

chemistry

September 2014

in Australia



Maritime cultural heritage: are we treading water?

Enjoy great savings this season with your RACI benefits

Save \$72* per year on Movie tickets

Example savings made on 6 Adult and 6 Child Hoyts tickets when purchased through the Member Advantage website.

Save on international money transfers

Enjoy free transfers through Ozforex¹ as part of your benefits, with significantly lower exchange rates than banks.

Save \$300 per year on Restaurant bills

Example based on 12 restaurant visits with \$25 discount applied. Visit the Member Advantage website to find restaurants in your area.

Call RACI Member Advantage on **1300 853 352** or visit www.memberadvantage.com.au/raci

All savings listed 27/03/2014 and subject to change.

* Offer available to Australian residents only. 1) Offer includes free transfers under \$10,000 and 10 free transfers over \$10,000.



Q-POD[®] Element Unit Ultrapure water for trace element analysis

Reliable, efficient and economic delivery of ultrapure water suitable for elemental analysis, in the quantities you need.

The Q-POD[®] Element unit employs ultra-clean materials and a succession of optimised water purification technologies to produce 18.2 M Ω .cm resistivity ultrapure water (at 25 °C), ideal for trace analysis methods.

Foot-pedal activation is included to allow hands-free delivery in a clean area, which eliminates the need to touch the unit, and thus further reduces the possibility of contamination.

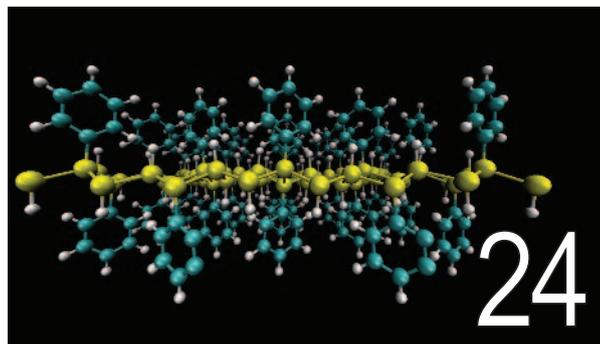
A built-in display provides information on all water purification system key parameters.

For more information contact Merck Millipore on 1800 335 571.

www.merckmillipore.com

Merck Millipore is a division of 





September 2014



cover story

Conserving ancient shipwrecks

Australians pioneered underwater cultural heritage conservation and have played key parts in the related UNESCO Convention, but we are yet to ratify it.

The 6938 ton aircraft transport vessel Fujikawa Maru, diver Bill Jeffery, 2002

16

20 Agricultural warfare

Agricultural innovation was a precursor to terrible conflict in the 20th century.

24 2D is the new 3D in nanotech

In nanomaterials research, super-thin is definitely 'in' because of its promising future in next-generation electronics.

28 Advanced spectroscopy

Ray Hodges considers three spectroscopy techniques linked to Nobel Prizes.

news & research

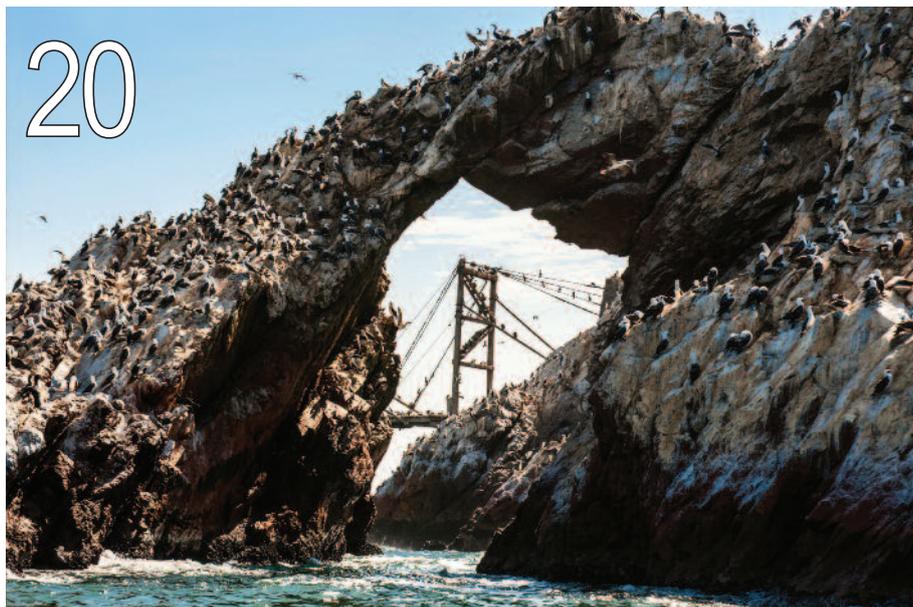
- 8 News
- 12 Research
- 42 Cryptic chemistry
- 42 Events

members

- 5 From the President
- 30 RACI news

views & reviews

- 4 Editorial
- 6 Your say
- 32 Books
- 34 MOOCs
- 36 Technology & innovation
- 38 Education
- 39 Grapevine
- 40 Postdoc diary
- 41 Letter from Melbourne



'Lite' chemistry in November

The year seems to be flying by, and this impression is stronger in my professional hours, when I'm often thinking months in advance.

So, as you read this in September, I'm asking you to cast your minds forward to November, when we'll be publishing a 'first' for *Chemistry in Australia* – and you're not invited! Well, that's not strictly true, but prepare to be sidelined.

November's unique edition is not just for you, but for those family members, friends and colleagues who are not of the chemistry persuasion. It will get them interested in what you do and encourage them to discover more about the ways that chemistry, whether they are aware of it or not, defines them and their natural and built environments.

Non-*Chemistry in Australia*? One contributor couldn't help but point out that the November issue will be appropriate: November was the ninth month in an early Roman calendar (from the Latin *novem*, meaning 'nine') and 'non' in organic chemistry denotes a nine-carbon chain. A humorous link, and a suitably light-hearted comment for the 'lite' chemistry edition to come. Our writers have responded to this forthcoming edition with enthusiasm, and we hope you enjoy the fruits of their ideas.

Colin Scholes' thought-provoking and very readable piece about permeate in milk (December 2012, p. 24) sparked a lot of general interest outside of our usual readership, with many RACI members discussing it with spouses and friends, and sharing it with colleagues in the tearoom at work. 'Why not a whole edition like this?' I thought.

I promise not to leave you out entirely – the November edition will still be related to the chemical sciences. The difference is that the content will be 'public friendly' and about topics that are likely to engage a general readership.

When you receive the November 'lite' chemistry edition, please pass it on. There'll be a downloadable pdf version on the website so that you can send it to as many people as you like. I'd really like to hear about what you and non-chemist readers think, so please share your opinions. A non-chemist piece might become part of the regular *Chemistry in Australia* fare.



Sally Woollett (wools@westnet.com.au)

Coming up

iStockphoto/lestyan4



Non-chemists rule in November!

So, what do chemists actually *do*?
 Chemistry in comic strips and at the cinema
 Swap screen time for science 'make and do'
 Cigarette butts: a toxic problem
 Questacon's director on cool chemistry events
 Top chemistry reading

chemistry
 in Australia
www.raci.org.au/chemaust

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

PRODUCTION EDITOR
 Catherine Greenwood
catherine.greenwood@bigpond.com

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



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

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

PRESIDENT
 Mark Buntine FRACI CChem

MANAGEMENT COMMITTEE
 Sam Adeloju (Chair) Sam.Adeloju@monash.edu.au
 Tatiana Anesbury, Helmut Hügel, Alan Jones,
 Amanda Saunders, Colin Scholes, Curt Wentrup

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

© 2014 The Royal Australian Chemical Institute Inc.
 Content must not be reproduced wholly or in part without written permission. Further details on the website.
 ISSN 0314-4240 e-ISSN 1839-2539



From the President

The RACI constitution, as amended 1 November 2011 (available at www.raci.org.au, under the Corporate Governance section), defines the Board as being the governing body of the Institute with legal powers and authority conferred under the Victorian Associations Incorporation Act 1981, as amended. The Constitution clearly articulates that, with the exception of limitations of law or matters required to be exercised by the RACI in General Meetings (Annual or Special), the affairs of the RACI shall be managed by the Board.

The Constitution defines that the Board shall consist of eight persons, all of whom shall be Corporate Members of the RACI: the President, President-Elect, Honorary General Secretary, Honorary General Treasurer and four elected Corporate Members. The President, President-Elect, Hon. Gen. Secretary and Hon. Gen. Treasurer, informally operating as the Board Executive, are directly elected by the total membership of the RACI.

The four Board members without portfolio responsibility are from the following electorates:

- *National* – the total membership of the RACI
- *North Eastern* – only RACI members residing in Queensland, New South Wales and the Australian Capital Territory
- *South Eastern* – only RACI members residing in Victoria and Tasmania
- *Western* – only RACI members residing in the Northern Territory, South Australia and Western Australia.

The President is the Chair of the Board and the President-Elect serves as Deputy Chair of the Board.

The RACI Board is required by the Constitution to establish an Assembly. The Assembly must include representatives of Branches and Divisions and exists to provide advice to the Board on a range of professional matters.

In essence, this governance arrangement has been in place since the RACI became an incorporated body under the Victorian Associations Incorporation Act in 2000; only minor constitutional changes, such as defining the President as Chair of the Board, have been made since 2000. After almost 15 years of operation, it is timely to review whether this governance model still meets the current and future needs of the RACI. Any changes to the structure and composition of the Board will require constitutional amendment, and thus careful consideration by all RACI members.

Over the past 15 years, many dedicated and hard-working members from across the country have served on the RACI Board with distinction. There is no suggestion that the performance of any Board, current or past, has in any way been problematic. Rather, it is timely to consider whether even better outcomes and engagement with RACI members can be achieved by alternative Board structures.

Although they were originally appointed to ensure RACI members in all geographic parts of Australia have a voice on the Board, the three regional Board members have played an ill-defined role, and true engagement with their electorate has

been problematic. In the absence of any clear constitutional demarcation of responsibility between a regional Board member and their local Branch Presidents, these Board members have defined the scope of their role individually.

The overwhelming majority of RACI member activities are organised by its eight state and territory Branches and 14 specialist Divisions. The Constitution defining the current Board structure remains almost silent on how Branch and Division perspectives may be explicitly considered beyond the Assembly (an advisory process held annually face-to-face and bimonthly via teleconference). Collectively, it is the RACI Divisions and Branches that actively engage with our members and the external community through conferences, awards, competitions and other outreach activities. These activities represent the vast majority of RACI financial turnover and are for many the most tangible benefits of RACI membership. It can be considered a significant corporate risk for the largest financial and member-benefit engines of the RACI not to have explicit representation at Board level.

For many organisations, changes in governance structure can be challenging for many reasons; a key one is engagement and communication with its members on the need for change. A discussion paper (Green Paper) has been prepared by the current Board to provide all RACI members with the opportunity to understand the potential benefits of possible changes to the Institute's governance and to contribute to the discussion as to what changes might be supported. The Green Paper is available on the RACI website, or can be obtained from the National Office staff upon request.

Contemporary practice in many member-based (not-for-profit) organisations like the RACI is to have their boards provide a sense of vision, strategic oversight and direction-setting expertise. A board has to be the source of inspiration for the attainment of goals that it sets and is responsible for the way in which the organisation achieves its goals. It also needs to develop standards to measure good performance effectively.

These roles are quite distinct from management (recall, the current RACI constitution defines the role of the Board as to *manage* the RACI's affairs). A challenge for the RACI is to formally evolve our Board structure from a management body to one that can provide the strategic oversight required for the future prosperity of our Institute. The Green Paper argues the case for change and makes several proposals for how the structure and composition of the RACI Board might change to best achieve strategic outcomes. I encourage all members to consider the Green Paper and contribute to the debate.



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

Vale Noel Cant

Earlier this year, Macquarie University lost one of its most highly respected academics. After a determined battle, Emeritus Professor Noel Cant MRACI CChem succumbed to lymphoma on 11 April 2014. This letter expands on an obituary for Noel, written by his early colleague Dr Clifford Jones, in the July 2014 issue of *Chemistry in Australia*.

Noel will be remembered by many as a quiet achiever, a brilliant researcher, and a dedicated teacher. Born on 5 February 1940 at Manjimup, Western Australia (about 300 kilometres south of Perth), he took a BSc (Hons I) and a PhD from the University of Western Australia. His 1963–6 PhD project, supervised by Dr L.H. Little, used infrared spectroscopy to investigate ammonia and ethene adsorbed on metallic surfaces – a precursor of Noel’s many fine later investigations of heterogeneous catalysis mechanisms. He then spent three postdoctoral years as a Fulbright Fellow working with Dr W. Keith Hall for Gulf Oil in the Mellon Institute, Pittsburgh, before, in 1970, becoming a lecturer in the early days of Macquarie University’s School of Chemistry. There he served the University and the scientific community vigorously for over 40 years. In my experience (which spans most of that period), one could depend upon Noel’s encyclopaedic knowledge, his sound judgement, and his wise opinions. Moreover, he was known to many as an exceptionally kind and considerate friend. He evoked loyalty and admiration from many people: his students, his fellow researchers, and colleagues at all levels.

A measure of Noel’s standing, both locally and internationally, is that he was one of the first to be elevated to a personal chair – back in the early 1990s when that was a rare distinction at Macquarie University. In 1986, Noel shared the RACI’s Erich Heymann Applied Research Medal with his great friends (the late) David Trimm and Mark Wainwright. His professional contributions included two terms (1984–6 and 1993–5) as Secretary of the RACI’s Solid State Division.

Noel Cant’s outstanding scientific legacy comprises over 250 publications with approximately 6000 citations, an *h*-index above 30, and a far-reaching network of Australian and international collaborations. I have recently enjoyed reading a selection of Noel’s most highly cited papers with much admiration and respect. A few common features of a typical Noel Cant paper are: a scholarly introduction that clearly defines the scientific problem (most often catalytic) of interest and its relevance to industry, the environment and/or the community; a rigorous identification of the instrumentation needed to explore that problem; a fascinating blend of careful measurement and expert interpretation that leads to some form of previously elusive mechanism or understanding; and a concluding denouement often worthy of Agatha Christie! It is evident that Noel and his co-researchers really knew their chemistry over a range and complexity that most of us would find quite daunting.

I last saw Noel a few weeks before we lost him. He and I spent an hour or so together in the morning sun, chatting

animatedly. It was clear that he was taking a highly constructive interest in the clinical investigations of which he and his medication were the subject – this, alas, was his last major research project ...

Macquarie University’s Professor Peter Nelson writes: ‘Noel was a truly outstanding physical chemist whose research expertise was in the mechanistic studies of industrial and environmental catalysis. He made seminal contributions to many of these areas and remained a very active researcher to the end.’

Another tribute from Noel’s long-standing research colleagues at the University of New South Wales states: ‘Professor Cant was a legend and the world is now a little less well-off with him gone.’

Finally, Dr Dennys Angove (a CSIRO research colleague and former PhD student), speaking at Noel’s well-attended funeral, reminded us of Noel’s amazing (and often humbling) general knowledge: ‘... his entertaining contributions at morning and afternoon tea with his eyes twinkling brightly ... Who else but Noel could link the cost of white goods in the US with the price of silver on the Austrian precious metal exchange?’ On a more solemn note, Dennys declared: ‘Noel Cant was a great man, a man of grace. He was my mentor and my friend ...’

Sympathy and appreciation go to Noel’s wife Jenny, daughter Susan (Taylor), sons Christopher and Anthony, and their families.

Brian Orr FRACI CChem

Calcium carbide/acetylene

Recent discussions in *Chemistry in Australia* (November 2013 issue, p. 4; February 2014 issue, p. 6) on the use of acetylene generated from calcium carbide prompt further comment.

Banana farmers, certainly in northern New South Wales but probably also elsewhere, used ‘acetylene’ to discourage flying foxes from attacking their fruit. In the evening, they placed a handful of carbide, sometimes wrapped in muslin, in old tins at the corners of their plantation. The dew acted on the carbide to generate acetylene, which was then considered to keep flying foxes away.

However, by the 1980s, there were claims that this procedure no longer worked. In a meticulous investigation in the early 1990s, Tony Rayner from the University of Queensland, tested 618 different odoriferous compounds against flying foxes and tabulated the response. The animals certainly did not like acetylene generated from an old batch of carbide obtained from the University of Queensland chemistry store, but they showed no aversion to pure acetylene (although they did not appreciate the sound of a gas hissing from a cylinder – snakes?). Crude acetylene scored highest on our aversion scale of any of the compounds tested; the only other repellents to test at all strongly were lacrimatory acid chlorides. We concluded that it was impurities in the ‘acetylene’ that had the repellent effects.

READY, STEADY, GO!



Turbo Charge Your Acid Digestions

Anton Paar's Master Stroke

The new Multiwave GO

Economic • Fast • Intuitive

- DMC Directed Multi-mode Cavity for the shortest heating times in a small-footprint system
- TURBO heating and cooling for the shortest overall process times
- One-vessel digestion mode for low-throughput applications
- Extremely lightweight aluminium rotor
- No deformation, no corrosion, no loss of stability

available at

 **MEP**
instruments

The right chemistry.

MEP Instruments Pty Ltd

Australia Tel 1300 720 485

New Zealand Tel 09 477 0620

www.mep.net.au

There are many known impurities in acetylene, phosphine and arsine being common, and these are responsible for the smell of carbide-based acetylene. These compounds were too toxic to test under our conditions (a residential area), and would in any case not be approved for plantation use. Calcium carbide is manufactured by roasting CaO (from limestone) with a source of carbon (needing >2000°C, and therefore an electric arc with sacrificial steel electrode coated with a bitumen binder, adding to the impurities). Obviously the purity of the carbide, with varying amounts of phosphide and arsenide, will depend upon the source of both the limestone and carbon. Reports are available of commercial carbide that was only 80% pure.

We have been unable to ascertain the source of the carbide used in New South Wales in previous decades; some was manufactured in Tasmania and some imported from Italy. Vast quantities were manufactured around Buffalo in New York state from the 1890s due to the availability of 'cheap' electricity from Niagara. With the widespread use of carbide for lighting, there were obviously 'industrial' grades manufactured around the world from available sources. With the diminution of this use, the market dropped and the carbide now available seems to be of a purer 'laboratory' grade, thus explaining its current lack of usefulness against flying foxes. It is also now vastly more expensive and harder to obtain – it used to be stocked at garages throughout the country when it was being used as a lighting source.

There are further claims that acetylene was used in plantations to ripen bananas, since it binds to the same receptor as does ethylene. This seems an extravagant use of an agent in a widespread plantation area, when its application in a confined space upon harvested bunches would be much more easily controlled.

Ray Carman



As your RACI member magazine, *Chemistry in Australia* is the perfect place to voice your ideas and opinions, and to discuss chemistry issues and recently published articles.

Send your contributions (approx. 400 words) to the Editor at wools@westnet.com.au.

iStockphoto/Nick Redeyoff

Future fuels may come in orange flavour

Biochemical engineer Timothy Brennan and his colleagues at the University of Queensland's Australian Institute for Bioengineering and Nanotechnology have helped genetically engineered yeast to evolve to make the oil limonene, which is found naturally in lemons and oranges, and also happens to be an efficient jet fuel.

They've worked out how to get the yeast to make more oil without killing itself in the process.

It is an important step in scaling up biofuel production so that it can become a serious alternative to traditional fossil fuels.

'When you open an orange, what you're smelling is limonene – it's a hydrocarbon that has excellent jet-fuel properties and recently outperformed traditional jet fuel in a model aircraft,' said Brennan, the Queensland winner of Famelab Australia.

'We can take genes from oranges or lemons and assemble them in yeast to turn them into tiny limonene factories, which eat sugar and spit out orange-flavoured jet fuels,' he said.

While there are plenty of researchers already producing small amounts of yeast-derived biofuels around the world, one common limitation is the fact that production volumes are limited by the toxicity of the fuel. Brennan and his colleagues have made two important steps forward.



The major stumbling block is that too much limonene is toxic to yeast cells, and this limits how much fuel the yeast cells can produce before it kills them.

'When you buy household cleaning products that smell like lemons or oranges, those flavour compounds aren't just there to smell nice – they actually help kill bugs, and they kill yeast too,' Brennan explained.

But Brennan and his colleagues have worked out how to help the yeast survive the toxic conditions to produce greater volumes of the fuel.

They've redesigned the bioreactor so the fuel is removed immediately after being produced by the yeast. This has allowed the same yeast to tolerate up to 700 times more fuel than it would in a traditional bioreactor.

And they're also altering the genes of the yeast to help it withstand higher

levels of limonene.

'By changing only a single gene, I can improve the cells' resistance to the fuel, so it can stand to produce more of it. But finding that gene wasn't easy – I had to use biology's oldest tool, adaptive evolution, to help me get there,' said Brennan.

'I couldn't wait for the yeast cells to evolve naturally on their own, so I sped up evolution in the lab. Each day I'd challenge them with a little more limonene than they had the day before. This constant environmental pressure ensured that only the fittest cells survived each day. Two months later, I isolated a yeast strain that was much more resistant than the one I started with.'

Famelab is a global science communication competition for early career scientists.

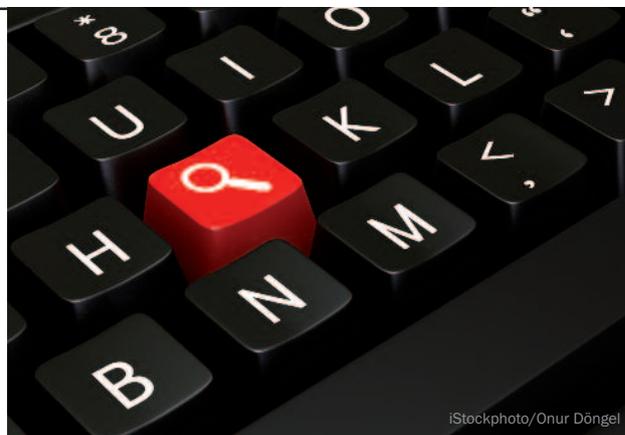
UNIVERSITY OF QUEENSLAND

chemistry in Australia

Online indexes

The latest *Chemistry in Australia* indexes are now online. Browse or search our archived back issues from 2003 onwards.

To view the latest indexes, visit www.raci.org.au/resourcecentre/further-information/indexes.



iStockphoto/Onur Döngel

Celebrating 20 years of Marsden research

New Zealand scientists, researchers and politicians gathered at Parliament in Wellington earlier in the year to celebrate the 20th anniversary of the Marsden Fund, New Zealand's largest fund for leading-edge, fundamental research projects.

'Looking back over the last two decades, it becomes clear how Marsden-funded research has benefited all New Zealanders,' said Professor Juliet Gerrard, chairperson of the Marsden Fund Council. 'Many projects have a long lead-in time, but increasing our basic understanding of the world has now brought improved environmental outcomes, new technologies and better medicines and health care.'

'What's important about the Marsden Fund is that it gives our best and brightest researchers the freedom to explore their most exciting ideas. This is how important breakthroughs are made,' said Gerrard.

'Who would have thought that finding a sheep that kept on having triplets would result in better IVF treatment for women? Or that investigating brain development would lead to a new product for healing wounds?

'The research being funded by the Marsden Fund today – ranging from understanding New Zealand drinking culture to investigating how pests will respond to global climate change – is work that will benefit New Zealand for decades to come.'

The Marsden Fund was started by government in 1994 and supports projects in the sciences, technology, engineering, maths, social sciences and the humanities. The fund is administered on behalf of the government by the Royal Society of New Zealand.

THE ROYAL SOCIETY OF NEW ZEALAND

New Federation of Canada's Professional Chemists

The provincial chemistry associations of British Columbia, Alberta, Saskatchewan, Ontario, Quebec and Nova Scotia launched a new Federation of Canada's Professional Chemists (FCPC) in Vancouver in June. The role of the provincial bodies is primarily to deal with existing and pending provincial legislation and regulations and to make sure that their individual provincial members meet the professional chemistry qualifications that provincial governments expect.

The Canadian Society for Chemistry (CSC) board has worked closely with the provincial chemistry associations over the past

decade to raise the profession of chemist profile. The new FCPC Council will have up to three CSC members; these CSC members will not carry a vote. The FCPC will have one non-voting member on the CSC Board of Directors.

The CSC and FCPC signed a Mutual Recognition Agreement on 2 June 2014 in Vancouver during the 97th Canadian Chemistry Conference and Exhibition. This will help set a new beginning in which both national organisations seek to promote the profession of chemist for the betterment of Canadian society.

CHEMICAL INSTITUTE OF CANADA

Healthful hotdogs now high on texture, too

Many backyard cooks are turning to more healthful alternatives to their savoured but fatty hot dogs. But low fat can sometimes mean low satisfaction. Now researchers are reporting new progress toward addressing the texture problem in low-fat sausages that are made with olive oil rather than pork fat (*J. Agric. Food Chem.* doi: 10.1021/jf501231k).

Ana M. Herrero and colleagues note that hot-dog consumers have come to expect just the right amount of chewiness and springiness, among other things, from their beloved summer fare. But traditional hot dogs come with a large dose of pork back-fat. To build a more healthful frankfurter, Herrero's team has developed olive oil 'bulking agents' to replace the saturated animal fat. The substitutes contain 55% olive oil, which contains more healthful unsaturated fats, and could reduce the calories by more than a third. But knowing that only alternatives that closely mimic the high-fat originals will win over barbecue fans, the researchers analysed them for texture and storage potential.

To explore factors important to texture, they used Raman spectroscopy to probe the protein and lipid structures of two

low-fat recipes and their relationship with textural properties. They also tested how well they held up during refrigeration. The researchers determined how protein and lipid structures affect texture. They also found that regardless of ingredients, all the sausages, including those made with pork fat, responded similarly to cold conditions for nearly three months – long enough to last through the entire summer.

AMERICAN CHEMICAL SOCIETY





Rowe Scientific PTY LTD

For accuracy and professionalism
www.rowe.com.au

MICRO FILTRATION



Versatile Millex syringe filters can be used for a variety of applications in the research laboratory, including sample preparation for HPLC and UHPLC analysis.



- Faster Flow Rate
- Higher Operating Pressure
- Colour-Coded
- A variety of membranes, pore sizes and diameters available

Call your local Rowe office to find out more

Stirring
Shaking
Mixing



Fine
Chemicals



Water
Analysis



Ovens &
Incubators



Air sampling pumps

Balances
& Titration



General &
Volumetric
Glassware



Flasks, Beakers, Pipettes, Bottles

Filtration &
Chromatog-
raphy



Filter Paper

Plasticware



Bel-Art Products

cowie

KartellLABWARE

Techno Plas



ADELAIDE	08 8186 0523	rowesa@rowe.com.au
BRISBANE	07 3376 9411	roweqlld@rowe.com.au
MELBOURNE	03 9701 7077	rowevic@rowe.com.au
HOBART	03 6272 0661	rowetas@rowe.com.au
PERTH	08 9302 1911	rowewa@rowe.com.au
SYDNEY	02 9603 1205	rowensw@rowe.com.au

REF 65

X:\MARKETING\ADVERTISING\Chemistry In Australia\65-Chem in Aust 01-09-14

Movement on polyethylene market

Global polyethylene demand is forecast to rise by approximately 3.7% per annum between 2013 and 2018, at a slightly higher level than its growth during the 2003–2013 period, says a July report from research and consulting firm GlobalData.

The company's latest report, *Global polyethylene industry – emerging markets in Asia-Pacific to drive modest growth* (bit.ly/1qUFA7k), states that this higher-than-historic increase will occur in the US and Europe, primarily in Russia. The US will witness a 2.4% growth rate per annum during the forecast period, in comparison to its 0.7% levels from 2003 to 2013. Meanwhile, demand in Europe, including Russia, will climb at 2.8% per year from 2013 to 2018, almost three times the level witnessed during the last decade.

GlobalData states that these demand rises in the US and Russia will be somewhat offset by a lower increase of 4.8% in Asia, compared to its 6% rate during 2003 and 2013. This will be due primarily to the region's slower economic growth.

Carmine Rositano, GlobalData's Managing Analyst covering Downstream Oil & Gas, said: 'Lower feedstock costs from US shale gas production are providing the country with a competitive advantage, with increasing investments in its petrochemical plants driving polyethylene demand growth in both domestic and international markets. Although below recent historical levels, demand in Asia remains fairly robust and will continue to boost expansion in the global polyethylene market.'

'As a result, polyethylene capacity is now expected to increase at about 5.3% per year between 2013 and 2018, which is higher than the 3.6% experienced over the last decade. Capacity additions will be most prevalent in the US, given its advantaged cost competitive position, and also Russia, which is augmenting its petrochemical industry to reduce its reliance on imports. New capacity will also continue to come online in Asia, but at a slower-than-historic rate.'

GlobalData states that despite the lower estimated cost of crude oil in the forward price curve to 2018, prices for polyethylene will increase at around 1.3% per year up to the end of the forecast period. This is attributable to petrochemical demand increasing at approximately three times the rate of that for oil.

Rositano continued: 'The key trend emerging in the polyethylene market will be the ongoing surplus position in the US, where excess production will be directed to expanding markets in South America and Asia. Additionally, the lower feedstock and fuel costs for US plants, compared with those in Europe, will likely result in future European plant closures and further adjust global polyethylene trade flows.'

GLOBALDATA

Academy welcomes new funding for strategic science plan

The Australian Academy of Science welcomed new Australian Research Council (ARC) funding to guide the future of three vital science disciplines in Australia.

Education Minister Christopher Pyne announced that the Academy will receive nearly \$500 000 over three years to develop 10-year plans for chemistry, agricultural science and the earth sciences. All three areas are fundamental to the Australian economy, particularly manufacturing, farming and minerals exploration.

Developed by the Academy's National Committees for Science, the plans will seek input from across government, industry, academia and the education sector to identify the future needs of each discipline and outline priorities for investment over the next 10 years.

They will make recommendations about research directions, infrastructure, workforce needs, career structure and educational reform.

Academy President Professor Andrew Holmes FRACI CChem said creating strategic plans for these crucial areas of science is fundamental to making Australia internationally competitive.

'These roadmaps will ensure Australia has the scientific capacity to meet future challenges,' Holmes said.

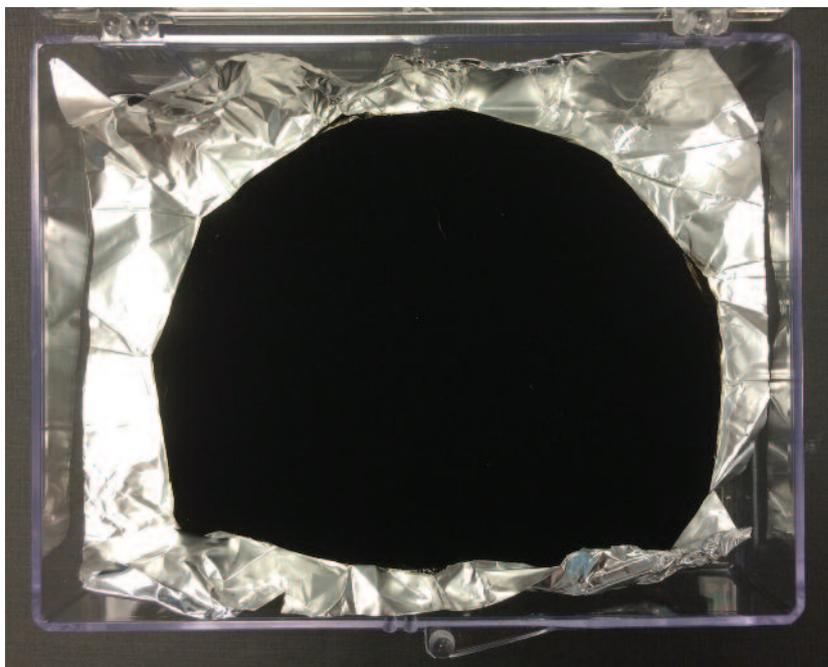
'The decadal plans will help to improve research outcomes and training, and build stronger engagement with industry, with a direct impact on the economy, health and wellbeing of Australia.'

In the past, the Academy's decadal plans for physics and astronomy have been strongly influential in shaping these disciplines and instrumental in securing Australia's involvement in building major international research infrastructure. The Academy is also currently developing a plan for mathematical sciences.

The new funding was allocated from the ARC's Learned Academies Special Projects scheme.

AUSTRALIAN ACADEMY OF SCIENCES

Nano is the new black



Sensitive electro-optical imaging and target-acquisition systems will achieve new levels of range and sensitivity performance thanks to a UK company's breakthrough in developing a 'super black' material.

Surrey NanoSystems' Vantablack® can be applied to lightweight, temperature-sensitive structures such as aluminium while absorbing 99.96% of incident radiation, believed to be the highest-ever recorded.

'Vantablack ... reduces stray light, improving the ability of sensitive telescopes to see the faintest stars, and allows the use of smaller, lighter sources in space-borne black body calibration systems. Its ultra-low reflectance improves the sensitivity of terrestrial, space and air-borne instrumentation', said Ben Jensen, Chief Technology Officer, Surrey NanoSystems.

Vantablack is the result of applying Surrey NanoSystems' patented low-temperature carbon nanotube growth process to the UK Technology Strategy Board's 'Space for Growth' program, working alongside the National Physical Laboratory and Energy's ABSL Space Products division. The manufacture of 'super-black' carbon nanotube-based

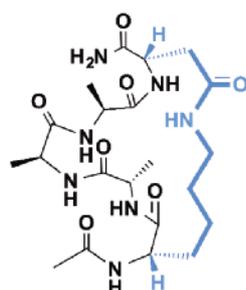
materials has traditionally required high temperatures, preventing their direct application to sensitive electronics or materials with relatively low melting points. This, along with poor adhesion, prevented their application to critical space and air-borne instrumentation. The two-year development and test program was completed in December 2013, during which period Surrey NanoSystems successfully transferred its low-temperature manufacturing process from silicon to aluminium structures and pyroelectric sensors. As part of the program, qualification to European Cooperation on Space Standardisation (ECSS) standards was also achieved.

Vantablack has the highest thermal conductivity and lowest mass-volume of any material that can be used in high-emissivity applications. It has virtually undetectable levels of outgassing and particle fall-out, thus eliminating a key source of contamination in sensitive imaging systems. It withstands launch shock, staging and long-term vibration, and is suitable for coating internal components, such as apertures, baffles, cold shields and micro electro mechanical system-type optical sensors.

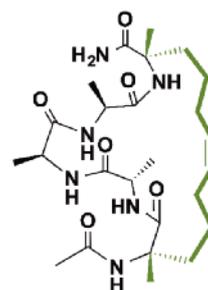
SURREY NANOSYSTEMS

One turn only

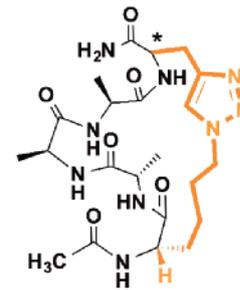
A new ARC Centre of Excellence in Advanced Molecular Imaging seeks to create images of single molecules, proteins, protein complexes, cells and animals (www.imagingcoe.org). A recent study from the Centre, specifically involving a collaboration between researchers at the University of Queensland and Pfizer in the US, investigated the smallest known alpha helix, just one helical turn, stabilised in water by chemical linkages (de Araujo A.D., Hoang H.N., Kok W.M., Diness F., Gupta P., Hill T.A., Driver R.W., Price D.A., Liras S., Fairlie D.P. *Angew. Chem. Int. Ed.* 2014, **53**, 6965–9). Three-dimensional structures of several one-turn alpha helices were imaged in water using 2D NMR spectroscopy and circular dichroism spectroscopy. The paper compares a small array of linkages to find the best way to lock a short peptide into an alpha helix. The significance is that short peptides



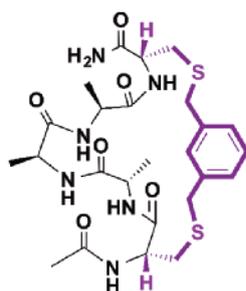
KD lactam linker



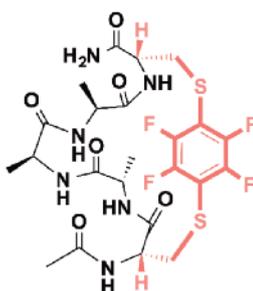
Hydrocarbon linker



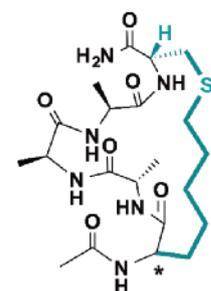
"Click" triazole linker



m-Xylene thioether linker



Perfluorobenzyl thioether linker

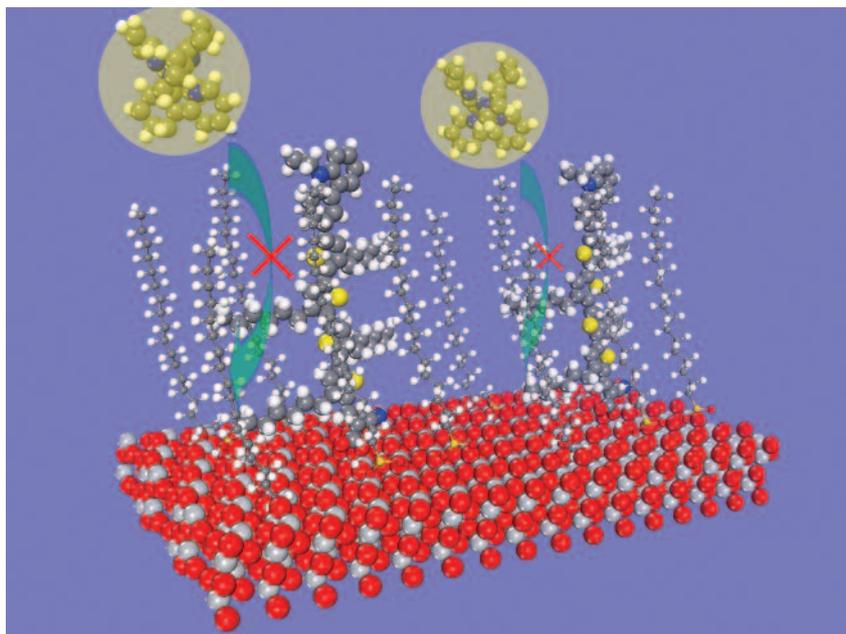


Alkyl thioether

generally do not display defined structures in water due to solvation disrupting the intramolecular hydrogen bonding of the amides. The findings of this study enable scientists to replicate

the smallest bioactive regions of proteins within small helical structures. These mimics may be valuable probes for biomedical studies and leads for new kinds of drugs.

More efficient aqueous dye-sensitised solar cells



Dye-sensitised solar cells (DSCs) based on aqueous electrolytes have several advantages over their counterparts made with organic electrolytes, owing to non-toxicity, non-flammability and the safety

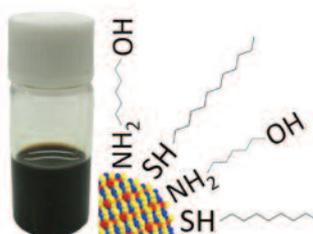
of water. The efficiency of water-based DSCs is, however, still much lower than that achieved with organic electrolytes. This is partially due to electron recombination at the dye/TiO₂ hetero-

interface. Following light absorption by the dye, electrons injected into the titania layer recombine with redox-active species in the electrolyte instead of generating current. The group of Leone Spiccia at Monash University, in collaboration with the group of Xin Li at Harbin Institute of Technology (China), has proposed a general, facile strategy to improve the performance of aqueous DSCs, which applies octadecyltrichlorosilane (ODTS) (Dong C., Xiang W., Huang F., Fu D., Huang W., Bach U., Cheng Y.-B., Li X., Spiccia L. *Angew. Chem.* 2014, **53**, 6933–7). The formation of an organic barrier layer (ODTS) on the titania surface, following adsorption of the dye, is shown to prevent redox-active species from approaching the surface. Electron recombination was suppressed and photogenerated electron loss reduced, leading to a record aqueous DSC efficiency of 5.6%. By applying such a strategy, further improvements in the photovoltaic performance of aqueous DSCs are envisioned.

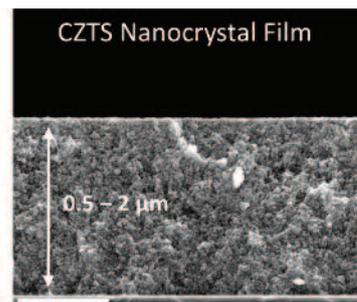
Printed solar cells using nanocrystals

One of the most promising solar cell materials is based on copper, zinc, tin and sulfur in the chemical form $\text{Cu}_2\text{ZnSnS}_4$ (CZTS). This material possesses ideal solar cell characteristics, is non-toxic, and its elements are earth abundant. However, a major scientific question remains unanswered: how can CZTS be processed to deliver efficient solar cells by low-cost and environmentally friendly methods? To address this issue, researchers from CSIRO Materials Science and Engineering, Melbourne, have developed CZTS-based solar cells using nanocrystals as building blocks (van Embden J., Chesman A.S.R., Della Gaspera E., Duffy N.W., Watkins S.E., Jasieniak J.J. *J. Am. Chem. Soc.* 2014, **136**, 5237–40). These nanocrystals were synthesised with a composition specifically designed for high-efficiency devices using a scalable synthetic approach. By carefully formulating the nanocrystals into non-toxic polar inks, the researchers have achieved solar cells with impressive efficiencies of about 8%.

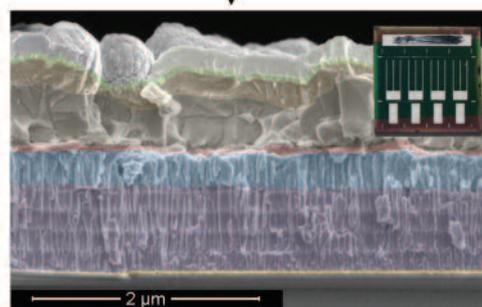
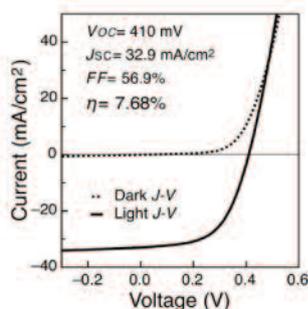
High Polarity CZTS ink



Film
Deposition



Device Processing



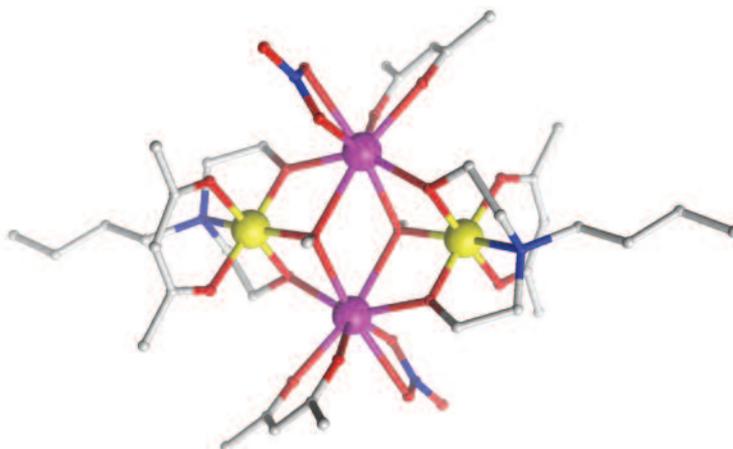
This work improves on existing systems by demonstrating that non-toxic inks are feasible for fabricating inorganic CZTS solar cells with high efficiencies. Capitalising on CSIRO's expertise in

printing and its strong links to industry, the team is solving the scientific challenges that currently impede the low-cost manufacturing of these and other promising solar cells.

Better single molecule magnets

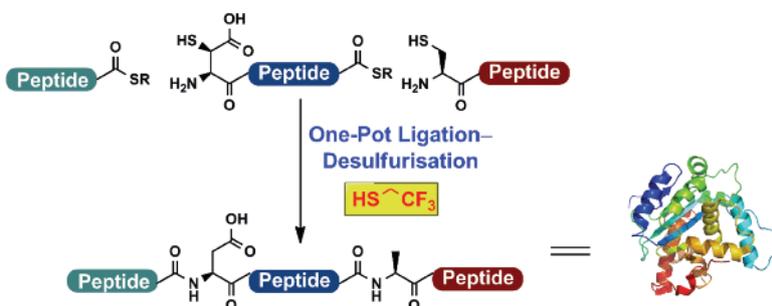
Following on from their paper in 2013 (see February 2014 issue, p. 9) that described a mixed 3d–4f single molecule magnet, $[\text{Cr}^{\text{III}}_2\text{Dy}^{\text{III}}_2(\text{OMe})_2(\text{O}_2\text{CPh})_4(\text{mdea})_2(\text{NO}_3)_2]$ ($\text{mdeaH}_2 = N$ -methyldiethanolamine), the Monash University team led by Professor Keith Murray and collaborators at the Catholic University of Leuven, and the University of Manchester, have extended their work to display chemical control of the various components of these 'butterfly' tetranuclear clusters that leads to important differences in magnetism (Langley S.K., Wielechowski D.P., Vieru V., Chilton N.F., Moubaraki B., Chibotaru L.F., Murray K.S. *Chem. Sci.* 2014, **5**, 3246–56). Incorporation of β -diketonate (acac) capping groups at the Cr and Dy sites has yielded a family of formula $[\text{Cr}^{\text{III}}_2\text{Dy}^{\text{III}}_2(\text{OMe})_2(\text{RN}\{(\text{CH}_2)_2\text{OH}\}_2)_2(\text{acac})_4(\text{NO}_3)_2]$ ($\text{R} = \text{Me, Et, Bu}$), each member of which contains two $\text{Dy}^{\text{III}}\cdots\text{Cr}^{\text{III}}$ bridging groups, compared to three bridges in the parent molecule. This leads to weaker $\text{Dy}\cdots\text{Cr}$ exchange coupling but each family member displays well-

resolved slow relaxation of the magnetisation, with smaller anisotropy barrier heights and with magnetic hysteresis plots displaying significant coercive fields. In this acac family, and in ongoing work involving a substituted benzoate family, the key finding is that the slow relaxation times relate to the $\text{Dy}\cdots\text{Cr}$ exchange coupling and lead to suppression of quantum tunnelling of magnetisation.



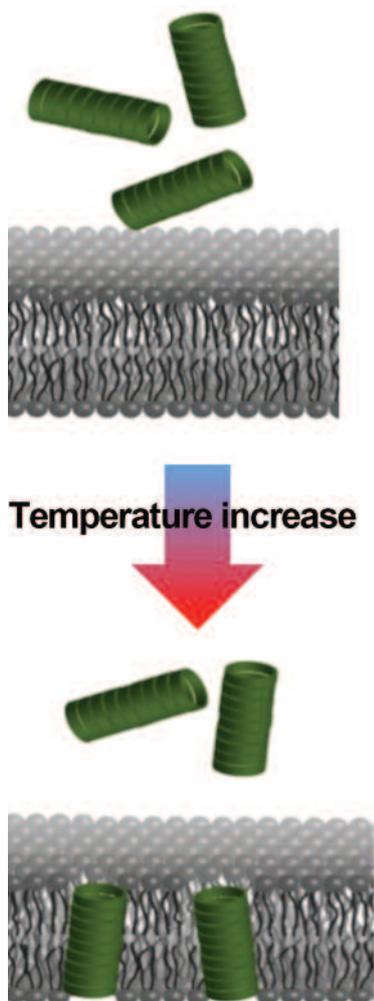
Streamlining chemical protein synthesis into one pot

Researchers at the University of Sydney have recently reported the implementation of 2,2,2-trifluoroethanethiol (TFET) as a highly efficient thiol additive for use in one-pot native chemical ligation–desulfurisation chemistry (Thompson R.E., Liu X., Alonso-García N., Pereira P.J.B., Jolliffe K.A., Payne R.J. *J. Am. Chem. Soc.* 2014, **136**, 8161–4). Importantly, this new technology can be applied to the total chemical synthesis of proteins that do not possess cysteine residues at suitable sites for assembly through traditional ligation techniques. Native chemical ligation reactions employing TFET as an additive proceed at rapid rates (comparable to those employing the current gold-standard aryl thiol additives). However, in contrast to aryl



thiol additives, which must be removed from the reaction (usually by chromatography) prior to carrying out a desulfurisation reaction, due to inherent radical quenching properties, the use of TFET enabled subsequent radical-desulfurisation reactions to be conducted in the same vessel, thus eliminating the need for intermediate purification steps.

The utility of TFET in streamlining the ligation–desulfurisation protocol is demonstrated through the one-pot total syntheses of two tick-derived antithrombotic proteins from three fragments. It is anticipated that TFET will find wide utility in the one-pot total chemical synthesis of a whole range of proteins in the future.



Synthetic membrane pore-forming materials

The transport regulation of ions, solutes, pH and water across cell membranes maintains optimal conditions for cellular environments, and plays an important role in a range of diseases. Understanding the mechanism of transport provides key answers to elucidate the mechanisms of cell activity and for the treatment of medical conditions. Since natural trans-membrane channels are limited by their functionality and pore size, synthetic alternatives are being investigated, but current materials lack the efficiency and selectivity of the natural equivalents, and their practical and large-scale production remains difficult. Now the teams of Professors Kate Jolliffe (University of Sydney) and Sébastien Perrier (University of Warwick) have developed a new family

of pore-forming materials based on the conjugation of functional polymers to cyclic peptides made of alternating L and D amino acids (Danial M., Tran C.M.-N., Jolliffe K.A., Perrier S. *J. Am. Chem. Soc.* 2014, **136**, 8018–26). The peptides associate via H-bonding and stack to form nanotubes with an internal channel diameter of sub-nanometre dimensions. The polymer conjugate enables the assembly to take place within a lipid bilayer, and form nanopores. The resulting channels can be fine-tuned, for instance by using temperature-responsive polymers, which cause the pores to open and close upon thermal stimulation. These materials form a new family of versatile and functional pore-forming systems, with applications in biology and medicine.

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

Aust J Chem

The August issue is dedicated to the memory of Roger F.C. Brown, who died 1 September 2013.

Experiments with low-pressure gas-phase pyrolysis, later to be known as flash vacuum pyrolysis (FVP) were started by Wilfred (Bill) D. Crow and Roger F.C. Brown in the Chemistry Department, School of General Studies, Australian National University, in 1965. At that time, there were two places in Canberra where one could do chemical research: the Medical Chemistry Department in the John Curtin School of Medical Research and the Chemistry Department in the School of General Studies (SGS), whereas the Research School of Chemistry opened in 1967. The name 'School of General Studies' (the former Canberra University College) was changed to 'The Faculties' in 1979.

Roger Brown arrived at the SGS as a young lecturer in 1961, and Bill Crow from the CSIRO in Melbourne had accepted an associate professorship at about the same time. At the SGS, Crow purchased a Lindberg tube furnace for his MSc student Richard (Dick) K. Solly to commence FVP experiments in 1964. He later purchased a mass spectrometer in order to pursue the then-popular line of research on comparison of thermal and mass spectrometric fragmentations. A series of topical papers by Brown, Crow and Solly on benzyne-related chemistry resulted in 1965–6. After Brown's move to Monash University in 1968, methyleneketenes and methylenecarbenes became a major topic for investigation in collaboration with Frank W. Eastwood, and this is where the 'Roger Brown rearrangement', viz. a 1,2-dyotropic shift in acetylenes, $R-C_1\equiv C_2-R' \rightleftharpoons R'-C_1\equiv C_2-R$, taking place via transient vinylidene intermediates, was discovered.

A review on FVP apparatus and methods is included as well as two papers on Roger Brown rearrangements and numerous papers on other subjects. Arvid Kuhn et al. (University of Queensland and Mie University, Japan) report on the characterisation of 1,2-dehydroheptafulvene (heptafulvyne) and several rearrangements of C_8H_6 -hydrocarbons. Two Roger Brown rearrangements are involved, including the interconversion of phenylacetylene and phenylvinylidene, which scrambles a ^{13}C label over the two acetylenic carbons.

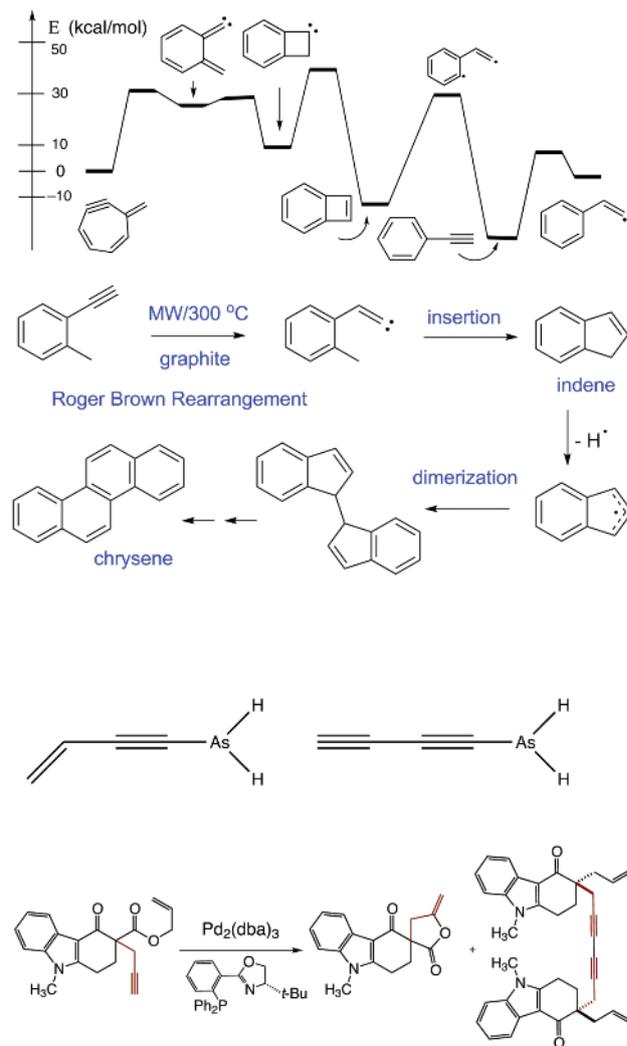
Richard Johnson (University of New Hampshire) and his students invented 'microwave flash pyrolysis' (i.e. pyrolysis in solution, induced by microwave irradiation and 'sensitised' by graphite), and they report here on its application in interconversion and dimerisation of C_9H_8 hydrocarbons (e.g. 2-ethynyltoluene and indene). Roger Brown rearrangements are prominent in this chemistry.

Larry T. Scott et al. (Boston College) report an investigation of aryl-aryl bond cleavage under FVP conditions, and Aaron Amick (Washington College, Maryland) has discovered that an external radical source (hexane) greatly facilitates thermal cyclodehydrogenation of polycyclic aromatic hydrocarbons.

Carl Th. Pedersen (University of Southern Denmark) has matrix-isolated and characterised the elusive ethene diselone, $Se=C=C=Se$, a member of the family of very unstable cumulenes with an even number of atoms in the chain, and Jean-Claude Guillemin (Université de Rennes, France) describes the synthesis of highly unstable functionalised alkynylarsines of the type $R-C\equiv C-AsH_2$.

David Lupton and coworkers (Monash University) describe how *N*-methyl carbazolone allyl carbonates bearing a propargyl side chain leads to the formation of enantioenriched γ -lactones rather than the expected products of decarboxylative allylation under $Pd[0]$ catalysis.

It is not possible in this space to do justice to the over 30 excellent papers published in this issue.





Conserving ancient shipwrecks

BY **GRAEME HENDERSON**

Australians pioneered underwater cultural heritage conservation and have played key parts in the related UNESCO Convention, but we are yet to ratify it.

Fifty-one years ago, in 1963, I had just reached the age of 16 when I found, by chance, while diving with friends, the 17th century Dutch shipwreck *Vergulde Draeck*, off the Western Australian coast. At the time, it was the oldest wreck found in Australian waters. Carrying 76 000 Spanish guilders, it was a sensation in the press, stimulating community interest in early Australian history and, for the first time, an awareness of the importance of the underwater cultural heritage: the legacy of submerged physical artefacts and intangible attributes inherited from past generations.

The deliberate act of keeping cultural heritage from the present for the future is known as conservation. But in 1963, there were no underwater heritage protection laws, only salvage law. That became a problem when the first silver coins were found. Salvage law involves the concept of 'salvor in possession', and encourages destructive and violent activity on heritage sites. A diver wanting to become salvor in possession used gelignite to extract the silver and frighten other divers from the wreck.

Events following the discovery of the *Vergulde Draeck* showed the need for heritage laws, management programs and community support. This took time to develop because Australia was a pioneer in the field of underwater cultural heritage conservation and there were no overseas models. Such laws must be consistent and interconnected, providing a web of protection covering the seabed locally, nationally and globally.

The first small local step was taken in 1963 by myself and my co-finders of the *Vergulde Draeck*. Dismayed by the violence, we drew up a Deed of Assignment with the State's Crown Law Department, transferring what legal rights we had to the Western Australian Museum. In accepting these rights, the Museum took responsibility for the protection and management of historic wrecks, even before any protective legislation. The state government legislated in 1964, vesting in the Museum the sole right of working on historic wrecks. But that failed to stop the destruction.

When I joined the Museum in 1969, my colleagues were mainly ex-Navy clearance divers, tough men with the



Bill Jeffery

Corrosion chemists using pH and voltage measurements on the Japanese Kawanishi 'Emily' bomber to monitor the changes in the environment, Chuuk Lagoon, Federated States of Micronesia. Comparative measurements with the same plane wrecks in Saipan Lagoon showed that the two Pacific World War II sites are corroding at different rates but that the aluminium alloys are the same in each plane.

experience to confront dangers, and dangerous people, on the high seas. During the first six months of my employment, I saw detonation wires on the wrecks of the 1622 *Tryal*, 1656 *Vergulde Draeck* and 1712 *Zuytdorp*, and blast holes on the 1629 *Batavia*. However, the Museum's active archaeological excavation program initiated in 1971 was welcomed by the community, and the looting decreased.

In 1976, a diver, Allan Robinson, successfully challenged the state legislation in the High Court of Australia, on the grounds that the state government lacked authority to pass laws affecting offshore waters. This prompted the passing of

Commonwealth legislation (the *Historic Shipwrecks Act*) and the development of management programs covering all Australian states.

Ships engage in trade in foreign waters, so much of the underwater heritage is shared heritage, multinational heritage, important to both the country of origin and the site's neighbouring state. Awareness of the need for a comprehensive international instrument of protection emerged in the 1970s. During the jurisdictional uncertainty in Australia, the Netherlands government offered assistance in protecting Dutch wrecks in Australian waters. In 1795, the Dutch

East India Company, owner of the ships *Batavia*, *Vergulde Draeck* and *Zuytdorp*, had been nationalised by the Dutch government, who became heirs of the Company and the cargoes of the wrecks. In 1972, the *Agreement of the Australia Netherlands Committee on Old Dutch Shipwrecks* (ANCODS) was signed, vesting the right of recovery in Australia, who in turn delegated the authority to the Museum.

ANCODS brought ongoing close cultural ties, the Dutch taking a strong pride in their traders and explorers – who first visited Australia in 1606, and visited Western Australia in 1616. The Agreement had an element of



Jon Carpenter, WA Museum

Molten wax impregnation and consolidation of heavily corroded bronze rudder pintle from the wreck of the American China Trader *Rapid* (1811); Ian MacLeod and Jennifer Edwards, intern from Australian War Memorial. The microcrystalline wax stops moist air getting to the extensively corroded object and causing accelerated decay. Analysis of the corrosion processes showed the pintle had been buried in 25–30 cm of coral debris.

one-upmanship – Robinson had challenged laws at the state level, but would he have the courage to challenge an international treaty? ANCODS, an example of successful international cooperation, has been tested in court, and has symbolic importance as a worthy model for other nations to pursue. A bilateral agreement, it can be seen also as the first step towards multilateral agreements providing a network of global protection through coordinated action.

Robinson's death in 1983 ended the era of destructive individual treasure

... wrecks on the deep seabed are of particular importance, since for various chemical and biological reasons, many are likely to be in an exceptional state of preservation.

hunters in Australian waters, but a new threat was emerging. Ronald Reagan and Margaret Thatcher argued persuasively that markets, not government, held the key to prosperity and freedom. But with the dissolution of the Soviet Union, some free-market entrepreneurs felt that everything, including the underwater heritage, should be commercially exploited. In his book *What money can't buy: the moral limits to markets*,

Michael Sandel argues that the developed world has drifted from having a market economy to having a market society. In Australia, beginning in the 1980s, investor-funded commercial salvage schemes targeted the underwater heritage. These schemes were led by sophisticated businessmen, with the charm to influence investors, public officials and politicians. But because the level of protection had so increased in Australia with the Commonwealth legislation, these ventures were generally focused overseas in the waters of nations lacking legislation, or in international waters.

On the positive side, by the mid-1980s Australian archaeologists and materials conservation experts were playing a lead role in educational initiatives in many parts of Asia, raising awareness of the importance of the underwater heritage and developing local management expertise. The Council of Europe, UNESCO, the

International Law Association (ILA), the Australasian Institute for Maritime Archaeology (AIMA), the International Congress of Maritime Museums (ICMM), and Australia ICOMOS (International Council on Monuments and Sites, a UNESCO affiliate) were progressing other fronts.

The discovery in 1985 of the *Titanic* wreck at 3700 metres, and its subsequent plunder, made the international community aware that sites in the deepest oceans were accessible to destructive activity. UNESCO immediately became involved. At a UNESCO Regional Seminar on the Protection of Movable Cultural Property, held in Australia in 1986, it was observed that wrecks on the deep seabed are of particular importance, since for various chemical and biological reasons, many are likely to be in an exceptional state of preservation. The Secretariat issued a statement that if positive steps were not taken immediately, the recent advances made by treasure hunters, particularly in South-East Asia, would result in a tragic loss of heritage.

In 1990, the ILA prepared a draft UNESCO convention on the underwater cultural heritage. Compiler Patrick O'Keefe envisaged that for the convention to be effective, nationals would be required to abide by specified criteria in excavating historic wreck sites, and that these criteria might be drawn from such documents as the 1956 UNESCO Recommendation on Archaeological Excavations and the 1990 ICOMOS Charter for Archaeological Heritage.

Australian archaeologists were concerned about the escalation of

auctions, such as Christie's \$15 million auction of the porcelain, salvaged by an Australian, from the wreck of the Dutch ship *Geldermalsen*. Australian archaeologists initially employed a different strategy from that of the ILA, developing non-prescriptive codes of practice, within Australia, with the ICMM, and with ICOMOS.

In 1989, AIMA, at the invitation of the Commonwealth Government, commenced its code titled *Guidelines for the management of Australia's shipwrecks*, comprising the principles and practice adopted by Australia's professional maritime archaeologists and intended to serve heritage bodies, developers, teachers, the diving community and museum visitors.

In 1987, I chaired a committee of the ICMM, whose 284 members comprised most of the world's largest maritime museums, with a brief to survey existing museum acquisition policies for objects from underwater sites. I saw this as an opportunity to address the demand side of the international market in antiquities from the underwater cultural heritage. If museums stopped buying, salvors would lose that market. The survey led to the adoption in 1993 of standards for the exploration of underwater sites, including the policy to not knowingly acquire or exhibit artefacts removed from commercially exploited sites in recent times.

Even as this code was published, there was evidence that it would be ineffectual without legal force. One museum entered into a contract with RMS Titanic Inc. to exhibit the material that company was salvaging. RMS Titanic was selling pieces of coal from the wreck, asking the public to help preserve the *Titanic* by purchasing items.

Australia ICOMOS facilitated a more successful strategy, matchmaking archaeologists with legal experts and so providing the opportunity for amalgamating the non-prescriptive and prescriptive approaches. ICOMOS members had



Jon Carpenter, WA Museum

The pair of bronze astrolabes, Dutch navigational instruments from the Batavia wreck used for determination of latitude. The left-hand astrolabe had been exposed to the full brunt of the surf on Morning Reef, Abrolhos Islands, for 350 years; the right-hand astrolabe was in pristine condition, having been buried in an iron cannon ball corrosion matrix, which protected it from corrosion by galvanic action.

been lobbying the Australian government in 1987 with their concerns about commercial projects. In 1991, I responded to a request by ICOMOS to develop a new vehicle, the International Committee on the Underwater Cultural Heritage (ICUCH). Its mission was the establishment of a structure of international environmental cooperation in the field of underwater cultural heritage.

The ILA envisaged that for the convention to be effective, nationals would be required to abide by specified criteria in excavating historic wreck sites. But there was no awareness within the maritime archaeological fraternity of the activities of the ILA in producing their draft UNESCO convention. So in August 1991, Patrick O'Keefe wrote to me, inviting ICUCH to prepare these criteria – standards by which deviant conduct could be measured. This was a better plan than using the 1956 UNESCO Recommendation, or the 1990 Charter, documents that did not deal with the underwater cultural heritage.

ICUCH developed the *International Charter on the Protection and Management of the Underwater Cultural Heritage*, adopted by

ICOMOS in 1996. UNESCO used this Charter, a statement of fundamental professional standards, to develop the *Annex* – rules concerning activities directed at underwater heritage – for the *International Convention on the Protection of the Underwater Cultural Heritage*, adopted by UNESCO in 2001.

To date, 48 States have ratified the Convention and the emerging matrix of protection is having a major positive impact. Sadly, ratification is not uniform across the globe and our region, rich in significant underwater cultural heritage, is one of the slowest to take up the Convention. Australians played important roles in the initiation and development of the Convention but the Australian government has not yet ratified it. The 100-year commemoration between 2014 and 2018 of events relating to World War I, and the 400-year commemoration in 2016 of Dirk Hartog's landfall in Western Australia, present timely opportunities for the Australian government to announce ratification of the 2001 Convention.

Graeme Henderson AM CitWA is a maritime archaeologist and writer. He was Director of the Western Australian Maritime Museum from 1992 until 2005. Thanks to Ian MacLeod FRACI CChem for supplying the images and captions.



Agricultural warfare

iStockphoto/peplow

BY **DAVE SAMMUT**

Agricultural innovation was a precursor to terrible conflict in the 20th century.

War is a terrible part of human existence. Early in the 20th century, the world was stunned by the scale and ferocity of a new conflict. Never before had so many nations gone to war with each other. Never before had so many people died, under conditions so horrendous, and with such rapid innovation in technologies for destruction. This was 'the war to end all wars'. How could it have come to this?

The 19th century had already set the scene of a world undergoing fundamental transition, at a pace neither imagined nor always welcome. Scientific advances, greater life expectancies and democracy had brought unexpected suffering through industrialisation, urbanisation, imperialism and nationalism.

As the century closed, political and industrial forces were coming together, leading inexorably to the first

global conflict. The mood of the day was captured in science fiction. Jules Verne's *Twenty thousand leagues under the sea* (1868) imagines a militarised submarine, captained by a fugitive prince seeking revenge against the British following the murder of his family during the Indian mutiny against the British East India Company in 1857. His 1870 novel *From Earth to the Moon* details the artillery science of gentlemen engineers, with the aim of colonisation, designing a cannon large enough to launch a projectile, complete with three men, two dogs, several chickens ... and no women.

While the development and use of chemical weapons during the Great War continues to live in infamy, I was interested to learn how developments in 19th-century agriculture (more specifically, fertiliser) contributed to the war – scientifically, industrially and politically.



Guano is widely reported to have been used by Andean populations for agriculture for over 1000 years, and the Incan empire had laws to restrict its use and mining (from small islands close to the Peruvian coast) to preserve the resource.

Alexander Von Humboldt began investigating guano's fertilising properties in 1802, and by 1840 the guano industry had taken off. Research in the era, including Justus von Liebig's 1840 text on organic chemistry, demonstrated the benefits of both nitrogen and phosphorus in fertiliser, for which guano was an outstanding natural source (up to 16% nitrogen, 12% phosphate and 3% potash). Liebig was particularly notable for applying chemistry to plant and animal physiology, where the prevailing theories firmly separated the two.

Guano was mined heavily from the Peruvian islands, as well as tropical islands around the world, from deposits sometimes 30–50 metres

deep. A very limited and non-renewable resource (at least over the short term), it quickly became subject to imperialist geopolitics. The Peruvian guano had particular advantages: the lack of rain on the islands allowed the accumulated droppings to bake in a dry atmosphere, better preserving the nitrates.

Britain was Peru's largest market for guano, with trade of about 20 million tonnes between 1840 and 1880. This period was one of substantial expansion and growth in the US, and the race to secure new sources was fierce. The US's 1856 *Guano Islands Act* declared exclusive rights to any American who found a new guano source on unclaimed islands. However, imprecision in navigation meant that many islands were mis-located, causing double-ups and counter-claims. The US claimed over 60 islands in total.

The human toll from this trade was enormous. Much of the mining was

performed by African slaves and Chinese labourers. Among the terrible conditions that they had to endure was ongoing exposure to airborne guano dust, which caused severe respiratory problems. Slavery was not abolished in Peru until 1854.

Within just 50 years, world guano reserves were substantially depleted. Industrial production turned to the heating of bone ash, and then to electric arc production from phosphate rock. By the turn of the century, the latter was the dominant source of phosphate fertiliser production.

Throughout the period, other sources of nitrogen and phosphate fertilisers were being developed. The Frank–Caro process for production of calcium cyanamide (CaCN_2) from calcium carbide and nitrogen gas commenced industrial production from 1905. Other contemporaneous processes were put forward: electric arc production of nitric acid in the US, the Birkeland–Eyde process for nitrous



istockphoto/Kseniya Ragozina

Once a site of major economic activity in guano mining, the Ballestas Islands on the south coast of Peru are now a wildlife sanctuary. Bridges for loading guano onto ships are still in place.

oxide production in Norway, and the Pauling process in Germany and the US.

In one of the more interesting developments, a process was developed to dissolve coprolites (fossilised animal droppings) in East Anglia in sulfuric acid to make 'super phosphate'.

Together, the use of and competition for nitrogen and phosphorus formed a major undercurrent in the building wave of economic pressure around the world. The 19th century saw a boom in agriculture, driven by the widespread use of fertiliser, industrialisation of processes and better agricultural science.

I am no historian, but I find it interesting to consider just how much the growth in available food combined with the associated population explosion and international

competition for resources contributed to the global powder keg at the beginning of the 20th century. Equally interesting is how the massive industrial complex that had been established to serve these bucolic, ostensibly peaceable, purposes, were so easily turned to the machine of war.

Take the Haber process as an example. It was a breakthrough technology in 1905 for the catalysed production of ammonia from nitrogen and hydrogen at high pressure and temperature (around 450°C and 200 atm) – and therefore for fixation of nitrogen for fertiliser production. Developed by Fritz Haber, the technology was implemented on an industrial scale by Carl Bosch in 1913, and conversion of these facilities to explosives production is widely credited as having significantly contributed to prolonging Germany's war effort.

Haber's work was a driving force behind Germany's chemical weapons program during World War I. He was expelled from the country by Hitler for his Jewish heritage, and died in Switzerland in 1934. Sadder still is that an insecticide (cyanide-based Zyklon B) invented by an assistant of Haber was then used to murder Haber's family members as part of Hitler's holocaust.

In a similar fashion, technology for the electrothermal production of fertiliser from phosphate rock (as a replacement for guano) yielded related processes for white phosphorus production, which became extensively used in matches during the later decades of the 19th century. Composed of a P_4 ring, white phosphorus degrades to red phosphorus (a polymeric structure) on exposure to heat and light, so that the common grades of material are

... the Haber process ... was implemented on an industrial scale by Carl Bosch in 1913, and conversion of these facilities to explosives production is widely credited as having significantly contributed to prolonging Germany's war effort.

typically yellow. It is highly toxic, and the exposure of workers in match factories caused severe necrosis of the bones of the jaw (called 'phossy jaw').

White phosphorus found a range of uses during World War I, including the production of smoke to obscure battlefields, tracer and incendiary bullets, and chemical weapon shells. Its uses in World War II were even more sinister, including as a major weapon in the incendiary bombing of Hamburg, the city in which it was originally identified in the 18th century. White phosphorus sticks to whatever it touches, and although it burns with a relatively low heat, it is very difficult to extinguish. Even if doused by water, it will re-ignite once exposed again to air. Phosphorus wounds must be thoroughly washed with a non-polar, non-flammable solvent before the burn can be treated.

Tracer bullets are a branch of the same technology tree. Towards the start of World War I, a shooter could only determine the accuracy of his shot by watching for the strike, which isn't possible at night. Moreover, this wasn't much use during aerial combat,

where a bullet that missed its target had no impact point. Britain's first tracer bullets were deemed to contravene the Hague Convention because they exploded on impact.

White phosphorus was added to bullets to create smoke during flight, and hence the early versions were called 'smoke tracers'. Later versions used a mixture of barium peroxide and magnesium. In flight, they burned with an intensity that was readily visible even in full sunlight, and although they burned only for a few seconds, this was still sufficient to follow the flight for a considerable distance – half a kilometre or more from the muzzle. However, the tracer bullets had a poor range. As the bullet lost mass during flight, its path became erratic.

Tracers were inserted as every fifth or so round in the magazine feed to a machine gun. A US report on the development of its own version from British and French technology stated:

The tracer bullet consisted of a cupronickel shell, the nose of which contained a leaden core to balance the bullet properly. The rear chamber of the



Fritz Haber (1868–1934), sketched in 1911 by W. Luntz

bullet held a cup containing the mixture of barium peroxide and magnesium. The rear end of the bullet was left slightly open, and through this opening the mixture was ignited by the hot flame of the propelling powder charge.

America's Munitions 1917–1918: Report of Benedict Crowell, the Assistant Secretary of War, Director of Munitions, United States War Department, Government Printing Office 1919

A special form of incendiary bullet was developed and used to shoot down hydrogen-filled zeppelins over Britain. Where conventional bullets just caused a slow leak, an incendiary bullet would cause a catastrophic ignition of the hydrogen.

During the 20th century, the pressures of conflict resulted in rapid advances in chemistry and technology. The use of tanks, air and chemical warfare all emerged during World War I. I have found it sobering to consider how the wider context of these developments helped set the scene for the war in the first place.

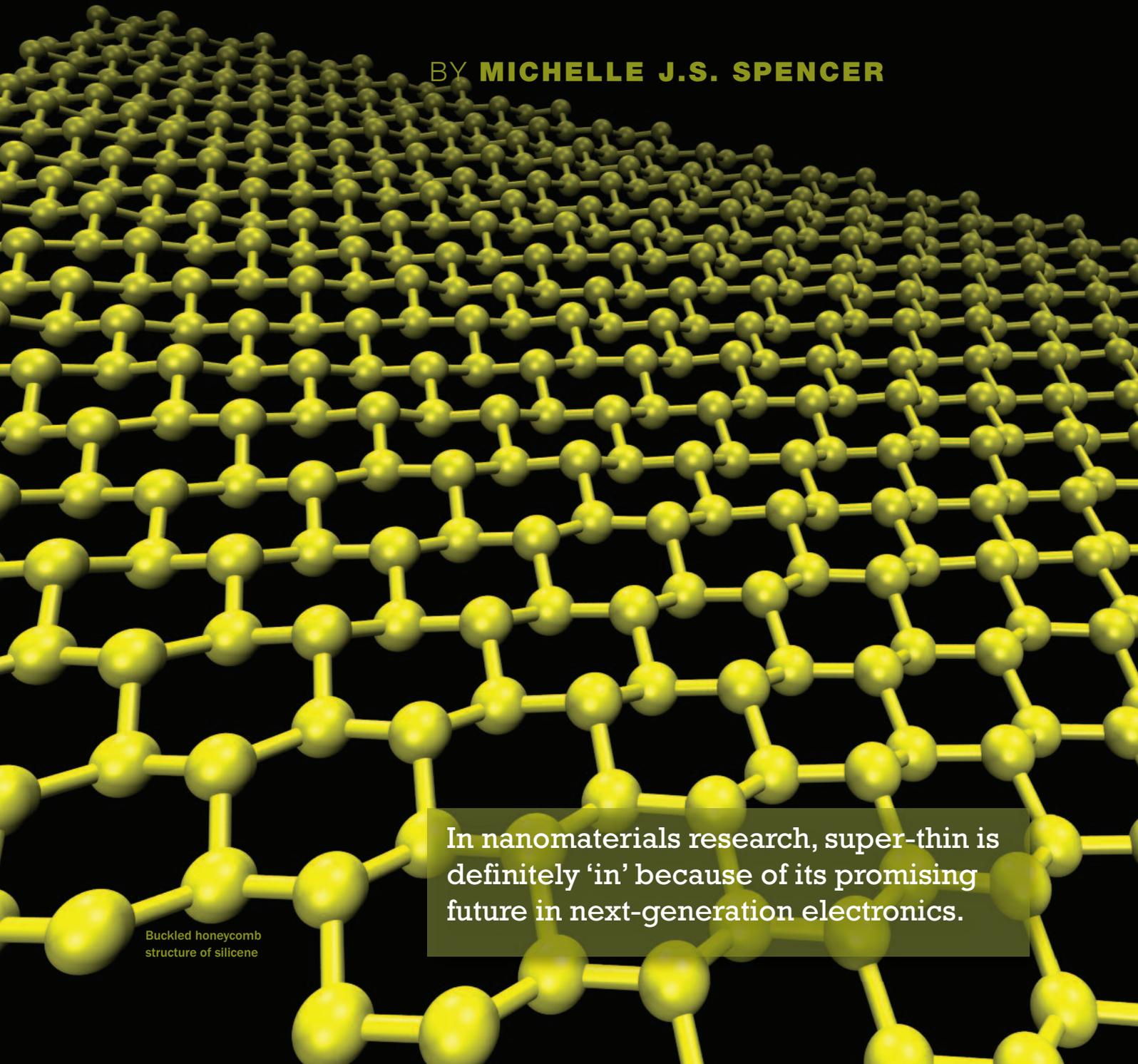
Dave Sammut MRACI CChem is principal of DCS Technical, a boutique scientific consultancy, providing services to the Australian and international minerals, waste recycling and general scientific industries.

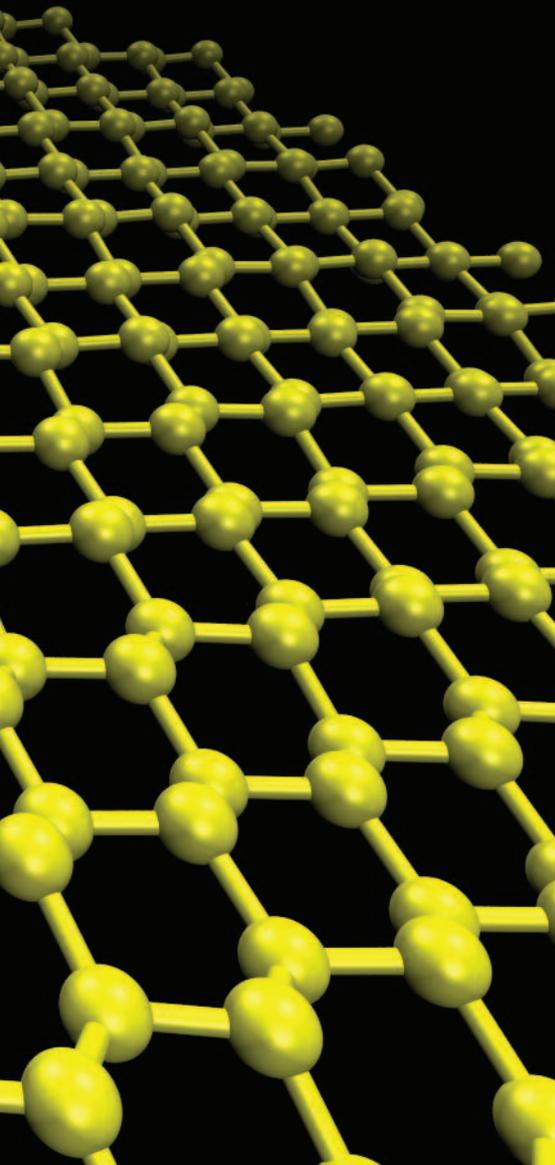
2D is the new 3D in nanotech

BY MICHELLE J.S. SPENCER

In nanomaterials research, super-thin is definitely 'in' because of its promising future in next-generation electronics.

Buckled honeycomb
structure of silicene





Nanomaterials may be relatively new to research, but our fascination with them has a much longer history. One of the first human uses of nanomaterials – as glassware – dates back to Roman times. The Lycurgus Cup, housed at the British Museum, is the only complete example of a Roman 4th-century glass-cage goblet. The dichroic glass appears opaque green under normal, external lighting conditions but a translucent red when lit from within. What the makers of the time did not realise is that the nanoparticles of gold and silver dispersed in colloidal form throughout the glass are what gives the cup its exceptional, multicoloured appearance.

Today, nanomaterials are a major area of research. They are receiving considerable attention due to their potential applications in a wide number of industries, particularly electronics and medicine. Researchers in the field of nanotechnology at RMIT are seeking ways to further improve the capacity of batteries to store energy from renewable sources that avoid the use of fossil fuels.

In these times of climate change mitigation, many countries are looking to energy sources that are clean, reliable, low cost and efficient. Generation of wind, solar and wave power can be intermittent and so these technologies cannot always compete dollar-for-dollar with conventional electricity generation. Batteries can overcome problems of intermittency, but tend to be bulky and not very environmentally friendly. Improving energy-storage capacity and efficiency while reducing costs is very attractive.

Since the first commercial release by Sony and Asahi Kasei in 1991, lithium-ion (Li-ion) batteries have revolutionised energy storage by offering superior energy density (the ability to hold charge) and high cycle durability (the ability to be recharged numerous times without suffering from

the memory effect – a gradual reduction in the maximum energy capacity over time). Li-ion batteries have the highest capability to store energy per unit weight or volume of all rechargeable batteries, and are relatively cheap and environmentally friendly. Due to their compactness, low weight and durability, they are commonly used in laptops, mobile phones and other portable electronics. They are also already entering the hybrid electric-vehicle market and are a serious contender to power the electric cars of the future. They do, however, have their drawbacks.

The working principle of Li-ion batteries involves repeated insertion and removal of Li ions (which are the charge carriers), through intercalation/de-intercalation or alloying/de-alloying, from the electrode material during electrochemical cycling. A rechargeable Li-ion battery, also known as a rocking chair battery, incorporates a two-way movement of Li ions between the anode and cathode. Accommodation of the Li ion during this charge/discharge cycle can cause structural and volume changes to the electrode material that lead to battery degradation and the memory effect.

Also, Li-ion batteries suffer from low thermal tolerance, poor low-temperature performance and the risk of thermal run-away in which the temperature of the cell rises to the melting point of the lithium, causing a violent reaction. If they are mishandled, overheated or overcharged, Li-ion batteries can catch fire or explode. There is a need for alternative charge carriers that eliminate or reduce safety issues inherent in the use of lithium.

It is the electrode material component of batteries that has a dominant impact on overall performance. One focus of recent research has been on finding new materials that can act as electrodes. Li-ion batteries use graphite as the

Nobel nanomaterials

- Harold Kroto, Robert Curl and Richard Smalley were awarded the Nobel Prize in Chemistry in 1996 for their roles in the discovery of the bucky-ball and the related class of molecules called fullerenes.
- Konstantin Novoselov and Andre Geim received the Nobel Prize in Physics in 2010 for 'ground-breaking experiments' related to graphene.

The unique structures and properties of nanomaterials and rapid advances in nanotech offer new opportunities for environmentally friendly energy storage systems.

anode material, but silicon offers a tenfold increase in maximum theoretical energy density because it can absorb more Li ions. The drawback is that bulk silicon has the tendency to swell by 400% during lithium absorption and then shrink back to its original size when the ions flow back out. This expansion and contraction leads to fracturing of the electrode, which is no use in a battery. Nanostructured materials could offer a solution to this problem.

The unique structures and properties of nanomaterials and rapid advances in nanotech offer new opportunities for environmentally friendly energy storage systems. Nanomaterials have at least one dimension that is 100 nm or less. Depending on their shape, they are classified as zero-dimensional (0D),

one-dimensional (1D) or two-dimensional (2D).

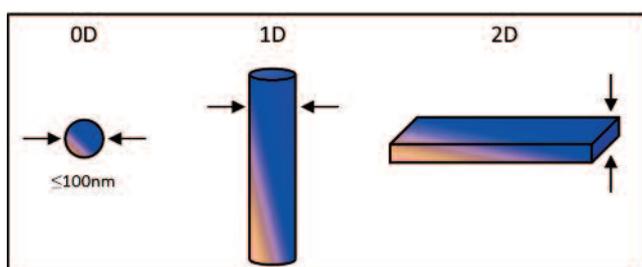
Zero-dimensional nanomaterials can be considered to have 'all' their dimensions in the nanometre range. A well-known example is buckminsterfullerene ('bucky-balls'), composed of pure carbon and arranged in the easily recognised soccer ball shape. One-dimensional nanomaterials have 'infinitely' long lengths but nanoscale-sized diameters – carbon nanotubes are a common example. Widespread interest in their properties was sparked by the work of Sumio Iijima, and his 1991 *Nature* paper. Two-dimensional nanomaterials have large lateral dimensions but thicknesses of only a few nanometres. These 2D materials bridge the gap between 0D or 1D materials and bulk 3D structures, with very useful

properties and morphology.

The most widely studied 2D nanomaterial to date is graphene, a single layer of carbon atoms arranged in a honeycomb lattice, or chicken-wire structure. Graphene is not the only 2D nanomaterial and it is not perfect for all applications. Interest in alternative ultrathin 2D nanomaterials has thus blossomed in recent years.

Other materials that have been grown or synthesised as nanosheets include silicates, metal oxides, metal mono-, di- and tri-chalcogenides and nitrides. Two-dimensional nanosheets comprising only single elements have also been synthesised. Their names generally have the suffix 'ene' and include germanene (made from germanium), silicene (from silicon) and phosphorene (from phosphorus). Unlike graphene, these other 'ene' nanomaterials are not atomically flat. Silicene, for example, still retains the honeycomb arrangement, but when viewed from the side has a buckled structure (see image, p. 24). It is cheap to produce, and silicon already dominates the electronics market.

One-dimensional silicon nanowires are already under active commercial development by Amprius, a leading manufacturer and developer of high-energy and high-capacity lithium-ion



0D, 1D and 2D nanostructures

batteries in Silicon Valley. In Asia, a recent collaboration between RMIT University, the Japanese National Institute of Advanced Industrial and Science and Technology (AIST) and Toyota R&D Labs, Japan, has been investigating the use of silicon nanosheets in battery applications. Such structures are highly promising as an alternative electrode material due to their large specific area, which allows efficient use of the effective space. Functionalisation and stacking of the nanosheets can also allow control over the interlayer spacing, which can enhance the intercalation/de-intercalation or diffusion of ions between the layers, which greatly improves both electronic conductivity and capacity.

Silicene is not quite as easy to work with as graphene. The covalent bonding in the silicon crystal structure is far stronger than the weak van der Waals type forces that hold the sheets of graphite together; unlike with graphene, sticky tape cannot be used to peel a single layer of silicene from a silicon surface. Instead, a top-down or bottom-up process has to be used to grow silicon nanomaterials.

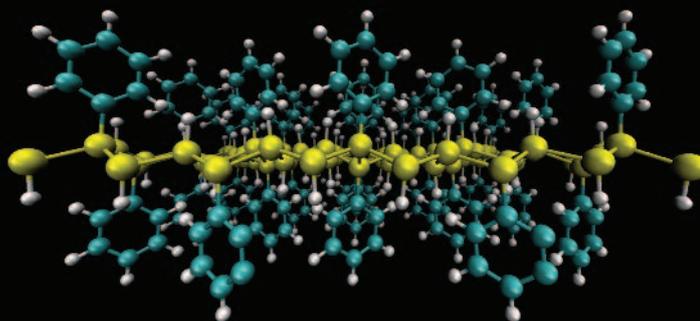
Silicene has now been grown free-standing, adsorbed on different substrates, and in a modified form with different chemical group terminations (see box at right). With this approach, functionalised 2D silicene nanomaterials can be synthesised that contain phenyl ($-C_6H_5$), n-decylamine ($-NC_{10}H_{21}$) or deanol ($-O(CH_2)_2NH(CH_2)_2$) chemical groups, thus imparting a range of different functionalities to the resulting material.

To determine the structure and properties of these nanomaterials, my group, together with Dr Tetsuya Morishita at the AIST in Japan, have been using a computational approach. Our first-principles calculations using density functional theory (a computational quantum mechanical modelling method used to investigate electronic structure) and molecular dynamics simulations (a computer

Adding functionality

Dr Hideyuki Nakano and his colleagues at Toyota Japan were the first group to synthesise functionalised silicene that was free from oxygen atoms (*Chem. Eur. J.* 2011, vol. 17, p. 9864). To make such a material, they first synthesised a stable binary Zintl compound (an intermetallic compound formed between a strongly electropositive metal, such as an alkali metal, an alkaline earth metal or a lanthanoid, with a somewhat less electropositive metal such as silicon).

There are a number of stable binary Zintl silicides, but calcium disilicide ($CaSi_2$) has a structure that includes 2D silicon 'puckered' sheets in which the Si_6 rings are interconnected. The layers are separated from each other by planar monolayers of Ca^{2+} ions. In the synthesis process, the resulting $CaSi_2$ structure can then be converted to a layered polysilane (Si_6H_6) by reaction with HCl.



Phenyl-modified silicene. Scan the QR code or visit <http://youtu.be/JD6quILAdn0> to view an animation.



simulation of the physical movements of atoms and molecules) have confirmed the structure of the functionalised silicene as well as the electronic and dynamic properties. Most recently we have shown, together with the group of Dr Nakano, that deanol-modified silicene $[Si_{10}H_8(O(CH_2)_2NH(CH_2)_2)_2]^{2-}$ can be used as an anode in a secondary-type battery, with graphite as the cathode (*J. Mater. Chem. A* 2014, vol. 2, p. 7588). The Li ions were replaced with BF_4 anions, which acted as the charge carriers. This battery showed superior performance under thermal abuse compared with Li-ion batteries, and was even operable at $-30^\circ C$, a temperature at which Li-ion batteries generally cannot function. Although this work is still in its infancy, the morphology and properties of these

new nanomaterials show great promise not only for components in batteries but also in applications such as gas sensors and electronic devices.

It would be rare to find anyone in Australia who didn't use a smartphone, tablet, laptop, or any form of powered transport on a daily basis. To power all this equipment, we are continually seeking faster, thinner, lighter but more powerful batteries, while keeping in mind the need for environmental sustainability. Two-dimensional-based nanomaterials could be a big part of our technologically expanding future.

Dr Michelle J.S. Spencer MRACI CChem is a senior lecturer in chemistry in the School of Applied Sciences at RMIT University, and a visiting scientist at CSIRO Materials Science and Engineering. She is grateful to Dr Oliver A.H. Jones MRACI CChem of RMIT University for his ideas and helpful suggestions in the preparation of this article.

Advanced spectroscopy

Ray Hodges considers three spectroscopy techniques linked to Nobel Prizes.

In concluding my series of topics 'Beyond the basics', I would like to inspire readers to consider things greater than most of us will ever achieve. The electromagnetic spectrum (EMS) extends from gamma rays (γ -rays; high-energy photons from radioactive nuclei) with wavelengths (λ) less than a nanometre to radio waves with wavelengths many kilometres in length. Most of the EMS has applications in spectroscopy and in this article I touch on three unique techniques used in research giving rise to Nobel Prizes. These scientists built on earlier discoveries by others who set the scene, and subsequently we all benefit from the developments.

For analytical chemists, the task becomes challenging when undefined samples are submitted for comprehensive elemental analysis. Where does one start? One possible decision tree has been outlined (*Chem. Aust.* 1999, vol. 66, no. 3, pp. 9–12) but the scanning electron microscope (SEM) makes the task comparatively straightforward (Nobel Prize in Physics 1986). This equipment uses a magnetically focused electron beam in a vacuum chamber and is capable of analysing individual phases in heterogeneous samples such as point defects in metals (inclusions) that can cause fatigue failures. Electron

beams exhibit quantum effects and the particles have wave characteristics with very short wavelengths, allowing magnifications of 100 000 times or higher. (Optical microscope images lose clarity for objects smaller than about ten times the wavelength used.) A fraction of this electron beam ejects inner (K and L shells) electrons* from atoms in the sample. As outer electrons fall back to these levels, characteristic X-rays (wavelengths slightly longer than γ -rays) for each element present are emitted. An inbuilt scintillation detector detects these and gives an XRF (X-ray fluorescence) spectrum for comprehensive elemental analysis of crystals or defects.

Two samples for which SEM proved useful to me were a white crystalline substance from a dried-out basin on Raymond Island in the Gippsland Lakes and boiler scale from a butter factory. Sea salt (mostly NaCl) forms cubic crystals, but these were whiskers (3 mm needles). The SEM showed these to be CaSO_4 (selenite or gypsum). Very large crystals (>10 metres) can form in nature (bit.ly/1r72yfg). For the boiler sample, scans (see graphs, p. 29) identified iron oxide and calcium phosphate phases.

A second notable spectroscopy technique, nuclear magnetic resonance (NMR), helps elucidate the structure of organic compounds. This uses radio waves in a magnetic field to reverse the spin of nuclei, the most sensitive being ^1H . Nobel Prizes for this were awarded in physics (1952) and chemistry (1991, 2002). For resonance to occur, the precise frequency is affected by adjacent chemical bonds. Scans are achieved by minutely varying either the magnetic field or the radio frequency (typically 0–20 ppm from the set starting value). (It has always amazed me that photons with wavelengths many billions of times larger than the proton nucleus require precisely the exact perceived energy in its chemical environment to be instantly absorbed by these minute nuclei.) One form, called MRI (magnetic resonance imaging, Nobel Prize in Physiology or Medicine 2003), is used in hospitals to scan patients – to detect abnormal cells such as cancer cells. Another extension called magnetometers is used for aerial geo-prospecting; this uses the Earth's magnetic field and very low electromagnetic frequencies (in the audio range) to detect mineral deposits up to a kilometre below ground.

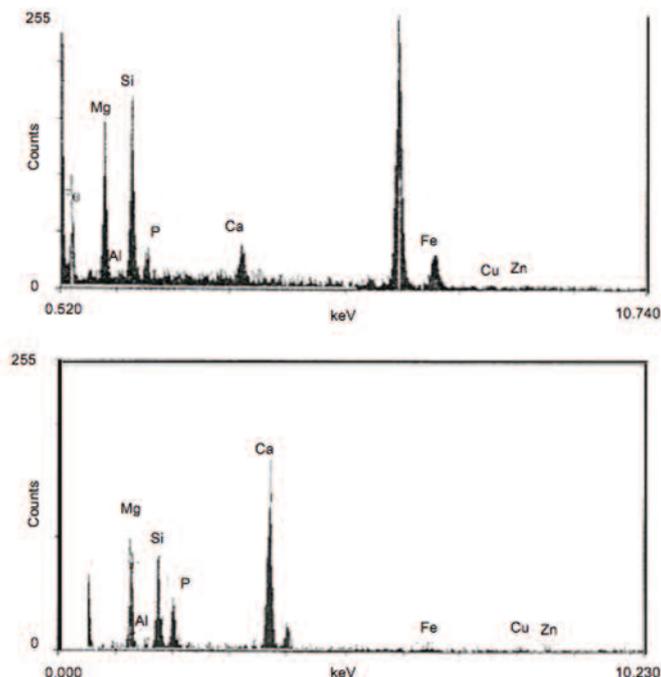
* These high-energy electrons give another form of spectroscopy called ESCA (electron spectroscopy for chemical analysis) and this is like photoelectron spectroscopy (see July 2013 issue, pp. 24–5).

Going back to the γ -ray end of the EMS, a third intriguing technique is Mössbauer spectroscopy (Nobel Prize in Physics 1961). To get an idea of how unique it is, we first need to consider more quantum effects and look at Heisenberg's uncertainty principle. Normally this principle is expressed in terms where uncertainties in momentum (Δp) and position (Δx) are linked by an equation $\Delta p \times \Delta x \geq h$, with h = Planck's constant.

The fundamental units of this product are mass \times length²/time or mx^2/t and interestingly these are the same for energy \times time. One can show this equivalence by considering, for example, (kinetic energy) \times time or $\frac{1}{2}mv^2 \times t$; this allows the uncertainty equation to be revised to $\Delta E \times \Delta t \geq h$. I am perplexed conceptually by this transformation, but it works for spectroscopy. In practical terms, it

means if electrons in an atom remain in their excited state for long enough, then the transition back to the ground state gives a photon with minute uncertainty in energy.

Let's recall how atomic absorption works: atomic spectral lines are very sharp, typically less than 0.001 nm wide, and this is why hollow cathode lamps are used for each element as light sources. In Mössbauer spectroscopy, radioactive nuclei stay in their excited state much longer than do electrons in elevated orbital states. Only a few nuclei are suitable for the technique but one such γ -ray source starts with



SEM elemental scans of two separate boiler scale particles

radioactive ^{57}Co . This isotope decays with a half-life of 267 days by K capture (i.e. the nucleus absorbs an electron from its own K shell), generating an excited state ^{57}Fe nucleus, which is stable long enough to emit a γ -ray of extremely precise energy. These γ -rays can be absorbed reversibly by samples containing iron via the naturally occurring isotope ^{57}Fe (2.2% abundance). Energy levels in this iron nucleus are ever so slightly perturbed by its oxidation state or chemical bonding, which minutely shift the nucleus's energy transition.

Scanning builds up an absorption spectrum of the iron's chemical environment. To scan, the sample is repeatedly moved towards and away from the source at speeds varied between 0 and 10 cm/s, and the associated Doppler shift brings iron nuclei in each chemical bond into resonance. Can you imagine just how minuscule this Doppler shift really is, knowing the speed of light (or these γ -ray photons) is 3×10^8 m/s? The technique can also be sensitive enough to prove in the lab how Einstein's space-time fabric affects atoms in the Earth's gravity.

Ray Hodges FRACI CChem, now retired, was an Associate Professor at Monash University.

Laureate spectroscopy

Nobel Prize in Physics 1952: Felix Bloch and Edward Mills Purcell

for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith

Nobel Prize in Physics 1961: Robert Hofstadter

for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons

and Rudolf Ludwig Mössbauer

for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name

Nobel Prize in Physics 1986: Ernst Ruska

for his fundamental work in electron optics, and for the design of the first electron microscope

Nobel Prize in Chemistry 1991: Richard R. Ernst

for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy

Nobel Prize in Chemistry 2002: John B. Fenn and Koichi Tanaka

for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules

and Kurt Wüthrich

for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution

Nobel Prize in Physiology or Medicine 2003: Paul C. Lauterbur and Sir Peter Mansfield

for their discoveries concerning magnetic resonance imaging

Source: Nobelprize.org

RACI Board elections

It's election time for Board positions and it's time to determine the future direction of our organisation.

There are two contested positions, which is a positive move towards good governance after a number of years of limited involvement. The two positions are National Representative and Western Representative.

1 National Representative is a position for which *all* eligible RACI voters can 'make their mark'. The candidates are Tatiana Anesbury, Steven Langford and Michael Kassiou.

Tatiana Anesbury is currently the National Representative Board member. She was the South Australian Branch President 2010–12 and over the last 20 years has been active in the South Australian Branch, Chemical Education Group, *Chemistry in Australia* and SA Joint Chemical Engineering and Chemistry committee. Her area of interest is education outreach and industry partnerships.

Steven Langford has been an active RACI member for 24 years. He is currently in his fifth year as Head, School of Chemistry at Monash University and is Director of the \$75 million Green Chemical Futures Initiative. Steven is a graduate of the Australian Institute of Company Directors, having completed their residential Company Directors Course in 2013. He has also undertaken the High Potentials Leadership Program at the Harvard Business School. Steven would pursue three main objectives:

- Instil strong governance processes in the Board's function so it can actively pursue the strategic goals of the RACI for the benefit of its members.
- Enact upon the strategic goals of the RACI in an impactful way, increasing the membership base by value-adding and look internationally at opportunities to strengthen the RACI as the chemical sciences peak professional body.
- Provide new energy and perspective to the Board.

Michael Kassiou has been an active member of the RACI for 25 years. He has served on the Management Committee of *Chemistry in Australia* and as Chair of the Medicinal Chemistry and Chemical Biology Division. The RACI needs to be at the forefront of national debates and policies which have an impact on the future of chemistry, which can only occur with a unified position of strength.

Michael is firmly committed to improved dialogue and interactions between RACI Divisions and its members. As someone who is involved in multi-disciplinary research and with several RACI Divisions, he feels he is well positioned to act as National Representative. The strength of the RACI lies in its members and the Divisions to which they're aligned.

2 Western Representative is a position reserved for eligible RACI voters who live in South Australia, Western Australia and the Northern Territory *only*. The candidates are George Koutsantonis, Stephen Clarke and Matt Sykes.

George Koutsantonis is an academic at the University of Western Australia and has been a member of the RACI since 1985, serving on the executive committee of the Inorganic Division for 14 years. He is currently the incumbent Western Representative and is working towards heightening the profile of the RACI in the general community.

George feels that the RACI will best benefit members by being recognised as the peak body for chemistry in Australia and in that way shape public policy and influence the organs of all levels of government. The RACI must change to reflect the new reality facing academia, industry and chemists in society.

Stephen Clarke has been a member of the RACI for 31 years and a member of the RACI Polymer Division Standing Committee for 11 years and is the current Treasurer of the South Australian–Joint Chemical Engineering Committee.

Stephen is an internationally recognised polymer chemist, an IUPAC Fellow, a member of the ACS Polymer Division Board and a member of the Editorial Advisory Board of *SILICON*, a peer-reviewed journal reporting solely on silicon chemistry.

Stephen has lived and represented chemistry in South Australia for 23 years and believes he is well placed to be the Western Representative on the Board, to further benefit chemistry in South Australia, Northern Territory and Western Australia and wishes to use the Board position to strengthen our international chemistry ties.

Matt Sykes has been an RACI member since 1995; he is currently a senior lecturer in chemistry at the University of South Australia. Matt has served on the South Australian Branch committee since 2007 and is currently president of the South Australian Branch. Matt has been instrumental in establishing the RACI presence at the annual Science Alive event and significantly growing the income of the Branch.

Matt is a trained RACI accreditor and a member of the 2014 Congress organising committee, and he represented the RACI at Science Meets Parliament in 2012. Matt has a particular passion for ensuring the RACI:

- engages more strongly with younger chemists
- expands the membership attractiveness to secondary and primary school teachers
- ensures its financial future by finding innovative ways to generate revenue while maximising the return to members.

Eligible voters are all individual members except Associates and undergraduate students. To vote, tick the box next to your preferred candidate on the ballot slip. Place the ballot slip inside the small envelope, write your name and member number and sign. Then place this in the self-addressed, postage-paid envelope and drop it in the post box. If you are eligible to vote for the Western Representative, complete both ballot slips and place them in the same envelope.

RACI National Congress

The RACI Congress in Adelaide will be the largest gathering of Australian chemists since 2005 and you are invited to be part of this exciting event. Over 100 plenary, keynote and invited speakers have been drawn from around the world and represent some of the most important work in chemical community.

More than 850 abstracts have been received and represent work in many important areas of chemistry as well as cross-disciplinary activities. The meeting will provide a great environment to meet colleagues, discuss current trends and explore new opportunities. There will also be a significant exhibition showing the latest equipment and technology.

For the latest list of speakers, please visit www.racicongress.com/speakers.html.

RACI 2014 will be held at the multi-award winning Adelaide Convention Centre, on the waterfront of the River Torrens near the heart of the city. The convention centre offers first-class facilities to delegates, partners and visitors, and is a short walk from accommodation, restaurants and the central business district of Adelaide.



raci
National Congress
7-12 December 2014
Adelaide | Australia
Building strong bonds

Social program

Sunday 7 December 2014: Welcome Reception

The Welcome Reception will be a cocktail-style event to welcome our delegates to the opening of RACI at the Adelaide Convention Centre.

Thursday 11 December 2014: Congress Dinner

The Congress Dinner will be a time for delegates to catch up with old friends and meet new ones. This evening will be the highlight of the social program, a real opportunity to experience the flavours, cultures and sights and sounds of Adelaide by night. (Tickets must be pre-purchased.)

Joe Shapter FRACI CChem, RACI2014 Congress Chair



Take advantage of your RACI benefits this Winter!

We've harnessed the collective buying power of over 5,000 members to provide you with exclusive discounts on a range of quality benefits through Member Advantage.

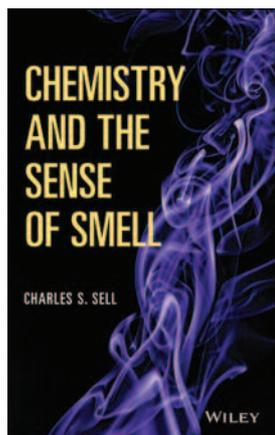
Your benefits include:

- **Dining** - discounts at hundreds of selected restaurants
- **Movie tickets** - available for pre-purchase from \$10.50*
- **Lifestyle experiences** - 12% off Adrenalin experiences
- **Accommodation** - up to 15% off global accommodation
- **Foreign exchange** - free international money transfers
- **Car rental** - corporate rates and reduced insurance excess

For further details, call 1300 853 352
or visit www.memberadvantage.com.au/raci

*Price current as of 06/05/14 and subject to change. Terms and conditions apply, see the RACI Member Advantage website for full details.





Chemistry and the sense of smell

Sell C.S., Wiley, 2014, hard cover, 480 pp., ISBN 9780470551301, \$190.95

Charles Sell and I worked with the late Professor A.J. Birch FRS in the Research School of Chemistry at ANU in the early 1970s. Charles was destined for the perfume industry, in which he spent his whole career. This book is his personal perspective on olfaction and the perfume industry.

Calling it a book is an injustice. It is more a veritable treatise on all matters associated with the sense of smell condensed into one (largish) volume. But it is not easy to read, with a vocabulary spanning several scientific disciplines and making extensive use, as it does, of space-saving acronyms throughout.

The treatise is presented in nine chapters, which follow a preface, acknowledgements and an introduction, and are followed by a glossary and an index.

Smell is one of the two chemistry-based senses in human beings. It is also the oldest, playing a part in evolution. The author attributes the current state of knowledge to two major advances: the discovery of the primary structures of the human olfactory receptors and how they function in the olfactory sensory neurons.

We learn that olfaction, unlike the sense of vision, has no fixed reference points. Olfaction depends on a combinatorial detection system and neuroprocessing to convert the physical input into a mental image (percept) we call smell. Thus, a smell can only be described in relation to previous experience, which produced a similar mental image. Smell is subjective, varies greatly between subjects and can trigger responses as diverse as the survival mechanism, recollection of previous events or avoiding spoiled food.

Chapter 1 asks and answers 'Why do we have a sense of smell?' We are warned in the introduction that Chapter 2 'The Mechanism of Olfaction' elucidated largely by molecular

biologists and biochemists, focuses a lot of attention on receptors, in human beings, other animals, insects and fish, which could make heavy going for chemists.

Instrumental chemical analysis of odour, discussed in Chapter 3, would be familiar to chemists, with the possible exception of GC-olfactometry, in which the emerging carrier gas stream is split, and a human nose becomes the second detector. Chapter 4 casts a wide net, from biblical references to perfumery, through olfactory acuity and the effects of age, malodorous warning signals, olfaction and health and anosmia, which is often associated with disease.

Chapter 5 'The Scents of Nature' introduces terpenoids, shikimic acid derivatives, lipids and polyketides and their biosynthetic pathways. Originally, fragrance ingredients were natural products such as musk and rose oil. Chapter 6 maps the shift to synthetic ingredients and presents syntheses for major ingredients such as citral and menthol as well as industrial scale routes to terpenoids, which produce high-quality products at lower cost.

The design of new fragrance ingredients, addressed in Chapter 7, is constrained by a host of factors, including ever-increasing safety requirements. Nevertheless, new fragrances continue to emerge and animal testing is declining. The author valiantly attempts to dispel the *natural equals safe* and *renewable is synonymous with sustainable*, arguments.

The relationship between molecular structure and odour is explored in Chapter 8. As early as 4 BCE, Aristotle and Democritus were opining on the subject, the latter in terms of sharp and smooth effects on the nose. Pharmaceutical chemists have been quite successful in correlating physical and chemical properties of molecules with activity (SAR). Fragrance chemists have their own structure/odour relationships (SOR) but due to the complexity of the olfactory process, these are in most cases still inadequate. It has been shown that experienced fragrance chemists can make better predictions than SORs. Stereochemistry can also have puzzling and largely unpredictable effects. Greater success has been achieved with olefactors, such as the fruity odours of simple esters.

Chapter 9, the last and shortest, discusses intellectual challenges, including design and process challenges in fragrance chemistry, both overcome and awaiting solution.

Overall, the result is very good. My only criticism is the amount of repetition, which reflects on the editors. Who will read the book? Fragrance chemistry is very limited and almost non-existent in Australia. If academic libraries purchase the book, their chemistry borrowers will benefit greatly from reading it. Anyone with an interest in olfaction and chemical communication will enjoy it too.

Peter G. Lehman FRACI CChem

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.



Rowe Scientific

www.rowe.com.au

Suppliers of:

CERTIFIED REFERENCE MATERIALS

Reference materials from all major worldwide sources including:

NIST (USA), CANMET (Canada), SABS (South Africa), BAS (UK), Standards Australia, BGS (UK), BCR (Belgium), NWRI (Canada), NRCC (Canada), Brammer (USA), Alpha (USA), Seishin (Japan)

ADELAIDE
08 8186 0523
rowesa@rowe.com.au

BRISBANE
07 3376 9411
roweqld@rowe.com.au

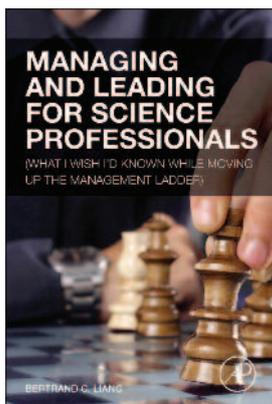
HOBART
03 6272 0661
rowetas@rowe.com.au

MELBOURNE
03 8795 7771
rowevic@rowe.com.au

PERTH
08 9302 1911
rowewa@rowe.com.au

SYDNEY
02 9603 1205
rowensw@rowe.com.au



Managing and leading for science professionals (What I wish I'd known while moving up the management ladder)

Liang B.C., Academic Press (Elsevier), 2013, hard cover, 168 pp., ISBN 9780124166868, \$52.95

A multitude of management books line the shelves in any book store; given that the standard career progression for scientists is

to move to more managerial roles, it is only natural that management books designed to help this transition exist.

Fortunately, I have read only a few management guide books, but they all appear to follow similar lines: how to be a boss, leadership, delegation of tasks, moving up the ladder, managing projects, and, of course, a chapter dedicated to helping you becoming a CEO.

This book, *Managing and leading for science professionals*, follows the standard formula very closely. There are chapters on developing your career and new skills, such as marketing and finance, making hard decisions, building relationships and managing upwards – all of which give very good, if not original, advice for any person taking on a more managerial role.

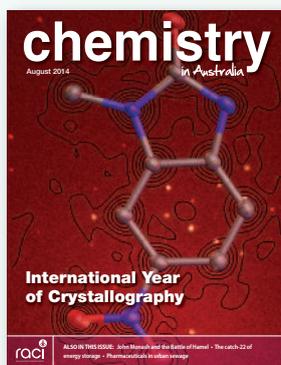
The underlying theme of the book is that most scientists are not trained for management because of their past experience in

'getting the data', while management roles require a different skill set. This is reinforced throughout by anecdotal stories about scientists struggling to make the transition from the laboratory bench or similar technical positions into a managing or leadership role. Most of these stories I found simplistic and clichéd because they relied on the stereotype of the introvert scientist or the scientist with no interpersonal skills to work with dynamic groups. This is disappointing, given the author's medical background. Almost any scientist at the bench today has already had ample experience in managing and interacting with large groups of people, such as fellow laboratory workers, collaborators and technical assistants, not to mention their supervisors. It is not possible to do modern science without already having some experience at managing and working with dynamic groups. I believe this book would have been significantly more relevant if it focused on how skills already developed by scientists can assist in the transition to a management position, and subsequently complement additional management skills such as marketing and risk management.

The biggest advantage *Managing and leading for science professional* has is that it is very short – only 148 pages long – and the messages come across concisely and to the point. Hence, if you are after a management guide book, then this one will tell you what you need to know in a fraction of the pages much more widely known management texts will.

Colin Scholes FRACI CChem

Receive 25% off this and other Elsevier books at www.store.elsevier.com (use promotion code PBTY14).



There's more to explore online

raci.org.au/resourcecentre/chemaust

Your member magazine and other great reads

View the latest issue or archives of *Chemistry in Australia*.

Archive access

Browse or search our index of issues from 2003 onwards.

Features and advertising

Find out about contributing a feature article or contact us about advertising.

Milking the MOOC

At a symposium with the theme of MOOCs at the University of Sydney in July last year, Diana Laurillard, Professor of Learning with Digital Technologies at the London Knowledge Lab suggested that global demand for higher education will reach approximately 200 million students by 2025, mostly from emerging economies. In her remarks, she says that this global demand requires ‘... investment in pedagogic innovation for MOOCs to deliver’ and that ‘technology enhanced learning must support students at a better than 1:25 staff–student ratio’. Her note of warning is that ‘... the fundamental academic aim is to improve the quality and scale of higher education globally and not merely to (i) access masses of data from desperate would-be students; (ii) market our courses more widely and (iii) provide free CPD [continuing professional development] to employed professionals’. Unfortunately, I think Professor Laurillard’s views are a little too altruistic in the business of Higher Education.

The MOOC

MOOC stands for Massive Online Open Course. The term ‘massive’ derives from the potential number of participants in any one subject. They are conducted online and open to all with no enrolment restrictions (although some carry recommended prerequisites) and they cover a wide range of subjects at varying degrees of difficulty of content.

There are three groups of participants. The first is the infrastructure provider. They provide the hardware, software, communications and support for the content providers and ‘students’. The second group, the content providers, are generally universities, although there are libraries and museums that provide content. The third group is the ‘students’.

According to the Grattan Institute’s Andrew Norton, a speaker at the symposium, the MOOC market differs from the traditional university model in that, while it provides knowledge for its own sake, student outcomes for MOOCs have more to do with knowledge, skills and personal development rather than getting a job or a better job. At the moment, MOOCs earn their revenue from charging for completion certificates, although some unbundled university courses charge fees with the carrot that the subject may count towards an enrolled course if the student eventually formally enrolls.

With a global market expected to reach about 200 million by 2025, global branding and commercial incentive has five of the group of eight (Go8) associated with MOOCs. A quick look at the Go8 – ANU and University of Queensland have signed up with edX; the universities of Melbourne and New South Wales with Coursera; Monash with FutureLearn; and University of Western Australia with ClassToGo, which is merging with the edX platform.

MOOCs are ... in their introductory stage and will probably progress through the normal developmental cycle of growth, maturity and decline, or regeneration into different products – the diet MOOC, the caffeine-free MOOC, the zero MOOC.



According to Norton, global brand recognition is one of the reasons the Go8 are signing up, but also the collection of data from the masses of global students is helping universities develop better teaching methods and delivery styles. It would not surprise me if this data collection from 'desperate would-be students' is also analysed from a marketing perspective so that courses, both MOOC and traditional, can be better targeted and 'marketed more widely'.

Coursera is the largest MOOC, with about 80 of the world's leading universities signed up and offering about 500 subjects.

If you think MOOCs might be a passing fad, consider the academic and commercial integrity of its CEO Richard C. Levin. Professor (of Economics) Levin was the President of Yale University from 1993 to 2013. Under his leadership, Yale's endowment grew from \$US3.2 billion to over \$US20 billion (Wikipedia), among other achievements. Also on the advisory board of Coursera is Margaret Sheil, Provost of the University of Melbourne.

The MOOC and I

Epigenetic Control of Gene Expression was run on Coursera, badged by the University of Melbourne and presented by Dr Marnie Blewitt, head of molecular genetics at WEHI. The course standard, in her words, is at third-year undergraduate or early first-year graduate. The assessment tasks, however, are pitched a lot lower. The course attracted an initial global participation of about 22 000, covering a wide range of age groups, qualifications and reasons for participation, with the main reason being the gaining of knowledge. While sign-on rates for MOOCs generally are extremely high, completion rates are only 5–10%. The completion rate for this course was 1076 students. However, one of the features of MOOCs is the ability to audit the course; that is, you can sign-on without intending to complete, but simply cherry pick the bits you want.

This course was exceptionally good and run over eight weeks with seven topics covered. Lectures were simply presented with weekly topics dissected into lectures of 8–17 minutes duration with total time at 1.5–2.0 hours per week. Assessment was mostly weekly multiple-choice questions and for week seven there was a peer-assessed short-answer quiz of four questions. The pass mark for the subject was 65% and at completion you are able to download a completion certificate. During the initial weeks, you could sign up to a validation system called 'signature track' which lets you securely link your coursework to your identity and your completion certificate was then a 'verified certificate' (extra cost?).

I enjoyed the course in all respects and look forward to my next MOOC experience, which will be immunology.

Links

<http://sydney.edu.au/elearning/pd/MOOC.shtml>
www.coursera.org
www.udacity.com
www.edx.org

The MOOC and professional development

At the moment, and contrary to Professor Laurillard's view, I think MOOCs provide an excellent avenue for cheap CPD.

RACI has a strategic aim to have in place a comprehensive portfolio of quality professional development programs easily accessed by a wide range of members progressing through all professional levels. These programs will include personal accreditation programs. Indeed, the RACI website now includes a PD Tracker. CPD is a cornerstone of any profession and many have mandated hours per annum or per triennium. Most also encourage personal and ethical development. CPD may also come at considerable cost – such as travel, meals and accommodation, conference attendance and the like – and generally budgets are tight. MOOCs, particularly while they remain either free or relatively inexpensive, provide a cheap and viable alternative, especially in areas complementary to a chosen vocation. All professionals face ethical decisions at some time in their careers, yet I wonder how many members have had formal CPD on the subject. I once asked a lawyer what he knew about ethics and he thought it was a county in England. So we might find a course on a MOOC on ethics. Perhaps marketing, communication in organisations or organisation theory would be useful to the employed professional chemist. Victorian branch president Richard Thwaites in his June newsletter was pondering the 5 Ps of marketing in relation to RACI's membership. So as professionals, administrators, leaders in our fields and in society we need to broaden our skills with personal development.

Future of the MOOC

Andrew Norton expressed many positive views about the future of MOOCs and the various models of higher education. He indicated that they are here to stay in both the wholesale and retail higher education markets. If you have 30 minutes to listen to his talk and you are involved with higher education, you will not be disappointed. But remember, MOOCs are very young and in their entrepreneurial phase. As a product, they are in their introductory stage and will probably progress through the normal developmental cycle of growth, maturity and decline, or regeneration into different products – the diet MOOC, the caffeine-free MOOC, the zero MOOC. I'm sure you get the idea.

If you are a university worker, don't start tearing down the sandstone castles just yet! The MOOC product will enhance the traditional higher education model simply by increasing the global market size, developing competition and encouraging people to achieve what a MOOC cannot yet grant – a recognised award.

Milk the MOOC

For whatever reason you may choose – CPD, gaining knowledge or entertainment (at the time of writing there is a course about to commence on the music of the Beatles) – I urge you to get on line and at least have a look. As Gerry Harvey might want to say 'If you're not milking the MOOC – why not?'

Denis McCann MRACI is a freelance peanut – in a world of anaphylaxis.

Rule number one: never bet against silicon

I have been wondering for quite some time why so many good researchers in Australia are working on organic solar cell technologies. I am sure they have their reasons, but, for those of us on the inside of the photovoltaics industry (I am, among other things, CEO of BT Imaging, Australia's sole exporter of manufacturing tools for photovoltaic manufacturing), these efforts leave us scratching our collective heads.

One of the primary arguments I have heard for doing research in the field of organic photovoltaics is that organic materials that are suitable for photovoltaics could, at some stage in the future, be very cheap. Well consider this: the price of purified silicon as used in photovoltaics is now just \$20 per kilogram and dropping rapidly. Sure, there are base polymers, such as polyolefins, which sell for around \$1 per kilogram, but as soon as you get into the area of electronic chemicals, material prices start reflecting the very complex synthetic chemistry required to make them, and tens, if not hundreds of dollars per kilogram is more representative of the prices in bulk.

Despite years of development, the best inorganic thin-film materials in production are still only just over half of the efficiency of silicon solar cells, and organic materials are only around typically half of that again.

A counter claim is that one can do 'thin-film' (say 10 μm or less) photovoltaics with organics and hence use much less material than with bulk silicon. However, Sunpower's silicon wafers are down to 120 μm and the rest of the industry is chasing them. Indeed, there are other inorganic 'thin-film' photovoltaic materials such as the raft of direct-bandgap compound semiconductors that are in development or on the market, in the case of cadmium telluride. Even these better-performing and much cheaper (than organic photovoltaics) thin-film inorganic materials are now struggling against silicon-wafer-based photovoltaic cells, so I can't see what natural advantage the organics have here.

Thin-film technologies, either inorganic or organic, are plagued with much lower solar cell efficiencies than silicon wafer photovoltaics. This is due to the much higher levels of electrical defects in these materials inherent in their molecular structure (in the case of organics) and resulting from their processing into solar cells, which leads to very high levels of recombination. Despite years of development, the best inorganic thin-film materials in production are still only just over half of the efficiency of silicon solar cells, and organic

materials are only around typically half of that again. Worse still, the rate of improvement in photon-to-electron efficiency is actually higher in silicon wafer photovoltaics than it is for all other technologies (including organic photovoltaics) because of the billions of dollars of annual industry-wide R&D investment into silicon photovoltaics.

You may hear that organic materials are cheaper to process than other materials. This is true if you are talking about extruding a plastic toy out of polyolefins, but not so true if you are talking about making a solar thin-film out of an inherently insoluble electronic organic material. These organic photovoltaic materials are very hard to process and require complex manufacturing processes often using dangerous solvents, which in turn, at the factory level require very expensive processing equipment. By comparison silicon solar wafers and solar cells are incredibly cheap to make, with very low capital equipment costs.

Konarka (which was the leader in organic photovoltaics until they went bankrupt) had been trying to make organic solar cells for a decade. After spinning out of MIT in 2001 and spending around \$200 million, they had managed to be 'ten times higher cost, and ten times lower efficiency and lifetime' (bit.ly/1r2P8P0) than the state-of-art silicon photovoltaics technologies. Not a good outcome. The real problem with organic thin-film photovoltaic materials is their ultra-low performance. Extracting the current is simply that much more difficult in organic materials than in a beautiful indirect bandgap bulk material like silicon. With much higher inherent recombination, organic photovoltaic materials will struggle to catch up to silicon. And what this means is extraordinary complexity in cell designs and processing technology that still results in lower efficiency and higher cost solutions.

Some claim that organic photovoltaics can be used to make flexible solar cells. However, there really isn't much of a market for flexible solar cells in mainstream applications since solar cells are usually placed in a fixed position designed to catch the maximum amount of daily sunlight. Solar cells are flat for a very good reason – to avoid local shading. If cells are ever moved to track the position of the sun, typically the module is rigid and the whole thing is moved, but this is becoming rarer as the cost of photovoltaics becomes cheaper and the mechanics and reliability issues of moving the modules with the sun are become economically unviable.

Further, if niche applications do emerge that require flexibility, this can be satisfied by any number of inorganic thin film photovoltaic technologies; these solutions already exist and they all have much higher energy conversion efficiencies than organic solar cells, and with lower costs. Even more astounding to note is that silicon-wafer-based photovoltaic cells can also be flexible. Once a silicon wafer gets to around 50 μm thick or less, it becomes flexible, and in pilot facilities around the world researchers are demonstrating these products today.

Some argue that organic photovoltaic materials can be applied to any substrate, such as a corrugated tin roof. The truth is that the substrate has to be: (a) flat (anything other than flat is silly because you get local shading); (b) impervious to oxygen and water (so the organic photovoltaics do not degrade too quickly); (c) impervious to UV degradation so it keeps on being a substrate; (d) able to withstand the processing solvents; (e) cheap enough; (f) not have a high thermal expansion, which would break the organic films on top, etc. The truth is, if you have a substrate suitable for an organic thin-film photovoltaic material, then that very same substrate will be just as good for any other cheaper inorganic thin-film photovoltaic materials, or even silicon wafers.

Another thing to note is that organic materials don't like being out in the sun – they degrade. Oxygen, UV, water and heat enhance degradation rates, so organic thin-film materials are encapsulated in extraordinarily expensive (compared to silicon) encapsulation technologies. Even so, they don't last too long in comparison to silicon because the molecules themselves absorb UV and suffer degradation.

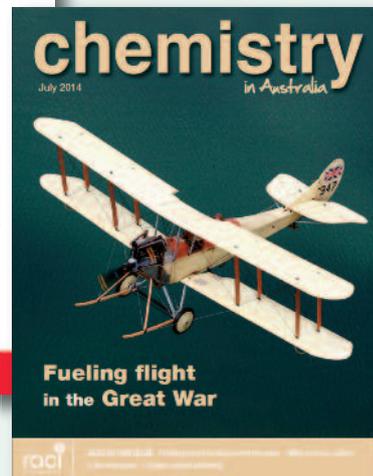
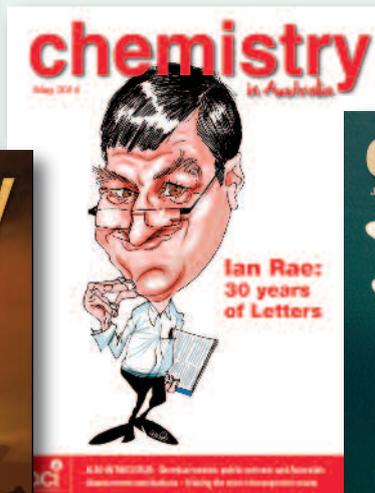
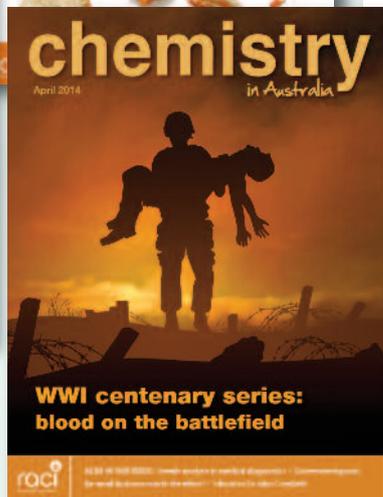
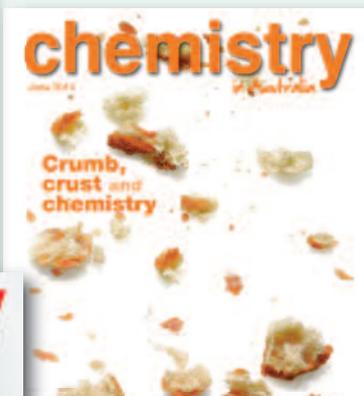
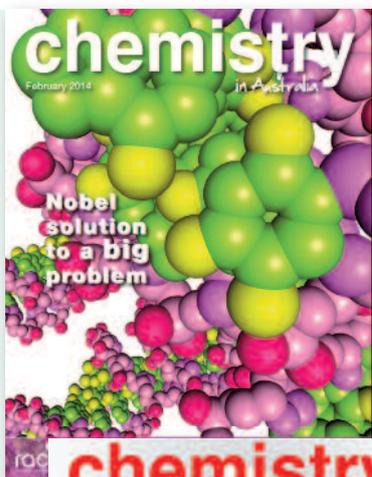
A typical solar panel installation today might cost say \$3 per watt in Germany. Of this total cost, only about \$0.30 per watt is the cost of the silicon; that is, about 10% of the total cost

and dropping quickly. In the market today, low-efficiency photovoltaics modules are almost unsaleable. When people install solar modules, they want the maximum amount of electricity and since most of the cost of installing a solar panel is not in the solar panels (which account for only about 25% of the total installed cost), installers automatically choose the highest-performing solar panels. This is because the economic rationale for doing photovoltaics is enhanced by higher electricity output at marginal differences in solar panel costs.

The idea of an alternative material to silicon for photovoltaics, such as organic thin films, was dreamt up more than 20 years ago when silicon photovoltaics was more than 10 times its current costs. It (sort of) made sense then. Today these quixotic efforts to replace silicon photovoltaics can only be compared to, say, an effort to replace the incandescent light bulb in the early 1900s just 20 years after this technology was first commercialised. Besides, everyone knows that you should never, ever bet against silicon.



Ian A. Maxwell (maxwell.comms@gmail.com) is a serial (and sometimes parallel) entrepreneur, venture capitalist and Adjunct Professor in Electrical and Computer Engineering at RMIT University, who started out his career as a physical polymer chemist.



Give a gift of six months of chemistry

Buy a gift subscription of six issues of *Chemistry in Australia* for \$80.

Your gift recipient will receive hard copy editions of the February–July 2015 issues.

Offer valid until 15 December 2014. Available for purchase by full members of the RACI. Delivery within Australia only. To purchase, visit <http://bit.ly/cheminaust>.

Bridging skills and content in teaching

The importance of understanding specific content in order to teach it effectively is clear. Similarly, it is now generally accepted that some pedagogical skills are helpful when teaching students, and so new academic staff at most Australian institutions are required to complete a tertiary education preparatory course. These courses typically focus on developing generic skills in curriculum and assessment design as well as reflective teaching practice and usually contain little or no discipline-specific information. Thus, the two pillars of content knowledge and educational theory are separate. The bridge to connect them is provided by pedagogical content knowledge (PCK).

PCK can be defined as teachers' interpretations and transformations of the subject-matter knowledge in the context of facilitating student learning. It encompasses useful analogies, examples, explanations and an understanding of student misconceptions, so that a subject can be formulated in a way that is comprehensible to students. It is topic, person and situation specific and is developed by teachers through experience.

The notion of PCK was first advanced in secondary teacher education in the mid-1980s, but this knowledge is also important for tertiary teachers. A strong call for the use of PCK has been made in the context of chemistry education, with Bob Bucat (University of Western Australia) writing in 2004:

The chemical education enterprise is crying out for 'applied research' that probes and documents the topic-specific PCK of respected teachers.

Currently in the teaching profession, the accumulated PCK of each of its participants grows with experience, peaks at retirement, and then disappears – often with hardly a contribution to the collective wisdom of the profession.

A prerequisite for development of PCK is a thorough and coherent understanding of the subject matter so novice tertiary teachers are ideally positioned to acquire PCK. These new staff are confronted with a student population that is large and very diverse, with many students lacking basic concepts or bringing misconceptions from high school. The use of PCK is ideal to combat misconceptions and promote student learning, particularly for students with weak backgrounds.

John Loughran (Monash University) and his colleagues have spent over a decade creating and refining tools to articulate and develop PCK at the secondary level. Their framework consists of two elements: CoRe (content representation) and PaP-eR (pedagogical and professional experience repertoire). The CoRe contains eight questions for a teacher to reflect on, each to be answered for each big idea to be taught in module, and should be developed and refined over time among small groups of teachers:

- What do you intend the students to learn about this idea?
- Why is it important for students to know this?

- What else do you know about this idea that you do not intend students to know yet?
- What difficulties and limitations are connected with teaching this idea?
- What do you know about students' thinking that influences your teaching of this idea?
- What other factors influence your teaching of this idea?
- What teaching procedures will you use; why have you chosen them to engage with this idea?
- How will you ascertain students' understanding or confusion around this idea?

Use of CoRes constitutes an important initial stage before starting teaching of a new topic. Determining the big ideas that underlie the topic is not trivial and the process of articulating these is a first step in the path of elucidating PCK.

PaP-eRs are the teachers' narrative reflections about teaching particular content in a particular context (including class composition and format) and are linked to the big ideas and answers in the corresponding CoRes, although each CoRe will require several PaP-eRs to illustrate the complexity of the knowledge. The structure of PaP-eRs is flexible and reflects the personal nature of teaching, with teachers describing their approach in informal language. Both CoRe and PaP-eR have been adopted worldwide as a framework for articulating PCK.

A new Seed Project funded by the Office for Learning and Teaching, led by Madeleine Schultz (Queensland University of Technology) and Gwen Lawrie (University of Queensland), aims to collect CoRes and PaP-eRs for topics in tertiary chemistry. If you are interested in participating in the project, please contact Madeleine Schultz (madeleine.schultz@qut.edu.au). A workshop will be held at the Australian Conference on Science and Mathematics Education in Sydney this month. A seminar and workshop on the topic will also be held at the RACI Congress later this year – all are welcome.

Madeleine Schultz MRACI CChem is a senior lecturer in Chemistry in the Science and Engineering Faculty, Queensland University of Technology.



Rowe Scientific

www.rowe.com.au

PTV LTD

Pledge to Chemists

If chemists in Australia are experiencing difficulty in obtaining supply, please send me an email on reg.rowe@rowe.com.au and I promise to help you. This is not a "subtle" attempt to obtain more business, but is 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. R.J. Rowe (FRAC)

ADELAIDE
08 8186 0523
rowesa@rowe.com.au

BRISBANE
07 3376 9411
roweqld@rowe.com.au

HOBART
03 6272 0661
rowetas@rowe.com.au

MELBOURNE
03 8795 7771
rowevic@rowe.com.au

PERTH
08 9302 1911
rowewa@rowe.com.au

SYDNEY
02 9603 1205
rowesw@rowe.com.au

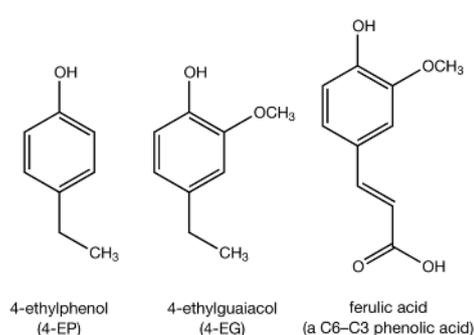
There's a Band-Aid in my wine

The aroma of Band-Aids in wine is a good indicator of so-called 'Brett character'. In some cases, the aroma may be even more medicinal, or in extreme cases, horse dung is a common descriptor. The aroma is related to the presence of 4-ethylphenol (4-EP), which may be coupled with that of cloves, bacon or wood smoke arising from 4-ethylguaiaicol (4-EG). On the palate, the tannins in red wine may seem gritty or metallic, lacking the smoothness that one seeks in a great red wine. The sensory threshold is wine dependent with the value for 4-EP being between 300 and 600 $\mu\text{g/L}$, considerably higher than that for 4-EG (around 10 $\mu\text{g/L}$). The production of these off-odours results from the actively metabolising yeast *Dekkera/Brettanomyces bruxellensis* (*Brett*) converting hydroxycinnamic acids (C6–C3 phenolic acids) to ethyl phenol compounds. More detail can be found in the article by Lorenza Conterno and colleagues in *Food Research International* (2013, vol. 51, pp. 670–8).

The Australian Wine Research Institute (AWRI) is at the forefront in understanding the science behind the development of *Brett* character as well as identifying strategies to control it. Residual sugar in a wine encourages the growth of spoilage yeasts and bacteria, so winemakers need to check the residual sugar concentration after fermentation is complete. Free SO_2 and in particular molecular SO_2 (see September 2012 issue, p. 38, for more detail on SO_2 chemistry) is an essential component for microbiological stability in wine, including active inhibition of *Brett* growth. Thus, careful use and constant measurement of SO_2 is a vital step in quality control. Similarly, pH is important – higher pH values encourage the growth of spoilage yeasts as well as lowering the molecular SO_2 concentration.

Regular topping up of barrels is another winemaking requirement for protection of the product. The air space (ullage) above the wine provides oxygen to support microbiological growth. Sanitation is always a critical winemaking issue and all equipment needs to be cleaned to ensure minimal microbiological contamination. Sanitising barrels does present a challenge, perhaps more so for older wood. On the other hand, older barrels tend to retain SO_2 better than new barrels. Turbid wines are more at risk from *Brett* and other spoilage processes, so clarification including filtration may assist in reducing the onset of contamination. You can find more detail on management strategies in an AWRI factsheet (bit.ly/W5pezm). Of course, many of these quality control issues cause a problem for those who follow the natural winemaking (essentially no intervention) approach.

There are times in the early life of a red wine when there is a strong potential for *Brett* to develop. Malolactic fermentation, when SO_2 needs to be absent, is one period. The growth of the spoilage yeasts can be slow and may even occur in the wine after bottling. Many winemakers often assume that *Brett* can only occur in red wines, perhaps forgetting that the hydroxycinnamic acid substrates are also present in white wines, albeit at lower



levels than in reds. These substrates include *p*-coumaric, ferulic and caffeic acids, often present as their tartaric acid esters, and thus perhaps overlooked in a global wine analysis scan.

One of the fascinating aspects about detecting *Brett* character is that individual sensitivities vary enormously. Wine industry consultant Nick Bulleid (Master of Wine) comments that what some see as complexity, others regard as badly spoilt wine. This tends to generate a competition around 'I can spot lower levels of *Brett* than you can' (bit.ly/1wo0EF1). This individual variation became obvious to me during my teaching days at Charles Sturt University. During wine-tasting classes, some students would immediately reject a wine because they could detect *Brett* (these were sometimes referred to as the 'Brett police') while others had no idea what the hardliners were talking about. Wine columnist Max Allen, writing for *The Australian* (bit.ly/1nq9c8N), also has a more generous approach to accepting *Brett* in wine, although he also recognises that there are two distinct camps of 'like/dislike' *Brett*. I am rather insensitive to *Brett* on the nose, but more sensitive to the metallic, gritty taste that goes with the off-odour.

While the science clearly supports the 'do not like' camp's position that *Brett* should not be present, marketing suggests that low levels may be advantageous. Max Allen, for example, makes some positive comments about older red wines from Bordeaux and the Rhône Valley that were often characterised by *Brett* but still maintained a strong market presence. One wine that I encountered had a 4-EP concentration over 3 mg/L, more than six times the sensory threshold, but performed well in the market. In my discussions with winemakers and consultants in the Rhône Valley, I was simply advised that the aroma reflected the 'terroir' of the region and was not due to any off-odours! Of course, for those who like traditional beers, especially Belgian lambic beers, the aroma profile is characterised by *Brett* characters. To each, her or his own, perhaps.

I acknowledge the contribution from Dr Eric Wilkes, manager of Commercial Services, AWRI, and Dr Tina Tran, AWRI, in the preparation of this article. Both Eric and I have doctorates in classical coordination chemistry, ideal training for a career in wine.



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

Chemico-economics

Chemistry is arguably the central science and it is what I spend the majority of my professional life engaged in. But in my down time, it is the so-called dismal science of economics that vies for my attention. Sometimes I like to think about chemistry in economic terms. How do the concepts of 'inflation' and the notion of 'Too Big to Fail' apply to us non-monetary scientists?

Inflation in an economic sense refers to the decreasing value of money with time. As each year goes by, the same amount of money buys you fewer goods and services. In the realm of academic chemistry, the one overarching metric by which you tend to be measured is your publication record. So the number of papers you have published can be thought of as your currency. Of course, there are several tiers of journals with varying amounts of prestige; however, the absolute number of publications is a convenient yardstick that is used all too often.

Thus there is implicit and explicit pressure on researchers to have a large number of publications. Some European and Asian institutes require their PhD students to have a certain number of publications as a graduation criterion. Of course, as the number of matriculating students increases each year, so will the number of papers they publish. This, combined with the pressure to publish, has seen a bounty crop of new journals spring up, keen to accept the findings of scientists who are all too eager to publish.

Unlike the license to print money, there is no license to print journals and as the number of journals and publications therein increases, with each passing year the statement 'I have published *x* papers' has a lower value. I once again stress that this is not the entire story and a diligent employer will probe in depth to an academic's records, peer past the mere numbers and look at the quality of the research, prestige of the journals, impact of the studies and capabilities of the academic before making a hiring decision. However, the lowered value of a 'paper' with time is almost a textbook definition of inflation.

While inflation is an age-old phenomenon, the next concept is relatively recent. In the wake of the 2008 financial crisis, we all despaired at the sight of public funds being spent on wayward banks who were bailed out simply because they were Too Big to Fail. What about the parallel in chemistry?

Cutting-edge science is an extremely complicated, often a multi-disciplinary, endeavour. The days of gentlemen scientists knocking out a series of experiments in their free time and then proudly presenting the results over port and cigars to a salivating Royal Society are long gone. Today, you are more likely to find teams of researchers working assiduously on reaching fruit on the higher branches of the tree of knowledge. These teams with their complicated machinery and specialised reagents need money as their primary source of fuel (although coffee also helps). And the money (at least in the public sector) comes from research grants.

Grant writing is an almost full-time preoccupation for some academics and winning grants is a true reason to celebrate as it



... the lowered value of a 'paper' with time is almost a textbook definition of inflation.

allows you to purchase, researcher time, instruments and consumables. And when you have enough of those three you *have* to achieve results. You *have* to. Failure certainly is an option, but it isn't an option that is likely to get you more funding. Of course, the bigger your pot of money is, the more researchers, instrument time and chemicals you can afford to throw at a problem. After a certain amount of the three are ardently expended, you will have data. And that data will be published. And, by at least some measure, you will not fail.

I don't mean to be terribly cynical about this. Of course it stands to reason that the best researchers will get the best grants since their excellent track record is a safe bet for funding agencies. And giving talented, motivated people the resources to achieve their goals is a sure-fire recipe for success. Too big to fail may not necessarily be a bad thing. What really concerns me though is the corollary: is there such a thing as too small to succeed? Are there talented researchers out there who don't have the funding to get results to get funding? I certainly think so, but that is a topic for another time. I have been less than economical with my words and column inches are a limited resource!

The author is fiscally responsible and currently balancing his academic budget in Switzerland.

Bubbles that go bang

Frank Philip Bowden was an Australian scientist who spent most of his professional life at Cambridge University, but he spent the years of World War II in Melbourne, working for CSIR on a range of war-related projects.

Born in Tasmania, Philip Bowden completed BSc (1925) and MSc (1927) studies in Physics there, winning an 1851 scholarship that took him to Cambridge where he was awarded his PhD (1929) and DSc (1931) degrees. He stayed at Cambridge as lecturer in physical chemistry and returned there after the war, as reader in physical chemistry from 1956 and then in physics after 1957. He was appointed to a personal chair in surface physics in 1966 but became ill not long afterwards and died in 1968, aged 65. His many awards included election as FRS in 1948 and being made CBE in 1956.

At Cambridge, Bowden first continued his work on electrochemistry but lubricants began to engage him, ostensibly because of his interest in skiing. At CSIR he was in charge of a lubricants and bearings section, but as he left he suggested that a more 'scientific and romantic' name might be found for it. His colleague David Tabor came up with 'tribophysics' and under this name the section became a division located on the campus of the University of Melbourne. Tabor was the author of the Royal Society's biographical memoir of Bowden, published in 1969, and it's a fascinating story that he tells. For example, one of Bowden's collaborators in Melbourne was Dr F.W. Eirich, a *Dunera* boy who was taken from internment camp to work on the project.

Bowden did work on lubricants while he was here and also on high-speed photography, but the work I found most interesting was on the initiation of explosives. In 1943, Bowden and his team published the results of their work in two CSIR Bulletins, 'The Detonation of Nitroglycerine by Impact' (No. 167) and 'The Detonation of High Explosives by Impact' (No. 173). 'It is usually considered that nitroglycerine and explosives containing nitroglycerine are relatively insensitive to detonation by impact', they wrote, but various 'unexplained' accidental explosions had made people cautious of the stuff. To cut a long story short, the CSIR scientists found that the presence of small bubbles in the liquid or air trapped between a curved impact plate and the explosive material dramatically reduced the impact pressure necessary to produce detonation. The reason was rapid (and therefore adiabatic) compression of the gas that sharply raised its temperature, leading to detonation. Bright flashes of light observed in the cavities suggested that the process began with deflagration (combustion) and that detonation followed. Practical applications of this knowledge included accident avoidance but also the development of detonators based on the adiabatic principle. Even solids could be detonated if air cavities were present.

After the war, the work was published in refereed journals and represented a major contribution to the field. The CSIR

... the presence of small bubbles in the liquid or air trapped between a curved impact plate and the explosive material dramatically reduced the impact pressure necessary to produce detonation.

Bulletins 'were printed in 1943 but their distribution was held up for security reasons' and the prologue to No. 167 says that it was later experiments that revealed the role played by tiny gas bubbles, as small as 5×10^{-3} cm in radius. No. 167 was also published as a CSIR Report in April 1942, but the section entitled 'The Effect of Compressed Gas Spaces in Increasing Sensitivity to Impact' was omitted from that early version.

While security no doubt accounted for the delayed publication, the delay also provided time for further experiments. It has been suggested that Bowden received advice from researchers at the Munitions Supply Laboratories, at Maribyrnong, on the possible role of gas bubbles and adiabatic heating. I have discussed this possibility with some of Bowden's collaborators, none of whom is aware of any such interaction, but that doesn't mean that it didn't happen, since such high-security information would have been shared at first only with more senior people.

How Bowden came to be in Australia is an interesting story in itself. He undertook a lecture tour of the US in the (northern) summer of 1939. At its conclusion, he came to Australia on a family visit, his wife and first child (of four) joining him there. When war broke out, he considered returning to Britain but felt that he might be more use in Australia, an unusual act of national loyalty. His erstwhile colleague C.P. Snow recalled that 'although he loved his native land, he didn't intend to go back', although set against this was Snow's view that Bowden 'longed to do scientific work which would justify his existence'.

In an article published in the *British Ski Year Book* in 1956, Bowden wrote that 'an experimental scientist is necessarily chained to the laboratory. If he is wise, he will invent a problem that takes him to some desirable place. It is also refreshing on occasion to turn one's attention to the physics of some simple everyday processes. With these supporting excuses I carried out an experimental study of the friction of ice and snow.' He concluded that friction is reduced not by pressure melting of the ice, but by melting brought about by frictional heating.



Ian D. Rae FRACI CChem (idrae@unimelb.edu.au) is a veteran columnist, having begun his Letters in 1984. When he is not compiling columns, he writes on the history of chemistry and provides advice on chemical hazards and pollution.

events

Chemeca 2014

28 September – 1 October 2014, Perth, WA
www.icheme.org/chemeca2014

Australian Conference on Science and Mathematics Education

29 September – 1 October 2014, Sydney, NSW
<http://sydney.edu.au/iisme/conference/index.shtml>

7th Asian Biological Inorganic Chemistry Conference (AsBIC-7)

30 November – 5 December 2014, Gold Coast, Qld
www.asbic7.org

11th Australasian Aluminium Smelting Technology Conference

6–11 December 2014, Dubai, United Arab Emirates
<http://11aastc.com>

RACI National Congress

7–12 December 2014, Adelaide, SA
www.raci.org.au/events-awards/raci-national-congress-2014
Early Bird registration closes 1 August 2014

Advanced Materials & Nanotechnology (AMN7)

8–12 February 2015, Nelson, New Zealand
www.amn-7.com

35th Australasian Polymer Symposium

13–15 July 2015, Gold Coast, Qld
www.35aps.org.au

Pacificchem 2015

15–20 December 2015, Honolulu, Hawaii
www.pacificchem.org

RACI events are shown in blue.

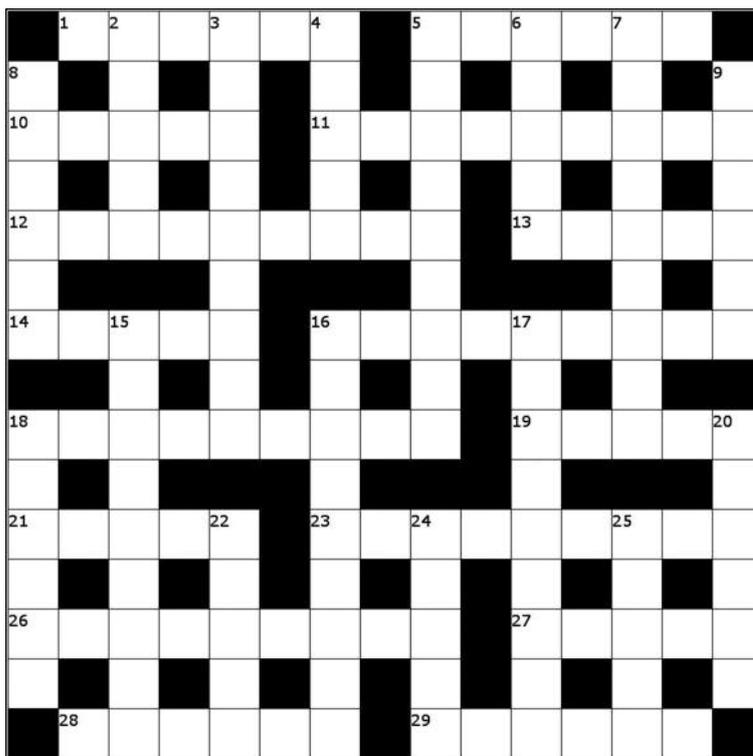


Coming up

Non-chemists rule in November!

So, what do chemists actually *do*?
Chemistry in comic strips and at the cinema
Swap screen time for science 'make and do'
Cigarette butts: a toxic problem
Questacon's director on cool chemistry events
Top chemistry reading

cryptic chemistry



Across

- 1 Impels change to make uncomplicated. (6)
5 Take in a Br/Sb/O compound. (6)
10 Hot lithium used to make RSH. (5)
11 Runs a live program without limits. (9)
12 Count over helium radical movement starting to use heat. (9)
13 Last year a man won a Nobel Prize for Physics. (5)
14 Argues about loss of electron from carbohydrate. (5)
16 A few lines fish around the point. (9)
18 Made up using yttrium in disorganised tin chest. (9)
19 Checks out matters before court. (5)
21 A most perturbed set of little ones. (5)
23 Frowned as mistake discovered lithium. (9)
26 Promising energy. (9)
27 Calm nevertheless. (5)
28 C_9H_8 in need of attention. (6)
29 Messy time over structure. (6)

Down

- 2 Elements of a claim in empty C=N container. (5)
3 Apply hormone mix eliminating a neon to yield one of several crystalline forms. (9)
4 Tie with uniform. (5)
5 Cyclopropene is formed from C_2I_2 adding clay lumps initially. (9)
6 Prune three elements. (5)
7 Like beerless man initially stumbling. (9)
8 Central to Angstrom neatly discussing condition. (6)
9 Mercury, perhaps, gives way in platinum. (6)
15 Nitrocellulose without one counting to detonation. (9)
16 I named the mess of Al_4C_3 , for example, (9)
17 Two metals drop, sulfur goes up. (9)
18 Sulfur compacts imprints. (6)
20 Individual gels in sink. (6)
22 Hearing, perhaps, 34734. (5)
24 Flicks and shoots. (5)
25 24 Down loses fluorine but gains an electron. A waste! (5)

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

OZFOREX

International money transfers at better rates than the banks!

Do you need to pay an international invoice, purchase a property or send money to family members overseas? Our partnership with OzForex allows you to transfer money worldwide at significantly lower rates than banks.

Benefits of using OzForex include:

- £ Free transfers under \$10,000 for RACI members
- \$ No receiving bank fees in most countries
- € Phone access 24-hours a day, 5 days a week
- ⌚ Online access 24/7
- ¥ Competitive foreign exchange rates across 52 currencies

Register online today to save on transfers, or speak to OzForex's accredited dealers for more information about the service.

Call OzForex direct on **1300 300 424** or visit
www.memberadvantage.com.au/raci/ozforex



RACI National Congress

The RACI Congress will be held shortly in Adelaide. It will be the largest gathering of Australian Chemists since 2005 and you are invited to be part of the exciting event. Over 100 plenary, keynote and invited speakers have been drawn from around the world and represent some of the most important work in chemical community (see website for a complete list of speakers www.racicongress.com/speakers).

Well over 850 abstracts have been received and represent work in many important areas of chemistry as well as cross disciplinary activities. The meeting will provide a great environment to meet colleagues, discuss current work and trends and explore new opportunities. There will also be a significant exhibition showing the latest equipment and technology.



Congress Venue – Adelaide

RACI 2014 will be held at the multi award winning Adelaide Convention Centre, on the waterfront of the River Torrens near the heart of the city.

Adelaide is a picturesque coastal city that's easy to get to, easy to get around, easy on the pocket, and 'green'. The Convention Centre offers first-class facilities to delegates, partners and visitors, and is a short walk from accommodation, restaurants and the central business district of Adelaide.

To register please visit the website:
www.racicongress.com/registration

Contact Us

RACI2014 Congress Secretariat
ICMS Australasia
Ph: +61 2 9254 5000
info@racicongress.com



raci
National Congress
7-12 December 2014
Adelaide | Australia
Building strong bonds

