemical Engineering and Industrial Chemistry, in 1987 until 1995 when he went to the Department of Engineering at the University of Aberdeen, from which he departed in 2014 having risen to the grade of reader. After a short time in the Former Soviet Union (where, because of his students' schedules, all his lecturing had to be done at evenings and weekends), he came to the Gippsland Campus of Federation University Australia as an adjunct professor.

Clifford's interests have been in fuels and combustion. His extensive publications list includes 23 books. The most recent is *Lignites: their occurrence, production and utilisation* (Whittles Publishing, Caithness, 2016) and he had the privilege of formally presenting a copy of this to Darren Chester MP during his recent official visit to Federation University. Clifford has major broadcasting experience and has held a number of visiting appointments, notably at Massey University in New Zealand

where he has a long-standing collaborator. He has participated in conferences in countries including the US (seven times), Hong Kong, New Zealand, India, Kuwait and Bahrain. He is a Fellow of the Royal Society of Chemistry.

Cornforth Medal



Carol Hua MRACI CChem completed her PhD in 2016 under the supervision of Dr Deanna D'Alessandro at the University of Sydney on the development of multifunctional redox-active materials (molecular complexes, metal-organic frameworks and porous organic polymers) whose properties can be altered as a function of redox state. Her honours project on Rh, Ir and Ru hydroamination catalysts, completed under the supervision of Professor Barbara Messerle at the University of NSW in 2011, earned her the University Medal in Chemistry.

Carol is currently a postdoctoral researcher at the University of Limerick, Ireland, with Professor Mike Zaworotko, working on the development of porous materials as sensors for CO₂ and for the storage and delivery of NO in biomedical applications.

In May 2017, Carol will commence a postdoctoral research position as a Dow Chemical Company Fellow of the American–Australian Association at Northwestern University with Dr David Harris, focusing on stimuli-responsive magnetic materials.

Fensham Medal for Outstanding Contribution to Chemical Education



Joe Shapter FRACI CChem obtained his PhD from the University of Toronto in 1990 working with Professor J.C. Polanyi on the detection of small molecules and the determination of their energies. From 1990 to 1996, he worked at the University of Western Ontario (London, Ontario) building a scanning tunnelling microscope and lecturing first year chemistry.

In 1996, he moved to Flinders and is now Professor of Nanotechnology and Dean of the School of Chemical and Physical Sciences. Joe led the establishment of and was the course coordinator for the Flinders Bachelor of Science Degree in Nanotechnology (2000–3, 2007–11). This was the first degree of its kind in the world.

He was the founding Director of the Defence Science and Technology Organisation (DSTO) funded Centre of Expertise in Energetic Materials and is currently the Director of the South Australian node of the Australian Microscopy and Microanalysis Facility.

His group works generally in the area of nanotechnology, using various techniques to examine material on the micrometre or nanometre scale. Work with carbon nanomaterials and other novel 2D materials is an active area of research in his group. These materials have been used for applications in areas such as sensing and solar cells.

H.G. Smith Memorial Medal



Michelle Coote MRACI CChem is a graduate of the University of New South Wales, where she completed a BSc (Hons) in industrial chemistry (1995), followed by a PhD in polymer chemistry (2000). Following postdoctoral work at the University of Durham, UK, she joined the Research School of Chemistry, Australian National University, in 2001, initially as a postdoctoral fellow with Professor Leo Radom. She established her own research group in 2004 and was promoted to Professor in 2011. Michelle has published over 200 papers in the fields of polymer chemistry, physical organic chemistry and computational chemistry, and is a member of the ARC Centre of Excellence for Electromaterials Science. Michelle has received many awards, including the 2001 IUPAC prize for young scientists, the RACI Cornforth Medal (2000), Rennie Medal (2006) and David Sangster Polymer Science and Technology Achievement Award (2010), the Le Fèvre Memorial Prize of the Australian Academy of Science (2010) and the Pople Medal of the Asia-Pacific Association for Theoretical and Computational Chemistry (2015).

In 2014, she was elected to the Fellowship of the Australian Academy of Science, and has recently been appointed as an Associate Editor of the *Journal of the American Chemical Society*.

Le Fèvre Memorial Prize (Australian Academy of Science and RACI)



Cyrille Boyer MRACI received his PhD from the University of Montpellier II (École Nationale Supérieure de Chimie de Montpellier, France) in 2006. At the end of 2006, he joined the Centre for Advanced Macromolecular Design as a senior research fellow.

In 2013, Cyrille was promoted to associate professor at the University of New South Wales and received the University of NSW Research Excellence Award at the Faculty of Engineering and was a finalist of NSW innovation award in 2014.

Cyrille's research interests mainly cover the use of photoredox catalysts to perform living radical polymerisation and polymer post-modification, hybrid organic–inorganic nanoparticles for imaging and drug delivery, and energy storage. Cyrille has published over 150 research articles, including seven patents, which have gathered over 6000 citations.

RACI Post Graduate Student Travel Bursary

The following students have won a travel bursary: Dylan Innes, Emma Watson, Joseph Collins, Karin van der Pal, Mohammadamin Haghighatbin, Prashant Mujumdar and Thomas Telfer.

Leighton Memorial Medal



Mark Buntine FRACI CChem completed a BSc(Hons) and MSc at Monash University before undertaking PhD studies in Chemistry at Stanford University, then postdoctoral studies at Yale. Buntine commenced his academic career at the University of Adelaide (Chemistry) in 1994, rising to full professor in 2007. From 2003, he served as Head of Chemistry, and then he moved to Curtin University in 2009 as Head of Chemistry. Since early 2014, Mark has also served as Deputy Chair of Curtin's Academic Board and often as Acting Head/Dean of Science.

Mark is a physical chemist with a well-established record of using laser-based techniques to explore gas-phase chemical reactivity, *ab initio* computational chemistry and the chemistry associated with the formation of metal nanoparticles via laser ablation. Together with collaborator Scott Kable, Mark cofounded the successful APCELL/ACELL/ASELL project in 1999. This project has made significant contributions to improving student learning in the laboratory, both in Australia and internationally, and the concept has now moved into secondary education to help improve the learning outcomes of middle school (years 7–10) students undertaking science experiments.

Mark has devoted more than 20 years of continuous service to the RACI: South Australian Branch committee, Treasurer Physical Chemistry Division, SA Branch President, Physical Chemistry Division Chair, RACI President and currently Chair of the Committee for the RACI Centenary Congress. As President, he overhauled the

RACI accreditation procedures for Australian university degrees and initiated a constitutional change to include up to two non-chemistry experts on the RACI governing board, providing flexibility to address the increasing complexity on not-for-profit corporate governance.

RACI Chemistry Educator of the Year Award



Elizabeth New MRACI undertook her undergraduate and masters studies at the University of Sydney before completing her PhD studies in 2010 at the University of Durham (UK). Elizabeth was then a Royal Commission for the Exhibition of 1851 Research Fellow at the University of California, Berkeley.

In 2012, she returned to the University of Sydney, holding an ARC DECRA 2012–14, and a Westpac Research Fellowship from 2016, focusing on the development of small molecule chemical sensors for the study of oxidative stress and metal ions in biology. Her research awards include the NSW Young Tall Poppy Award (2015) and the Premier's Prize for NSW Early Career Researcher of the Year (2016). She was the 2014–2015 RACI NSW Nyholm Lecturer, and currently serves on the executive for the Early-Mid Career Researcher Forum.

Elizabeth significantly redeveloped the second-year laboratory curriculum, incorporating a range of research-led investigations, and helped to lead the school-wide redesign of first-year teaching, involving the use of weekly video, self-assessment tools and in-class active worksheets. She was awarded the University of Sydney Vice-Chancellor's

Award for Excellence in Teaching (2015), and an Office of Learning and Teaching Australian Award for Teaching Excellence (2015).

Rennie Memorial Medal



Ravichandrar Babarao MRACI CChem graduated with a PhD in Computational Chemistry from the National University of Singapore in July 2010. His research focused on accelerating the discovery of novel porous materials for efficient gas capture and separation applications using computational modelling. He was awarded a competitive postdoctoral research associate position at Oak Ridge National Laboratory, Department of Energy Laboratory, USA. He then moved to CSIRO Material Science and Engineering as a SIEF postdoctoral fellow in Dr Anita Hill's group and was later promoted to research scientist.

During his time at CSIRO, he focused on developing structure–property relationships by combining theory and experiments in order to tailor the properties of materials for efficient CO₂ capture and conversion.

Ravichandrar recently moved to RMIT as a senior research fellow in the School of Science and has a visiting scientist position at CSIRO.

His progress as an early career researcher is outstanding; he has published more than 45 papers in international peer-reviewed journals and has attracted more than 2000 citations with an *h*-index 23.

New RACI board member receives Victorian Tall Poppy Award

Newly elected RACI Board member Katherine Locock MRACI has received a Victorian Young Tall Poppy Science Award for her research into antimicrobial polymers. She was among ten leading young researchers recognised late last year with Young Tall Poppy Science Awards at a ceremony at Swinburne University.

Locock's research focuses on novel antimicrobial polymers that take inspiration from naturally occurring antimicrobial peptides. These peptides, which are typically produced as part of an organism's immune system, are of particular interest because they display reduced susceptibility to the development of bacterial resistance. Locock has been able to identify and suitably mimic the essential structural features of these antimicrobial peptides using polymers, such that they retain the high potency antimicrobial effects and low human cell toxicity. This offers promising leads for the development of a new generation of antibiotics.

These winners showcase the diversity of research being carried out in Victoria. The Tall Poppy awards are run by the Australian Institute of Policy and Science (AIPS) to honour up-and-coming scientists who combine world-class research with a passionate commitment to communicating science. The awards are held on a state-by-state basis to celebrate researchers across science, engineering and mathematics.

'They are helping to be positive science ambassadors by working with the education and community sectors to encourage greater engagement in science,' said AIPS General Manager, Ms Camille Thomson.

As part of the Young Tall Poppy campaign, award winners will spend a year sharing their knowledge with school students, teachers and the broader community through workshops,



Katherine Locock and Greg Simpson FRACI CChem, RACI past President, at the Young Tall Poppy Science Awards night.

seminars and public lectures.

Young Tall Poppies are nominated by their peers and are early career researchers who have less than ten years' postdoctoral experience. Selection is based on research achievement and leadership potential. Over 500 young scientists have been honoured nationally since the awards were established in 2000.

Details of all winners are available at www.aips.net.au/tall-poppies.

With Australian Institute of Policy and Science

RACI Board members 2017

RACI Board members for 2017 were confirmed at the Annual General Meeting on 19 November 2016 in Melbourne. Newly elected/appointed Board members are Vicki-Anne Gardiner (President-elect), Katherine Locock (elected Board member) and Pamela Sutton-Legaud (appointed Board member).

Continuing Board members are Scott Kable (Honorary General Secretary) and Amanda Ellis and Tania Notaras (ordinary Board members). Peter Junk (previously President-elect) is now President and Steven Langford (previously ordinary Board member) is Treasurer.

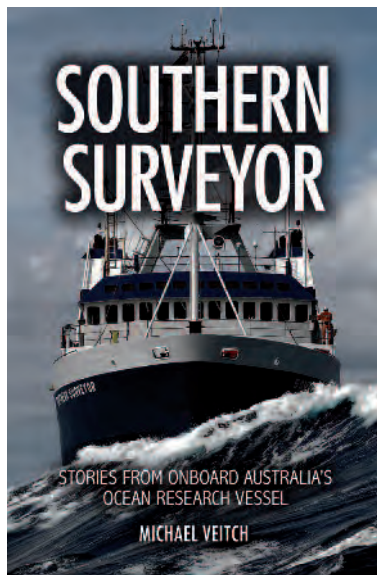
Outgoing Board members are Paul Bernhardt (President), David Edmonds (Treasurer) and Matthew Sykes (appointed Board member).

Board member profiles are available at www.raci.org.au/theraci/board-profiles.

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Southern Surveyor: Stories from onboard Australia's ocean research vessel



Veitch M., CSIRO Publishing, 2015, paperback, ISBN 9781486302642, 272 pp., \$35

Southern Surveyor is a collection of stories about the voyages completed by an ocean research vessel and the people who sailed on her. The book begins with a retelling by the author, no other than Michael Veitch of ABC comedy series fame and author of several other books, of his first on-board visit on *Southern Surveyor* while moored at CSIRO's Marine Laboratories on the Derwent River, Hobart. The ship had

finished its 10-year and nearly 500 000 nautical miles of research voyages as CSIRO's Marine National Facility (MNF), being replaced by the made-to-order and aptly named *Investigator* research vessel in 2014. To mark *Southern Surveyor's* retirement from duty, Michael Veitch was commissioned for a year to interview people who knew and worked aboard the vessel and catalogue her history and achievements. The author admits his scientific illiteracy several times in the book and it is to his great credit he took this commission on. He certainly manages to explain the significance of *Southern Surveyor's* work and the bond the crew and all working aboard developed with her.

The book's chapters are arranged on the type of staff working on or with the vessel, namely oceanographers, crew, geoscientists, support staff, biologists and other MNF staff, with each chapter consisting of stories and research achievements recounted by a staff member in one-on-one interviews with the author. A lovely touch to each chapter is a quote from the staff member concerned, which sets the scene for the chapter. The chapters are diverse in content, which adds to the book's readability, but all have a common thread of completing or supporting amazing scientific research under sometimes trying conditions and overcoming unforeseen problems with the resources available.

The scope of the research in which the *Southern Surveyor* was engaged was amazingly varied, from studying huge current eddies off Western Australia's Rottnest Island, plankton and rock lobster larvae numbers to algal blooms and unusual ocean stratification events. Extensive geoscience studies were also completed, including seabed dredging for oil and gas source rocks and seabed mapping, which often uncovered huge

unexpected geological features such as submarine volcanic craters and submerged carbonate reefs. Sometimes the micro and macro would meet, with one 'plankton scientist' recounting a story where a deep trawl for plankton resulted in the fine, so-called 'EZ net' being snagged on a whale skeleton!

The book also describes a large variety of very interesting equipment that was used on the vessel to conduct research. One reason the *Southern Surveyor* replaced the previous ocean research vessel, the *Franklin*, was because of its spacious rear deck and much vaunted 'A frame' from which heavy equipment could be winched to and from the water. This included the sonar 'gondola' mounted below the ship's hull for seafloor mapping, a heavy duty seafloor rock dredge nicknamed 'Sherman' (as in the tank), the ever-present CTD (conductivity, temperature, depth) device that surveys the oceans at different depths, and 'SeaSoar', a plane-like robot towed by the ship to collect a variety of ocean data while profiling the seabed.

The book's most impressive feat is how Veitch manages to make the very committed scientists he has interviewed into real people, which they are of course, but so often not portrayed as such in other books and the media. A summary of each scientist's very impressive career is given in each chapter and how and what led them to working on the *Southern Surveyor*, and often includes statements of sheer delight regarding the opportunity to work on such a research vessel. They form a real bond with the ship and the rest of the research and support staff, creating an extremely strong team environment.

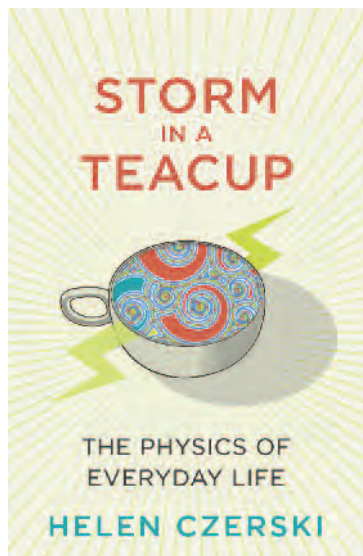
Southern Surveyor was a book I enjoyed immensely, not only as an entertaining read, but also as a window into the complex world of oceanographic research and how it helps us understand our planet's history and perhaps predict its future. I am a bit concerned potential readers may be put off by the scientific subtitles used in each chapter, although they are printed in smaller text next to the scientist's name. However, once they start reading the first few lines of the book, which most people do while browsing, I'm sure they will be 'hooked'. The book's last chapter looks to the future and briefly describes the MNF's present research vessel, the stunning *Investigator*. I hope we don't have to wait for its retirement to read about the scientists and support staff who sail in her.

Alf Larcher FRACI CCChem

John Wiley & Sons books are now available to RACI members at a 20% discount. Log in to the members area of the RACI website, register on the Wiley Landing Page, in the Members Benefits area, search and buy. Your 20% discount will be applied to your purchase at the end of the process.

Receive 25% off Elsevier books at www.store.elsevier.com (use promotion code PBTY15).

Storm in a teacup: the physics of everyday life



Czerski H., Bantam Press, 2016, paperback, ISBN 9780593075432, 320 pp., \$34.99

Storm in a teacup: the physics of everyday life is a book that reflects on many of the fundamental forces that have shaped and continue to shape our world. Author Helen Czerski currently studies weather and climate through understanding the formation of bubbles underneath ocean waves. She lectures in mechanical engineering at University College London and is a sought-after BBC presenter and newspaper columnist.

Storm in a teacup employs straightforward and approachable language to form a vivid window into the Earth's patterns, many of which would often be explained through pages of mathematical formulas, intelligible only to a select few. This divergence from the usually complex discussion of scientific concepts allows a wider audience to be drawn into the physics of our world.

Storm in a teacup develops from a series of nine chapters, each considering a physical topic such as gravity, magnetism, surface tension or waves. The unique structure of the chapters allows the discussion to progress from a simple question, such as 'Why don't ducks get cold feet?' or 'How do we describe waves?' Looking back when the end of the chapter is reached, that first simple question has transformed into an examination of the physical world around us.

The 'Making waves' chapter provides an example of such a progression, forming a complex pattern of its own. The discussion begins by describing waves at the beach, how waves form in places like Hawaii, and then how light waves travel through media such as water. The next part of the chapter begins to describe how a device such as a toaster transforms heat to light waves, with a segue into a description of how we are surrounded by light waves on Earth, particularly from the Sun. By the end of the chapter (via a number of other discussions, including the greenhouse effect and radio waves), the reader has gained a deep appreciation for the functions of waves, although they are for the most part invisible.

For anyone who is interested in the forces that shape the world around us, *Storm in a teacup* is an enjoyable way to learn much more, in a manner that is immediately accessible. And for those of us who wish to share our passion for science with friends and family, the book's enthusiasm creates a means to deeper discussions and greater understanding.

Samantha Profke MRACI

**Our 2017 media kit
is now available at
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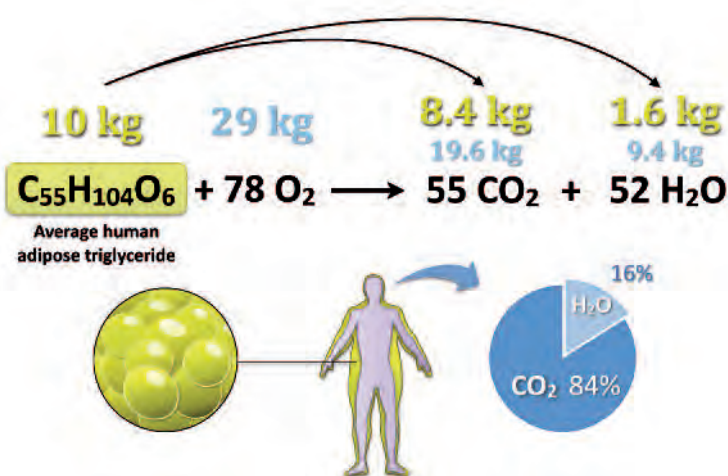
For further information,
contact Marc Wilson at
Gypsy Media Services:
marc@gypsymedia.com.au,
0419 107 143

A breath of fresh air

Ruben Meerman's *Big fat myths, when you lose weight, where does all the fat go?* (see review in Dec 16/Jan 17 issue, p. 36) appears refreshingly different from the usual diet of diet books. It has chemical equations!

Hence this column.

Let's start with the introductory figure, originally from a Christmas issue of the *British Medical Journal* (bit.ly/2fqMmSi) and described by Meerman as his 'pride and joy'.



Meerman R., Brown A.J. When somebody loses weight, where does the fat go?
BMJ 2014; 349, <http://dx.doi.org/10.1136/bmj.g7257>

There are three ways of looking at this equation:

- 1 Stoichiometry shows the atom balance: 10 kg of fat reacts with 29 kg of oxygen to produce 28 kg of carbon dioxide and 11 kg of water.
- 2 The loss of fat comes 77% from carbon, 11% from oxygen and 12% from hydrogen.
- 3 Fat's carbon and hydrogen atoms can only go to carbon dioxide and water respectively, whereas it was demonstrated 50 years ago that the oxygen atoms in burning fat are scrambled between carbon dioxide (4) and water (2).

The pale blue numbers in the diagram show this distribution of (all the)* oxygen.

The result is that 84% of the weight of fat goes to carbon dioxide and 16% goes to water, as shown in the figure.

$$\frac{660 \text{ Da } (C_{55}) + 64 \text{ Da } (O_4)}{860 \text{ Da } (C_{55}H_{104}O_6)} \times 100 = 84\%$$

$$\frac{104 \text{ Da } (H_{104}) + 32 \text{ Da } (O_2)}{860 \text{ Da } (C_{55}H_{104}O_6)} \times 100 = 16\%$$

*The diagram suggests and the *BMJ* article seems to state that the 29 kg is only from the external oxygen, not including fat oxygen.

This is normalised in the figure (dark blue numbers) to 10 kg of fat.

The clear message is that the measured carbon dioxide in the exhaled breath is totally correlated with the amount of the fat 'burned' and acts as surrogate measurement for that process, as indeed used by sport scientists

Ruben Meerman, a one-time physicist, the Sydney Surfing Scientist, media presenter and now PhD candidate in biochemistry, conducted comprehensive surveys on the understanding of this mass balance concept by professionals (doctors, nutritionists, dieticians and personal trainers). Their understanding was very low. So what hope the general public?

His argument is that the concept of mass balance is more fundamental to an understanding of weight gain and loss.

The chemical equation (left) measures the amount of fat metabolised from the amount of carbon dioxide exhaled (84%). Sure, the rest is water (16%), which is not immediately lost but instead is recycled; however, it is ultimately excreted mainly as urine and sweat. A similar equation would apply to carbohydrates for which the average carbon content is 40%.

At rest, an average 70-kilogram person consuming a mixed diet (respiratory quotient that accounts for the different energy values of the food components, taken here as 0.8) exhales about 200 millilitres of carbon dioxide per breath at a rate of 12 breaths per minute. Each of those breaths therefore excretes 33 milligrams of CO_2 , of which 9 milligrams is carbon.

Say you spend three lots of eight hours asleep, at rest, and performing light activities, respectively. This will double the resting metabolic rate overall and you will exhale 740 grams of carbon dioxide so that 202 grams of carbon are lost from the body. Artificially breathing faster doesn't help because you just dilute the normal exhaled level of carbon dioxide (4%).

Conclusion? Your loss in weight depends on how much you eat compared to the carbon dioxide you breathe out. Obviously, you can control the former with your appetite. You can influence the latter to a greater or lesser extent by the activities you engage in.

Supermarket food labels provide the calorific value of the food (in kJ and kcal) but don't give the available carbon content. However, data are available for estimating carbon out, depending on what you do every day. Ruben directs us to a tabulation called the Compendium of Physical Activities (bit.ly/2fqK9Gt).

The first lesson to be (re-)learned is that it is not only how much the BMR is raised by exercise but also the time spent that counts, so Ruben argues that running fast for a short burst is equivalent to jogging for a longer time or just walking for longer still. 'Light activities' can also mean just doing a lot of domestic jobs around the house. Raising the metabolic rate to seven times that of resting by jogging removes an additional 39 grams of carbon per hour from the body, raising the total by about 20% to 240 grams. But this is roughly the same as three

to four hours of domestic chores. In each case the increased rate applies during the activity and for a variable time afterwards. This allows you to calculate how much stored fat you can expect to be reduce.

While you can increase the time spent exercising, you can't increase the time spent breathing beyond 24 hours. Breathing is the rate-limiting step for the amount of stored fat you can lose (for a particular amount of exercise).

People who don't seem to put on weight in spite of what they eat are often found to be micro active; that is, they are always anxiously on the move and/or they fidget. And the amount of energy used by this tends to be underestimated.

The second lesson is to consider the digestible carbon content of the food intake. For pure sugar and fat that is easy.

The 40 grams of sugar in a can of soft drink produces 60 grams (33 litres) of carbon dioxide (equivalent to 55 party-sized balloons) and that takes around 1840 breaths to exhale. For that many breaths, you need an hour and forty minutes (at rest).

Ruben goes through a range of meals and calculates the time needed to exhale their carbon. For this, the rated kJ for each food digested was converted back to grams of carbon.

Jamie Oliver's classic spaghetti carbonara, as per published recipe, yields 87 grams of carbon that will take almost ten hours to exhale, while a slice of Donna Hay's banana bread cake

At rest, an average 70-kilogram person consuming a mixed diet (respiratory quotient that accounts for the different energy values of the food components, taken here as 0.8) exhales about 200 millilitres of carbon dioxide per breath at a rate of 12 breaths per minute.

contains 50 grams of carbon; a teaspoon of butter on top adds a further 3 grams. The carbon dioxide from this snack would take six hours to exhale. Even a medium cappuccino (300 millilitres) contains 15 grams of carbon requiring a two-hour breathing spell before the next if a weight gain is to be avoided. Don't even go to the Big Mac and large Coke unless you want a 12-hour breathing breather to break even.

This is all very sobering. (Ruben doesn't do alcohol.)

The approach of using conservation of matter rather than expenditure of energy is better. High-school chemistry students should find this personal approach closer to the bone.

Digestible carbon in, compared to carbon breathed out, totally determines weight gain or loss. And chemistry is agnostic regarding which diet achieves this best.

Overall, the total energy comes from weak bonds in food forming strong bonds in carbon dioxide (and water) and is fixed, and in the end it all comes out as heat.

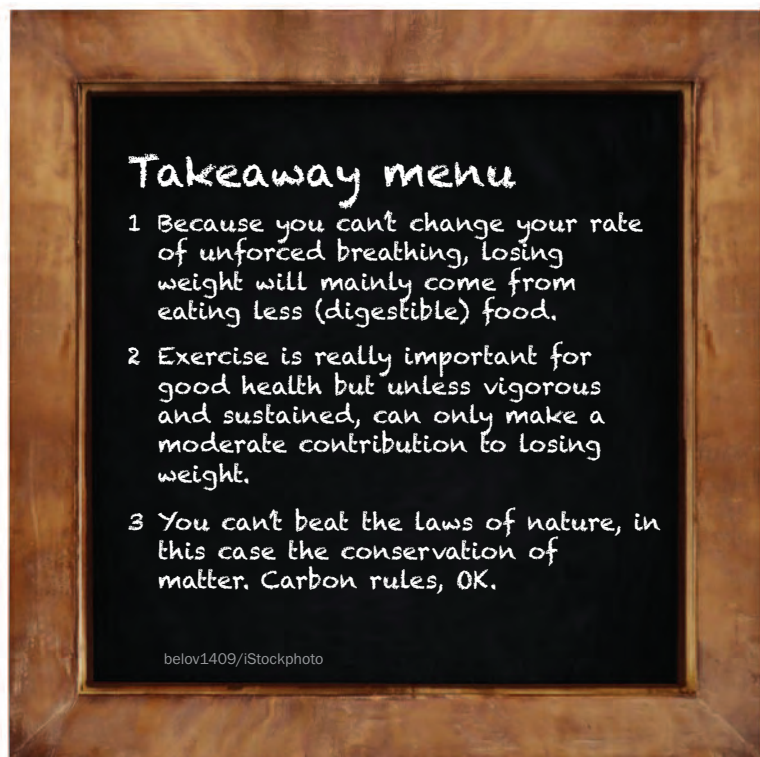
Our packaged food will continue to be labelled in kJ energy not kg of digestible carbon. Conversely, our bathroom scales will still measure kg and are unlikely to switch over to kJ you need to expend (or better still, not eat) since last stepping on.

However, a more effective public health message might be delivered if manufacturers were required to label food with 'Just balancing a serving of this food requires x hours of breathing'. The limit that nobody breathes for more than 24 hours a day is hard to dispute!

So, to dispose of your adipose, breathe thoughtfully.

And think long and hard before you have that next Rueben sandwich.

Ben Selinger FRACI CChem is Emeritus Professor of Chemistry at ANU and, along with ANU colleague Associate Professor Russell Barrow, will be releasing the sixth edition of *Chemistry in the Marketplace* (CSIRO Publishing) in June 2017.



Ammonia – fertiliser production at a crossroads



Ammonium phosphate plant in Queensland.

The fertiliser industry is based on the production of synthetic ammonia for the production of nitrogenous fertilisers. These fertilisers have revolutionised food production and allowed seven billion people to exist on the Earth without frequent mass starvation events. Nitrogen fertilisers are particularly important for the growth of grass and cereal crops – wheat, rice, barley, sugar cane etc. – the main staples for most people.

Today, about 120 million tonnes of synthetic ammonia are produced for fertiliser production. The main fertiliser product is urea, which, as a stable solid, can be transported in bags on trucks and shipped by bulk carriers from various production sites to the farm. Fertiliser is also delivered as ammonia itself, as a dilute solution, and can be shipped in specialist tankers (many of which also ship LPG) and as a compressed liquid piped to distribution centres.

There are other nitrogen fertilisers such as ammonium sulfate (produced as a by-product from processes using sulfuric acid) and ammonium phosphate. These fertilisers also deliver other important elements (sulfur and phosphorus) to plants. Adding potassium salts (potash) produces complex fertilisers, delivering the three most important growth elements (N, P, K) for vegetables and flowering plants.

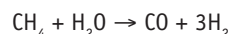
The primary route for the uptake of nitrogen in the plant requires oxidation of the ammonia to nitrate. Ammonium nitrate is therefore used as a solid fertiliser for immediate impact, delivering nitrate directly to a plant. However, ammonium nitrate is dangerous and is used as an explosive. Its use as a fertiliser is restricted in many countries. In Australia, there is a large demand for blasting explosive in the mining industry and large quantities are produced for this purpose. So ammonia manufacturers in countries such as Australia supply both nitrogenous fertilisers (as urea) and blasting explosives (as ammonium nitrate/diesel slurry).

Because the supply of fertiliser is critical to a country's well-being, feedstock, fertiliser production, distribution and price to the farmer are often controlled by central governments. This often takes the form of subsidies to producers and farmers so as to minimise the farm input cost. This restricts the extent of international trade so that the lowest cost producer is often excluded from the market. Australia is not in this camp and

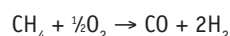
production here has to be competitive with other low-cost producers around the world.

In the export trade, the lowest cost producer is often considered to be Russian/Ukraine operations based on the Black Sea, and many other low-cost producers, such as those in the Middle East, reference export prices as a premium or discount to the Black Sea price.

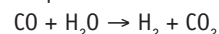
The major feedstocks used for the production of ammonia are natural gas and coal. These feedstocks are used to produce synthesis gas (a mixture of hydrogen and carbon monoxide) by steam methane reforming or partial oxidation (known as gasification in the case of coal). From methane, the basic reaction is:



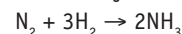
or by partial oxidation



The carbon monoxide is converted to hydrogen by the water-gas-shift (WGS) reaction and the residual carbon dioxide is removed by an absorption process.



Nitrogen is added via a partial oxidation step of residual methane or using air in the partial oxidation/gasification reaction. This produces the ammonia synthesis gas required for the high-pressure conversion into synthetic ammonia:

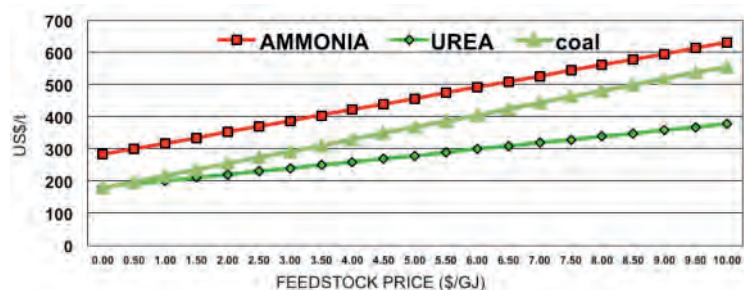


In many facilities, the carbon dioxide produced in the WGS reactor is added to the ammonia at pressure to produce urea:



One quirk in the production of urea is that substantially all of the carbon in the methane feedstock ends in the product and thereby reduces the producers' carbon emissions. However, on application by the farmer, the urea is oxidised to produce carbon dioxide and the nitrates required for plant growth so that overall there is no carbon emission benefit. In considering carbon taxes, who pays for the emissions is moot – the manufacturer or the farmer.

Typical production costs are illustrated in the graph for the production cost of gas-based ammonia, urea and ammonia from coal. These are plotted as a fixed variable with the variable being the feedstock price (coal or gas) in energy units (\$/GJ).



Influence of feedstock costs on ammonia and urea production costs.

The plots are for typical new world-scale operations: ammonia 850 kt/year, urea 1500 kt/year and coal/ammonia 1200 kt/year. Approximate construction costs are for late 2015 with the gas-based ammonia and urea plants having a three-year construction period and the coal facility requiring four years. The estimate is for new gas-based facilities with similar construction costs to Australia with a 30% loading over US Gulf construction costs. These are compared to a coal-based ammonia facility in a western China location with a capital cost discount of 30% relative to US Gulf.

The gas-based plants have a thermal efficiency of 65% and the coal plant has 60%. No by-product credits are assumed, though in reality these could be significant if the facility could export power; coal processes also produce by-products such as ash for cement and sulfur.

The gas-based ammonia plant has the highest unit capital cost (\$/t), which determines the fixed costs and is hence the top line. The lowest unit capital cost (\$/t) is for urea, which contains a large amount of unwanted material in the CO moiety in the molecule and is hence the bottom line.

From the top line of the table, which is the cost of ammonia production from natural gas (methane), it can be seen that at a gas price of \$2/GJ (which is the typical mid-2016 gas price at Henry Hub in the US) the estimated production cost is about \$350/t. This is below the quoted ammonia cost of \$400/t in late 2015 but is about \$50/t above the mid-2016 price. Given that the cost of ammonia transport by ship is typically in the range \$50–100/t, an Australian-based plant with these statistics would be profitable against ammonia import. If gas was available below \$2/GJ, which may be the case in Western Australia, then export opportunities may still be profitable at the current low ammonia prices.

Unfortunately, this is not the case with ammonia plants on the eastern seaboard where the volatility in the cost of natural

Typical quoted Black Sea export prices and typical gas prices (US\$)

	Second half 2015	Mid-2016
Ammonia (\$/t)	400	300
Urea (\$/t)	290	200
US Gas (Henry Hub) \$/GJ	2.0	2.0
East coast gas (wholesale)		~6



Orica Kooragang Island ammonium nitrate manufacturing plant, New South Wales. © Copyright 2016 Orica Limited

gas (see October 2015 issue, p. 36) as a consequence of the establishment of large export LNG facilities now results in wholesale gas prices of about US\$6/GJ (A\$7/GJ), which delivers production costs well above the world parity price at \$492/t. This production cost is above current ammonia import costs even on a cash-cost basis when no capital charges are considered.

A similar situation occurs for the production of urea where high east coast gas prices currently being paid undermine the profitability of urea production against imports.

The cost of coal production in China (and in large open-cut mines in Australia) is well below \$2/GJ (typically \$30–45/t) at the mine. Run-of-mine coal is often used for gasification and ammonia production. At these feedstock prices, and given the low capital cost of Chinese facilities, the ammonia production cost is below world parity prices.

Clearly, the production of ammonia for an Australian east coast fertiliser manufacture is at a crossroads. If the east coast gas crisis is not resolved in the coming months, then we are likely to see facility closure and import of fertiliser into Australia. Without domestic production placing a cap on the prices charged by importers, prices to farmers will inevitably rise, placing further stress on the agricultural industry.



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Vinegar bicarb with a twist

I am a huge fan of chemistry demonstrations that surprise people. Any time a demonstration surprises someone, they are instantly engaged and begin to think and ask questions: 'What was that?' or 'How does that work?' These moments when a scientific curiosity is sparked in someone tell me I am doing my job well.

As an avid science show presenter actively involved in engagement and outreach, these moments of inspiration are what I strive for. In my career so far I have worked with audiences from preschool to university level, as well as general public audiences of all ages. While all of these experiences are rewarding, some of the most satisfying are those involving younger audiences. Children are natural scientists, showing curiosity and enthusiasm for anything and everything from a very young age. These traits should be nurtured and encouraged.

Often, my demonstrations involve materials that are hazardous and not generally available. Others require only the simplest household equipment. This one is my absolute favourite.

Warning: Children should be closely supervised when using matches and candles. Depending on age, it may be appropriate for an adult to conduct the experiment.

What you'll need

- 3 tea light candles
- Matches or a lighter
- Kitchen jug
- Vinegar (contains acetic acid)
- Bicarb soda (sodium bicarbonate)
- For a chemistry demonstration, I use a conical flask. For 'kitchen chemistry', you can substitute any clean container – taller jugs with a pouring spout/lip are best. If the container is too wide, you might have problems getting the experiment to work correctly. If the neck is too narrow, such as that of a soft drink bottle, you might end up with an overflow of vinegar and bicarb soda. This might make a bit of a mess, but kids will love it! A key part of science is learning from your mistakes, so simply clean up and try again.

What to do

- 1 Light the tea light candles.
- 2 Put about 30 grams of bicarb soda into the jug.
- 3 Slowly add vinegar and observe the reaction. The flask can be swirled to pop the bubbles more quickly, to avoid the mixture overflowing. Ideally, the bubbles will reach about halfway up the container.
- 4 Once the bubbles have died down, pour *very gently* over the flame of the candles, with the edge of the container as close to the flame as possible, making sure that none of the liquid pours out. It will appear to anyone watching that you are pouring nothing.
- 5 The flames should be extinguished!



What's happening?

There's so much science going on here. The main purpose of this experiment is to spark curiosity, so you could choose to discuss one or more of the concepts below depending on age and interests.

Acid-base reactions: The vinegar contains acetic acid (an organic acid), which undergoes a chemical reaction with sodium bicarbonate (an inorganic base). This reaction produces sodium acetate, water and carbon dioxide. Observing the formation of a gas is the key indication of a chemical reaction taking place in this experiment.

Gases: Gases and liquids together are known as 'fluids'. The carbon dioxide that is formed is more dense than air, which means that it sinks to the bottom of any container and can be poured.

Fire: Fire on a candle is a chemical reaction between the wax and oxygen in the air. When carbon dioxide is poured over the flame, the oxygen is displaced, causing the reaction to stop and the flame to go out.

Want a challenge? Pour some of the carbon dioxide into a second empty container before pouring it over the candles. The flask you are pouring from will appear to be completely empty!

Perhaps the most common response I hear from people when I mix the vinegar with the bicarb soda is 'I've seen that before'. I delight when I hear this because it lets me do two things. First, I can ask them to explain to me what they know about the experiment. Second, I ask them to wait until the final part because they generally have not seen this experiment all the way through.

So many other simple experiments can easily and safely be conducted at home. Visit the websites below for other engaging activities for all ages. Get amongst it and have fun!
www.stevespanglerscience.com/lab/categories/experiments/
chemistryscifun.chem.wisc.edu/homeexpts/homeexpts.html
www.csiro.au/en/Education/DIY-science



Jeremy Just MRACI is a Hobart-based PhD candidate in organic chemistry and a passionate science communicator, specialising in chemistry shows and demonstrations.

The electronic tongue

The electronic tongue for wine analysis burst onto the research scene in the early 2000s, following to some extent the introduction of the electronic nose. Professor Andrey Legin from St Petersburg University was one of the early proponents of the general applicability of the electronic tongue (ET) for food analysis in general and not just for wine (see bit.ly/2fDU2RV, now rather out of date). In his invited keynote lecture at the *In Vino Analytical Scientia* conference in Melbourne in 2007, Professor Legin presented data to demonstrate the broad possibilities of the ET for wine analysis because, with correct sensor design, reproducible responses to a range of compounds in wine could be achieved. These responses could also be calibrated in relation to human sensory perception.

For example, in 2003, Professor Legin, together with Dr Alisa Rudnitskaya (see bit.ly/2gfOX50) and other colleagues, reported the analysis of Italian wines and showed that, not only could the ET obtain an acceptable measurement of wine quality parameters, including acidity, ethanol, tartaric acid, SO₂ and total polyphenol concentrations, but it was also capable of predicting human sensory scores with average precision between 8% and 13% (see *Anal. Chim. Acta* vol. 484, pp. 33–44).

This work led to a flurry of activity with several publications appearing on the application of the ET for wines and fortified wines. As an example, collaboration between the St Petersburg group and the chemistry group at the University of Aveiro in Portugal led to fascinating applications of the ET for the prediction of the age of port wine, detection of cork contamination from Mancha Amarela (yellow spot; a potential marker for cork taint) and the quantification of organic acids and phenolic compounds in Madeira wines.

Dr Leigh Schmidtke, presently acting director of the National Wine and Grape Industry Centre in Wagga Wagga, worked with these two groups during his study of wine micro-oxidation (MOX). Using an ET consisting of an array of 26 potentiometric sensors, Leigh and colleagues looked at the influence of MOX and oak chip maceration on wine (*Anal. Chim. Acta* 2009, vol. 642, pp. 235–45), showing that the potentiometric-based ET could predict wine colour density and hue, as well as the total phenolic concentration and chemical age. Extending this study, Leigh examined the commonality between sensory, chemical and ET assessment of wines treated by MOX and oak chip maceration (*J. Agric. Food Chem.* 2010, vol. 58, p. 5025–33). The ET data showed good prediction of several sensory descriptors including oak, pencil shavings, stewed plum, vegetal and spice.

Critical to the success of correlating ET data with chemical or sensory scores is the use of the most appropriate chemometrics tool. Leigh, in collaboration with Professor Doug Rutledge of AgroParisTech, developed a 'Procrustes rotation and alignment of the chemical, electronic tongue and sensory data sets followed by PLS1 regression' to extract the ET/sensory descriptors mentioned above (see *J. Agric. Food Chem.* article

... not only could the ET obtain an acceptable measurement of wine quality parameters, including acidity, ethanol, tartaric acid, SO₂ and total polyphenol concentrations, but it was also capable of predicting human sensory scores with average precision between 8% and 13%.

above). While the name of this chemometrics technique might not roll easily off the tongue, the study shows clearly how powerful chemometrics tools can extract useful and meaningful information from complex data sets.

Two distinct types of ETs were used in these early studies, essentially based on sensor type: potentiometric or voltammetric. In reality, the critical point is finding a group of sensors that respond in a reproducible way to a group or class of compounds. This means that several sensors are commonly required. For example, in Leigh's work described above, the array of 26 sensors that was used showed sensitivity to phenolic compounds and organic anions and cations as well as some with a redox response. Sensor design is an on-going area of research (see Tahara and Toko, *IEEE Sensors J.* 2013, vol. 13, pp. 3001–11) with biosensors based on biological tissues being one area of potential advance in the use of an ET.

Even with all the initial euphoria, the possibility of the ET being used as a surrogate for wine analysis and sensory scoring seems to have diminished markedly over the last 5–8 years. It was therefore somewhat surprising to see a recent paper in *Talanta* (doi: 10.1016/j.talanta.2016.09.055) describing an ET for wine sensory descriptors. The proposal in this paper regarding the ability of the ET data to model taste scores made by sommeliers, while not particularly new, was sufficient for the paper to make a column in *New Scientist* (bit.ly/2fnv74l). The main conceptual advance in the *Talanta* paper would appear to be the use of voltammetric sensors, rather than potentiometric sensors that were commonly used in most previous studies.

In essence, I agree with the comments in the *New Scientist* article by Dr Heather Smyth from the University of Queensland (bit.ly/2giWor7) that attempting to replace the integrated responses of our human senses with an instrument is not possible. Now, it seems like time to get my taste buds back in action!



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Hallett Wind Farm, South Australia.

Ian Sutton, Collinsville and Oberon/CC-BY-2.0

Winds of change?

It was Adelaide, in 1980, and I was in my Honours year. It was just after 10 a.m., and I was about to start the day's work in the lab after an early lecture. But lo! The fumehood was hushed, the lights went out and the radio was silent. Power failure!

A quick trip around campus, to the library and the refectory, told me that this was more than just a blown fuse in the Chemistry building. Gradually, the news filtered through. Traffic lights were out in the CBD and hospitals were on emergency power. This was a blackout over a wide area. By mid-afternoon, we knew that 90% of the state had been blacked out because two maintenance fitters had accidentally cut off the fuel supply to the gas-fired power station that provided base load power. When that station went down, the rest of the system was overloaded and, one by one, the other power stations tripped out. By dinner time, much of the grid had been restored, and life went on, and the community accepted the explanation, if collectively shaking their heads in disbelief that such an event could occur.

Fast forward to September 2016 when wild storms damaged more than 20 transmission towers on multiple lines of the South Australian distribution grid. One by one, power stations tripped out, and finally the interconnector with the Victorian grid also tripped out, unable to take the increased load. The difference this time was that anyone with access to a mobile phone, including many public figures, took to social media to immediately claim that it was all the fault of renewable energy and that South Australia's grid was unbalanced. The wind turbines had stopped because the wind was too strong, they said. None of these comments, as far as I am aware, was attributed to an electrical engineer. Even days later, when images of grotesquely twisted transmission pylons had been widely shared, wind power was still copping the blame.

What I found noteworthy in the commentary about the 2016 blackout was that the collective memory of 1980 seemed to be missing in action. For South Australia to be without electricity was not unprecedented, but in 2016 it was treated as if it had never happened before. The scapegoating of renewable energy in general, and wind power in particular, was hardly surprising given the identities and political inclinations of some of the

commentators, many of them with no close connection to South Australia. What seemed missing from discussions in the calmer, more measured days that followed was any recognition of why renewable energy had been promoted. The case seems to be well made that CO₂ emissions to the atmosphere need to be reduced in order to arrest the potential for changing climate. The argument continues that any climate change is likely to affect a range of environmental settings, including melting icecaps, rising sea levels, Pacific Island Nations disappearing, and more weather events of greater severity.

The storms last year in South Australia would seem to fit the description of 'extreme', as the transmission towers were subjected to winds beyond the strength they were designed to withstand. Is this a sign of the times in other ways as well?

Around the time of the blackout, the media were discussing other evidence that global climate may be changing. Radio reports talked of increased numbers of polar bear incursions into human settlements, as the bears were driven from their usual locations by lack of ice. *New Scientist* also featured an article about thinning arctic ice. According to the travel media, the possibility of cruising the Northwest Passage, the Holy Grail of navigation between the Atlantic and Pacific Oceans, might soon be a reality because summer ice is receding further each year.

Even if you don't care about the fate of polar bears, or if cruising the Northwest Passage sounds appealing (if unaffordable), it seems that self-interest should be a motivator to do something about climate change. The affluent Western lifestyle, dependent on a regular electricity supply, will be threatened if damage to vital infrastructure continues. If the climate is changing and the weather continues to become more severe, will we need to keep upgrading and strengthening infrastructure to withstand stronger and stronger winds? When will the limit be reached, and how much will it cost? Isn't it rational to consider reducing emissions of CO₂, and so reduce potential for changing climate and its effects. Or is that just too hard?



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How to speak chemical

I only have to inspect successive editions of the Macquarie Dictionary to see new words entering the language or, sometimes, *trying* to enter the language that we speak in Australia. Many of these new words are used, at first, in small social and ethnic groups, from where they can spread into wider society. Politicians are adept at picking up new words, perhaps in attempts to show that they are 'with it'.

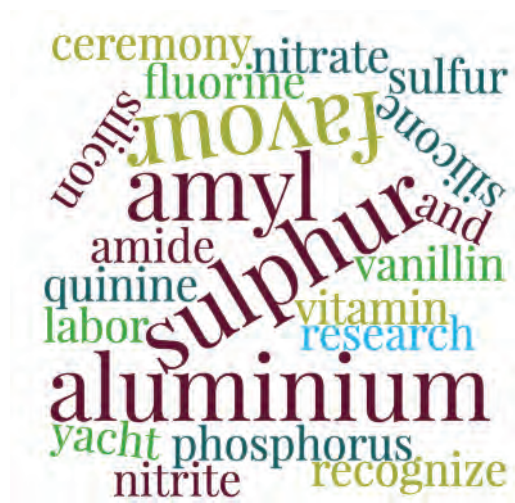
The spellings of some familiar words are changing, but many alternatives are long entrenched, ascribed by many to Cocacolonisation since the differences are most often between American and English spellings. Pairs like color/colour, favor/favour and labor/labour come readily to mind and then there are z/s examples like recognize/recognise, and c/s cases like defense/defence.

Pronunciations of everyday words change more slowly but examples can be heard, even on ABC radio. I hope you can follow my phonetic rendering of the words through the inclusion of double letters, breaking up syllables and sometimes underlining the part to be stressed. So I can juxtapose ceremoany/ceramunny (the latter with the Australian ugh sound that we use a lot, as in Melbunn, for instance). Sometimes it's just a matter of emphasis, as in Canbra versus Canberrar, or even more subtle as in tomayto/tomarto. For a really complicated case, I invite you to wonder why The Cousins pronounce solder as sodder, and say Caribbean rather than Caribbean, although I reckon there is some sense in yacht for what we say is a yott.

So far I have selected my examples from the public domain, but there are chemical examples, and I'll use some words from the borderlands to transition (a noun masquerading as a verb, to pick up another piece of pedantry) from the public to the chemical. For spelling, I give you sulfur/sulphur and aluminum/aluminium. Moving a bit further in, the American pronunciation of the bitter principle in tonic water, and old fashioned antimalarial, they call quinine while we stick to the short i, as in quineen.

We have our differences with the Old Country, too, although these are more often ascribed to idiosyncrasy or class-and-status in Australia. I'm thinking of r'search and re-search, vittamin and vitamin, and amidd for amide. Vanillin tends to be chemical usage, while public usage is more likely to be vanillin.

Sometimes the alternative spellings that I spot in the media are just plain wrong. Take phosphorous and phosphorus, for example. Phosphorus is the name of the element, a soft whitish substance that burns readily in air, but I often see 'phosphorous', which sounds the same. Phosphorous is the adjective that tells us that the substance contains phosphorus attached to three other atoms; its brother is phosphoric, when there are five atoms attached to phosphorus. So far, so good, but most phosphorous and phosphoric substances are given simpler and more systematic names that don't require knowledge of the code words. For example, phosphorus



trichloride (PCl_3) and phosphorus pentachloride (PCl_5) are both named that way.

Scientific journals where our research work is published gave up on sulphur many decades ago, and since then the editors (linguistic gatekeepers) have insisted on sulfur. In the humanities I still find sulphur, however. There are subtle differences in the naming of compounds based on sulfur, depending mainly on how many oxygen atoms are attached to each sulfur atom. Sulfuric acid (H_2SO_4) is a familiar substance although you would need to have some chemical education to appreciate the molecular formula, and more than a little of that education to recognise sulphurous acid (H_2SO_3). These acids are made by combining water (H_2O) with the sulfur trioxide (SO_3) and sulfur dioxide (SO_2), respectively. Adding up the atoms is a simple piece of arithmetic. The salts formed from these two acids require more special names, sulfates and sulfites, respectively. Calcium sulfate (CaSO_4) (plaster of Paris) and calcium sulfite (CaSO_3) (a laboratory curiosity) serve as examples. It's obvious to us, I suppose, but not to outsiders. Substance names with 'ite' endings are less common than those with 'ate' endings, which probably accounts for media confusion between the heart-starter, therapeutic substance and sometimes party drug – amyl nitrite – and the explosive amyl nitrate.

In the days when secretaries typed our papers, I encountered a problem when fluorine was rendered for me as flourine, a name that seemed more reasonable to a non-chemist. There was confusion, too, between silicon (the element) and silicone (polymer). Given the systematic name for the polymer, polydimethylsiloxane with repeating unit $-\text{O}-\text{Si}(\text{CH}_3)_2-$, you can see why the trivial name was invented.

I have heard it said that learning chemistry has all the elements (pun recognised) of learning a foreign language. It sure does!



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2nd European Organic Chemistry Congress

2–3 March 2017, Amsterdam, Netherlands
<http://organicchemistry.conferenceseries.com/europe>

Solutions for Drug Resistant Infections

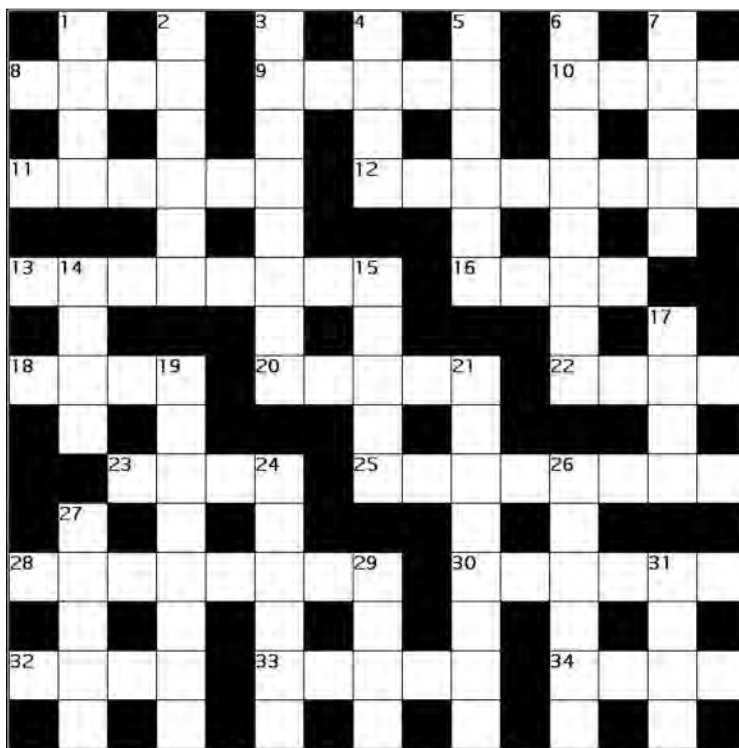
3–5 April 2017, Brisbane, Queensland
www.sdri2017.org

Australian Society of Cosmetic Chemists (ASCC 2017)

3–5 May 2017, Sunshine Coast, Queensland
<http://ascc.com.au>

International Conference and Exhibition on Pharmaceutical Nanotechnology

27–29 October 2017, Rome, Italy
<http://nanotechnology.pharmaceuticalconferences.com>



Across

- 8 See 30 Across.
 9 Model iodine agreement. (5)
 10 Limits aims. (4)
 11 Three elements in unknown mythical creature. (6)
 12 Present 13 Across covers. (8)
 13 Incorporated alternate and mused over. (8)
 16 An abundance of property. (4)
 18 First methyl isobutyl carbinol acetate sheet silicate mineral. (4)
 20 16 to 10: calculus?! (5)
 22 Staple first rinsed with hard water. (4)
 23 Four elements of aspiration. (4)
 25 Frame knot else undoes. (8)
 28 Our table at regular intervals. (8)
 30 & 8 Across *Beta Cephei* is one part/litre sulfur solution. (6,4)
 32 Additional rule of thumb with henium. (4)
 33 Acids with the structure $\text{RC}(\text{OH})_3$ next to each other. (5)
 34 Beginning of thin, end of lean. (4)

Down

- 1 Upon a head. (4)
 2 Many have a 20 Across output. (6)
 3 Bull! Iodine in money compounds with the formula $\text{R}(\text{NOH})_2$. (8)
 4 Burnt the midnight oil hanging on to a combustion chamber with a domed cylinder head. (4)
 5 Golly! Adding carbon to form a compound with the formula $\text{R}(\text{OH})_2$. (6)
 6 It's a logical conclusion. Leave in user mixture. (8)
 7 Promotion finished without a put on. (5)
 14 One 20 Across, perhaps. (4)
 15 Unusual solid compounds with the formula $\text{R}(\text{OH})_2$. (5)
 17 Repeat: last reactive aldehyde. (4)
 19 Liaised over nitrogen compounds formed by acylation of $\text{C}_6\text{H}_5\text{NH}_2$. (8)
 21 Novel 25 Across with radical addition of carbon to replace potassium and sulfur? Negative. (8)
 24 A small positive surrounding historically duller oration. (6)
 26 Is way out of place with S_2 . (6)
 27 Less than 4 short. (5)
 29 These two elements are perky. (4)
 31 These three elements connect. (4)

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