

chemistry

April 2018

in Australia



Bright ideas for food waste

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- Glen Deacon: 50 years and counting at Monash
- Maths and science feature in Australian of the Year Awards
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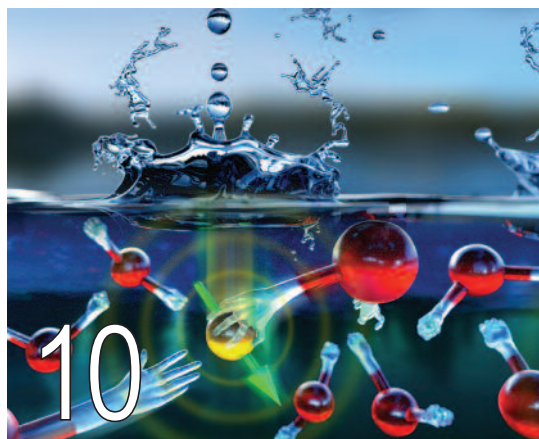
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cover story

Value-added chemicals from food wastes

Australia is throwing away more than four million tonnes of food each year. It's too good to waste, say environmental chemist Nanthi Bolan and chemical engineer Dan Tsang.

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20 Monash's Glen B. Deacon: 50 years and counting

A past student recalls the many contributions of 'Dr Deacon' during 50 years at Monash.

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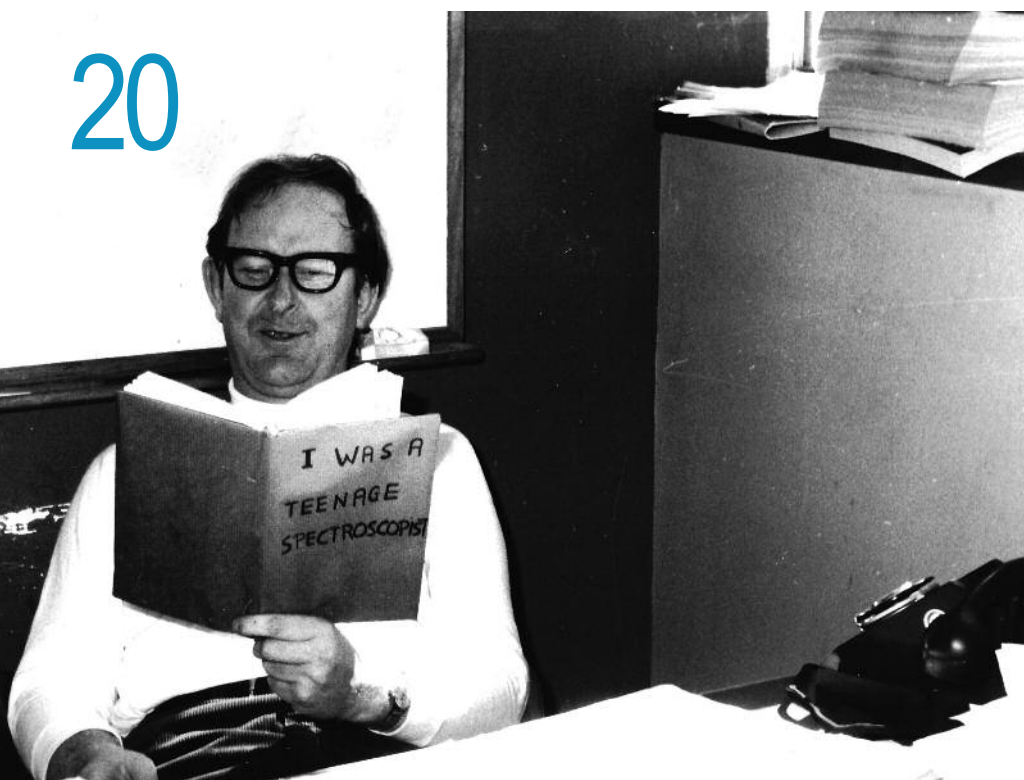
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Towards zero – big move for *Chemistry in Australia* from July 2018

For some time now, the RACI Board and the *Chemistry in Australia* Management Committee have been considering how to continue to deliver the magazine to members in the more financially restrained environment we operate under as a result of recent declines in membership numbers and income. Faced with this scenario, the need to cut RACI's contribution to the production of the magazine is ever more pressing.

For a considerable period, RACI has delivered 11 issues of *Chemistry in Australia* per year to all members. The cost of delivering the magazine in hard copies has escalated over the years because of rising printing and delivery (postage) costs. In an attempt to arrest the costs, in 2015 members were asked to choose one of two delivery options: online only or print (with a subscription fee to cover postage costs). With these changes, we achieved a considerable reduction in RACI's contribution to the magazine production. However, as postage and printing costs continue to rise, the required level of contribution from RACI continues to creep up further. A more sustainable strategy is therefore needed to minimise or eliminate RACI's contribution. Such a strategy requires us to consider how we produce the magazine, frequency and number of affordable issues, modes of delivery and possible new items for inclusion.

After considering various options, the magazine management committee has chosen to embark on a 'Towards Zero (RACI contribution)' strategy. The strategy is aimed at minimising or eliminating RACI's contribution to the magazine's production. To achieve this, we have to reduce production costs, such as the number of issues published and associated editorial and print costs, as well as hard-copy delivery costs (posting fewer issues).

To this end, from July 2018 the magazine will be published under the Towards Zero arrangement to ensure that the magazine is more financially sustainable and requires little or no RACI financial contribution. The Towards Zero strategy will involve reducing the current number of annual magazine issues from 11 to six per year, and having a new bimonthly national branch newsletter, provided to members by the National Office, in alternate months. So, members will receive 12 items (six magazines and six national newsletters) per year instead of the current 11 issues of *Chemistry in Australia*.

The national newsletter will have a unique benefit of broadening and enhancing members' national perspectives and experience of RACI. The newsletter will be provided online only to minimise production and delivery costs. This will involve developing a well-designed consolidated newsletter with inputs from all branches in lieu of their usual monthly newsletter. For the first time, RACI members anywhere will be able to know what is happening at all RACI branches.

For this new strategy to be successful, we must achieve a conservative advertising income of about \$40 000 p.a. However, this will only be possible if more RACI members read the online version of the magazine. The more member visits to the website, the better our chances of attracting more advertising income and the lower the required contribution from RACI. Visit chemaust.raci.org.au for each issue, and click, browse and share. Your RACI is counting on you!



Sam Adelejo FRACI CChem, Chair RACI *Chemistry in Australia* Management Committee

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

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Black Thursday, February 6th, 1851 (1864). By William Strutt (1825–1915).

State Library Victoria (www.slv.vic.gov.au)

Dickensian accounts of Australian bushfires

Charles Dickens never visited Australia, although his sons Alfred and Edward went there to live. Australia does feature frequently in Dickens' work, so much so that in 2011 Sydney University Press published *Charles Dickens' Australia: selected essays from Household Words 1850–1859* by Margaret Mendelawitz. *Household Words* was a magazine owned and edited by Charles Dickens. With a few exceptions, Dickens was not the author of articles in *Household Words*; authors were not identified, and issues of the magazine stated that the content had been 'conducted' by Charles Dickens.

It will possibly complement the recent major article on bushfires by Dave Sammut (December 2017/January 2018 issue, p. 22) to summarise descriptions of bushfires in *Household Words*. In issue 74, dated 23 August 1851, is an article entitled 'Bush Fire in Australia'. It was posted to Dickens, in his role as 'conductor' of the magazine, on 12 March 1851, having been written by a recent settler in Australia. It describes the Black Thursday bushfires that occurred in Victoria on 6 February 1851. There is no mention in the article of *Eucalyptus* trees, which, by reason of their oil content, are a major factor in bushfires in Australia. We

do read, however, that 'the lighted leaves came flying about us in a fiery shower' and this is straightforward to interpret. As the leaf material started to burn, *Eucalyptus* oil was released from glands in the leaves, and burnt in the vapour phase (a 'fiery shower'). This is a widely observed occurrence in bushfires where eucalypts are present.

There is another article about these bushfires, entitled 'Black Thursday', in issue 320, which was published on Saturday 10 May 1856. The statement in the article that 'the fire leaped from tree to tree' strongly suggests acceleration by *Eucalyptus* oil. In issue 413 (Saturday 20 February 1858), an article entitled 'Coo-ee' was also communicated to Dickens by somebody having fairly

recently gone to live in Australia. It too contains information on the Black Thursday bush fires and the writer is viewing them from close to Mount Alexander. The Coliban plains also feature.

A painting of the Black Thursday bushfires by English artist William Strutt is held by the State Library of Victoria.

The expert in fire finds many other points of interest in Dickens' work, one of which does have an Australia connection. In *David Copperfield*, published in 1850, Mr Micawber refers to the 'galley fire' of the sailing ship that conveyed him to Australia. A galley fire in such a ship was for cooking, and danger to the wooden structure of the ship is of course obvious.

Clifford Jones FRACI

'Your say' guidelines

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

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Send letters to wools@westnet.com.au.

Maths and science feature in Australian of the Year Awards



Left to right: Australians of the Year, Graham Farquhar, Michelle Yvonne Simmons, Eddie Woo and Samantha Kerr, at the awards ceremony.

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Prime Minister Malcolm Turnbull presented the four Australian of the Year Award recipients with trophies at a ceremony in the Great Hall of Parliament House in Canberra earlier this year, and three of these were for achievement in maths and science. The fourth – the 2018 Young Australian of the Year – is sportsperson Samantha Kerr.

The 2018 Australian of the Year is professor in quantum physics Professor Michelle Yvonne Simmons.

Michelle Simmons has pioneered research that could lead to a quantum leap in computing and reshape the way we live and how we experience the world – her work is helping develop leading technology on a global scale, right here in Australia.

Since arriving in Australia from the UK in 1999, Simmons has transformed the University of New South Wales quantum physics department into a world leader in advanced computer systems.

In 2012, Simmons and her team created the world's first transistor made from a single atom, along with the world's thinnest wire. The breakthrough means Australia is now at the forefront of what Simmons calls the 'space race of the computing era'.

Simmons' aim is to build a quantum computer able to solve problems in minutes, which would otherwise take thousands of years. Such a discovery has the potential to revolutionise drug design, weather forecasting, self-driving vehicles, artificial intelligence and much more.

Simmons is an evangelist for Australian scientific research and a role model to young scientists everywhere. The 50-year old actively encourages all students – girls and boys – to dream big, challenge themselves and to achieve ambitious goals in science. Through her work, she is naturally an inspiration for young women and a strong supporter of women in science, technology, engineering and mathematics.

The 2018 Australia's Local Hero is mathematics teacher Eddie Woo.

Eddie Woo is arguably Australia's most famous mathematics teacher, making maths fun and attracting young people to engage with maths by making it relatable and interesting.

The head mathematics teacher at Cherrybrook Technology High School in Western Sydney (the largest secondary school in New South Wales), Woo started posting videos online in 2012

for a student who was sick with cancer and missing a lot of school. Before long, he was sharing the videos across the country and beyond.

'Wootube' now boasts more than 100 000 subscribers and has attracted more than eight million views worldwide. With infectious enthusiasm, the father-of-three's unique and caring approach to teaching destigmatises mathematics as an inaccessible and difficult subject.

Outside his high school classroom, 32-year-old Woo is a volunteer facilitator with the University of Sydney's Widening Participation and Outreach program and has motivated more than 1400 students from disadvantaged backgrounds.

A brilliant student, Woo could have chosen any field, but in defiance of social convention and his parents' wish for him to become a doctor, he followed his passion and opted for teaching. Today, he is using his vocation to 'pay it forward' and make education equitable for all.

His modern and flexible approach to teaching is taking education beyond the classroom and making it part of young people's device-driven lives, not just in his own school but nationally and internationally. He is a highly energetic, passionate teacher and a proud spokesperson for the important role teachers play in shaping young lives and the future.

The 2018 Senior Australian of the Year is biophysicist Dr Graham Farquhar AO.

Dr Graham Farquhar is helping reshape our understanding of photosynthesis – the very basis of life on Earth. His work focuses on food security and how the world will feed growing populations into the future.

After growing up with a Tasmanian farming family background, Farquhar has used his love of science to deliver practical benefits to the agricultural sector. His study of mathematics and physics formed the bedrock of a career creating mathematical models of how plants work.

His research addresses agriculture and climate change and aims to solve some of the greatest challenges of our generation. Farquhar has received a string of accolades during his distinguished career for his research examining how water-efficient crops can protect food security in a changing climate. Importantly, he has worked to improve world food security by developing strains of wheat that can grow with less water.

In 2017, Farquhar became the first Australian to win a Kyoto Prize – the most prestigious international award for fields not traditionally honoured with a Nobel Prize.

From his long-term base at the Australian National University in Canberra, and now aged 70, Farquhar is tackling some of the most profound challenges facing humanity and the environment.

National Australia Day Council. See page 30 for Australia Day award recipients for chemistry and chemical engineering.

Static electricity splits chemical bonds

Researchers from Curtin University, the Australian National University and the University of Wollongong have been able to demonstrate how chemical bonds between atoms are affected by static electricity, unlocking potential benefits for the manufacturing and electronics industries.

The research, published in the *Journal of the American Chemical Society* (doi: 10.1021/jacs.7b11628), found that an external electric trigger can selectively split chemical bonds between carbon and oxygen atoms, the 'glue' of common organic molecules, shedding light on an overlooked aspect of chemistry and nanotechnology.

Lead researcher Dr Simone Ciampi, from Curtin University's Department of Chemistry, said the research findings were unexpected, adding they can potentially revolutionise the way electrical circuits of digital devices are made.

... research findings ... can potentially revolutionise the way electrical circuits of digital devices are made.

'Through our research, we were able to observe that alkoxyamines molecules, common additives used in the manufacturing of plastics, were prone to undergo very fast chemical transformations, when aligned in an external oriented field', Ciampi said.

'This research will allow for other scientists to pursue the cutting-edge field of synthetic organic electrochemistry, as well as allowing for the development of micro-devices in the electronics industry.

'We have been able to determine how the electric charges can promote chemical reactions, which means, for example, we have identified the possibility of making transistors out of small organic molecules, smaller and less-power-thirsty electrical devices.'

Co-author Dr Nadim Darwish, also from Curtin University's Department of Chemistry, said the research was significant because it will potentially assist with developing new, greener and more efficient ways to control chemical reactions.

'The impact of static electricity is now beginning to emerge as an important branch of material science and can lead to new ways of studying chemical bonding', Darwish said.

'By being able to determine the impact of static electricity on chemical bonds, our research could potentially break down further barriers between the chemical and electronics industry.'

Curtin University

Cheaper way to test handheld chemical detectors



An ampoule of chemical simulant, meant to imitate the deadly chemicals used in warfare, is loaded into the Threshold Confidence Checker. Jason Stoughton/NIST

The Joint Chemical Agent Detector (JCAD) has become an important defence tool on battlefields and in war-torn cities over the last few years. About the size and shape of a VHS tape or a hardcover novel, JCADs sound an alarm and begin to light up if nerve agents such as sarin or blister agents such as mustard gas are present.

The detectors are already designed to withstand intense environments and repeated use. But when the US Department of Defense wanted a way to check the devices' sensitivity to chemicals over time, a measurement team at the National Institute of Standards and Technology (NIST) was called in to provide a cost-effective solution.

The result is an accessory device, known as the Threshold Confidence Checker, or TCC, which weighs just a few grams and looks vaguely like a cigarette lighter. The TCCs can be slid on top of the chemical detectors so that an exact measurement can be made of each device's sensing capabilities.

TCCs demand no special operator training or scientific knowledge and offer a repeatable test that costs less than \$1

per use. The test takes only a few moments, and detectors do not need to be taken out of service while the critical components are verified.

The small, inexpensive TCCs are vastly different from the first solution that was offered to the testing problem, which involved using a large spectrometer to identify vapours by detecting their chemical signatures in infrared light.

'We realised those wouldn't work very well in this situation', said Pamela Chu, the researcher in charge of the NIST team. The heavy spectrometers are about the size of a refrigerator and cannot be easily transported to the kinds of remote places where troops are often deployed. In addition, each spectrometer system can cost more than \$100 000 and requires specially trained staff. Detectors would also have to be periodically pulled out of the field and sent in for testing at a centralised depot, often at a distant location.

'The solution we were able to develop instead is inexpensive, effective and reproducible for other, similar detection equipment', said Chu.

To run a test, an operator simply loads

the TCC onto the intake area of the detector. Inside the TCC, a small glass ampoule contains a known quantity of chemical simulants that are safe and non-toxic to people, but that cause the devices to react as if they had been exposed to the dangerous nerve and blister agents.

As the ampoule is crushed, the simulant provides a measured amount of harmless gas meant to trigger the detector just above its set sensitivity limit. If the alarm sounds and a specific number of lights are activated, the soldier or testing personnel know the device is still in working order and can be returned to the field immediately.

JCADs that fail to display the required number of lights are subjected to additional maintenance, and then, if they still don't pass, are returned to the depot for additional checks and any needed maintenance.

The amount of simulant used for TCCs can be traced to established standards and reference methods. What's more, the technology used to develop the current round of TCCs can be replicated as sensor technology evolves and the handheld chemical agent detectors change and evolve, too. Although the TCCs themselves might need to be adapted or reconfigured, the principles established through their research and development will remain the same and can be repeatedly reapplied.

Research and development for the TCCs was done by Chu and her team over several years, beginning in 2010. The Department of Defense, which funded the research, has now announced it will begin large-scale production of these testing devices, and a private company has already been contracted to make 60 000 for immediate use.

National Institute of Standards and Technology

Buckingham Palace built with mineralised microbes from the Jurassic

A study led by the Australian National University (ANU) has found that the building blocks of Buckingham Palace in London and many other iconic buildings were made by microbes that lived up to 200 million years ago during the Jurassic period.

The material, known as oolitic limestone, is a popular building material around the world and is almost completely made of millimetre-sized spheres of carbonate called ooids.

Co-researcher Dr Bob Burne said the new study found that ooids were made of concentric layers of mineralised microbes, debunking the popular 'snowball theory' that ooids were formed by grains rolling on the seafloor and accumulating layers of sediment.

'We have proposed a radically different explanation for the origin of ooids that explains their definitive features', said Burne from the ANU Research School of Earth Sciences.

'Our research has highlighted yet another vital role that microbes play on Earth and in our lives.'

Different types of oolitic limestones have formed in all geological periods and have been found around the world, including the UK, Germany, the USA, the Bahamas, China and at Shark Bay in Western Australia.

Burne said humans had known about and used oolitic limestone since ancient times.

'Many oolitic limestones form excellent building stones because they are strong and lightweight', he said.

'Jurassic oolite in England has been used to construct much of the City of Bath, the British Museum and St Paul's Cathedral.

'Mississippian oolite found in Indiana in the US has been used to build parts of the Pentagon in Virginia and parts of the Empire State Building in New York City.'

Professor Murray Batchelor led an international team of researchers on the study, which is published in *Scientific Reports* (doi: 10.1038/s41598-017-18908-4).

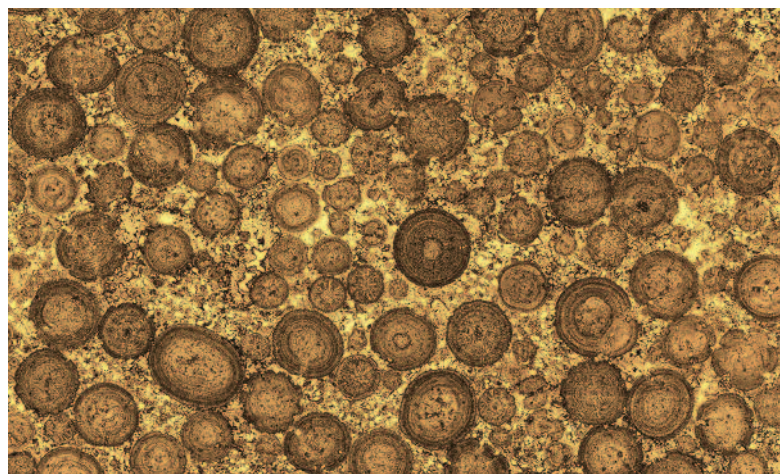
'Our mathematical model explains the concentric accumulation of layers, and predicts a limiting size of ooids', said Batchelor from the Research School of Physics and Engineering and the Mathematical Sciences Institute at ANU.

'We considered the problem theoretically using an approach inspired by a mathematical model developed in 1972 for the growth of some brain tumours.'

Batchelor said the research findings could help better understand the effects of past climate change.

Other researchers involved in the study were Professor Bruce Henry from the University of New South Wales, Dr Fei Li from Southwest Petroleum University in China and Professor Josef Paul from Geowissenschaftliches Zentrum der Universität in Germany.

ANU College of Science



Oolitic limestone (top) and its ooid components (bottom).



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A better picture of what happens when electrons get wet

A new study paints a more accurate picture of how electrons behave after striking water, and how quickly they're snatched up in chemical reactions.

There's a particular set of chemical reactions that governs many of the processes around us – everything from bridges corroding in water to your breakfast breaking down in your gut. One crucial part of that reaction involves electrons striking water, and despite how commonplace this reaction is, scientists still have to use ballpark numbers for certain parts of the equation when they use computers to model them.

An article published in *Nature Communications* (doi: 10.1038/s41467-017-02673-z) offers a new and better set of numbers from researchers at the University of Chicago, Argonne and Lawrence Livermore National Laboratories, and the University of California-San Diego. By improving computer models, these numbers may eventually help scientists and engineers create better ways to split water for hydrogen fuel and other chemical processes.

When an electron is injected into water, the liquid captures it. The energy gain due to this process is called the electron affinity of water, and it is key to understanding and modelling processes such as those occurring in photoelectrochemical cells to split water to generate oxygen and hydrogen, according to Alex Gaiduk, a postdoctoral fellow at University of Chicago and the lead author of the study.

Until now, scientists faced technical challenges while experimentally measuring the electron affinity of water, said co-author Giulia Galli, the Liew Family Professor at the Institute for Molecular Engineering at the University of Chicago and senior scientist at Argonne.

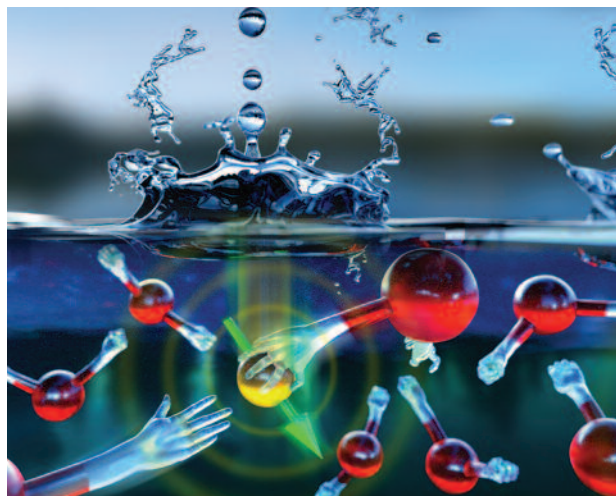
'Most of the results quoted in the literature as experimental numbers are actually values obtained by combining some measured quantities with crude theoretical estimates', Galli said.

Accurate theoretical measurements have been out of reach for some time because of the difficulty and high computational cost of simulating the interactions of electrons with water, said University of California-San Diego Professor Francesco Paesani, a co-author of the study who has spent years developing an accurate potential for the modelling of liquid water. But through a combination of Paesani's models, Galli's group's theoretical methods and software and Argonne's supercomputer, they arrived at a new and surprising conclusion.

Fundamentally, the researchers sought to understand whether the liquid binds the electron right away. This determines whether the electron can eventually participate in chemical reactions as it hangs out in the liquid.

According to the results, the electron is bound, but its binding energy is much smaller than previously believed. This prompted the researchers to revisit a number of well-accepted data and models for the electron affinity of water.

'We found large differences between the affinity at the



Peter Allen/Institute for Molecular Engineering

According to the results, the electron is bound, but its binding energy is much smaller than previously believed.

surface and in the bulk liquid. We also found values rather different from those accepted in the literature, which prompted us to revisit the full energy diagram of an electron in water', said Lawrence Livermore National Laboratory scientist and co-author T.A. Pham.

This finding has important consequences both for the fundamental understanding of the properties of water, as well as for understanding a type of reaction called reduction/oxidation reactions in aqueous solutions. These reactions are widespread in chemistry and biology, including how cells break down food for energy and how objects corrode in water.

Particularly, the information about the energy levels of water is often used during the computational screening of materials for photoelectrochemical cells to break apart water to produce hydrogen as fuel. Having a reliable estimate of the water electron affinity will lead to more robust and reliable computational protocols and better computational screening, the researchers said.

The methods for excited states used in this study were developed over the years by Galli and her co-workers, within collaborations involving Pham and Marco Govoni from Argonne. The study also used supercomputing resources at Argonne.

University of Chicago

Boosting cancer therapy with artificial molecule

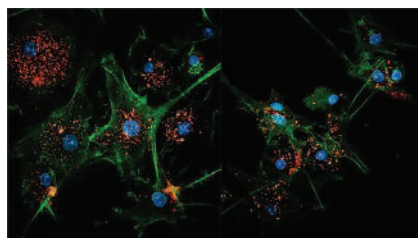
Researchers at Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, have created artificial molecules that can help the immune system to recognise and attack cancer tumours. The study is published in *Nature Methods* (doi: 10.1038/nmeth.4579).

Immunotherapies are breakthrough treatments that stimulate a patient's immune cells to attack the tumour through the recognition of aberrant molecules called tumour antigens. They can be very effective, but currently can only cure a minority of patients with solid tumours. Researchers and physicians are now looking into ways of increasing the precision and strength of the immune attack on the tumour.

One approach is the 'dendritic cell vaccine'. Dendritic cells are specialised immune cells whose role is to capture antigens from foreign bodies and present them to the immune system's killer T cells, which will then attack and destroy the invaders.

For the vaccine, dendritic cells are taken out of the patient, 'force-fed' with tumour antigens, and re-injected into the patient. The idea is to facilitate the ability of the dendritic cells to prime killer T cells against the tumour, which is notoriously skilled in concealing itself from the patient's immune system.

Dendritic cell vaccines have achieved some clinical success but not without several limitations. For example, the tumour antigens used to 'feed' the dendritic cells are generally not taken from the patient's tumour but from lab-grown cancer cells that are only partially similar to those



Two images of EVIR-engineered dendritic cells (green) capturing tumour antigens in exosomes (gold/red). Cell nuclei are coloured blue. C. Cianciaruso/M. De Palma/EPFL

of the patient. This can limit the power of the vaccine because its tumour antigens may differ from those of the patient's tumour, meaning that the killer T cells would not be properly activated to recognise and attack the tumour.

A group of researchers led by Michele De Palma at EPFL have now created artificial receptors called EVIR (extracellular vesicle-internalising receptors), which enable the dendritic cells in the vaccine to selectively and efficiently capture antigens from the actual patient's tumour. This is achieved by inserting the EVIR into the dendritic cell, where it recognises a protein on small vesicles called exosomes.

Exosomes are profusely released by the tumour and contain a variety of tumour antigens. They are also increasingly implicated in the promotion of metastasis and other processes that may facilitate the growth and spreading of cancer. By capturing exosomes coming from tumours, the EVIR help the dendritic cells to precisely acquire tumour antigens from the cancer cells. The dendritic cells then present these antigens more efficiently to killer T cells, thus amplifying the patient's immune response against their tumour.

Imaging techniques also revealed that EVIRs promote the direct transfer of tumour antigens from the exosome surface to the outer membrane of the dendritic cell.

The study opens up new avenues for developing more sophisticated and potent cancer immunotherapies. 'The EVIR technology can intercept a natural phenomenon – the release of exosomes from tumours – to the patient's benefit', said Mario Leonardo Squadrato, first author of the study. 'It exploits pro-tumoural exosomes as selective nanocarriers of tumour antigens, making them available to the immune system for cancer recognition and rejection.'

Although the new technology has the potential to increase the efficacy and specificity of dendritic cell vaccines, further pre-clinical work is required before it can be translated into a cancer treatment.

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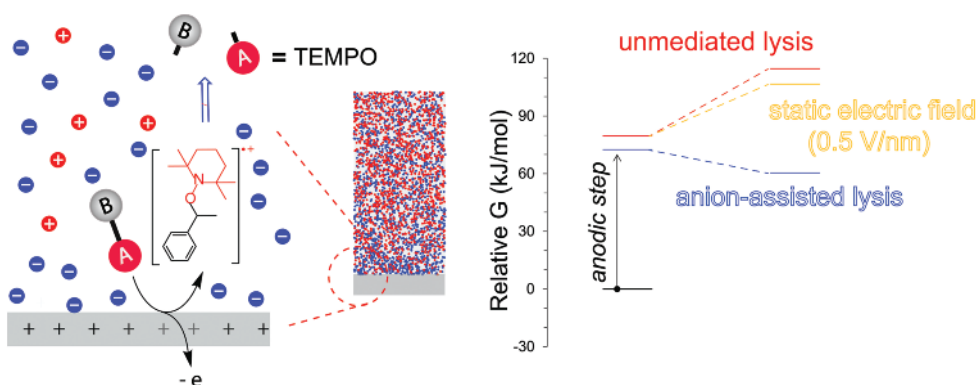
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Anodic chemistry, ionic aggregates and Debye fields
- room temperature lysis of alkoxyamines -



Electricity has long been used in chemistry to trigger electrochemical reactions, but only recently have static electric fields been shown to catalyse non-electrochemical reactions. But implementation has to date required scanning tunnelling microscopy (STM) to orient the reagents appropriately in the electric field. Now, a team of researchers

from Curtin University, the Australian National University, the University of Wollongong, ANSTO, the Silesian University of Technology, Poland, and the University of Murcia, Spain, has shown that electrostatic factors contribute to the catalysis of a chemical process that follows an anodic reaction in an electrochemical cell (Zhang L.,

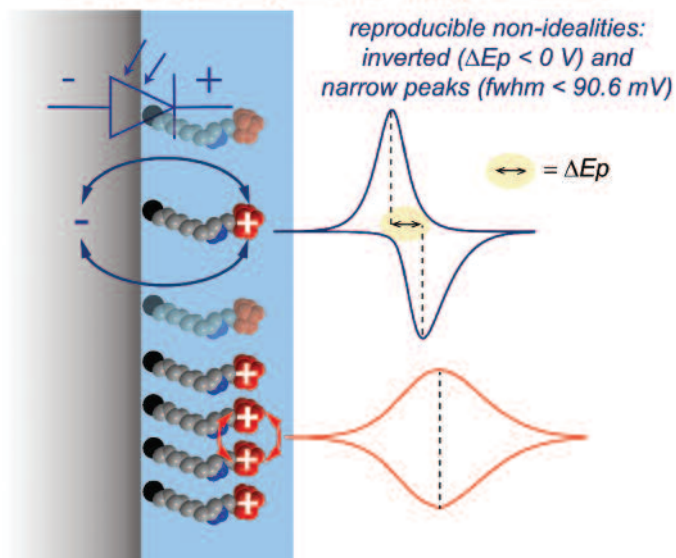
Laborda E., Darwish N., Noble B.B., Tyrell J.H., Pluczyk S., Le Brun A.P., Wallace G.G., Gonzalez J., Coote M.L., Ciampi S. *J. Am. Chem. Soc.* 2018, **140**, 766–74). Using STM, the researchers first showed that thermally stable alkoxyamines underwent room-temperature homolysis when exposed to an appropriately aligned electric field. Then, they showed that cleavage also occurred at an electrified electrode–electrolyte interface, albeit with an important twist. The alkoxyamines first underwent one electron oxidation prior to exceedingly fast cleavage into carbocations and nitroxides, the latter driven by the presence of an external static field. Electrochemical cleavage was shown to proceed for free alkoxyamines in solution, and for alkoxyamines tethered to a silicon electrode, the latter providing a strategy for in situ generation of surface-tethered nitroxides or surface-tethered carbocations.

When electrochemical measurement artefacts are real

Researchers from Curtin University, the University of Murcia, Spain, the University of Wollongong, the Australian National University and the University of New South Wales have been

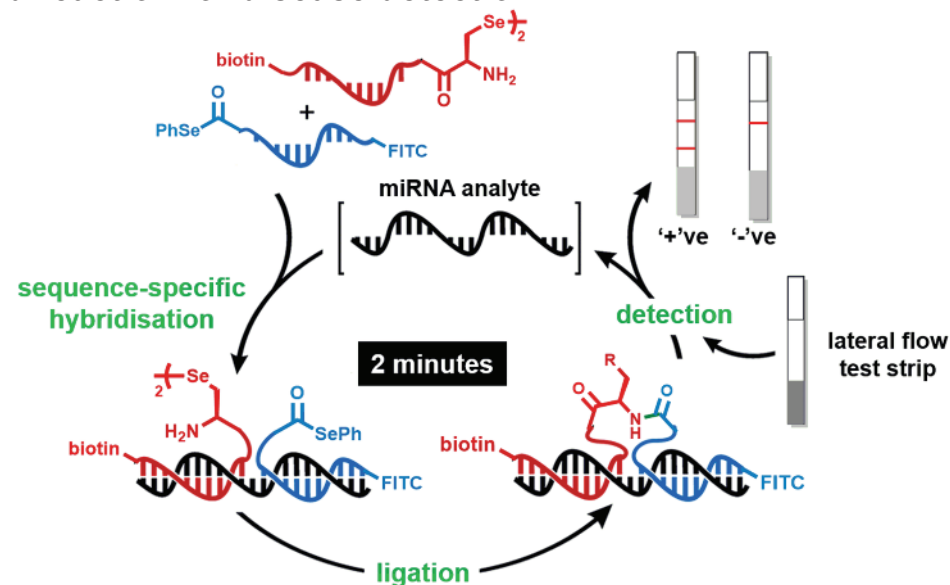
able to reproduce and explain the often puzzling behaviour of electrons that enter or leave semiconductor materials (Vogel Y.B., Zhang L., Darwish N., Gonçalves V.R., Le Brun A., Gooding J.J., Molina A., Wallace G.G., Coote M.L., Gonzalez J., Ciampi S. *Nat. Commun.* 2017, **8**, 2066). Cyclic voltammetry is the most commonly used technique to study the kinetics of electron transfer at semiconductor interfaces, providing precise control of the potential and sensitive measurement of the resulting current. Voltammograms often contain non-idealities, such as narrow waves and ‘inverted’ peak positions, which are often overlooked as flaws. The research team showed that ‘non-ideal’ voltammograms measured at Si(111) electrodes are not necessarily flawed data, but rather the manifestation of electrostatic interactions between dynamic molecular charges and the semiconductor’s space-charge barrier. The so-called flaws can become very reproducible current responses under precise tuning of the electrode kinetics, indicating that either commonly used kinetic models must be revised or precautions must be taken to limit these effects. More broadly, the work has implications for the study of how static surface charges or externally applied electric fields can influence chemical bonding and reactivity, an area that is starting to attract enormous interest.

When **flaws** are accounted for: semiconductor space-charge effects on the activity of surface charged molecules



New nucleic-acid-templated reaction for disease detection

Inspired by nature, chemical transformations catalysed by oligonucleotide templates have found applications in programmed organic synthesis, biomedicine and device development. In templated reactions, reagents are brought together via sequence-specific nucleic-acid hybridisation. The enhanced effective molarity allows the process to occur at concentrations lower than would be possible for typical bimolecular reactions (e.g. in the nanomolar range). Thus, the templating effect improves both the rate of the desired reaction and its selectivity over background reactions within complex or biological mixtures. Collaborating with the University of Geneva, researchers at the University of Sydney have developed a novel peptide nucleic-acid-templated reaction using an additive-free diselenide-selenoester ligation technology (*J. Am. Chem. Soc.* 2015, **137**, 14 011–14) recently discovered by the authors (Sayers J., Payne R.J., Winssinger N. *Chem. Sci.*



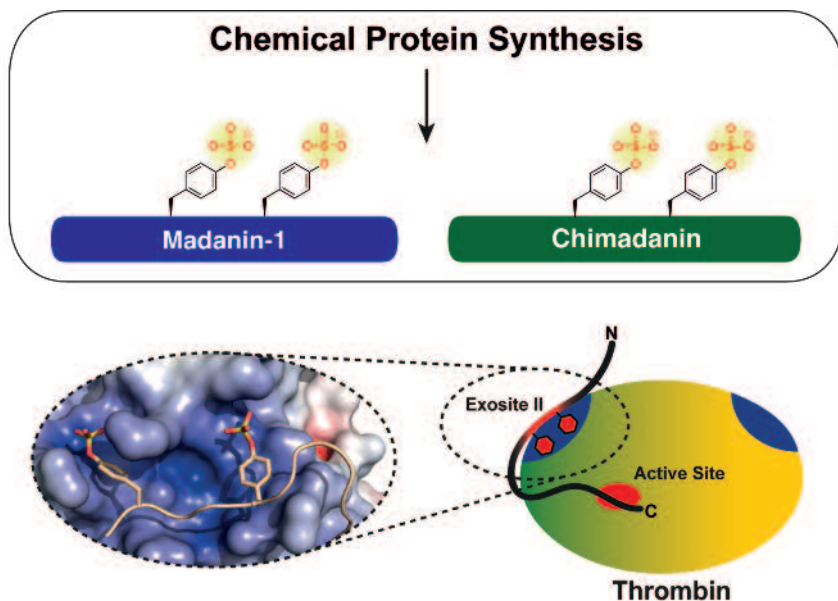
2018, **9**, 896–903). Kinetic analysis of the reaction revealed that this template reaction is the fastest peptide ligation reaction reported to date ($t_{1/2} = 13$ s). This impressive rate, coupled with the operational simplicity, enabled application of the method in a novel

paper-based lateral flow assay for the rapid and sequence-specific detection of disease-associated microRNA. This technology platform has the potential to find widespread application as a fast diagnostic assay for early-disease detection.

How tick salivary proteins enable blood feeding

The saliva of blood-feeding organisms such as leeches and ticks contains a cocktail of bioactive proteins with potent anticlotting activity. Many of these proteins are inhibitors of the enzyme thrombin, a protease that is central to the clotting cascade. In most cases, the physiologically relevant chemical structures of these inhibitors, which are subject to extensive in vivo post-translational modification, are unknown because of difficulties inherent to isolating sufficient quantities of authentic material for biochemical characterisation. A team led by Professor Richard Payne at the University of Sydney has used a cross-disciplinary approach to uncover the molecular mechanism by which two tick-derived anticoagulants, chimadanin and madanin-1, exert their potent inhibition of thrombin (Thompson R.E., Liu X., Ripoll-Rozada J., Alonso-García N., Parker B.L., Pereira P.J.B., Payne R.J. *Nat. Chem.* 2017, **9**, 909–17). Using streamlined methods for chemical protein synthesis developed in the Payne laboratory, the researchers generated the two proteins in multiple modification states. In vitro biochemical analysis showed that sulfation of key tyrosine residues common to both proteins led to increased inhibition of thrombin by almost three orders of magnitude compared with the

weakly active unmodified inhibitors. X-ray crystallographic analysis of the thrombin–madanin-1 complex showed that these ligands bind thrombin in a manner unique among known unstructured anticoagulant proteins that is driven by the presence of sulfated tyrosine residues.



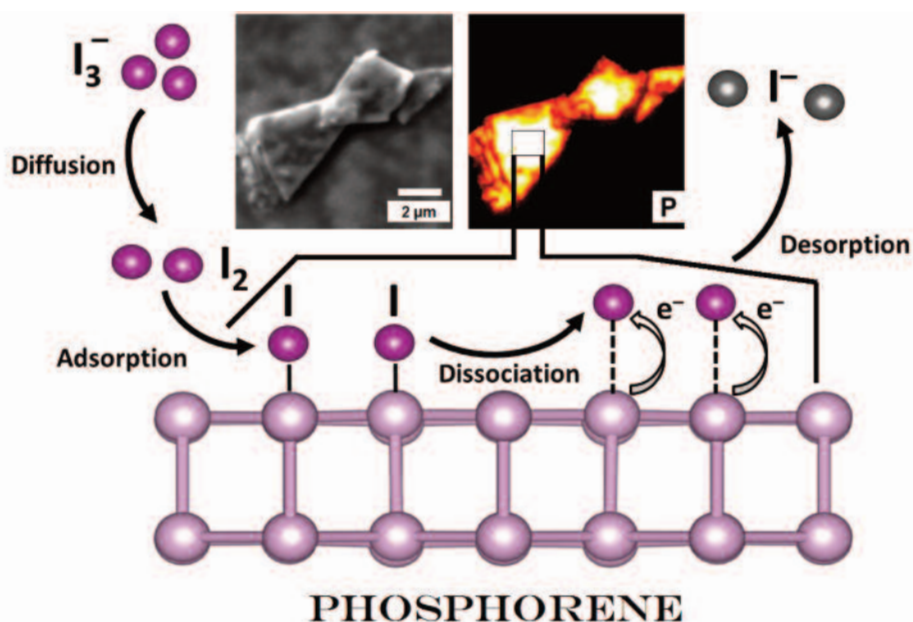
Phosphorene for photoelectrochemistry

Researchers from Flinders University, the University of Adelaide and University of Technology, Sydney, have used experimental and density functional theory studies to show that few-layer black phosphorus (FL-BP) sheets, or solution-processed phosphorene, can act as catalytically active sites and show excellent electrocatalytic activity for triiodide reduction in dye-sensitised solar cells (Batmunkh M., Shrestha A., Bat-Erdene M., Nine M.J., Shearer C.J., Gibson C.T., Slattery A.D., Tawfik S., Ford M.J., Dai S., Qiao S., Shapter J.G. *Angew. Chem. Int. Ed.* 2018, <https://doi.org/10.1002/anie.201712280>). The FL-BP sheets were prepared by microwave exfoliation. A

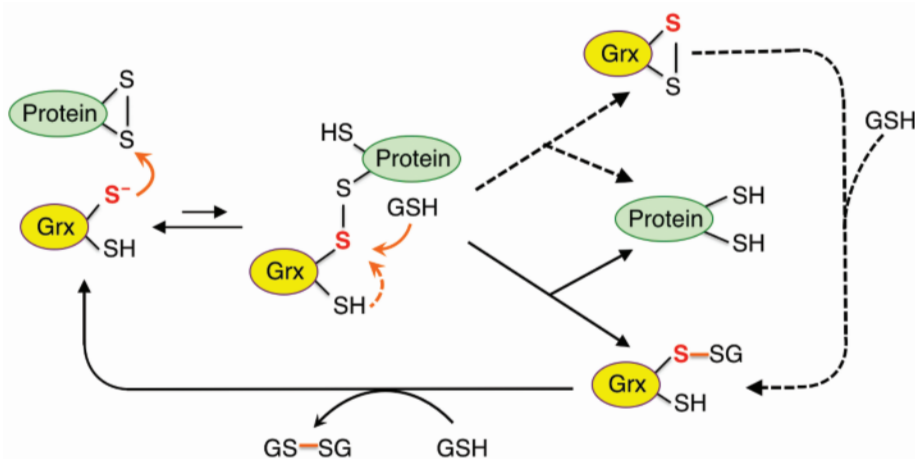
photoelectrochemical device was fabricated with a newly designed heteroelectrocatalyst consisting of carbon nanotubes co-doped with nitrogen and sulfur that were decorated

with cobalt sulfide (CoS_x) nanoparticles and coated with FL-BP. The device displayed an impressive photovoltaic efficiency of 8.31%, outperforming solar cells based on the commonly used

expensive platinum-based electrode. This work paves the way to advance phosphorene research and to use phosphorene-based electrocatalysts for next-generation energy-storage systems.



Parallel catalytic mechanisms of glutaredoxin enzymes



Glutaredoxins (Grxs) are a family of glutathione (GSH)-dependent thiol-disulfide oxidoreductase enzymes. They feature GSH-binding sites and catalyse reversible thiol-disulfide exchange reactions between protein thiols and the

abundant cellular non-protein thiol pool. This is a vital process for maintaining cellular redox activities and redox balance. However, the catalytic mechanisms of these enzymes remain elusive, with several different

possibilities debated in the literature. By employing a novel approach of quenching the catalytic reactions with excess iodoacetamide, followed by protein speciation analysis via electrospray mass spectrometry, a research team led by Dr Zhiguang Xiao and Professor Anthony Wedd at the University of Melbourne was able to intercept and characterise the reaction intermediates along the reaction path for both substrates and enzymes (Ukuwela A.A., Bush A.I., Wedd A.G., Xiao Z. *Chem. Sci.* 2018, **9**, 1173–83). The researchers demonstrated that these enzymes shuttle between three catalytically competent forms during the catalysis and employ conserved parallel monothiol and dithiol mechanisms for their versatile catalytic functions.

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

FLEXINITY™: structured glass for smaller electronics

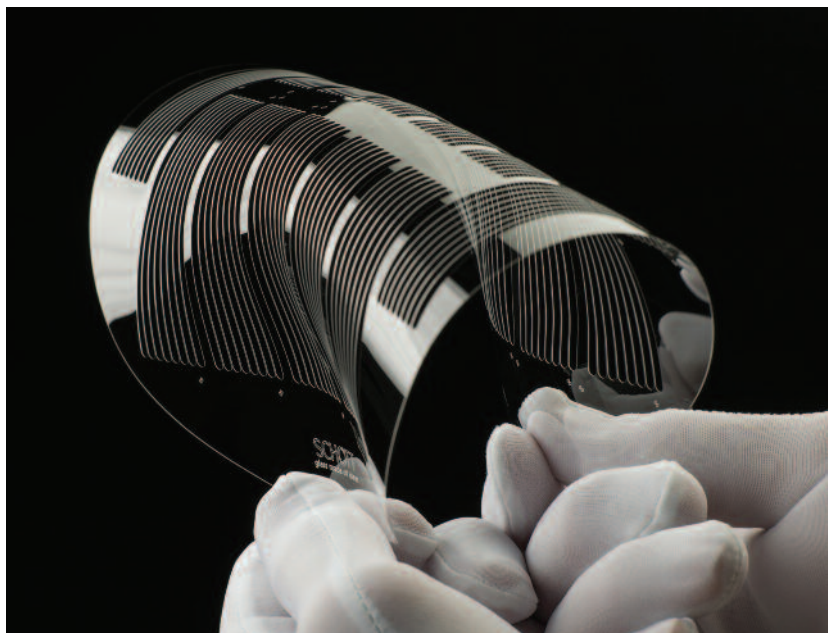
SCHOTT is introducing a new, innovative portfolio of structured glass substrates that offers highly accurate and versatile features: FLEXINITY™. Structured thin or ultra-thin glass wafers are used as a substrate for sensors, batteries and diagnostic technology. The glass will enable new applications and further miniaturisation of electronics through thinner glass wafers and more precise structures.

An increasing trend towards miniaturisation in IC packaging, biochips, sensors, micro-batteries and diagnostic technology has pushed demand for high-precision structured glass wafers, even as technology to create them has reached its limits. This has made it difficult to shrink wafers any further, and limited the pace of innovation.

With FLEXINITY™, any shape is possible, and the process allows extremely tight tolerances and structures. Structured wafers are available made of glass types from SCHOTT's unique down-draw glass portfolio, or plano-plano-processed BOROFLOAT 33® borosilicate glass.

SCHOTT's structured glass wafers are available in 4-inch to 12-inch wafers, in thinness ranging from 0.1 to 3.0 mm. The smallest structuring radius is set to 150 μm and the feature size tolerance is lower than $\pm 25 \mu\text{m}$. Customers can choose from several different glass types, such as borosilicate glass (MEMpax®, D 263® family, BOROFLOAT 33®) and alkali-free glass (AF 32® eco).

SCHOTT has already created sampling capabilities; mass production will be ready 2019.





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D-glucose

Score: 3

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Value-added chemicals *from* food wastes

Australia is throwing away more than four million tonnes of food each year. It's too good to waste, say environmental chemist **Nanthi Bolan** and chemical engineer **Dan Tsang**.

According to the UN Food and Agricultural Organization, around 1.3 billion tonnes of food waste were discarded globally in 2011. This number is predicted to reach around 2.2 billion tonnes by 2025. In Australia, an estimated 35% and 21.5% of municipal and industrial waste, respectively, is food. Australia rejects an estimated 4.06 million tonnes of food with a total annual value of \$8.04 billion. Currently, food waste represents the single largest type of waste entering landfills. These wastes contribute to major environmental, economic and social problems. The environmental impact of food waste is twofold: depletion of natural resources such as water and nutrients used for the production of food, and environmental costs associated with the safe disposal of food waste.

Waste and loss of food happens throughout food supply chains – it begins before a product even leaves the farm gate. Food losses can occur before, during or after harvest. Pre-harvest losses can be due to weather extremes (i.e. droughts) or pest infestations. Examples of food waste are perishable commodities damaged during storage and transport, and food products prepared by restaurants and

community facilities such as hospitals that are never consumed. Food waste is also a principal constituent of the household waste stream, contributing to a significant fraction (globally around 20%) of domestic waste. More consumer choices of food products and an increasing share of disposable income disbursed on food are manifest as wasteful behaviour at the consumer end of the food supply chain.

Developing countries contribute up to 21% of the global share of food waste, which is predominantly post-consumption food waste (mainly due to the lack of appropriate collection and management plans). In developed countries, post-consumption food waste is dominant, mainly because of consumers' hyper-concerns about food quality. In developed countries, much more food waste is generated in the home than along the entire food supply chain.

Two approaches can be used to manage food wastes. The first, reduction of preventable food waste, can be achieved by enhancing consumer behaviour and knowledge towards healthy food consumption and preventing waste generation; improving food storage, transport and marketing strategies; increasing food

Food waste is becoming a sustainable resource with a significant potential to be utilised as a feedstock material for the synthesis of fuels, chemicals and biomaterials ...

shelf-life through improved food packaging; and encouraging the consumption of low-carbon, locally produced food.

The second approach, value-added utilisation (valorisation) technologies of non-preventable food waste, can be achieved by bio-refining food-waste streams for the production of value-added speciality products. These

include chemicals and biofuels; developing waste-specific processing technologies and schemes; and encouraging re-utilisation of food-waste-derived products. A number of prevention and mitigation measures including legislation have already been implemented to reduce food waste. However, technologies for the valorisation approach are urgently needed.

Current waste management/recycling practices for food waste include animal feed, composting, combustion (i.e. incineration) and landfill. Production of animal feed food waste is generally considered to be the most cost-effective method for beneficial utilisation of these wastes; however, it is sometimes limited by the nature and volume of the co-product derived in the process. Composting involving anaerobic digestion followed by land spreading or soil injection is considered environmentally friendly and reduces farmers' needs for fertilisers. In contrast, not only does combustion of food wastes result in greenhouse gas emission, but the

energy recovery through incineration is not always economically feasible, mainly because of the energy required to evaporate the high volume of water in these wastes. Landfill is becoming increasingly prohibitive, and the damage this triggers encompasses more than just occupying space at landfill sites and leachate generation, with food wastes generating an estimated 6.8 million tonnes of greenhouse gases such as carbon dioxide and methane into the atmosphere in Australia.

Food waste is becoming a sustainable resource with a significant potential to be utilised as a feedstock material for the synthesis of fuels, chemicals and biomaterials, given the presence of diverse functionalised chemical components (i.e. carbohydrates, proteins, fatty acids, polyphenolics). However, when using food wastes as a feedstock for electricity power generation (i.e. through anaerobic digestion) or fuel generation (i.e. conversion of cellulosic biomass to bioethanol), part of the chemical components are lost

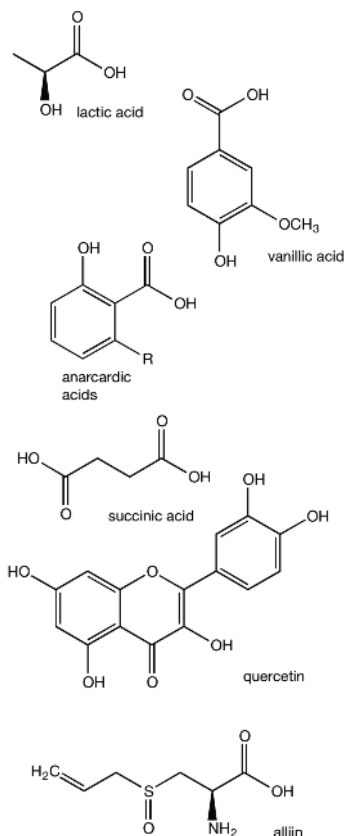
Cereals, vegetables, potatoes, fruits and rice make up more than 80% of total annual food waste.

Love Food Hate Waste NZ/CC-BY-SA-4.0



Examples of chemicals from food waste

Waste source	Chemical	Examples of commercial uses
Orange peel	Pectin Polysaccharide	Gelling agent, thickening agent and stabiliser in food Thickener or a fibre source – starches, dextrin, polydextrose, inulin and gum
Mango peel	Lactic acid	Food preservative, curing agent, flavouring agent and decontaminant during meat processing
Pineapple waste	Vanillic acid	Flavouring agent
Rice straw	Ethanol	Fuel source
Cashew waste	Anacardic acid	Production of cardanol, used for resins, coatings and frictional materials
	Succinic acid	Active pharmaceutical ingredient
Cooking oil	Glycerol	Animal feed
Onion peel	Quercetin	Bioflavonoid
Garlic	Alliin	Antioxidant and antimicrobial
Sugarcane bagasse	Ethanol	Fuel source
Potato peel	Polyphenols	Source of dietary antioxidants
Mango seed	Oleic acid	Major component of soap as an emulsifying agent
Grape seed	Linoleic acid	Medical application – skin treatment
Pumpkin seed	Hexadecanoic acid	Personal care products and cosmetics
Coffee waste	Pectinase enzyme	Wine production



Food supply chain wastes

Food loss

During food production, for example due to weather and pests
During food processing, for example poor food grading and packaging practices

Food waste

In commercial food settings, for example failure to repurpose ingredients or maximise shelf-life
In domestic settings, for example buying or cooking more food than needed

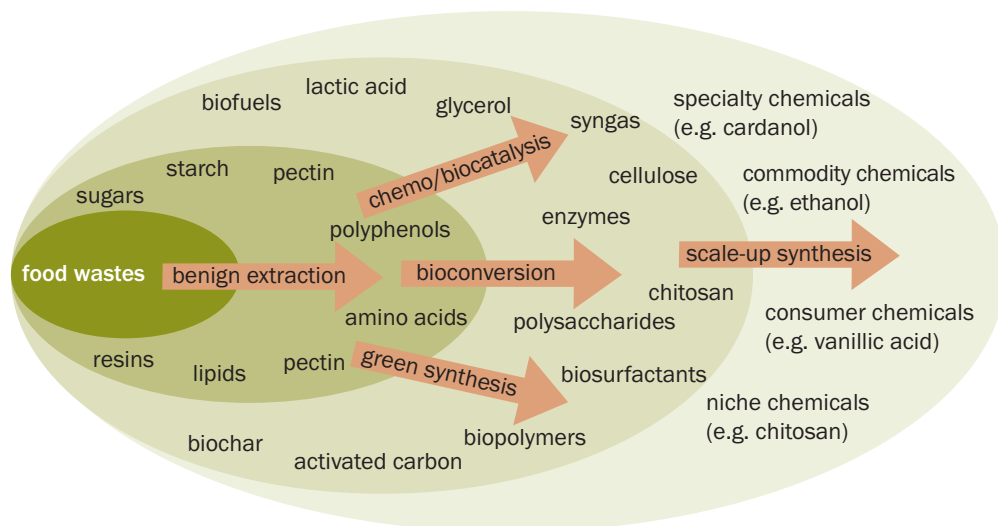
Food loss can occur during the production or processing of food. Food waste is generating during food distribution, and food use in commercial and domestic settings.

and/or underutilised. An array of valuable chemicals can be synthesised from food wastes (see table). The average value of bulk chemicals, transportation fuels and animal feed produced from food wastes is estimated to be around \$1000, \$200–400 and \$70–200 per tonne of biomass, respectively, which highlights the significant differences in economic value between final products derived from food wastes.

At the University of Newcastle, our environmental chemistry group, in collaboration with Hong Kong Polytechnic University (Associate Professor Dan Tsang), is looking at the potential value of food waste as a feedstock source for the production of methane (CH_4) for energy and fertiliser for agricultural production.

The biomass from food wastes provides a major source of building block chemicals.

The biomass from food wastes provides a major source of building block chemicals. These molecules have an array of functional groups that can potentially be transformed into new secondary chemicals. For example, 12 major building block chemicals have been identified that can be produced from sugars (one of the dominant components of food wastes) through biological or chemical conversions (Lin et al. *Energy Environ. Sci.* 2013, vol. 23, pp. 426–64). The 12 sugar-based building blocks include 1,4-diacids (succinic, fumaric and malic), 2,5-furan dicarboxylic acid, 3-hydroxypropionic acid, aspartic acid, glucaric acid, glutamic acid, itaconic acid, levulinic acid, 3-hydroxybutyrolactone, glycerol, sorbitol and xylitol/arabinitol. A second-tier group of building block chemicals include gluconic acid, lactic acid,



Chemicals produced from food waste (modified from Lin et al. *Energy Environ. Sci.* 2013, vol. 23, pp. 426–64).

malonic acid, propionic acid, triacids citric acid and aconitic acid, xylonic acid, acetoin, furfural, levoglucosan, lysine, serine and threonine. These building block chemicals can be subsequently used to synthesise a large number of value-added bio-based chemicals or materials.

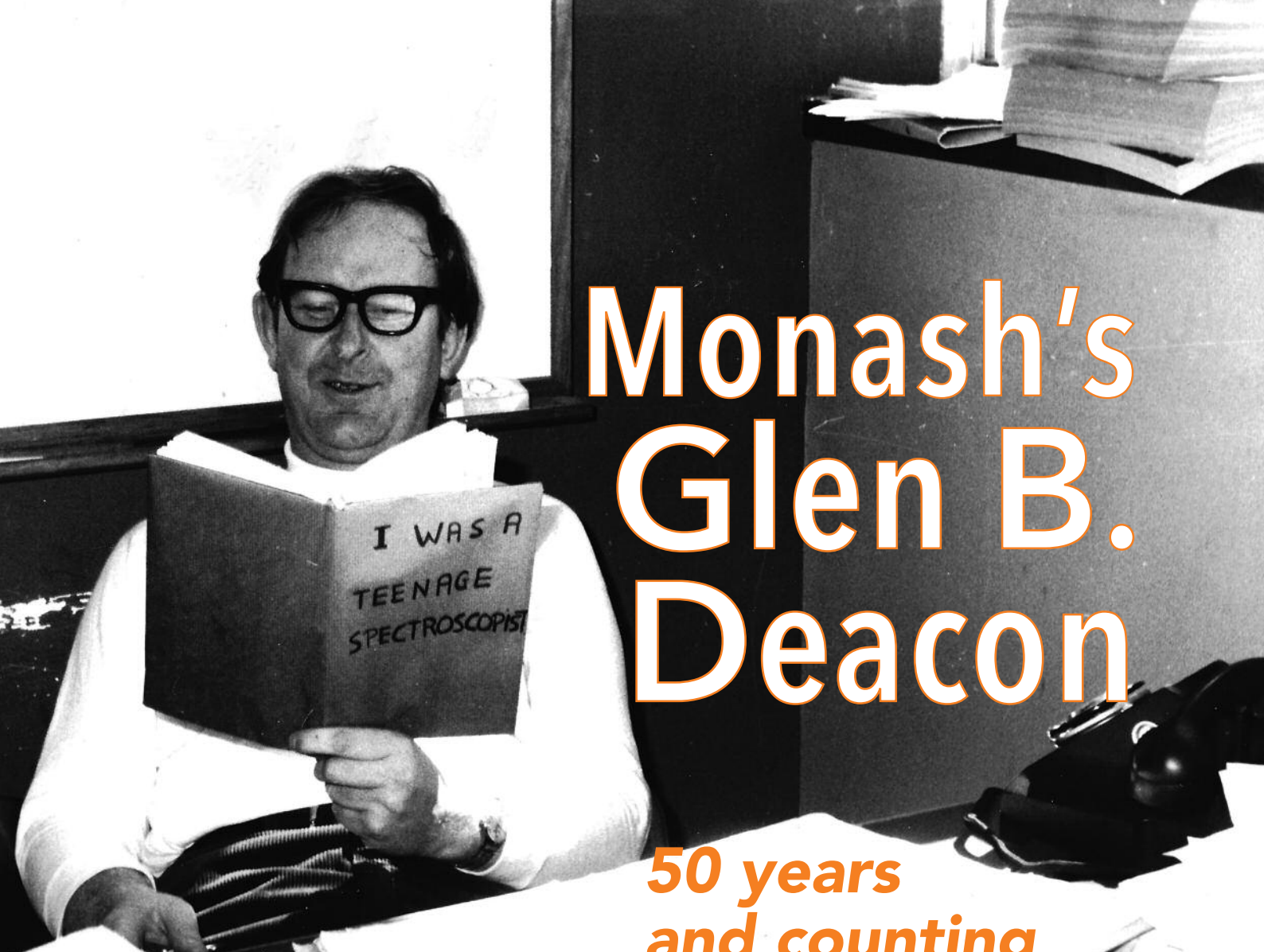
It has been demonstrated that a number of chemicals, including sugars (e.g. sucrose), organic acids (lactic acid), pectin, polysaccharide, polyphenols and fatty acids, can be synthesised from specific food wastes (see table). However, currently ethanol and biodiesel are the two major chemicals produced on a commercial scale from general food waste. These two chemicals are used as biofuels mainly in the transport sector. During the production of these two major chemicals from food wastes, other secondary chemicals are also generated. For example, biodiesel production from food waste is likely to generate about 10% (w/w) glycerol as one of the main by-products. It was estimated that the global biodiesel demand would reach 170 billion litres by 2020, which indicates that approximately 17 billion litres of crude glycerol would be generated as a co-product. Because purified glycerol is a high-value commercial chemical with many applications, the crude glycerol provides great potential benefits for new applications, including the synthesis of secondary chemicals such as 1,3-

propanediol, which is used as a building block in the production of polymers.

Strategies to utilise food wastes, such as animal feeding and composting, cannot achieve an abundant processing of food waste residues. In this regard, advanced food wastes utilisation practices aiming to achieve sustainable development should focus on technologies that convert these waste resources into value-added products. These include integrated green chemistry technologies involving biochemical processes to synthesise value-added chemicals and biofuel precursors, and extractive processes for the bio-recovery of valuable compounds such as antioxidants.

The diversity of functionalised chemical components found in food wastes reflects the range of chemical industry sectors that can use such a renewable feedstock, thereby increasing the sustainability of their processes. Through the increased utilisation of food waste for non-food applications, such as synthesis of chemicals, the public perception about food waste will change, thereby helping to create the renewable supply chains required to achieve for a closed-loop economy.

Dr Nanthi Bolan MRACI is Professor of Environmental Chemistry at the Global Centre for Environmental Remediation (GCER), University of Newcastle. **Dr Dan Tsang** is Associate Professor of Chemical Engineering at Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University.



Monash's Glen B. Deacon

**50 years
and counting**

Glen Deacon in his old Monash office in 1976, posing for a gag photo. Nick Thomas

**A past student
recalls the many
contributions of
'Dr Deacon' during
50 years at Monash.**

BY NICK THOMAS

As a PhD candidate in the Monash University Chemistry Department from the late 1970s to the early 80s, I was occasionally interrogated by undergraduate students enquiring why I chose to work with Glen Deacon. Glen – who was last year recognised for 50 years of service as an educator and researcher at Monash – had a bit of a tough teacher undergrad reputation due to the blistering fast pace of his inorganic lectures. My response to such queries was usually straightforward: 'If you have an interest in chemistry, work with someone who has a passion for it.' Glen had – and at 81 still has – that hunger for scientific

inquiry. And while the booming voice and no-nonsense lectures could be intimidating, he could also appreciate (and dispense) a dose of humour.

As an undergrad myself in 1976 and knowing 'Dr Deacon' as an encouraging third-year lab instructor, I barged into his office on 15 September that year to persuade him to be photographed for a gag gift I was preparing for a fellow chemistry student's birthday. He agreed, posing at his desk holding a copy of the faux volume *I was a teenage spectroscopist* (in reality, a chemistry book recovered in brown paper and retitled in hastily handwritten black lettering).

Photo shoot complete, I dashed off

to a friend with developing and enlarging equipment to produce a splendid 8 × 10 black and white print, which was promptly signed by Glen, framed, wrapped and presented to its intended recipient that same evening to much acclaim. How could a student contemplating honours not consider collaborating with an educator so willingly complicit in such a delightfully bizarre scheme?

Glen Deacon was born in the Adelaide suburb of Unley, in 1936, to parents with no science background. 'My mother was a school teacher and my father was the numismatologist at the art gallery who, as editor of a coin journal, probably published more than I have!' recalled Glen, when we spoke last December, and who has accumulated almost 600 refereed publications to date. A high school teacher, Sid Eberhard, motivated his interest in chemistry. 'He made chemistry fun. His showpiece was adding phosphorus in CS₂ to a mixture of potassium perchlorate and sugar. He would wait until the solvent evaporated, turn to the fume cupboard and announce "Now!" and there would be this almighty explosion. Something like that was bound to impress a young student.'

Glen's curiosity in inorganic chemistry developed towards the end of high school when students were permitted to perform cation/anion analyses in the lab after school – unsupervised. 'By the end of the year, I probably did 60 of these, learning a lot of chemistry. Needless to say, time in the lab wasn't restricted to only doing unknowns!' Glen later completed his PhD with Bruce West at the University of Adelaide. 'I was supposed to study reactions of phosphines with CF₃I, but ended up doing mostly mercury coordination chemistry.'

Several years of subsequent postdoccing further inspired a life-long interest in main group metals, and included three years at University College London with Ron Nyholm. 'He didn't care too much what you did so

Glen's research strategy ... was 'to let your chemical imagination run wild and also to give your underlings a bit of rope to express their own creativity'.

long as you wrote it up and put his name on it. I was supposed to be making Tl^{II} compounds with Tl–Tl bonds, but did mostly fluoroaryl chemistry of thallium as well as fluorocarbon mercury synthesis in collaboration with Alywn Davies, who was an outstanding organometallic chemist. This collaborative work led to an interest in decarboxylation reactions.'

Glen was appointed to a Monash lectureship in 1966, two years after Bruce West became the Inorganic Chair. Bruce would later write in the department's 1986 Silver Jubilee Commemoration booklet that Glen's background in organometallic and coordination chemistry of main group metals would bring 'this important interest to strengthen both teaching and research in the department.'

Allan Canty (now Emeritus Professor, University of Tasmania) joined Glen's group in the late 60s to explore weak coordination interactions in organomercury complexes and remembers Glen's exceptional attention to detail. 'If IR spectra of a solid clearly indicated a change from the two reactants, he still insisted on X-ray powder photographs and UV spectra. Every peak in an IR spectrum was reported in publications, a very rare practice at that time or subsequently.'

A new research direction opened up in the 70s after Glen discovered rare earths during a sabbatical. 'I was heading back to University College but Ron died while I was on the ship going over', he recalled. 'It was a great tragedy because he was only 52 and drove his car into a bus, which I suspect was due to falling asleep at the wheel.'

With Nyholm's demise, Glen filled a spot in Alywn Davies' lab, but also visited Alan Hart at Queen Mary College. 'He was doing some f-block chemistry, believing it would generate grant money opportunities. That seemed a good reason to bring lanthanoid chemistry to Monash, around 1974. It proved successful and was of national interest.' Nyholm's earlier influence also helped shape Glen's research strategy, which he says was 'to let your chemical imagination run wild and also to give your underlings a bit of rope to express their own creativity'.

Ewan Delbridge completed honours and PhD lanthanoid work with Glen during the late 90s and today works for the Lubrizol Corporation, Ohio. 'I was tasked with making lanthanide/main group heterocyclic cyclopentadienyl complexes', recalled Ewan. 'We discovered some new ligand binding modes we never thought possible.' Personal memories of Glen remain vivid, as well as GBD (as we sometimes referred to him) the researcher and educator.

'He had a formidable (classroom) presence and was a little intimidating – no one dared ask a question that might be deemed stupid. And that distinctive Abraham Lincoln beard was a GBD classic signature. He also donned the lab coat often and behaved as the perpetually tinkering professor. His office was littered with seemingly random piles of paper – all of which were readily accessible to him. But Glen was very passionate about his projects and people – he was a cheerleader, which is so very important. More than anything else, he gave me the skill to be a holistically well-rounded scientist, which I have

Glen expected group members to display a high level of professionalism in their daily interactions and wasn't shy about rebuking us with his characteristic wit should we fall short of expectations.



(Top) Glen's ruthenium group in the early 1980s consisting of third-year, honours and PhD students supervised by Drs Glen Deacon and David Black (back, right). Glen began ruthenium work in the late 1970s. Nick Thomas (Bottom) The Deacon Group in 2016 consisting of postdocs, honours and PhD students. Courtesy Peter Junk

applied over the last 17 years either as a postdoc, assistant professor or technologist at Lubrizol.'

Ewan says Glen was a perfectionist when writing manuscripts, although their completion could take an infuriatingly long duration – at least to students, impatient to see their names immortalised in print. 'He'd shape my results into prose that was rich with accurate, yet elegantly simple, description and his writing was so descriptively dense – packed with meaning and no redundancy.' Ewan also recalls formal meetings with Deacon Group members. 'They were "chalk talks", which forced one to think on one's feet and develop an articulate style. And they were regular, which engendered accountability for one's progress. It was something I subsequently adopted in my own career.'

Naturally, Glen expected group members to display a high level of professionalism in their daily interactions and wasn't shy about rebuking us with his characteristic wit should we fall short of expectations. Geoff Stretton (1986 PhD in NMR studies of organomercury compounds) remembers Glen's frustration during a period of poor meeting attendance in the early 80s, prompting a memo to all. 'The only acceptable excuses for not attending were hospitalisation or death!' recalled Geoff, of Glen's proclamation. On another occasion, when an honours student 'forgot' to return to the lab after a pub 'lunch' one Friday afternoon, Geoff says this yielded another memorable Deacon declaration: 'If the weekend begins at Friday lunchtime, the week begins Sunday lunchtime.'

Geoff also recalls Glen's uncanny memory. 'He enjoyed answering questions in a conversation by quoting references by name, publication and page number. More often than not, he was correct.'

Although Glen's research branched out successfully into many areas, including environmental chemistry,

ruthenium chemistry and platinum anticancer work, he believes his lanthanoid studies produced some of the best results. 'My chief interest has always been simply to make new compounds and develop new synthetic methods. With Bruce in Adelaide, I did a lot of reactions with volatile phosphines, which were air-sensitive so I developed a taste for difficult chemistry. Working with unstable lanthanoids can be very challenging, but extremely rewarding.'

In fact, collaboration with just one researcher produced over 140 joint publications. Glen refereed Peter Junk's PhD thesis in the late 80s. 'He took me on as a postdoc in December 1995 after one of his postdocs left suddenly to start a restaurant in Canada', recalled Peter, who worked in industry before the postdoc, and is now Nevitt Professor of Chemistry at James Cook University. 'I jumped at it, because I thought rare earth organometallics was a place to get into around that time.' Originally from Western Australia, Peter still recalls first meeting Glen in the department corridor. 'He said "you must be Junk. You look like a surfy type I expected from the West"'.

Despite being what Peter calls 'polar opposites in many ways', the two shared an interest in sports as well as chemistry. 'Glen would reel off the scorers, best players, results, and any controversies. He follows sport like no one I know. But we are also deeply passionate about our research and can talk hours upon hours upon days about rare earth chemistry. Academia is a difficult place to have success and without Glen's mentoring, I would more than likely have ended up back in industry. I do believe we have forged a working relationship that is well-known worldwide in rare earth circles.'

Over the years, Glen has indeed been recognised with the international Terrae Rarae Award for rare earth chemistry (2006) and the RACI Burrows medal for Inorganic



Peter Junk, Glen Deacon and wife Merrowyn at a conference in Tuebingen, Germany, October 2017. Courtesy Peter Junk

Chemistry (2007). Six years ago, he received an unexpected honour: in discussing three metal-mediated ligand decomposition reactions in a 2012 *Organometallics* article, the lead author unofficially christened the desulfonation of a metal sulfonate as the 'Deacon reaction'.

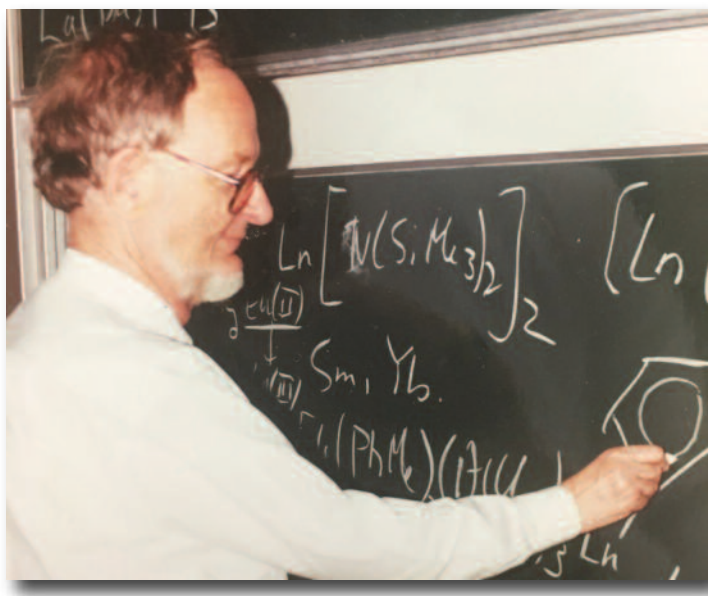
'CO₂ and SO₂ eliminations have names (Pesci and Peters reactions, respectively) so naming one for SO₃ was reasonable', notes Glen. 'Richard O'Hair from the University of Melbourne named it after me which was very nice indeed. He did ask if I objected and naturally I didn't!' Richard says the designation was logical, given Glen's contributions to the area. 'My motivation was simple: I am interested in the history of chemistry and how we stand on the scientific advances and achievements of those who went before. I don't think there are any IUPAC rules for naming a

reaction – we just managed to sneak it passed the editors and reviewers!'

Of course, students also resort to sneakiness, especially when relieving a chemistry department of hazardous chemicals for unauthorised 'experiments'. This occasional appropriation of dry ice, liquid nitrogen or alkali metals was demonstrated during the 1978 Deacon Group barbecue – an anticipated annual event held for many years. That year's late March outing at a local park was memorable when a chunk of sodium metal residues (best described as the size of a partial brick) was smuggled in. Loosely wrapped in weighted protective wax paper, the projectile was launched into the lake, submerging with predictable results moments later.

The deafening detonation attracted the attention of an agitated park ranger, determined to identify its

... in discussing three metal-mediated ligand decomposition reactions in a 2012 *Organometallics* article, the lead author unofficially christened the desulfonation of a metal sulfonate as the 'Deacon reaction'.



Glen Deacon, chalk in hand, at the blackboard in 2001. Courtesy Peter Junk

‘ ... I was influenced by Bruce West’s style of lecturing, which was to pour out the facts of inorganic chemistry on those old rotating chalkboards.’

origin. ‘Yes, we wondered what that noise was’, commented one snarky PhD student as a wave of thinly disguised smirks swept through our ranks. Unable to identify the culprit, the frustrated ranger retired defeated. Despite projecting an image of the sober-minded academic, we always suspected Glen relished such incidents, if only to briefly rekindle youthful memories of his own thrilling chemical experiments that have probably also ignited an interest in science for more than a few professional chemists.

During his half-century at Monash, Glen brought in millions of dollars in grant money and supervised over 130 honours and postgrad students, each with their own reasons for pursuing a career in chemistry – whether it be the discipline’s more flamboyant side or from experiencing an addictive dose of theory during one of Glen’s notoriously rapid undergrad lectures. ‘I suppose I was influenced by Bruce West’s style of lecturing, which was to pour out the facts of

inorganic chemistry on those old rotating chalkboards. I also found it helpful to find one student in the audience who looked interested and deliver the whole lecture to them – that certainly keeps you focused. In later years, I began wandering up the aisles while lecturing, which has a very deterring effect on misbehaving students.’

While creativity, good technique and a willingness to work hard are valued qualities he assesses in potential students, Glen also has advice for those considering doctoral work. ‘The primary requirement is to choose a project you will enjoy doing.’ His past students would probably agree, but also acknowledge profiting from Glen’s encouragement to explore their own research ideas.

Today, as an emeritus professor still with an office, lab, students, some research funding and lighter teaching duties, Glen maintains an impressive output – some 10 publications a year. ‘That gives me some degree of security. I was turfed out of my old

office in 2004 and now have a microscopic office near physics, but that’s an advantage, too, because no one will want it!’

Last May, Glen was officially honoured for his 50 years at Monash with a formal ceremony. ‘It was actually my 51st year by the time they got around to doing anything, but that was fine. There was a presentation with a medal allegedly composed of silver.’ I suggested to Glen that perhaps the medal should have been cast in a metal more befitting a noted lanthanoid chemist, such as europium!

‘That certainly would have been more valuable, but not a good idea’, he replied. ‘You couldn’t use any and have a shiny surface – far too reactive and air-sensitive.’

I see ... my bad. Thank you, Glen – still the educator!

Nick Thomas (nthomas@aum.edu) is currently a professor of chemistry at Auburn University at Montgomery, in Alabama, USA. He has also written features, columns and interviews for over 650 magazines, such as *Nature*, and US newspapers including the *Washington Post*, *Chicago Tribune* and *Boston Globe*.

Did you say ‘a shortage of cocoa beans’?

Dr Marianne Repacholi, Patent Attorney, FB Rice



The thought of the cocoa bean extinction on the horizon due to climate change gives me the shivers. Without cocoa beans, there is no chocolate! Don't panic; science and innovation is working towards future-proofing the chocolate industry.

Intellectual property (IP) may not immediately spring to mind when biting into a delectable piece of chocolate, but as with almost any type of product, IP can be an extremely important marketing strategy.

Patents

You may be surprised to know that there are a host of patents to all manner of chocolate-related inventions. Examples include US 2,224,637 to chocolate-flavoured chewing gum back in 1939, and the multi-tiered chocolate fountain, which was patented as recently as 2004.

A key point is that for your patent to be successful, your invention needs to be useful, new and not obvious. So, how does this sound – chocolate that melts in your mouth but not in your hands. Well you are in luck because the likes of Nestle, Hershey Co and Cadbury are all currently hard at work.

It goes without saying that global warming is affecting every part of our lives. Did you know that cocoa beans obtained from identical varieties of cocoa plants can have different characteristics, i.e. inferior or lower quality cocoa beans, caused by changes of climate? US 9,833,009 claims a method for improving the quality of cocoa beans by removing contaminants.

Trade marks

Trade marks and chocolate have a long-standing relationship. In Australia, trade marks need to be capable of distinguishing the goods or services to which the mark is applied. However, if they meet those criteria, words, logos, shapes of products, colours, scent and sound may all potentially be registrable.

This has led to trade marks being registered not only for chocolate manufacturer's logos, but also for the shape of the chocolate itself.

In a recent battle in the UK between Toblerone and Poundland, a deal was reached allowing Poundland to sell their 'Twin Peaks' bar after a copycat dispute in which Poundland asserted that Toblerone's shape trade mark had lost its distinctiveness because the shape of the Toblerone product had been changed to have 'fewer chunks'. That case did not reach the courts, but there are situations where shape is not always considered sufficiently distinctive, with Guylian being denied registration of a trade mark application for the shape of their chocolate seashells as a trade mark in Australia.

Designs

To be a registrable design, the appearance of the product must vary from that of any existing products. A design right will afford you protection for the appearance of the product and its packaging. Cadbury's Easter bunny chocolates are an example of a successfully registered design for the appearance of the product.

Trade secrets

As the name suggests, a trade secret is a compilation of information that is kept confidential and preferably protected by a signed confidentiality agreement. While a trade secret is not a type of registrable IP, it is a common strategy for protecting IP where the owner derives economic value from the information being kept confidential. An example of a well-guarded trade secret is the process for making Hersey's chocolate. Although the process is still top secret, there are rumours that it involves lipolysis of milk producing butyric acid and stabilising it.

Even with chocolate on your mind, it is clear that your IP may be your most valuable asset and can give you a competitive advantage over your competitors. Having a sound understanding of your IP needs will ensure you make the most of this invaluable tool.

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

FB RICE



The IP Navigators

Centenary fellows

RACI's centenary ends on 30 June, and as part of this special year the RACI Board, Branches and Divisions are suggesting names for consideration for fellowship status. Congratulations to the following people on becoming Centenary fellows during the centenary year so far.



Dr Despina Anastasiou
Dow Chemical Company



Dr Deborah Beswick
Elizabeth College



Associate Professor Deanna D'Alessandro
University of Sydney



Professor Christopher Barner-Kowollik
Queensland University of Technology



Professor Stephen Blanksby
Queensland University of Technology



Dr Andrew Eaton
Wollondilly Anglican College



Mrs Elaine Bergmann
RACI Chemical Education Queensland
Group Coordinator Australian National
Titration Competition



Professor Yuan Chen
University of Sydney



Professor Bronwyn Fox
Swinburne University of Technology



Professor Karen Hapgood
Deakin University



Professor Claire Lenehan
Flinders University



Professor Tina Overton
Monash University



Associate Professor Jason Harper
University of New South Wales



Dr Peter Lye
University of New England



Associate Professor Ekaterina Pas
Monash University



Mr Alasdair Hey
The Armidale School



Associate Professor Lisandra Martin
Monash University



Ms Helen Patronis
CS Executive Group Inc. ChemSkill



Associate Professor Gwendolynne Lawrie
University of Queensland



Dr Keith McLean
CSIRO Manufacturing



Ms Samantha Read
Chemistry Australia



Professor Mark Rizzacasa
Bio 21 Molecular Science and
Biotechnology Institute



Dr Andrew Seen
University of Tasmania



Associate Professor Jason Smith
University of Tasmania



Professor Andrea Robinson
Monash University



Mrs Jenny Sharwood OAM
Retired



Associate Professor Uta Wille
Bio 21 Molecular Science and
Biotechnology Institute



Professor Alison Rodger
Macquarie University



Associate Professor Danielle Skropeta
University of Wollongong



Professor Brian Yates
University of Tasmania

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is now available at
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For further information,
contact Mary Pappa:
mary.pappa@raci.org.au,
(03) 9328 2033



New awards as part of RACI's diversity strategy

The RACI Inclusion and Diversity Committee (RIDC) was formed in late 2016 in response to longstanding issues related to the lack of diversity within the RACI, in particular the poor representation of women on the Board, as invited speakers at RACI conferences and as award recipients. An article summarising the background to the formation of the committee appeared in the November 2016 issue ('Gender equity in the RACI and beyond', pp. 32–3). It is worth noting that there has been essentially equal female representation at PhD and postdoctoral levels in chemistry in Australia for over two decades, and yet female representation at higher levels in academia (and elsewhere) and among invited speakers, national award winners and the academy fellowship remains poor. There have been only two female recipients of the RACI's highest research award (both in the last two years), female fellows of the Australian Academy of Science who are chemists can still be counted on one hand, and Australian-hosted international conferences boasting 'Shakespearean casts' of all-male plenary speakers are still common.

Research suggests that the reasons for this are complex, but some key issues have been identified, including the:

- importance of effective networks for mentoring, for research collaborations, for invitations to conferences, for nominations, and so forth. These networks currently tend to be male dominated and women often miss out on opportunities as a result
- unattractiveness to many young female chemists of the perceived hyper-competitive, male-dominated and non-family-friendly culture of academia, and the lack of inspiring female role models to counter this perception.

To help address these problems, the RIDC has drafted a policy (available at www.raci.org.au/theraci/advocacy/the-raci-inclusion-and-diversity-policy) and a strategy, including a list of measures for the RACI to improve the performance in these areas, and these have been endorsed by the Board. As part of the diversity strategy, two new awards were initiated, one at the early career level and one at a senior level. Both of these awards are intended to be open to women chemists both within academia and in teaching, industry or government roles. The aim of these awards is to provide both opportunities and role models for the next generation of female chemists.



The Margaret Sheil Award

The aim of this award is to recognise an outstanding female leader working in a chemistry-related field, including academia, teaching and the public or private sector, who has helped to inspire and mentor junior female chemists and/or help to provide a more equitable work place. The award consists of a medal and the recipient

undertakes a lecture tour within Australia with the aim of inspiring the next generation.

The award has been established to honour the trail-blazing contributions of Margaret Sheil, the first Australian female professor of chemistry. Margaret has worked tirelessly to progress the participation, success and recognition of women in chemistry, and science and engineering more broadly.

The inaugural recipient of this award is **Mary Garson** FRACI CChem from the University of Queensland (see March issue, p. 34). Mary has been an outstanding advocate for chemistry generally, with formal roles within IUPAC for over a decade, including as President of Division III (Organic and Biomolecular). She has also worked to support female chemists formally and informally throughout her career. In 2011, she organised a global event 'Women sharing a chemical moment in time' for the International Year of Chemistry; over 40 countries shared their individual events with each other through social media websites. This event will be repeated in 2019 during the centenary celebrations for IUPAC.

Rita Cornforth Lectureship

The aim of this award is to provide an outstanding female early career chemist with an opportunity to achieve broader recognition of their career achievements to date, and to help form collaborations and networks that will further assist them in establishing an independent career. The award recognises an outstanding contribution to chemical research in any sphere, including industry, the public sector and academia. The award consists of a medal, and the recipient undertakes a lecture tour within Australia.

The award has been established to honour the pioneering contributions of Lady Rita Cornforth (1915–2012), the wife of Nobel Laureate Sir John Warcup Cornforth (1917–2013), and collaborator on 46 of his papers. In his Nobel Lecture, Sir John paid tribute to his wife's pivotal contributions to their joint work: '... with patience and great experimental skill [she] executed much of the chemical synthesis on which the success of the work was founded.'

The inaugural winner of this award is **Lidia Matesic** MRACI CChem from ANSTO (see March issue, p. 35). She is a radiochemist and her primary research interest has been in the field of radiopharmaceutical development using the radioisotope fluorine-18. In particular, her research involves the synthesis of radiopharmaceuticals by microfluidic flow chemistry.

Michelle Coote FRACI CChem is at the Research School of Chemistry, Australian National University. **Madeleine Schultz** FRACI CChem is at the School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology. Madeleine Schultz maintains an email list with up-to-date news of interest to women in chemistry in Australia. Contact her at madeleine.schultz@qut.edu.au to be added to the list.



RACI National Awards 2018

Call for nominations

Nominations are called for the following awards. You can apply for some of these awards yourself; others require nomination. **All national awards except the Post Graduate Student Travel Bursary (closing date 15 May) close on 15 June.**

Applied Research Award
C.S. Piper Award
Citations
Cornforth Medal
Distinguished Contribution to Economic Advancement – Weickhardt Medal
Distinguished Fellowship
Fensham Medal for Outstanding Contribution to Chemical Education
H.G. Smith Memorial Award
Leighton Memorial Medal
Margaret Sheil Lectureship Award
Masson Memorial Medal
MRACI Post Graduate Student Travel Bursary
RACI Chemistry Educator of the Year Award
Rennie Memorial Medal
Rita Cornforth Lectureship

See www.raci.org.au/events-awards/awards or email awards@raci.org.au for more information about the requirements for nominations for each award.



Australia Day Honours 2018

Congratulations to all chemists and chemical engineers who received Australia Day awards this year.

Companion (AC) in the General Division of the Order of Australia

Emeritus Professor Lewis Mander FRACI CChem

For eminent service to science through pioneering contributions to organic chemistry in the field of plant growth hormones, to higher education as an academic, researcher and author, and to national and international scientific societies.

Professor Jennifer Martin FRACI CChem

For eminent service to science, and to scientific research, particularly in the field of biochemistry and protein crystallography applied to drug-resistant bacteria, as a role model, and as an advocate for gender equality in science.

Professor Ezio Rizzardo FRACI CChem

For eminent service to scientific technological research and development in the field of polymer chemistry, to its application in the biomedical, electronics and nanotechnology context, as an author, and through mentorship roles.

Officer (AO) in the General Division of the Order of Australia

Professor Martin Banwell FRACI CChem

For distinguished service to science education as an academic, author and researcher, particularly in the field of synthetic organic chemistry, to scientific institutes, and as a mentor of emerging scientists.

Member (AM) in the General Division of the Order of Australia

Emeritus Professor Denis Crane

For significant service to education in the field of biochemistry and molecular biology, as an academic and researcher, and to scientific bodies.

Mr Russell Scott FRACI


For significant service to chemical engineering through leading roles in developing and improving professional education.

Professor Anthony Weiss

For significant service to science in the field of biotechnology, as an academic, researcher, author and mentor, and through executive roles with scientific institutions.

Professor David Wood FRACI CChem

For significant service to chemical engineering education as a researcher, mentor and academic, and to professional organisations.



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Why can't dogs eat chocolate?

Most pet owners know chocolate and dogs don't mix. Despite this, chocolate poisoning in dogs remains a problem, particularly at Christmas and Easter, as a new study in the journal *Vet Record* shows (<http://dx.doi.org/10.1136/vr.104762>).

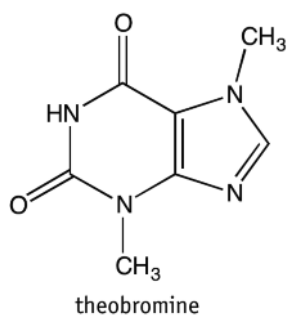
Chocolate and cocoa are products of cacao beans (*Theobroma cacao*) after they are fermented, roasted, shelled and ground. Chocolate contains two ingredients potentially lethal to dogs – theobromine and caffeine.

There are 1–9 milligrams of theobromine per gram of chocolate, with higher levels in darker chocolate. White chocolate has zero risk of toxicity.

How much chocolate makes dogs sick?

Toxicity to chocolate starts at around 20 milligrams of theobromine per kilogram of body weight. In a small dog weighing five kilograms, this means 100 milligrams of theobromine (around 70 grams of milk chocolate or 20 grams of dark chocolate) will cause problems. There are about 25 grams per square of a chocolate block, so that's around three squares of milk chocolate.

Cocoa powder contains higher levels – only four grams of cocoa powder contains 100 milligrams of theobromine.



A few years ago, my best friend's dog, a dachshund, ate cake-decorating chocolate stored in her spare room. How she managed to jump up onto the bed to get it remains a mystery. Dogs will find chocolate even if you think they can't.

Luckily in this case, her dog vomited a large part of the chocolate before it could cause problems (although not so lucky for the cream carpet) and she was OK.

What are the signs your dog has eaten chocolate?

One of the first signs to look for if you suspect your dog has eaten chocolate is restlessness and hyperactivity. Caffeine is absorbed ten times faster than theobromine, which takes up to ten hours to peak. Signs are usually seen 2–4 hours after eating the chocolate and can last up to 72 hours.

Both caffeine and theobromine cause elevated heart rate and blood pressure, and abnormal heart rhythms.

Vomiting, diarrhoea, muscle tremors/shaking and hyperthermia (high body temperature) can occur at toxic levels. Your dog might seek out cooler places, although will be unlikely to settle anywhere. The hyperthermia causes panting, the main way dogs lose body heat.

In more serious toxicity, it may cause muscle rigidity (stiffness), ataxia (uncoordinated movement), seizures and coma. Death results from problems with heart rhythm or failure of the respiratory system.

Theobromine causes increased levels of cyclic adenosine



monophosphate (cAMP), an important chemical messenger in the cell. Theobromine and caffeine also increase the release of adrenalin, and affect the calcium flow in and out of the cell. This increases muscle contractions.

When combined, all of these biochemical changes stimulate the central nervous system and the heart muscle. Other types of muscles in the rest of the body called smooth muscles relax, which can cause respiratory problems and increased urination.

Why do so many dogs manage to eat chocolate?

The first reason is dogs like sweet things, unlike cats who lack the taste receptor for sweet.

The second is we underestimate the motivation and sense of smell of dogs. They can smell chocolate a mile away.

Once we had a family Christmas in a local park, and while I was unwrapping a present my Labrador swept past and grabbed the parcel. I didn't know there was chocolate in it but she did! Twenty of us ran after her screaming 'Don't eat it!', but by the time I caught her all I got was the paper. Luckily there wasn't enough chocolate to hurt her.

Remember, chocolate is potentially lethal to our best friend, so put it somewhere impossible to reach. A closed cupboard will be safer than somewhere a motivated dog can jump.

The problem at Christmas time is that everything is so hectic, we forget or don't notice. If you have a dog, educate everybody you know on the risks of chocolate and keeping it out of their reach. If you have young children, you will need to keep a close eye on them as they won't understand and love to feed dogs – children and dogs should always be closely supervised anyway.

In the case of an accident or if you suspect your dog has eaten some chocolate, contact your veterinarian. There will be time to give it something to induce vomiting if it has only just eaten the chocolate.

Humans and dogs are on the same wavelength in so many ways, but while some of us run on chocolate and caffeine, dogs just can't. Remember that and have a happy Christmas with all your four-legged family members.

Susan Hazel is Senior Lecturer, School of Animal and Veterinary Science, University of Adelaide. First published at The Conversation (www.theconversation.com).

A good measure of Beer and sunscreen



Seven teaspoons (35 millilitres) – that's the recommended amount of sunscreen to provide the correct thickness for an average maximally exposed sunbaking body, with application to be repeated early after the initial sun exposure period. If you use sunscreen frequently, you'll be aware that this wipes out a standard 110-millilitre tube very quickly (and don't forget to take your teaspoon to the beach).

According to the relationship known as Beer's law, absorbance (which takes into account light absorption, reflection and scattering) is proportional to thickness. For a closer look at the Beer's law prediction for sunscreen, check out the box.

Through thick and thin

According to Beer's law, reducing the applied thickness from the level now used to test sunscreens internationally (2 mg/cm^2) to around what consumers actually use (1.25 mg/cm^2), the product labelled SPF would decrease from 50 to around 10. However, in practice this result doesn't follow.

A multicentre study (bit.ly/2jPTway) on the influence of applied quantity of sunscreen on SPF for a variety of sunscreen preparations showed that, at the quantities consumers are found to apply:

- effective sun protection factor (SPF) was about a third of the label's declared value
- the experimental relation between SPF and thickness is pretty close to linear, not exponential.

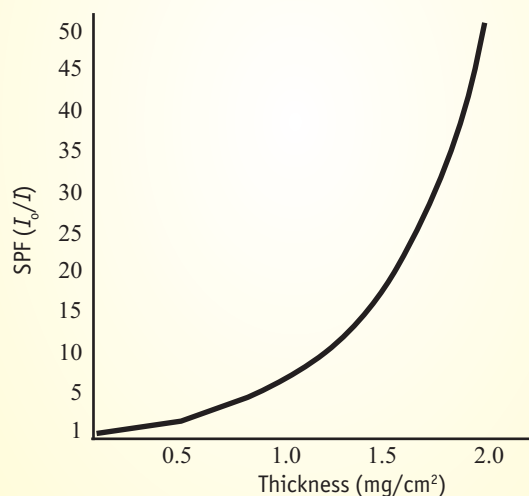
There goes the theory.

Why the discrepancy?

Unless you use something like opaque zinc cream, there really isn't any way of telling whether you have done a good job of uniformly covering the exposed skin or of measuring

Beer's law and SPF

- Define I_0 as the intensity of the incident light and I as the intensity of the light transmitted through the sunscreen and hitting the skin.
- Keep constant the composition of the screening chemicals used and their concentration (manufacturer's prerogative).
- Define absorbance as $\log(I_0/I)$.
- Define SPF as I_0/I .
- It follows that the SPF is proportional to $\exp(\text{thickness})$.



SPF versus application of sunscreen, assuming Beer's law.

Chemistry in the marketplace, 6th edn, CSIRO Publishing, 2017

deterioration of the screen with activity. (In contrast, the coverage by clothing is unambiguous. Even non-UV-rated clothing is generally good enough protection under most circumstances.)

Importantly, the skin surface isn't smooth – it has valleys and ridges whose prominence and depth vary with the age of the skin. Just how sunscreens behave when spread on this wrinkled landscape is a subject of tantalising research by DSM Nutritional Products (bit.ly/2FvndU0). According to this research, we need to move from chemistry of absorbance to the physics of spreading and fixing the sunscreen film. We need rheology (the physics of flow) with its yield stress and the (negative) Marangoni effect (the positive effect of which is seen when alcoholic drinks rise up the sides of a glass).

Thus, sunscreens can be expected to initially cover the skin very unevenly, like a first coat paint job on a rough surface. To allow for this, thicknesses were set very (unrealistically) high for testing. (High applied thickness was also selected for the international sunscreen tests because anything less did not allow for reliable results.)

Quality of sunscreens and absorption by the skin (with one exception – see bit.ly/2DlaMmt) no longer appear to be a problem with modern ingredients, so this is probably not a factor.

Sun strength and skin type

SPF is the ratio of how long you can stay out in the sun with and without sunscreen. So how long can you stay in the sun without it?

This depends on strength of the sun and skin type. For compliance to the standard, the strength of the sun is set at the maximum found in the strongest exposed global regions, at midday, and for the worst possible behaviour in the sun (lying flat, motionless and exposed all the time) (bit.ly/2DlaMmt). (See the box for more about the effects of UV on skin.)

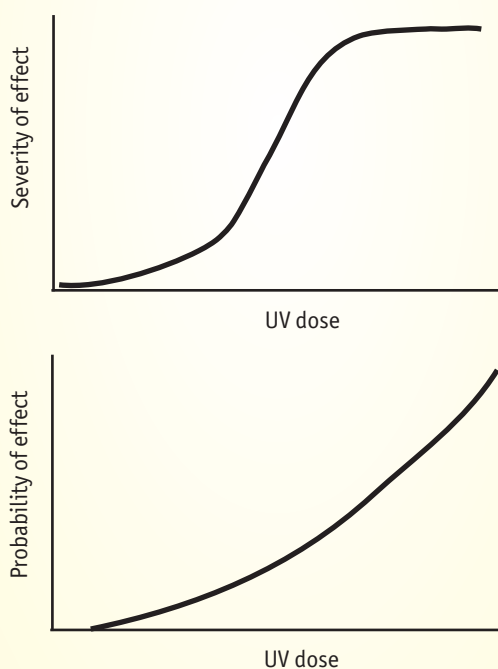
The standard erythemal dose (SED) is a unit of UV exposure. A very fair-skinned person can receive sunburn and skin damage from only two SEDs. A full day under the extreme conditions yields 70 SEDs of UV exposure. So for this sensitive person, an

Clinical effects of UV

The relation of sun exposure to clinical effects, such as sunburn, tanning, vitamin D production, skin damage and various skin cancers, is complicated.

These clinical effects of UV exposure can be either deterministic (where the magnitude of the effect is related to exposure and a threshold dose is possible) or stochastic (in which the probability of the effect is related to exposure and is non-linear and there is no threshold dose).

Sunburn is an example of a deterministic effect and skin cancer is a stochastic process. So linearity doesn't hold for many clinical effects initiated by UV. With basal and squamous cell skin cancers (the two commonest forms) the risk is roughly proportional to the square of the UV exposure.



Deterministic (top) and stochastic (bottom) effects of UV exposure.

Courtesy Emeritus Professor Brian Diffey

SPF of 35 will, given all the safety factors, provide more than enough adequate protection for a day in the sun, *provided the screen is applied and renewed as per instructions*. Non-conforming application may lead consumers to rely on a level of protection that just won't be provided. As Hamlet might have said, 'There's the rub'.

Getting the blend right

How do we work the realities of sunscreen application and sun exposure into useful advice for the consumer? Should the labels on sunscreen display an SPF that is less than the test-accredited SPF? Should we stop using the 'SPF' label, and instead identify sunscreens as 'low' (SPF 4–7), 'medium' (SPF 8–14), 'high' (SPF 15–24) and 'ultra high' (SPF > 25), as done in the EU?

The use of opaque sunscreens such as zinc cream has diminished (except for children). Incorporating a pale pigment that fades in the sun would allow monitoring of proper application, and, to please the aesthetes, it should disappear fairly quickly. (Such a product appeared on the market but has since disappeared.)

Non-conforming application may lead consumers to rely on a level of protection that just won't be provided.

So slip, slap and be conscientious with the slop. To read more, get a copy of *Sun, skin and health* (ed T. Slevin, CSIRO Publishing, 2014).

Acknowledgements

My thanks to John Staton of Eurofins Dermatest Pty Ltd for many discussions, and to Professor Brian Diffey for correspondence and the graph of UV exposure effects.

I acknowledge the input from industry members of Australian Standards committee CS/42 [1976–1985], which I chaired. Ten years of 'consensus building' then needed lobbying of the government of the day to finally make this standard mandatory (a world first), and then to convince the supermarket chains to sell large packs of sunscreen at a low price; that is, not as a cosmetic (very cooperative).

Ben Selinger FRACI CChem is Emeritus Professor of Chemistry at ANU and, along with ANU colleague Associate Professor Russell Barrow, released the sixth edition of *Chemistry in the marketplace* (CSIRO Publishing) in June 2017. For more information, visit www.publish.csiro.au/book/7366.

Inquiry-based investigations

Over the last few years, the Australian curriculum and its variants have increased the emphasis on inquiry-based activities. What is inquiry-based learning? According to the National Research Council (USA), inquiry focuses on a scientifically oriented question, problem, or phenomenon, beginning with what learners know and actively engaging them in the search for answers and explanations. In the Australian curriculum, inquiry is embodied in a set of Science Inquiry Skills (SIS). Broadly, SIS fall into five main categories of formulating questions and/or hypotheses, planning and conducting scientific investigations, processing and analysing data and information, evaluating the validity of methods and conclusions, and communicating and justifying scientific ideas and information.

There are also year-level variations. For example, at years 4 and 5, students need to be able to identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge, but with guidance; at years 7 and 8, students need to be able to do this without guidance and for unfamiliar contexts; but they do not have to formulate their own questions or hypotheses until years 9 and 10.

There are many reasons why inquiry-based activities are good for learning. First, modern education emphasises that learning is more than mere factual knowledge, but involves the ability to apply knowledge to solve problems. Second, in constructivist models of learning, learners construct new knowledge on the basis of pre-existing ideas (see April 2014 issue, p. 33). When pre-existing ideas are inconsistent with accepted scientific knowledge, inquiry permits exploration of observations and concepts; discovery and resolution of these discrepancies in knowledge can lead to better and deeper understanding. Third, in social constructivist models of learning, social interactions associated with evaluating and justifying conclusions, and critiquing different approaches to the investigation, help to reinforce student ideas that are consistent with accepted scientific knowledge. Fourth, when students direct what they do in their learning and have social interactions, there is greater ownership and engagement in the process of learning. Finally, inquiry-based activities enable students to have a small experience of the processes of scientific investigation, which is a part of the Science as a Human Endeavour (SHE) area of the curriculum.

The ultimate goal is for students to be able to undertake open inquiry, which means that that they have achieved mastery, and are able to plan and undertake all aspects of the investigation independently of the teacher. Over a sequence spanning 1–2 years, individual laboratory learning activities will range from little or no inquiry at introductory stages to open inquiry at the mastery stage. The ‘openness’ of inquiry is normally divided into prescription (no inquiry), confirmation, structured inquiry, guided inquiry and open inquiry.

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An example of prescription is where students follow a prescribed procedure such as learning how to use a set of balances by weighing standard masses: there is no link to any scientific question and no inquiry. A confirmation inquiry is very similar, where again students follow the teacher’s detailed instructions, but work towards a scientific question. In structured inquiry, the teacher leads students by asking questions and providing guidance; the students have the opportunity to adapt and refine procedures that have been suggested by the teacher. In guided inquiry, the teacher acts as the students’ guide by giving broad outlines, giving advice on procedures and implementation; the students make the final selection or refinement from a range of options. Open inquiry resembles authentic scientific research: the student-researcher defines and drives the investigation. A variation is that of coupled inquiry, in which a single investigation is divided into two parts, or there are two closely aligned investigations: the first part is done as a guided inquiry, while the second part is open inquiry.

For a long time, an entire investigation was considered as a single entity when deciding on the level of ‘openness’, but in 2000, the National Research Council (USA) recommended that each separate aspect of inquiry (formulating questions, planning investigations, and so on) should have its own level of ‘openness’. This gives teachers greater flexibility in planning how to progress students in different inquiry skills from introductory level using prescription or confirmation activities, through development of skill level using structured and guided inquiries, to application of mastery using open inquiry. Australian projects, such as ASELL for Schools (see February 2016, p. 36) provide professional development to help teachers better implement inquiry.

Ultimately, learning through inquiry-based investigations is one approach in a range of pedagogical strategies. While inquiry-based learning has many benefits and advantages, it is not always appropriate. As always, it is up to individual teachers, as learning experts, to decide on the appropriate level of inquiry to be used in any particular activity.



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Inquiry-based learning: assessing students' science inquiry skills

Inquiry-based approaches to teaching yield substantial benefits to students, but an assessment of students' science inquiry skills indicates more emphasis is needed on the development of inquiry-based teaching and learning.

Findings from an ACER evaluation of the science inquiry skills of students from Class V to VIII in schools in India suggest there is room for improvement in implementing an inquiry-based teaching approach, at least in terms of students' abilities to undertake scientific inquiry.

The evaluation draws on data from the International Benchmark Test (IBT), a large-scale assessment for students in Classes III to X in English, Mathematics and Science conducted in schools in India, the United Arab Emirates, Malaysia and South Africa.

The study used IBT multiple-choice questions designed for students from Classes V to VIII to assess science inquiry skills in:

- reading and interpreting information on a graph
- evaluating and suggesting improvements to an investigation
- identifying a scientific problem
- making scientific predictions
- drawing conclusions based on evidence.

Assessing critical thinking and problem-solving skills

Using results from the IBT, the study found that, while students across Classes V to VIII have a moderate ability to read and interpret bar graphs correctly, there is no significant improvement in this skill as students move from Class V to VI to VII and VIII.

At Class VIII, 50% of students can read a simple line graph and identify a single piece of information on a graph but find it difficult to identify patterns or trends indicated on the graph.

Two farmers each used fertiliser on **half** of their field. Both farmers planted corn on their **whole** field.

On Farm 1 all the corn grew tall.

On Farm 2 only the fertilised corn grew tall.

Farm 1 Farm 2

■ Fertiliser
□ No fertiliser

39 What is the most likely reason for the differing results on Farm 1 and Farm 2?

A Farm 2 did not get the same amount of sunlight.
B The soil on Farm 1 did not need the fertiliser.
C Farm 1 got more water than Farm 2.
D Farm 1 did not get as much fertiliser as Farm 2.

In terms of their ability to evaluate and suggest improvements to an investigation, 60% of students at Class V are unable to understand the variables involved in a simple experiment related to dissolving salt in water at varying temperatures.

Similarly, around 50% are unable to identify a scientific problem when presented with a real-life context related to understanding the purpose of a simple day-to-day investigation.

Students at Classes VI, VII and VIII struggle with questions based on science inquiry. More than 60% of Class VII students cannot make a scientific prediction related to the outcomes of a context involving the concept of camouflage in animals.

Students have particular difficulty drawing conclusions based on evidence of the kind provided in the IBT item shown here, and in general more than 60% lack the ability to think critically and draw conclusions based on observations.

Challenges in adopting an inquiry-based approach

One of the difficulties in implementing an inquiry-based teaching approach is that there is substantial variation in what educators mean by inquiry-based teaching, and a lack of understanding of the skills required to help students generate their own inquiries and guide rather than direct the investigation that follows.

Inquiry-based teaching requires planning and skills in:

- providing students with learning experiences that stimulate curiosity and inquiry
- developing relevant and individualised questioning sequences that guide students in their own appropriate inquiry-based learning
- managing multiple student investigations at the same time
- continuously assessing the progress of each student as they progress from formulating inquiry questions to articulating detailed answers
- responding to students' emerging queries and providing inquiry-based support when they turn down blind alleys or reach an impasse.

Findings from the study suggest that teachers need professional learning not only in inquiry-based teaching techniques but also in understanding how students learn.

Analysis of data from the 2015 cycle of the *OECD Programme for International Student Assessment* by Mona Mourshed, Marc Krawitz and Emma Dorn suggests that engaging, carefully planned instructional lessons also remain important.

Overall, the message for teachers and students is that science is not simply a body of knowledge to be learned, but a way of thinking and problem-solving that can be applied to a range of real-life situations.

Dr Abha Bhagat is a Research Fellow at the Australian Council for Educational Research – India, New Delhi. This article was first published in *Teacher* 2017, 11(4). Reproduced with kind permission.

Greener blue jeans

Who doesn't like blue jeans? They're practically wrinkle-proof. The indigo dye that provides their distinctive colour holds up to detergents, but ages into that soft, worn look. No wonder the average American wears jeans four days a week. No wonder it's a \$66 billion a year industry, with three billion pairs of jeans manufactured each year.

Indigo is one of the oldest dyes used for colouring textiles. For thousands of years it was extracted from tropical plants in Asia, the Middle East and the Americas. An indigo-dyed garment discovered in a Thebes excavation dates back to 2500 BC.

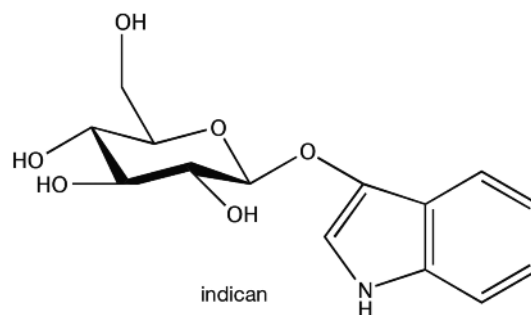
Commercial synthesis of indigo dye replaced the plant source around 1900. Today, the jean industry uses about 40 000 tonnes of indigo a year. But there is a dark side. Industrial synthesis of indigo from petroleum is a 'dirty' chemical process. Chemical production of indigo into an effective dye requires a chemical that becomes toxic to fish and some other aquatic life. And when sent to waste-water treatment plants, it severely corrodes the piping.

Jeans manufacturers are interested in finding a cleaner route to produce the iconic dye. Berkeley bioengineering professor John Dueber has studied the chemical steps plants use to naturally make indigo, and he thinks he has found an environmentally green way for the industry to churn out the dye without the use of the toxic compound.

When plant leaves are healthy, a chemical precursor to indigo, called indican, is caged within a sugar molecule and isolated from the rest of the cell in an organelle. Only when leaves are damaged is indican released from this compartment. The sugar protective cage is removed, allowing a chemical change that makes indigo. Green leaves turn blue.

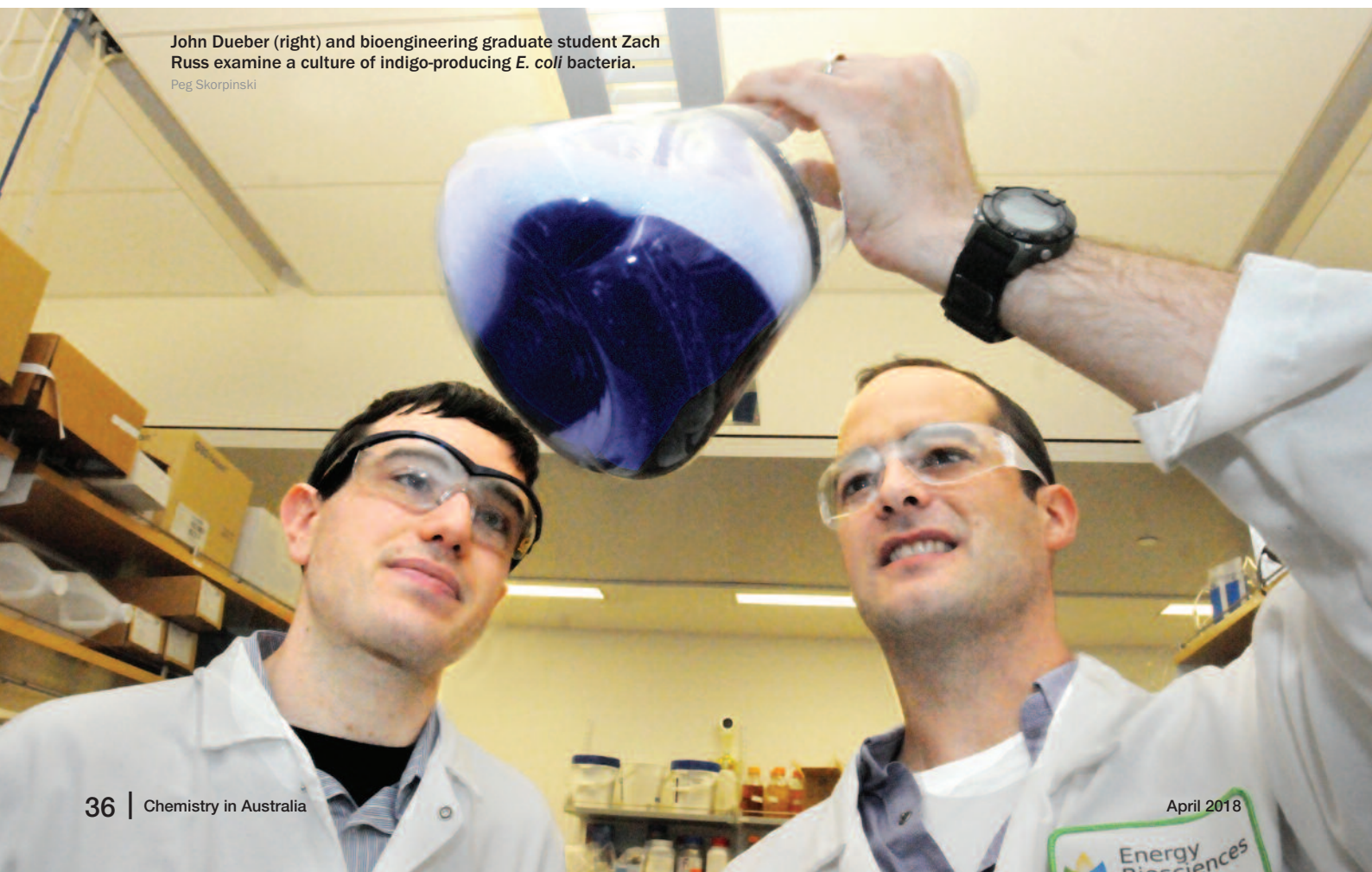
Dueber's lab very recently identified the plant enzyme that is essential for adding the protective sugar cage. They plan to insert its gene into bacteria. Addition of a second gene as well as tweaks to a few of the bacteria's genes should enable the bacteria to produce indican.

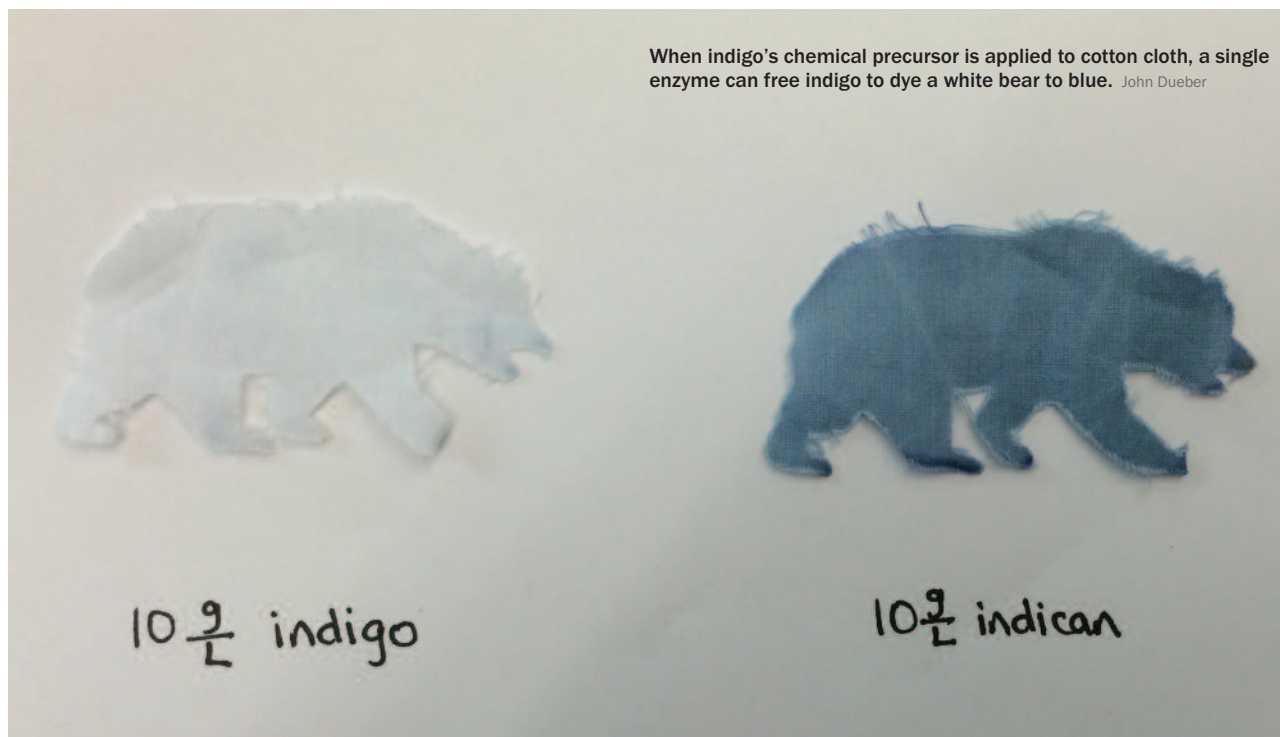
Hundreds of litres of the harmless bacteria growing in fermentation tanks would churn out indican, held within the sugar's molecular embrace. Later, outside the cell, a second



John Dueber (right) and bioengineering graduate student Zach Russ examine a culture of indigo-producing *E. coli* bacteria.

Peg Skorpinski





enzyme could remove the protective glucose cage, triggering the final chemical transition to indigo. The result: environmentally cleaner jeans.

'To find green solutions, our lab looks towards nature', Dueber says. 'We thought going back to the plants would be smart. If we can identify the enzyme the plants use to produce the sugar cage and clone its gene, we think the microbes can make large quantities of indican for dyeing jeans without the use of highly "dirty chemicals".'

The process would be cleaner in another way. Current indigo production starts with petroleum. But the microbes thrive on cheap and plentiful glucose.

Grad students Tammy Hsu and Zachary Russ worked in a greenhouse last summer, planting seeds, harvesting about half a kilogram of green leaves from a Japanese indigo plant and grinding them up. 'As you grind the leaves', Dueber says, 'they turn into a blue paste because you have released indican from its sugar cage'.

Dueber's project is supported by a five-year Bakar Fellowship. Since he is in the early stages of the novel indigo project, he needs the time the multi-year support provides to work out the science and then develop a viable commercial strategy.

'Moving our lab's research to market is something I have not been trained to do', he says. 'I'm excited to be part of this fellowship that connects us with people who can help us identify exactly what we should be filing patents on, and how much proof-of-concept work should be done before we file.'

Addition of a second gene as well as tweaks to a few of the bacteria's genes should enable the bacteria to produce indican.

He's also finding that the practical business guidance is just what his students are looking for. 'They want to move their research into the commercial world. For the next five years, they'll be able to learn from experts who know this world. It's a fantastic opportunity for all of us.'

The Berkeley indigo research started in 2013 as an entrant in an undergraduate competition called iGEM – the International Genetically Engineered Machines. Dueber advised the Berkeley team. Five undergrads and two graduate student mentors advanced the research, demonstrating that the planned chemical steps could be made to work efficiently and that indican can make a good dye. They received a gold medal and advanced to participate in the world competition.

'Students want to make a difference with their research', Dueber says. 'We're still going to focus our research on academically interesting questions, but when there are industrial applications, we want to be aware of that. We'd all like to see our indigo research lead to greener blue jeans.'

By **Wallace Ravven**, UC Berkeley. Reused with permission.

Growth in lithium demand

I have received quite a bit of feedback and interest in my column on lithium (March 2016 issue, p. 34) in which I gave rough estimates for the cost of lithium production from brines and spodumene ore. One of the main conclusions was that production from hard rock, spodumene, which is widely distributed in the pegmatite rocks of Western Australia, is energy intensive and would require a low-cost energy supply of either coal or gas.

The growth in demand for lithium for batteries has continued apace and is seeing year-on-year growth of 12% or more for lithium carbonate. The growth in lithium demand is in step with the growth in electric vehicles sales. With more vehicle manufacturers introducing new electric vehicles or hybrids over the past two years and outlining plans for major expansions in the coming years, growth in lithium demand could become even higher. If (and it still somewhat a big 'if') electric vehicle penetration is 4.5% of the new vehicle fleet, then lithium carbonate demand may approach 200 000 t/year by 2020. Furthermore, issues with supply have seen the price of lithium carbonate escalate above US\$10 000 per tonne with similar price escalation for intermediates such as spodumene ore.

If this development goes to completion, Rio Tinto could supply up to 10% of expected world lithium demand by the mid 2020s.

In response to this demand, there have been several developments of note. Several Australian-based companies have mined or are about to start mining and exporting spodumene ore in WA and one is well on the way to producing lithium from a brine lake in Argentina.

Through a facility at Greenbush in WA, Talison Lithium is the largest producer of hard rock lithium, which is exported as the beta-form through the Port of Bunbury. The US company Albermarle is in the process of building a lithium hydroxide plant near Bunbury with a capacity of 20 000 t/year. Another company (Altura Mining) has published the results of a feasibility study for the mining of alpha-spodumene and concentrating the raw ore to a 6% lithium content. The company has embarked on developing a project to export upgraded alpha-spodumene. This would avoid the energy requirements in converting the alpha-spodumene to the beta-form from which lithium can be readily extracted. Another company (Neometals) has stated its intention to upgrade alpha-spodumene to the beta form and then to produce lithium hydroxide in a processing plant in WA.

Unfortunately for the smaller players, although the short

term seems rosy, the long-term future of lithium supply would seem to be in the hands of owners of Tier 1 lithium resources.

Rio Tinto is continuing its development of the large jadarite deposit in Serbia. Jadarite is a lithium borosilicate discovered in 2004 in the Jadar basin near the town of Loznica in Serbia. Having already had \$90 million spent on it, the project is in the prefeasibility phase with the aim to bring the mine and upgrading facilities on-stream in 2023. The size of the resource is very large with resources of 2.5 Mt Li_2O and 21 Mt B_2O_3 . The technology for extracting lithium has been developed by Rio Tinto's laboratory at Bundoora in Melbourne. If this development goes to completion, Rio Tinto could supply up to 10% of expected world lithium demand by the mid 2020s.

The largest producer of lithium is SQM (Sociedad Química y Minera de Chile S.A.), who has announced that it has settled a long-running royalty dispute with the government of Chile that will allow it to increase production from about 63 000 t/year of lithium carbonate to over 163 000 t/year in 2024. SQM is said to be in talks with Tesla to lock in supplies of the battery material.

SQM's principal business is supplying chemical supplements to the agricultural industry – sodium nitrate, potassium and sulfates – and in recent years it has rapidly developed lithium production from brines.

SQM was founded in 1968 to reorganise the Chilean nitrate industry. It was at one time nationalised but since 1983 has been privatised. SQM produces a range of products from caliche ore (which contains sodium nitrate and iodine) and lithium, potassium and borates from brine lakes in the Atacama desert of Chile.

Lithium is produced from brines of the Salar de Atacama, a brine lake formed by natural leaching of the Andes mountains. The large BHP/Rio Tinto Escondida copper mine lies to the south. The brines are pumped from beneath the saline crust in two different areas. One area produces boric acid and the other area produces high levels of potassium and lithium (the lithium concentration is said to be 2700 ppm), and with low magnesium content extraction costs are low. The high concentration of lithium in the Chilean lake is said to produce lithium cheaper than the larger salt lake Salar de Uyuni in Bolivia, which is thought to contain more than 50% of the world's lithium resources.

After extraction, the brines are evaporated in ponds with an evaporation index of 3.2 metres, and with precipitation of only 15 mm/year this leads to very efficient salt recovery. This is in contrast to brines in colder parts of the continent that have much lower evaporation rates.

The caliche ore contains the only known nitrate and iodine deposits in the world. The ore is covered by a small amount of overburden (0.4–2.5 metres), which is removed by an excavator. The ore body is then broken with explosives and the broken rock is crushed and leached to produce sodium and potassium nitrate and sodium iodide.



Salar de Atacama in the Atacama Desert, Chile, is a major global source of lithium. iStockphoto/TatsuyaOhinata

The caliche ore beds were first exploited in the 1830s and rapidly replaced older methods for making nitrate for gunpowder by the controlled oxidation of mainly horse urine. Carlyle (*History of the French Revolution*) tells a story that it was common for the citizens of Paris to dispose of their waste in the house cellars; over the years, the waste became oxidised to produce nitrate in sufficient quantities that the revolutionaries of the 1790s dug up the cellar spoil to extract sodium nitrate to produce gunpowder independently of the royalist arsenals.

In the approach to World War I, Germany realised, that in the event of war, they could be denied access to the Chile saltpetre (as it was widely known) by a British blockade, and strenuous efforts were made by German scientists to produce synthetic ammonia. The main discoveries were made by Fritz Haber, who was awarded the Nobel Prize in 1918. This successfully led to the Bosch–Haber process for producing synthetic ammonia, which in modified and improved forms is still used today to produce first ammonia, which is then oxidised to nitric acid for explosives manufacture.

The invention of the synthetic ammonia process led to the demise of the Chilean saltpetre industry. There was some demand for the sodium nitrate for fertiliser, which maintained the industry in Chile in the early decades of the 20th century.

The high concentration of lithium in the Chilean lake is said to produce lithium cheaper than the larger salt lake Salar de Uyuni in Bolivia, which is thought to contain more than 50% of the world's lithium resources.

Because current battery technology uses various cobalt compounds as one of the electrodes, and because cobalt is scarce, in recent years there has been a large increase in the value of cobalt and cobalt ores. In fact, the scarcity of cobalt may force a reconsideration of the current approach to battery manufacture.



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Wine filtration

The filtration of wine remains a controversial issue, especially as there are an increasing number of 'natural' wines on the market. Critics of filtration say that the process strips the character from the wine, although I cannot find any studies that validate this claim. The pro-filtration camp argues that clear, brilliant wines are essential for customer acceptance. The presence of observable solids, including crystals or particulate 'floaties', is deemed to detract from the wine's acceptability. The clarity of the finished wine is something that I have always promoted in my teaching days and this is from the occasional consumer of Cooper's sparkling ale!

There are different requirements for wine clarification, based on whether white wine or red wine is being produced.

There are different requirements for wine clarification, based on whether white wine or red wine is being produced. For white wine, it is common practice to clarify the juice after crushing and pressing the grapes to give a clear juice prior to fermentation. The extent of clarification depends to some extent on winemaking philosophy and tradition. For new world wines, reasonably clear juice is used to produce a fruitier wine because fermentation on solids can give baggy or wet cardboard aromas. On the other hand, and this is more of an issue in new world winemaking, extensive clarification can reduce the amount of yeast nutrients, which may require supplementation. The benefit of having some solids present in the ferment is wine with greater depth of flavour.

Allowing the juice from white grapes to settle over time can be effective, although it is slow because the juice in the tank must be held at low temperature to stop the onset of fermentation. Centrifugation was popular for some lower-end wines as was the use of diatomaceous earth as a filtration medium. As discussed later, there are issues with the use of diatomaceous earth in wineries. Flotation has come back into favour as a method for rapid clarification. The grape skins or lees are floated to the surface using gas bubbles, usually nitrogen, and the floating lees (FLEES!) are swept off, giving juice of sufficient clarity to commence fermentation. Clarification by flotation can be achieved in hours, rather than days by settling, and juice losses are minimal (bit.ly/2nEQDIF). Pectin from the crushed grapes can make clarification a challenge, although pectolytic enzymes can be added to break down many of the pectic substances. The fermentation of red wine occurs on skins for colour extraction, so clarification prior to inoculation is not required.

After fermentation and removal of yeast lees, the wines are stabilised either in tank or barrel. Further processing, such as malo-lactic fermentation or protein stabilisation in white wines may occur. Prior to bottling, the crunch time for a decision regarding whether and how to filter occurs. When I first started a close involvement in the wine industry, diatomaceous earth was in wide use as a filter medium. Diatomaceous earth is cheap but really only useful for coarse filtration, and unless care is taken in treating the earth before use, iron contamination may occur. There are many other downsides to diatomaceous earth. It is expensive to dispose of, it can remove colour in red wine filtration and it can also affect aroma. Health and safety issues require careful workplace management.

In essence, the choice falls between depth or membrane filtration. In depth (sometimes 'pad') filtration, cellulose is probably now the most commonly used or preferred filtration medium (bit.ly/2E6MSpF). The so-called Begerow cellulose filters possess significant advantages over older materials, particularly in relation to physical strength and minimal impact on the wine itself. Essentially, the separation process works by capturing material within the structure of the filter, so it is only possible to claim a nominal pore size with this method.

Membrane filters work by surface trapping of components larger than the declared pore size of the membrane. Some capturing within the membrane itself may also occur. Common materials for the filters are cellulose acetate, polyether sulfone and nylon, and these are generally available in 0.45 μm and 0.2 μm pore size. We have compared these filters in some of our recent work on copper sulfide filtration, about which I will write soon. Cellulose acetate and polyether sulfone are relatively inert with respect to impact on wine. However, nylon, owing to its amino acid structure, can absorb colour and is thus of limited value for red and even rosé wines (see bit.ly/2E6MSpF where there are some great images of before and after filters).

Cross-flow, sometimes called tangential-flow, is more effective than perpendicular or depth-flow, especially for wines with high particulate load. While some winemakers claim that cross-flow filtration is also effective for sterile filtration, others question this. Sterile filtration is better left for another day. Establishing a cross-flow filtration system involves considerable capital cost. Pad filtration is cheaper, but as most winemakers will say, it is a pain to set up. A small cross-flow system might involve an outlay of \$30 000 or more. Alternatively, mobile units can be leased, making cash flow a little easier to manage.



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Old and new carbon

In the early 1950s, only a few years after Willard Libby's invention of the technique of radiocarbon dating, the Museum of Applied Science in Melbourne decided to establish a dating laboratory. The basics of the technique are probably well known to chemists but – just to recapitulate – cosmic ray neutrons interact with nitrogen-14 nuclei to produce carbon-14 and a hydrogen nucleus. The carbon-14 is radioactive, losing an electron (β -particle) to revert to nitrogen-14, with a half-life of about 6500 years. In living organisms, an equilibrium concentration of carbon-14 is maintained by constant exchange with the atmosphere, but when an organism dies this equilibrium is no longer maintained and the concentration of carbon-14 falls steadily as the atoms decay. Ages up to about 40 000 years can be determined by careful counting. Libby checked the validity of his method by determining the age of wood from archaeological sites of known longevity, and he also showed that really old materials such as natural gas and coal had no remaining radioactivity.

Libby burned the wood or charcoal, and treated shells with acid, to get carbon dioxide. This gaseous product was reduced with magnesium metal to give solid carbon, which was coated on the inside of a Geiger counter. The game had moved on a bit by the time chemist Anne Bermingham was setting up the Melbourne laboratory: she converted the carbon back to carbon dioxide and filled a proportional counter with it. The Museum's main client was E.D. Gill, curator of fossils at the National Museum of Victoria, who had already begun to send samples of charcoal from Aboriginal hearths to Libby and to other overseas dating facilities, before the Melbourne one opened.

At first, a vacuum line was constructed and sample preparation was carried out in the basement of the Chemistry Department of the University of Melbourne, with assistance from staff there. In the mid-1950s, the facility was transferred to the Museum and its official opening took place in 1961, but it was always under-resourced and this had consequences. The laboratory struggled through the 1960s and it was eventually closed down in 1970. My article about it has just been published in *Historical Records of Australian Science*.

Other combustion-based radiocarbon dating laboratories opened at the University of New South Wales, the University of Sydney, and – the only one still operating – the Australian National University. Dates are also determined at ANSTO where the measurement is done by accelerator mass spectrometry.

In my wider reading, I came across a lot of information that did not fit into the main narrative but was nonetheless of considerable interest. For example, carbon-14 dating has been used to date historic iron samples. Since the Industrial Revolution, iron and steel production has been based on coke that is in turn produced from coal that is millions of years old

and therefore bereft of radioactive carbon-14. Before then, iron was produced with wood charcoal that, at the time of combustion, did contain measurable concentrations of carbon-14. When first produced, the iron (cast iron) can contain up to 5% carbon, and that's enough to enable dating if a large sample is taken. Burning at about 800°C serves to release carbon dioxide, which can be purified in traditional fashion via calcium carbonate and used in a counter.

South Africa's N.T. van der Merwe did his PhD at Yale in the late 1950s, applying the carbon-14 dating technique to samples of American colonial cast iron. Archaeological evidence suggested the iron was from the 17th and 18th centuries, and this was confirmed by carbon dating. For example, iron from a Massachusetts site where production had occurred in the period 1648–78 was dated as 1600 ± 60 . Older iron was available from excavations in China; for example, one from Szechwan thought to be from 221–220 BCE was dated at 180 ± 100 BCE. Back home, van der Merwe turned his attention to local sites. Charcoal excavated from ancient Transvaal dwellings had carbon-14 dates in the range 960–1130 CE, and 19th century dates were assigned to slag from some iron and copper smelters.

Some carbon-14 determinations are made not to see how old a sample is, but to see whether its carbon is ancient or modern.

Some carbon-14 determinations are made not to see how old a sample is, but to see whether its carbon is ancient or modern. Since most industrial chemicals are manufactured from coal or petroleum sources, they will not contain any carbon-14. An organic natural product, by contrast, will be more or less in equilibrium with the global pool of carbon-14 and therefore easily distinguished from its industrial cousins. It has been demonstrated that certain marine natural products that contain bromine attached to aromatic rings, such as the polybromodiphenyl ethers, are natural products and not synthetic flame retardants. And it has been shown that certain biofuels really were 'bio' rather than just look-alike products of the petrochemical chemical industry.



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ALTA 2018 – Nickel-Cobalt-Copper, Uranium-REE & Gold-PM Conference & Exhibition

19–26 May 2018, Perth, WA
altamet.com.au/conferences/alta-2018

AOCR-5 – 5th Asian & Ocean Regional Congress on Radiation Protection

20–23 May 2018, Melbourne, Vic
aocrp-5.org

Units 3 & 4 Chemistry Extended Practical Investigation Made Easier

30 May 2018, Monash University, Vic
ivvy.com.au/event/VCG774

22nd Annual Green Chemistry & Engineering Conference

18–20 June 2018, Portland, Oregon, USA
gcande.org

Macro 18 – World Polymer Congress

1–5 July 2018, Cairns, Qld
macro18.org

ICCE2018 – International Conference on Chemical Education

10 July 2018, University of Sydney, NSW
ivvy.com.au/event/CED681

ICCE 2018 – 9th International Conference on Chemistry and Chemical Engineering

11–18 July 2018, University of Liverpool, Liverpool, UK
icce.org

ICABC 2018 – 5th International Conference on Advances in Biology and Chemistry

6–8 August 2018, National Taipei University of Technology, Chemical Engineering & Biotechnology, Taipei, Taiwan
icabc.org

8th IUPAC International Conference on Green Chemistry

9–14 September 2018, Bangkok, Thailand
greeniupac2018.com

8th International Conference on Environmental Chemistry and Engineering

20–22 September 2018, Berlin, Germany
environmentalchemistry.conferenceseries.com

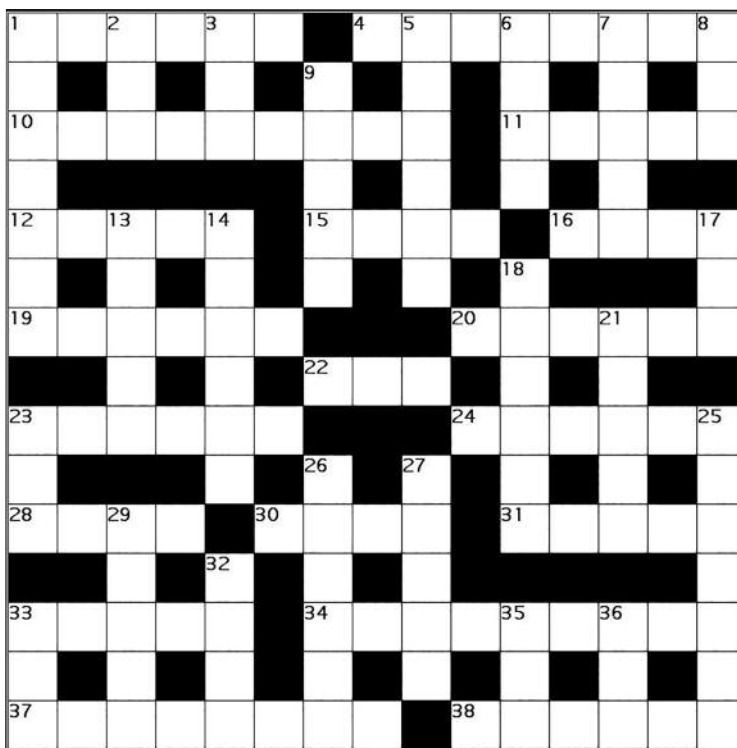
CBEE 2018 – 10th International Conference on Chemical, Biological and Environmental Engineering

27–29 September 2018, Hotel Berlin, Berlin, Germany
icbee.org

Organic 18 – 24th RACI Organic Chemistry Conference

2–6 December 2018, University of Western Australia, WA
ivvy.com.au/event/OGD780

RACI events are shown in blue.



Across

All of the Across words have something in common but their clues do not provide definitions.

- 1 Spooner's swindle in the pub. (6)
- 4 7 Down smashed with 22 Across. (8)
- 10 Annul math result. (9)
- 11 Carries no next chance to get back. (5)
- 12 Starts below overall rate of neutralisation. (5)
- 15 Last in 1 Across. (4)
- 16 Press. (4)
- 19 Broken emu rib. (6)
- 20 Ear modifier key. (6)
- 22 Can. (3)
- 23 Central to pressuring schoolfriend favourably. (6)
- 24 Air mud throwing. (6)
- 28 Finally something aged. (4)
- 30 Nitrogen age. (4)
- 31 Pairs ground even. (5)
- 33 On after loud attack. (5)
- 34 22 Across's tumor operation. (9)
- 37 Lichen or mould. (8)
- 38 Sour lime. Uh! (6)

Down

- 1 Cooked rice with lab quality. (7)
- 2 Manage two elements. (3)
- 3 Hydroperoxyl surprise. (3)
- 5 Resistant to intramuscular μ -neon?! (6)
- 6 Radical! Radical! Huge theatre! (4)
- 7 Held back, they were no good on the way out. (5)
- 8 Store uranium in an inert atmosphere, sister! (3)
- 9 End rocks in strata quartz – topaz! Excitement! (5)
- 13 Even tree beetle is insurgent. (5)
- 14 v-alum cooked fare. (6)
- 17 Clear over 30 Across. (3)
- 18 Not as a fixed composition. (6)
- 21 Cutting down discharge. (5)
- 23 Drop off over 38 Across, perhaps. (3)
- 25 Littlest little woman. (7)
- 26 So near to becoming an argument. (6)
- 27 11, 30, 31, 33 and 38 Across are in odd errata. (5)
- 29 $C_{15}H_{26}O$ ingested by the bushy-tailed olingo. (5)
- 32 Called back to growl. (4)
- 33 Carbon or return of a big bird. (3)
- 35 Neon electron born. (3)
- 36 Japanese ideal to add potassium iodide to iodine. (3)

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



Invitation to ANCQ 2018

The RACI invites all students to participate in the ANCQ 2018, being held in Australia on Thursday 2 August 2018.

The quiz has been in operation since 1982, growing from humble beginnings into an international event spread over 21 countries, seven languages, 1400 schools and more than 100 000 students.

The ANCQ is a unique chemical education activity.

It provides a major focus for secondary school students on the relevance of chemistry in an exciting and stimulating way. It is not a nationwide assessment of chemistry knowledge, but rather a promotion of chemistry that allows teachers and students to gauge their level of teaching and learning.

The quiz comprises 30 multiple-choice questions and takes one hour to complete. It is available both in hard copy and online.



**Registrations open:
Monday 5 March 2018**

Entry cost: \$6 per student

Website: www.ancq.com

For further information,
including quiz dates for other
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