# chemistry in Australia

for family and friends

November 2015

# PUBLIC EDITION

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Royal Australian Chemical Institute

- Great science games
- Downsides of 'organic'
- Isotopes to save salmon
- Rethinking e-cigarettes
- Our chemical future
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# An open letter to chemists

Dear chemists

I know that your work is sometimes misunderstood and under-appreciated, so I hope that you draw encouragement from this letter.

Thank you for the countless hours you spend in labs, sheds and fields and at your desk doing the 'boring but essential' stuff – repeated testing that stalls and sideshifts and succumbs to error, and only sometimes succeeds. Unfortunately it's only those shining moments of success – so few and far between – that see the spotlight. Thanks for popping in on the weekend or in the middle of the night to check on that experiment. And here your supportive (or long-suffering) families and friends deserve a special mention, too.

Thank you for picking up an idea and running with it – sorry, I mean having an idea, fighting tooth and nail to get funding, then picking up the idea again and running with it.

Thanks for talking to others about your work, to raise awareness of chemistry or to teach it formally. Teaching must be a tough gig, and I congratulate those brave enough to do it. And when you chemists get together to talk with other scientists, all sorts of great things happen.

Thanks to you, many diseases can be avoided, cured or their ravages diminished. We have clean water, plentiful food and comfortable homes. We know so much about the intricate workings of the natural world.

I think others would be just as grateful if they knew just how much they owe you. We need to dispel the common conception that you dispense medicine, and sing your praises loudly and clearly. I've put together this public edition of *Chemistry in Australia* to spread the word about how brilliant and important you are. I'm sure that chemistry readers will pass it on, and for the recipients I hope that it brings chemistry to life.

Oh, and one more thing: please, please keep up the good work. We need you.

*Sally Woollett*
*Editor*



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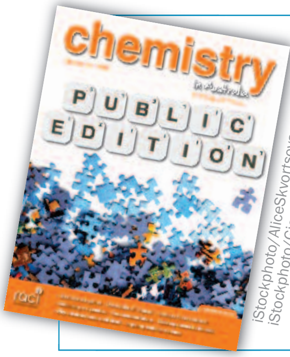


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# From the President

I hope you enjoy reading this public edition of *Chemistry in Australia*, which follows on from the inaugural November 2014 issue that was edited specifically for a general readership. When chemistry is your lifelong profession and occupation it's easy to take for granted things that might seem astonishing or even incomprehensible to those outside the chemistry field. Chemistry is in no way unique in this respect. The seemingly endless legalese in the terms and conditions, to which most of us routinely agree when purchasing something, is surely not there to educate or enlighten any reader lacking a law degree. For a good example, look at the iTunes terms and conditions.

When communicating with peers, or students within a teaching environment, there is always tacit knowledge that is not restated in the interests of covering new topics unfamiliar to the audience. Of course the boundary between what is well known (to those that know it well!) and what is not is difficult to define. I find it annoying when a seminar presenter assumes everyone in the room is familiar with their field and knows all the special terminology (particularly when I don't). If I can't understand the introduction and background to the topic, then I have no hope in understanding the new results that are about to come. Communication of the importance and relevance of what chemistry brings to society is now, more than ever, a responsibility of all chemists.



It almost goes without saying that chemistry is everywhere. Ironically, complicated chemistry terminology is often used in advertising (by non-chemists) to convey an erudite message of the science behind the product that is being promoted, yet rarely are these benefits (if real) properly explained to the consumer.

Organic chemistry terminology is used in communicating the relative benefits of 'unsaturated' and 'saturated' fats (fatty acids) in food products such as margarine and olive oil compared with butter and other animal-derived fats. However, I don't ever recall the difference between saturated and (poly)unsaturated fats being explained or even what beneficial properties were delivered. Given the ambiguity of the word 'saturated', I expect that many people think it has something to do with water content. Even higher-level organic chemistry language is now being introduced that is *meant* to inform (rather than confuse) the public. It doesn't always succeed. I cringe when the misnomer 'omega 3' is used in the advertisement of products (particularly vitamin supplements) containing unsaturated fats (*everyone* knows that 'omega 3' is good, don't they?). The correct expression is actually 'omega – 3'. Unfortunately, the minus sign is invariably mistaken for a hyphen and then omitted altogether, rendering the expression meaningless. For the record, the '– 3' refers to the position of the carbon–carbon double (unsaturated) bond three atoms *before* (hence the minus) the last (omega) carbon in the molecule (alpha being the first carbon). 'Trans-fats', 'good cholesterol' and 'bad cholesterol' – it's asking the public to accept a lot of 'facts' with very little background explanation.

When reading the November 2014 public edition of *Chemistry in Australia* (see bit.ly/1FeKV5o), I was taken by the fact that the topics were appealing to the general public yet the scientific content was not compromised. A paraphrased and often quoted saying (attributed to Albert Einstein) is that every explanation should be made as simple as possible, but not simpler.

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


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# Why organic may not always be the best choice

Eating organically grown food might make you feel good inside, but a University of Queensland researcher says organic agriculture is not necessarily sustainable and – contrary to popular belief – often relies on chemical sprays.

Professor Ian Godwin, from the UQ School of Agriculture and Food Sciences, argues that genetically modified organisms (GMOs) are perfectly compatible with organic agriculture, and can actually improve production and food safety.

'Genetically modified products fit in perfectly with organics,' Godwin said.

'GMOs allow the creation of disease-and-pest-resistant plants, which require less fertiliser for the same yield and product quality.'

He said GMO food required less space to grow, which meant much higher yields per hectare.

Godwin said there were misconceptions about organic production as well as about GMO foods.

'People think organic crops don't get sprayed, but in commercial farming that's not possible.

'You can't use fungicides in organic production, so people use various different combinations of chemicals, but mostly copper.

'Farmers who've been doing this with potatoes over the years are now getting higher levels of copper in the soil then the World Health Organisation recommends.

'It doesn't matter if it's organic or not, if you're growing potatoes, you'll be spraying them every few weeks.'

Godwin explains the myths around GM foods in the first episode of Science Over Coffee, a video series created by UQ researcher Dr Lee Hickey.

The series aims to dispel common misconceptions surrounding science.

UNIVERSITY OF QUEENSLAND

These barley plants are the subject of research to identify their underlying resistance genes.


Queensland Alliance for Agriculture and Food Innovation, University of Queensland

# Citizen scientists purge beaches and waterways of 20 000 plastic pieces

Dr Tom Creswell (ANSTO radioecologist – aquatic ecosystems) gave a lesson to children in years 5 and 6 at Cronulla Public School about the impact of plastics on the marine environment, and how they can play their part in reducing their impact. After the lesson, Creswell led the children on a beach walk around Gunnamatta Bay to collect plastics and micro plastics from the beach, which have been sent to ANSTO to be sampled for their origins, age, and whether they contain any heavy metals.

Between Australia Day and July this year, ANTSO citizen scientists collected 20 000 plastic particles from Sutherland Shire (New South Wales) beaches and waterways.

The citizen scientists are part of the Australian Nuclear Science and Technology Organisation's (ANSTO) Plastics Project – encouraging locals to assist with environmental research into the lifecycle of plastics.

Community organisations such as the local Nippers, council, Surf Life Saving Clubs and Ocean Ambassadors have all contributed, pitching in to collect and catalogue plastic litter from local beaches and waterways.

ANSTO is home to the country's only nuclear research reactor, OPAL, at Lucas Heights, and the Australian Synchrotron in Melbourne.

Selected plastic samples sent to ANSTO are being tested with nuclear instruments, contributing to research into the way plastics break down, and the way they interact with the environment around them.

The registered citizen scientists were mailed collection kits and have been logging their data on the ANSTO Plastics Project website, which has now clocked 20 000 pieces of plastic collected.

The data is enabling ANSTO scientists to gain an understanding of plastic litter arriving in the shire's beaches and rivers, and identify hotspots where plastic litter is deposited due to tides, winds and weather.

ANSTO's Professor Richard Banati's research demonstrates how plastic litter breaks down within an aquatic environment, and found evidence at the atomic level of elements in plastic also being present in the feathers of sea birds on Lord Howe Island.

The contributions from local citizen scientists are helping Banati and partners from Monash University to continue this research, and define and understand how this transference of elements from plastics occurs.

'We are on the path to understanding the route taken by the huge amount of the end-of-life waste products from plastics, especially when plastic litter has degraded enough to be invisible,' said Banati.

'It is crucial that we have a clear picture of how plastics move through the ecosystem and food chain at the atomic level, and the impact this atomic level transfer has on the environment.'

The testing using nuclear instruments is essentially to trace elements from plastic through a system, and this helps us understand what happens to plastics as they start to break down.

The data collected by citizen volunteers will map the points where plastics are distributed into the local environment, and then test how they have weathered and begun to break down and change.

AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION

# Scientists don't turn a blind eye to bias


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Scientific journals should insist on more robust experimental processes, say biologists after reviewing nearly 900 000 experiments.

The team found that non-blind experiments – that is, where scientists knew which samples they were recording – averaged a 27% stronger result than blind trials.

However, their review suggests that less than one in four experiments used blind data recording.

'We found that non-blind papers tended to exaggerate differences between the experimental group and the control group,' said lead researcher Dr Luke Holman, from the Research School of Biology at the Australian National University (ANU).

'For example, a non-blind trial of a new drug might conclude that it is way more effective than a placebo, when in fact the drug's true effect is rather modest, simply because the researchers' expectations biased the results.'

The paper is published in *PLOS Biology* at a time when experimental processes are under the microscope following increased levels of retractions, and some journals are reviewing their peer-review procedures.

In the largest study of its kind, the team analysed nearly 900 000 papers from the PubMed life sciences database, using automated 'data mining'. They also – in a blind trial, of course – compared 83 pairs of evolutionary biology papers on similar topics, in which the data was collected blind in one, and not in the other.

The team also found that non-blind studies rejected the null hypothesis more strongly, said Dr Holman.

'Non-blind studies more confidently concluded that differences between treatment and control groups were real, and not just due to chance variation.'

Co-researcher Dr Megan Head, also from ANU Research School of Biology said self-reflection is important.

'Science is still the best method we have for understanding the world, and we have to keep working to make it better.'

Holman and his colleagues believe that journals should insist on blind trials more strongly, perhaps by making prominent statements to authors and peer reviewers about the necessity of using blind trials.

**Scientists are aware of their biases, and use techniques such as blind trials to minimise them, but the pressure to get things done faster leads to some people skimping on experimental design...**

Scientists are aware of their biases, and use techniques such as blind trials to minimise them, but the pressure to get things done faster leads to some people skimping on experimental design, said Head.

'It is not necessarily slower to take data blind, you just need to be a little creative,' she said.

Holman suggested better training is part of the solution.

'Many researchers are unaware that their expectations can introduce such strong bias, and so they don't feel the need to work blind,' he said.

AUSTRALIAN NATIONAL UNIVERSITY

# Size does matter when it comes to academic papers

Scientific papers with shorter titles gain more citations, new research has found.

A statistical analysis of 140 000 papers found that the length of a paper's title can be related to the number of citations it receives.

Adrian Letchford, Suzy Moat and Tobias Preis, of Warwick Business School's Data Science Lab, analysed whether the length of a paper's title bore any relationship to the paper's success.

Their paper, with the suitably succinct title 'The advantage of short paper titles', published in *Royal Society Open Science,* examined the 20 000 most cited papers each year from 2007 to 2013, with titles ranging from one to 55 words.

Dr Letchford, Research Fellow in Data Science, said: 'There have been previous studies on this that have proven inconclusive, but our study uses a much bigger sample.

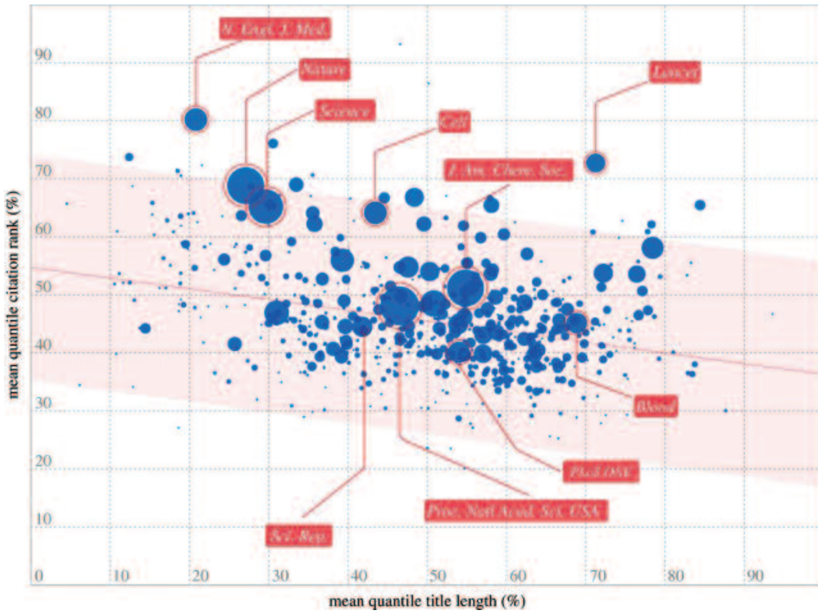
'Our analysis suggests that papers with shorter titles do receive more citations.

'Some journals attract more citations than others and when we control for the journal in which a paper is published the strength of the relationship is reduced, but it is still significant.

'Our results do also reveal that journals which publish papers with shorter titles tend to receive more citations per paper.'

For papers published in 2011, for example, the study reveals that each character added onto a paper's title had a tendency to reduce the number of citations by approximately 1.8%.

Letchford added: 'One potential explanation is that high-impact journals might restrict the length of their papers' titles, or that shorter titles may be easier to understand, enabling wider readership and increasing the influence of a paper.




**Journals that published papers with short titles receive more citations per paper. In the graph, each blue circle represents a journal, the size of each circle represents the number of papers in the sample for that journal. The horizontal axis plots the title length and the vertical axis the citation rank.**

## ... the length of a paper's title can be related to the number of citations it receives.

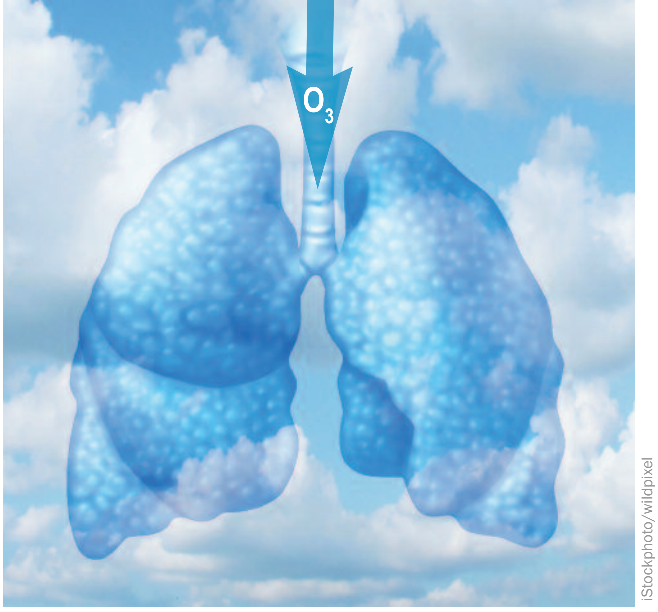
'Ultimately, research quality and intrinsic significance should have the most impact on a paper's success. However, our findings provide evidence that elements of the style in which a paper is written may also relate to the number of times it is cited.'

Dr Preis, Associate Professor of Behavioural Science and Finance and co-director of the Data Science Lab at Warwick Business School, said: 'So much of our communication now takes place online. This research provides another example of how huge digitalised records of communication can be analysed to provide new insights into human behaviour.'

Dr Moat, Associate Professor of Behavioural Science and co-director of the Data Science Lab, added: 'Our previous work has focused on analysing data from sources such as Google, Wikipedia, and Flickr to predict and measure human behaviour in the real world. These results show that analysing how scientists communicate can uncover interesting behavioural patterns too.'

UNIVERSITY OF WARWICK

# Looking at lung damage from ozone



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New research conducted by scientists at the Universities of Melbourne and Wollongong and Queensland University of Technology has provided a first glimpse at how free radical damage might be initiated in the human lung upon exposure to the urban air pollutant ozone.

The research team led by Professors Stephen Blanksby and Richard O'Hair from the ARC Centre of Excellence for Free Radical Chemistry used the techniques of electrospray ionisation and multistage mass spectrometry to shed light on how radicals are formed in the reactions of ozone with models of lung proteins. Their work is featured in *Angewandte Chemie International Edition* (Khairallah G.N., Maccarone A.T., Pham H.T., Benton T.M., Ly T., Da Silva G., Blanksby S.J., O'Hair R.A.J. *Angew. Chem. Int. Ed.* 2015, doi: 10.1002/anie.201506019).

'This is an important problem, especially since surface concentrations of ozone have more than doubled over the last century and predictions that background urban ozone levels may ultimately exceed internationally accepted levels for human health in the 21st century,' said Professor Blanksby.

The team studied how the amino acid cysteine and related amino acids and peptides from which a hydrogen ion has been removed react with ozone when isolated under idealised near-vacuum conditions, and tracked the formation of primary oxidation products including radicals.

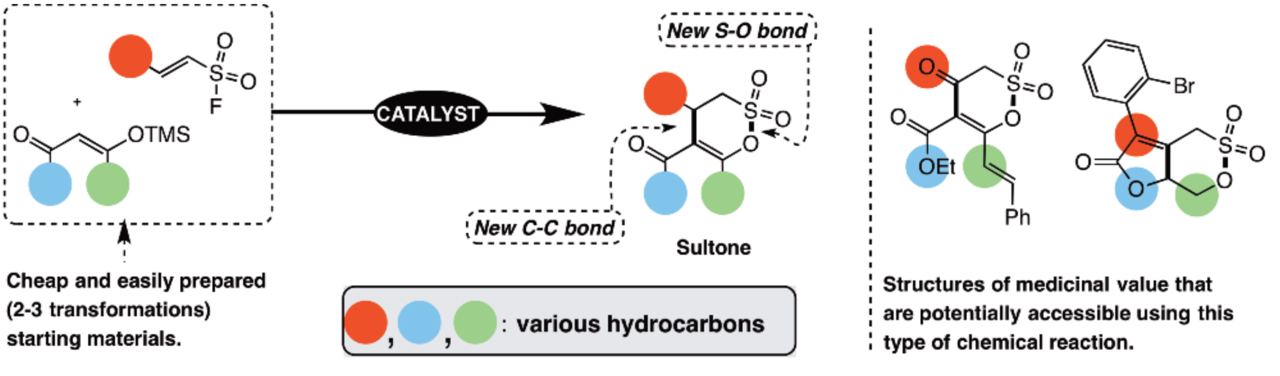
Free radicals are 'unhappy' molecules that have an unpaired electron and so tend to react with other molecules around them, initiating a cascade of chemical transformations. When this happens in the body, such as at the lining of the lung, damage occurs, which ultimately may result in inflammation and breathing difficulties.

'We have observed that the amino acid cysteine – a component of lung proteins – becomes "radicalised" in the presence of ozone,' explained Professor O'Hair.

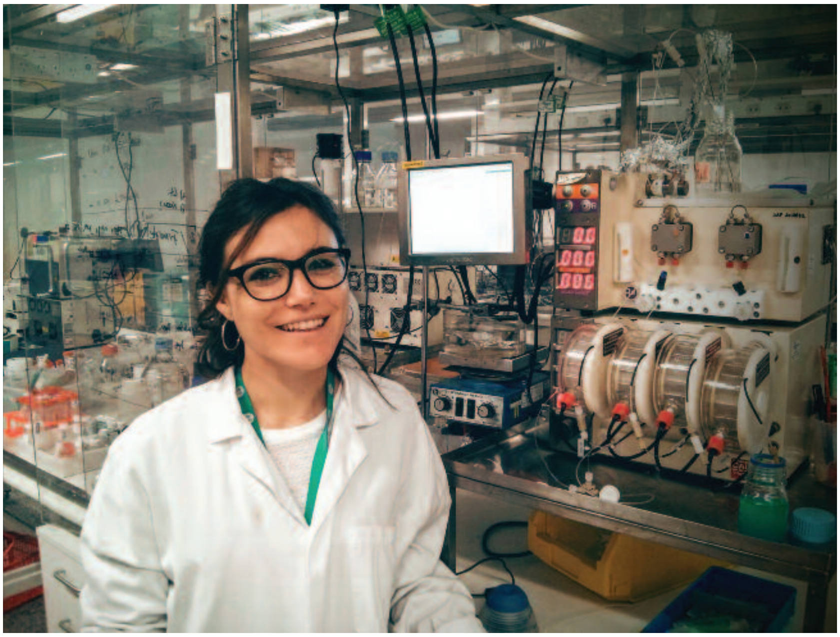
'We hope this work will inspire scientists to search for ozone-induced protein free radical formation and damage at the air-liquid interface of the lung.'

# Catalysing easy access to overlooked family of molecules

Modern society exploits materials accessible only through chemical synthesis. While the value of these materials is rarely disputed, it is essential for chemists to continue to evolve the methods used for their manufacture. The key focus of many advances in chemical synthesis resides in the twin goals of (a) discovering new materials, with properties designed to improve quality of life, and (b) discovering strategies with enhanced efficiency. Studies led by Associate Professor Lupton at Monash University have focused on using new catalytic methods to address these two goals. For example, recent work by graduate students Andrei Ungureanu, Alison Levens and Lisa Candish has unveiled a new mode of reactivity that can be reached using catalysts composed entirely of C, H, N and O. These discoveries have allowed access, in an efficient fashion, to sultones, materials that have received little attention in the past due to challenges in their manufacture (Ungureanu A., Levens A., Candish L., Lupton D.W. *Angew. Chem. Int. Ed.* 2015, doi: 10.1002/anie.201504633). With this new method in hand, it will be possible to study the properties of these materials and examine their potential to enhance quality of life through applications in fields such as materials science and medicinal chemistry.



## Nanocrystals for a cleaner future



CSIRO postdoctoral researcher Marta Rubio-Martinez with flow-chemistry apparatus for scale-up of production of metal–organic frameworks.

Advances in chemistry have fashioned a new class of porous materials called metal–organic frameworks (MOFs). Their scaffold-like structure is made of metal atoms connected by organic linkers. Every atom is exposed to empty space, forming a network that is up to 80% unoccupied, creating an enormous amount of internal surface area – for example, one teaspoon of these materials has the same area as an entire football field.

These ultra-porous powders can store, separate or release almost anything. For example, MOF fuel tanks would allow safe storage of green fuels such as hydrogen gas, permitting the construction of clean cars that leave only water as a waste product, and specially designed MOF filters could dramatically reduce greenhouse gas emissions from factories.

In the last 15 years, thousands of MOF structures with a wide range of potential applications have been synthesised in small quantities in research laboratories. Usually, these synthesis reactions are slow and produce only a few milligrams of high-quality crystals. However, real-world applications would require much larger amounts of MOFs (kilograms or tonnes) produced in a cost-effective way.

The team led by Dr Matthew Hill at CSIRO has approached this problem by adapting flow chemistry, a method that comes from the pharmaceutical industry, to MOF production. They are able to dramatically reduce reaction times (from days to minutes), and increase production yields to several kilograms per hour, without loss in quality (Rubio-Martinez M., Batten M.P., Polyzos A., Carey K.-C., Mardel J.I., Lim K.-S., Hill M.R. *Sci. Rep.* 2014, **4**, 5443).

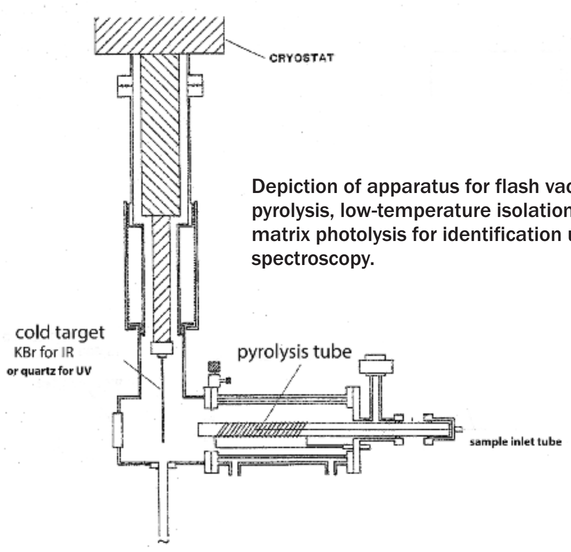
The ability to produce faster and cleaner on a large scale is a game changer for MOFs, opening up pathways to new wider markets. The CSIRO team is now working with industry partners to implement MOF technologies for a cleaner future.

## Understanding molecules with split personalities

Chemical reactions usually take place in stages involving short-lived and often undetected 'reactive intermediates'. In order to understand chemical reactivity, and hence to be able to make informed and useful predictions of new reactions, it is necessary to understand the nature of these reactive intermediates. Professor Curt Wentrup and co-workers at the University of Queensland have contributed decisively to the development of a number of techniques for this purpose, with the aim of capturing the reactive intermediates at very low temperatures, within 10° of absolute zero (–273°C). Under these conditions, reactive intermediates are stable and long-lived and therefore amenable to investigation by spectroscopic methods, in which the molecules are probed by how they interact with light.

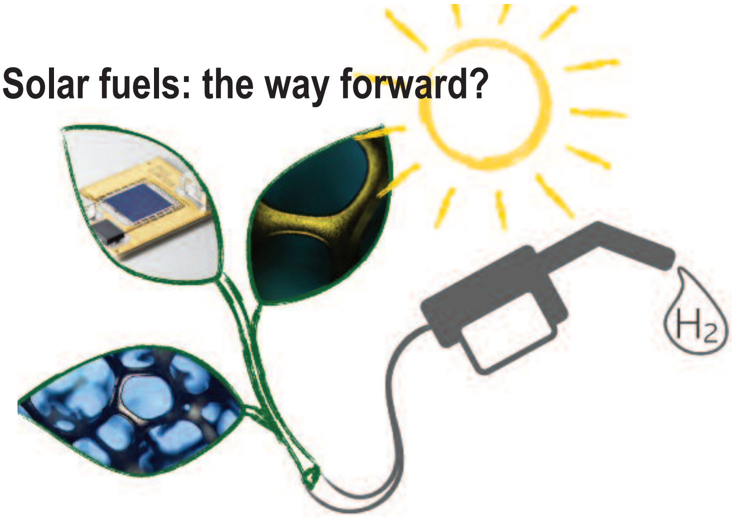
Thus, a large variety of reactive intermediates and other molecules not usually isolable have been generated by light-induced reactions at low temperature as well as in gas-phase thermal reactions with very short contact times (so-called flash vacuum pyrolysis) followed by immediate low-temperature isolation of the products so formed. In addition, several pyrolysis reactions can instead be performed in solution using microwave irradiation (solution flash pyrolysis). Using such methods, it has been possible to generate and probe the detailed properties and behaviours of molecules with unusual bonding types (such as free radicals). Recently, in collaboration with colleagues in France and Portugal, it was shown that some molecules can exhibit split personalities by existing simultaneously in two different bonding forms not previously thought possible (Nunes C.M., Reva I., Fausto R., Bégué D., Wentrup C. *Chem. Commun.* 2015, doi: 10.1039/C5CC03518J).

Not only are investigations of this sort important in order to gain fundamental knowledge about bonding and reactivity, they also allow practical syntheses of useful compounds on a multi-gram scale. For example, the method of falling solid flash vacuum pyrolysis (see *Chem. Aust.*, August issue, p. 14) allows the rapid and high-yielding synthesis of acetylenes, which are important building blocks for preparing numerous other compounds and materials (Wentrup C., Becker J., Winter H.-W. *Angew. Chem. Int. Ed.* 2015, **54**, 5702–4).




**Depiction of apparatus for flash vacuum pyrolysis, low-temperature isolation and matrix photolysis for identification using spectroscopy.**

## Solar fuels: the way forward?




While climate change remains a delicate topic of discussion and intense political debate, there is no doubt that fossil fuels will eventually run out. Humanity must, therefore, look to other energy sources. The sun has the greatest potential to power the modern world as more solar energy strikes Earth in one minute than humanity currently uses in a whole year. This abundance of energy has inspired a global research focus on solar cells that capture and convert solar energy into electricity. Yet, storage of electricity for power at night has not been fully addressed. Currently our primary sources of energy are fuels, such as oil and coal. So why not use solar energy to produce our own fuels?

Fuel can be produced during the day, when sunlight is abundant, then stored for use at night, or whenever it is needed. Plants already do this in the process of photosynthesis in which they convert sunlight into usable energy. Hydrogen is one ideal fuel since it produces only water as a by-product when burnt. The use of sunlight to convert carbon dioxide into carbon-based fuels is also attractive, since these fuels can be directly used to power existing technologies.

The research groups of Professors Leone Spiccia and Douglas MacFarlane at Monash University have devised a new way to use solar energy to split water into hydrogen, a fuel, and oxygen, a by-product. Since the energy comes from the sun, an almost unlimited amount of this fuel could be made.

It is generally accepted that a 10% conversion of solar energy into fuel is sufficient to have an impact as a practical process. The simple technology developed by the Monash University researchers, which is described in the journal *Energy & Environmental Science*, delivers an efficiency of 22%, the highest recorded so far (Bonke S.A., Wiechen M., MacFarlane D.R., Spiccia L. *Energy Environ. Sci.* 2015, **8**, 2791–6). It couples a high-efficiency solar cell to a water-splitting cell that has been optimised to make the best possible use of electricity generated by the solar cell. Importantly, rare and costly metal components such as platinum, which are commonly used in such systems, are avoided in this new process. Approaches like this represent an attractive way for humanity to move away from fossil fuels as, in principle, they allow fuel to be made when and where it is needed.

## Precise polymers

Polymers are large molecules consisting of many repeated subunits. Natural polymers play important roles in living organisms, while many synthetic polymers such as plastics are central to modern society. Nature has long been a source of inspiration for generating polymers with perfect control of molecular weight (number of repeating units), regiochemistry (sequence of units) and stereochemistry or tacticity (three-dimensional arrangement of substituents along the polymer backbone). By controlling these various parameters, nature is able to produce complex polymers, including proteins, DNA and enzymes, which can perform key biological functions that are precisely dictated by their structure and composition.

Using modern polymerisation techniques, chemists are usually only able to produce polymers with poor control over tacticity. Although attempts have been made to control regiochemistry in polymerisation to confer new physicochemical properties for industrial applications, progress in controlling stereochemistry has been slow. Stereochemical control is a key goal in polymer chemistry as it plays an important role in dictating physical and chemical properties of polymers, including solubility, crystallinity, melting point and mechanical strength.

Living radical polymerisation, a technique in which all the chains grow at the same rate, provides a means of controlling polymerisation to engineer novel materials. In recent work, Associate Professor Cyrille Boyer and PhD candidate Sivaprakash Shanmugam at the University of New South Wales have pushed the boundaries of tacticity control in living radical polymerisation by introducing simultaneous stereo-, temporal and chemical control. Their new process, which is described in the *Journal of the American Chemical Society*, uses a new type of catalyst that is activated by visible light and produces polymers with unprecedented control of molecular weight and tacticity (Shanmugam S., Boyer C. *J. Am. Chem. Soc.* 2015, **137**, 9988–99).

The catalyst, in combination with mediators, can control the polymer sequence, molecular weight and tacticity. One advantage of the new approach is the ability to perform the reaction at room temperature instead of the normally elevated temperatures used for polymerisation. This reduces energy consumption and improves control of tacticity. Another advantage is the ability to manipulate the polymerisation rate by varying the light intensity or by switching off the light. By exploiting such control under visible light, polymers with unique properties can be generated, opening up possibilities for a range of new industrial applications, including surface modification.


**New polymerisation catalyst activated by visible light gives unprecedented control over polymer molecular weight and tacticity, the three-dimensional arrangement of substituents along the polymer backbone**

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

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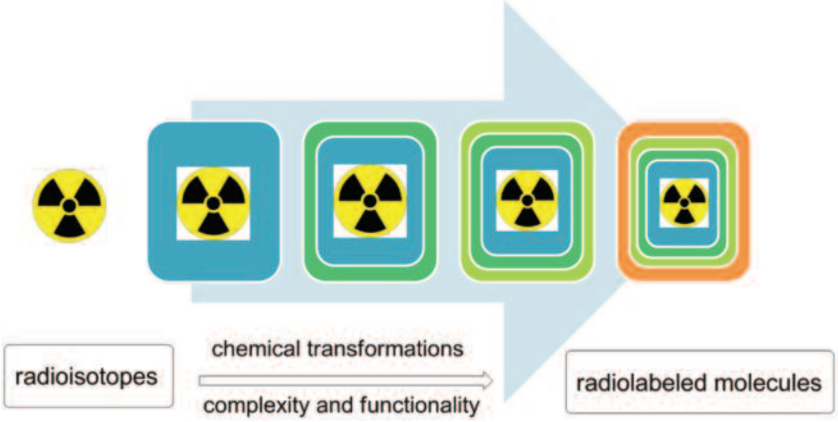
Member ADVANTAGE®

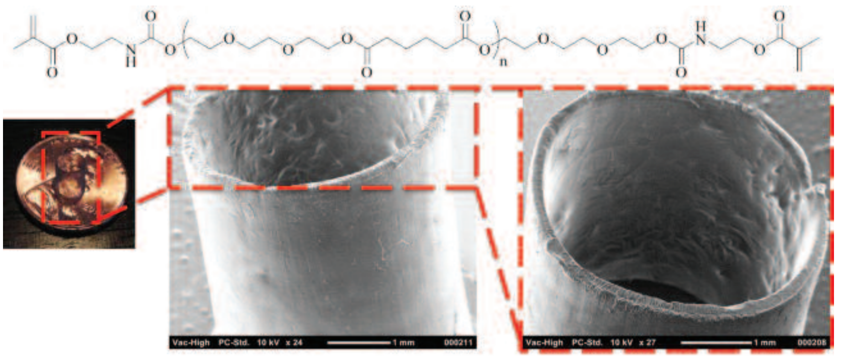
# The importance of PETs




PET scanning stands for positron-emission tomography scanning and is a valuable method for the three-dimensional imaging of molecules within the body; it allows the direct observation of the movements of drugs, pharmaceuticals and metabolites. For example, it can monitor in real time how and when a pharmaceutical arrives at particular organs, and whether it arrives at the intended target at all. The catch is that it is necessary to incorporate positron-emitting radioactive atoms (radioisotopes) in the molecules of interest, and this is hampered by the extremely short half-lives (the time it takes for half of them to decay and disappear) of suitable atoms such as $^{11}C$ and $^{18}F$ (half-lives 20 and 110 minutes, respectively). The positrons emitted by these nuclei are high-energy particles, which, as soon as they meet an electron, annihilate with the production of gamma rays, and it is these that are detected by the PET scanner.

In the September issue of the *Australian Journal of Chemistry*, Steven Liang and Neil Vasdev from the Massachusetts General Hospital and Harvard Medical School recount some of their new synthetic strategies, which include fixation of $^{11}C$-labelled $CO_2$ and [$^{18}F$]fluorination with a special group of molecules called iodonium ylides, to produce radiopharmaceuticals suitable for human PET imaging. Successful completion of the syntheses of complex radiolabelled molecules as well as their separation and purification within the short lifetimes of these radioactive elements necessitate sophisticated state-of-the-art automation technologies such as microfluidic flow chemistry and rapid purification methods.

3D printing is an entirely different, new technology with important applications in the manufacturing of a wide variety of plastic components, including scaffolds for use in human medicine. The fundamental principle here is polymer chemistry, whereby solid materials (plastics) are produced by polymerisation of liquid monomers. Also in the September issue of *Aust. J. Chem.*, Timothy Long and co-workers at Virginia Tech, US, report the synthesis of a bio-compatible, biodegradable, and 3D-printable polyester made from three small molecules – triethylene glycol, adipic acid and isocyanatoethyl methacrylate. A simplified structure of the resulting polymer is shown below; photo-curing results in a cross-linked material. 3D-printing allows the polymer to be used in the engineering of vascularised soft tissue scaffolds with the ability to attach to cells and thus potentially to replace damaged tissue. A cylinder about 4 mm across manufactured in this way is shown below.



This year is the International Year of Light. For this reason, the November issue of *Aust. J. Chem.* will contain a collection of papers on photochemistry and photovoltaics. Photochemistry uses light (UV or visible) as a direct energy source to drive chemical reactions. The light generates excited states of molecules, which can then perform reactions not achievable by other means, e.g. heat. In photovoltaics, molecules have to be constructed to absorb as much as possible of the incident sunlight (both visible and UV). The resulting energy injected in molecular excited states then has to be converted to electricity. Improving the efficiency of these two steps is the major goal of current solar energy research. A paper by Ken Ghiggino, Ezio Rizzardo and co-workers (University of Melbourne) outlines these concepts.

**Curt Wentrup** FAA, FRACI CChem (wentrup@uq.edu.au), http://uq.edu.au/uqresearchers/researcher/wentrupc.html?uv_category=pub


iStockphoto/maroznc

BY **DAVE SAMMUT**

Far from the stereotype of the mad loner scientist in his or her isolated laboratory, there are many examples of science as a family affair.

Together, the Curie family hold the record for the most Nobel Prizes received: Marie (Physics, 1903, and Chemistry, 1911), Pierre (Physics, 1903), their daughter Irène Joliot-Curie (Chemistry, 1935, with husband Frèdèric Joliot-Curie) and another son-in-law Henry Labouisse (Nobel Peace Prize, 1965, as director of UNICEF).

The Bragg father and son team first demonstrated the use of medical X-rays (on five-year-old William after he fell off his bike). They went on to pioneer the field of X-ray crystallography, which was later used to identify the structure of DNA.

The Leakeys, the Huxleys, Nobel Prize recipients C.V. Raman (Physics, 1930) and his nephew S. Chandrasekhar (Physics, 1983), the Sammuts (regrettably unlauded) – all

## Bring chemistry and the other sciences out of the lab and into the loungeroom with these great games.

of these families have carried the love of science across generations.*

So with an intergenerational theme in mind, this public issue of *Chemistry in Australia* seems an ideal time to look at some of the fun science and maths games and activities for families, or to do with friends.

Starting with the classics, there are any number of kits and books for science experiments in the home. The acid–base volcanoes and rocket launchers are a particular favourite for my eight-year-old son, Billy (debuting to the world in this issue), as is the kitchen science of crystal growth.

Sodium borate (borax) dissolved to saturation in hot water will grow quite spectacularly large crystals, particularly if you put it in an esky or thermal bag to keep the water warm for as long as possible. Using simple pipe cleaners for the structure, you can easily grow the crystals onto ornamental shapes. However, use plastic containers for your experiments. The hardened borax crystals tend to crack glass containers when you try to clean them out.

If you teach students who are keen on competition (and prizes), why not get involved in the RACI's annual crystal growing competition (bit.ly/1NJwDMW) for primary and secondary levels. Entry is just $10 per school, with no limit to the number of crystals submitted.

Chemistry kits tend to be a bit more restricted than they were in my youth, given the modern fanaticism for safety, but electronic kits have become really accessible. There are great kits available with easy-to-use interchangeable parts, and great explanations of the principles being tested.

Chemistry and electronics can be readily combined in the form of a simple lemon battery. All you need is a lemon, a piece of zinc or galvanised iron (such as a large nail), and a piece of copper metal. I use the copper plant tags sold in hardware stores for gardeners. Each zinc–copper couple gives off approximately 0.9 V of power, so two in series is basically equivalent to a standard AA battery.

Another Billy Sammut favourite is the book *The elements* by Theodore Gray, (see April 2014 issue, p. 32; chemaust.raci.org.au). This has been made into a jigsaw puzzle, and was a huge success at the traditional Sammut family Christmas. As old fashioned as it might seem, doing a puzzle as a family is a shared task from youngest to oldest, and involves hours of togetherness. And the Boxing Day Test makes a great audio accompaniment.

In the modern era, there are simply excellent new tools for home science. Black lights and low-power lasers are readily accessible and cheap. They make available all sorts of interesting experiments with light, and with the benefit of polarising filters (from cameras or sunglasses), many plastics can reveal wonderful secrets.

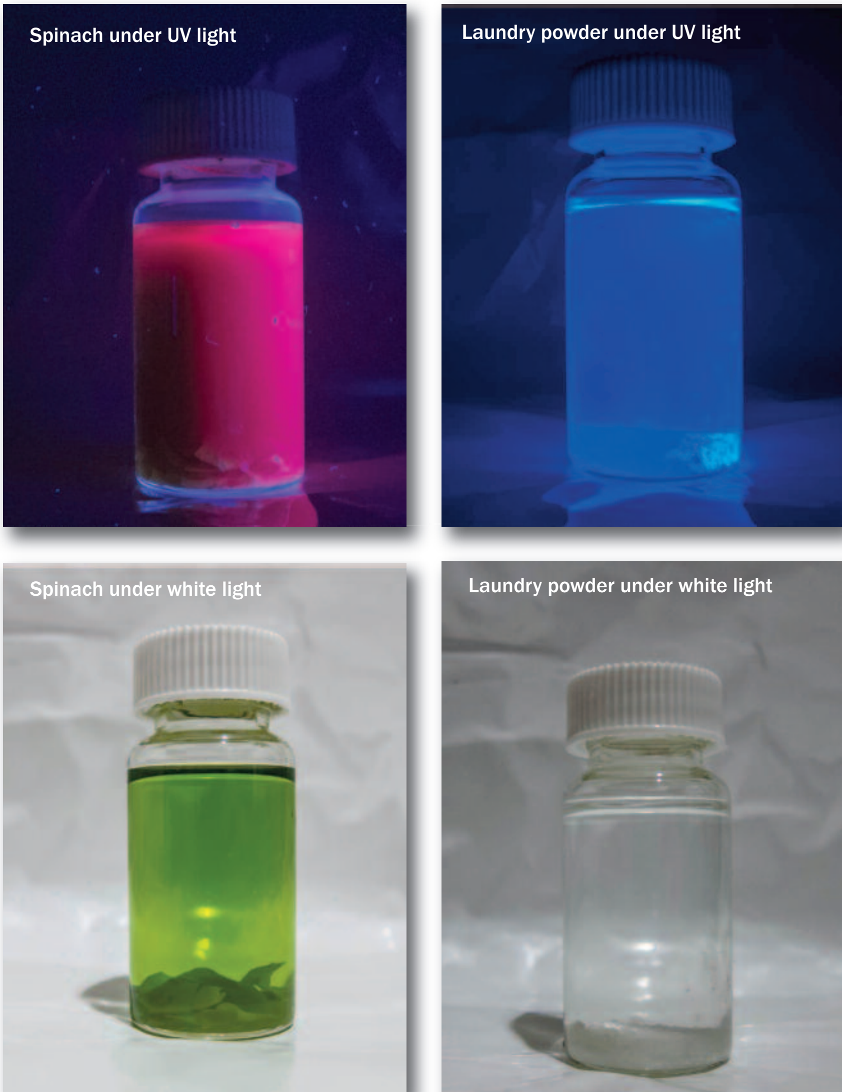
During her successful RACI Nyholm Youth Lecture series to senior secondary students (bit.ly/1MYIRiQ), Dr Liz New of the University of Sydney demonstrated some wonderful experiments in fluorescence, using household materials and a black light. Laundry powder in water or finely chopped spinach in alcohol both give spectacular results, while the properties of fluorescent pens might surprise you.

There are plenty of solar kits on the market, but most of the ones I have seen have been pretty mediocre. They go together in just a couple of ways, with very limited potential for lasting interest. If instead you are spending money on games and toys with an engineering focus, it is hard to go past the classics of Lego and Meccano.

A couple of construction-based products have been developed with girls in mind. Roominate is a modern take on the classic dollhouse, where children build the house out of interconnecting modules and parts, and can even wire up motors, lights and buzzers to bring their work to life. By contrast, GoldieBlox has been criticised by some that while it markets itself as challenging the gender

Chemistry kits tend to be a bit more restricted than they were in my youth, given the modern fanaticism for safety …

*For brief biographies of some of these science families and other influential scientists, visit bit.ly/1N5MjKh.



Clara Shen

**Compounded … was marketed under the tag line: 'A chemistry board game with elements of strategy, social interaction, just a bit of luck – and, oh yeah, explosions.'**

stereotypes of building toys and 'the pink aisle' of toy stores, it has relatively few configurations, its packaging and materials are still almost entirely pink and pastel, and its lead characters are still variations on the princess theme. There may be better ways to engage the interest of young girls in science-based play than by royal charter.

For biological and geological science at home, digital microscopes can be relatively inexpensive fun. There are hand-held and classic-format versions, both of which connect via USB to your computer. What I love about this is that you can easily purchase interesting pre-prepared slides online for various samples of the natural work, but the family can go outside together and just as easily collect items from the garden for a more detailed examination.

As a family, we often like to play board games after the dinner table has been cleared. With a young son at school, many of these are educational in nature, such as Zeus on the Loose – a counting game. It's quick paced and enough fun that the adults don't feel the urge to chug a wine glass of cyanide (which, as chemists, we actually know how to make), and it happens in short rounds so that a few games pass swiftly.

For the adults, the game Timeline has been a late favourite. It's a simple game based on laying out cards for historical events in chronological order, with multiple (separately purchased) versions from general history to science and discoveries, and different sets that can be easily mixed for variety. More than just a memory game, success comes as you build on the context of scientific and historical progression, and it becomes increasingly difficult as the number of cards on the table increases.

Although I haven't yet had a chance to play them myself, four other board games have been very well rated in my research. Pandemic is a co-operative board game about the outbreak of four diseases in the world. Players must work together to discover the cure before game-ending conditions are reached. Its popularity is such that there are multiple expansion packs, and a second edition was released in 2013.

Compounded is the successful product of a Kickstarter (crowd funding) campaign. It was marketed under the tag line: 'A chemistry board game with elements of strategy, social interaction, just a bit of luck – and, oh yeah, explosions.' The game was launched in late 2013, and has been getting great reviews (although note that one of the game extension packs has a theme of illicit substances).

I like the sound of Bone Wars: The Game of Ruthless Palaeontology. From the publisher's website: '… players take the role of palaeontologists during the great ''Dinosaur Rush'' of the late 19th century. Out in the field, fossil hunters must survive natural disasters and attempts by other players to steal and destroy dinosaur bones.'

The New Science board game is set in 17th-century Europe. Players compete to make discoveries, test hypotheses, publish papers and accumulate prestige to be appointed as the President of the Royal Society.

In its best form, science is more than just a way to overcomplicate a simple agrarian existence. It's a way of life, and fun for the whole family. So this year we should all encourage Santa to say '$H_2O$, $H_2O$, $H_2O$', and bring a little science fun home for Christmas.

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

**Kitchen science: Billy Sammut having fun making crystal ornaments with borax.**

# New tool to save salmon

## Isotope tracking

BY **LEE SIEGEL**

**Chinook salmon on the Lower Tuolumne River in the Central Valley of California.**
US Fish and Wildlife Service/Wikimedia Commons

## Strontium ratios in ear bones reveal where fish were born and lived.

Salmon carry a strontium chemical signature in their 'ear bones' that lets scientists identify specific streams where the fish hatched and lived before they were caught at sea. The new tool may help pinpoint critical habitats for fish threatened by climate change, industrial development and overfishing.

'Using this method, we can trace where the salmon were born and where they moved while they were growing in the rivers and streams,' says University of Utah geochemist Diego Fernandez, a co-author of the study published 15 May in *Science Advances*. 'This could be useful for protecting fish and understanding how many salmon we can take from nature.'

Genetic studies of salmon caught in saltwater previously determined the watershed where fish hatched, but not sets of streams and not where they spent time as they grew, says Thure Cerling, also a University of Utah geochemist and co-author.

In the new study, researchers from the universities of Utah, Washington and Alaska Fairbanks and the US Geological Survey analysed strontium isotope ratios in otoliths – also known as ear stones or ear bones – from 255 chinook salmon caught in southwestern Alaska's Bristol Bay. The study determined where the fish hatched and spent time in seven different sets of two to five streams within the watershed of the Nushagak River, western Alaska's third-largest river.

Wild salmon worldwide are under pressure by many interests: mining, logging, hydroelectric dams, hatcheries, industry, and commercial, sport and subsistence fishing.

'Disturbances to salmon populations can range widely from large-scale disturbances due to a rapidly changing climate to smaller-scale disturbances such as habitat loss or contamination from industrial development of the freshwater streams that are the spawning grounds of salmon,' says the study's lead author, Sean Brennan, a 2007 University Utah biology graduate and now a postdoc at the University of Washington.

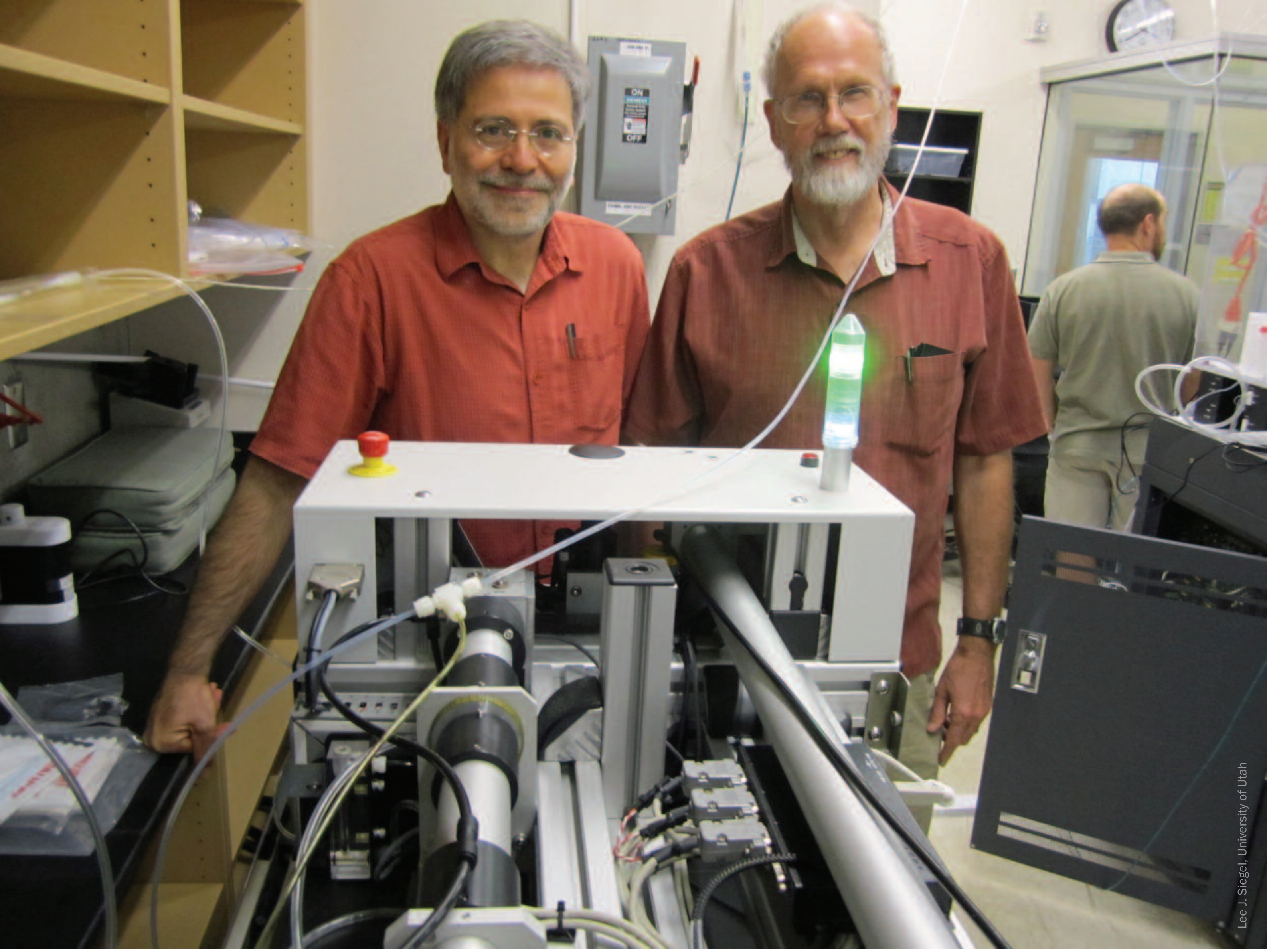
'Without knowing which habitats are producing fish and what habitats are used by fish during critical periods of their lives, it is very difficult to understand how populations might respond to some disturbance and to design effective conservation strategies,' says Brennan, who ran the study as a doctoral student at the University of Alaska Fairbanks and a visitor at the University of Utah, where the lab work was done.

He says the study could have important implications in understanding how habitat loss and contamination could affect salmon if the proposed Pebble Mine is built in the headwaters of the Nushagak. Development of the copper, gold and molybdenum mine is opposed by fishers and hunters, environmentalists, local residents and federal regulators.

Brennan, Fernandez and Cerling did the study with Christian Zimmerman of the US Geological Survey in Anchorage, and Megan McPhee and Matthew Wooller of the University of Alaska Fairbanks. The USGS and Alaska Sea Grant funded the study.

### Salt Lake, Fairbanks, Seattle – and salmon

Brennan grew up in Salt Lake City, and his parents still live there. As a biology undergrad at the University of Utah, he worked with Cerling and biology professor Jim Ehleringer, who pioneered analysis of various chemical isotope ratios for many uses. Those include tracking the sources of drugs, counterfeit currency and explosives; determining where both people and elephants have lived by analysing their hair; dating ivory to learn if it is illegal or exempt from bans; and using fossil teeth to analyse the diets of human ancestors and animals during the course of their evolution.



Lee J. Siegel, University of Utah

**University of Utah geochemists Diego Fernandez (left) and Thure Cerling (right) stand behind a laser machine that blasts tiny samples off 'fish ear bones' as part of a new method of tracking salmon caught at sea to learn where they hatched and spent time. The tube in front of Cerling carries debris from the laser blasts to a mass spectrometer in another room. That device analyses strontium isotope ratios in the fish ear stones to reveal the life histories of the salmon.**

'I cut my teeth – pun intended – in isotope ecology in Thure's and Jim's labs,' Brennan says. For the new study, 'all of the analysis and laboratory work were at the University of Utah under the guidance of Diego and Thure. I spent two to six months a year over the course of the project at the University of Utah lab.'

## Geology and water reflected in fish ear bones

When it is time to reproduce, salmon leave the sea and swim up rivers to spawn and die. The hatchlings grow in freshwater streams, swim to sea and reach adulthood.

The study involved chinook salmon otoliths, the stones found in the ear canals of fish. They are not true bones. Unlike bone, which is calcium phosphate, otoliths are calcium carbonate and function like an inner ear, involved in orientation, balance and sensing sound. They are lozenge-shaped and range up to a centimetre in length in salmon.

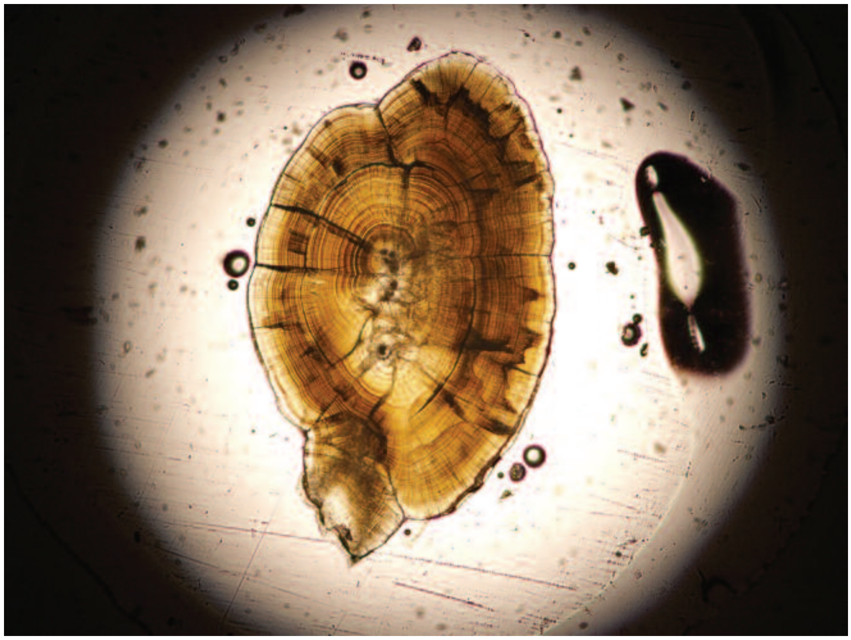
Otoliths grow new outer layers or bands daily as a juvenile fish matures, and those layers incorporate strontium from stream water where salmon are born and swim. The ratios of strontium-87 to strontium-86 in water – and thus in otoliths – ultimately reflect the ratios in the rocks eroded by the streams.

In earlier research, the scientists sampled water from Nushagak tributaries and otoliths from juvenile salmon and slimy sculpin – fish that stay in place for life – to demonstrate strontium ratios in rocks correlate with those in streams and otoliths.

In the new study, Brennan collected otoliths from chinook salmon unloaded from boats at the Peter Pan Seafoods cannery in Dillingham, Alaska. It was the sockeye salmon season, and the chinook were incidental bycatch in that fishery.

At the University of Utah, the otoliths were cut lengthwise. Then a laser

**The ratios of strontium-87 to strontium-86 in water – and thus in otoliths – ultimately reflect the ratios in the rocks eroded by the streams.**



Sean Brennan, University of Washington

A cross-section of a salmon otolith, also known as a fish ear stone or fish ear bone. By measuring strontium isotope ratios in different layers of otoliths from salmon caught at sea, researchers from the universities of Utah, Washington and Alaska Fairbanks and the US Geological Survey were able to determine not just the watershed, but a set of streams where the salmon hatched and grew before migrating downstream to the ocean. The new fish-tracking method may help pinpoint critical habitats for fish threatened by climate change, industrial development and overfishing.

zapped each otolith repeatedly, from the inner to outer layer, providing samples with changing strontium isotope ratios from the time the fish hatched until after it entered the sea.

'There are literally thousands of measurements on each otolith,' Cerling says.

Fernandez adds: 'They're like microexplosions. You create tiny, tiny particles that are carried into the mass spectrometer.' By showing how the ratio of strontium-87 to strontium-86 changed over time, 'we get the entire life history of the salmon,' he says.

The study revealed where each fish was hatched and lived on a map showing seven different colour-coded sets of streams in the 145-by-240-kilometre Nushagak watershed. Each colour represents a range of strontium isotope ratios.

Cerling says the ratios vary because the rocks closer to Bristol Bay are Aleutian arc volcanics, while rocks farther north are much older, sedimentary rocks.

## The findings

The study found 71% of the chinook salmon analysed came from only three of the seven stream groups in the Nushagak watershed. One basin alone was home to 27% of the chinook.

'If you know some percentage goes to a stream, you know that stream is important,' Fernandez says.

The proportion of chinook salmon from each of the seven different streams or stream groups correlated well with the estimated amount of habitat in each of those areas.

During the three days when Brennan collected chinook, the proportion of the salmon from some of the streams increased, while it decreased in other tributaries, mainly the upper regions of the Nushagak watershed.

Tracking the fish by their strontium isotope ratios revealed the chinook salmon had four distinct life histories: 72% of the fish stayed where they hatched until they swam downstream to Bristol Bay and the Pacific; 17% stayed mostly where they hatched, except for short forays downstream in the lower Nushagak River just before swimming to sea; 7% swam to another stream from where they hatched, then stayed there until going to sea; and 4% left their birthplace for another stream, and then made a foray into the lower river before heading for sea.

Cerling notes almost 30% of the salmon had a more complex life history than simply hatching and growing up in one place. The study 'provides a baseline of how this watershed is used by the fish at this time – a baseline for future comparison related to climate change, overfishing or other environmental stresses,' he adds.

The researchers believe their method will work on other salmon and fish species and in other settings where the geology produces varying strontium isotope ratios in different streams.

**Lee Siegel** is senior science writer at University of Utah Communications. First published at newswise.com.


# The future is chemical

Chemistry is vital to our future in countless ways – so what's the plan?

BY **TERRY CLAYTON**

As in life, there are lots of *oops* moments in chemistry. Sometimes it's a bad oops, like destroying our ozone layer to keep the milk from spoiling. But not always. Good oops moments include Joseph Priestley's discovery of soda water (1772), Charles Goodyear and rubber (1839), Roy Plunkett and Teflon (1938), Harry Coover and super glue (1958) and a dozen other 'accidental' discoveries that have become so common we never stop to think about them. These and many other chemical discoveries have spawned multibillion dollar industries employing hundreds of thousands of people worldwide.

Of course, not all chemistry happens by accident. Chemists have developed powerful new tools for delving ever deeper into the structure of matter, paving the way for new industries such as nanotechnology and 3D printing. The chemist's toolbox has also brought us major advances in agriculture, food, packaging and waste management, to name but a few.

Consider the challenges of cheap, clean energy as an example.

More than 70% of our electricity comes from coal, which also produces 35% of our greenhouse gas emissions. Australia has abundant sunshine, so why are we getting less than 1% of our electricity from solar panels? All things considered (politically and economically), it is still cheaper to produce electricity with coal. Solar panels are still too expensive to produce.

Pause here for fierce debates about this claim. Placards and shouting may be involved.

The good news is solar panels are getting cheaper by the day. Deutsche Bank energy analysts are predicting the cost of power produced from solar cells to fall by as much as 40% over the next two years. Chinese manufacturers already have the cost of panels down to about US$0.36 per watt. There will come a point, and soon, when the economics will be just too attractive for investors to ignore, and Australian chemists are making significant contributions towards that end.

Here is just one example. At the University of New South Wales, solar researchers have converted over 40% of the sunlight hitting a solar panel into electricity. This is the highest efficiency ever reported anywhere in the world. For comparison, most thermal power stations have an efficiency of 33–48%, and hydropower is about 90% efficient. If you are wondering what chemistry has to do with solar panels, have a look at the box.

In the meantime, what do we do about coal? Rather than abandon a cheap, abundant fuel, major employer and export earner, why not make it clean?

In Queensland, a group of engineers recently tested Australia's first carbon-capture coal-fired power plant on the outskirts of Biloela. For the past two years, this 30-megawatt plant has generated enough power for around 30 000 homes using a technology called oxy-fuel combustion. Most of the plant's carbon emissions are captured and pumped underground and air pollution in the area has fallen by more than 85%. So how does it work and where is the chemistry?

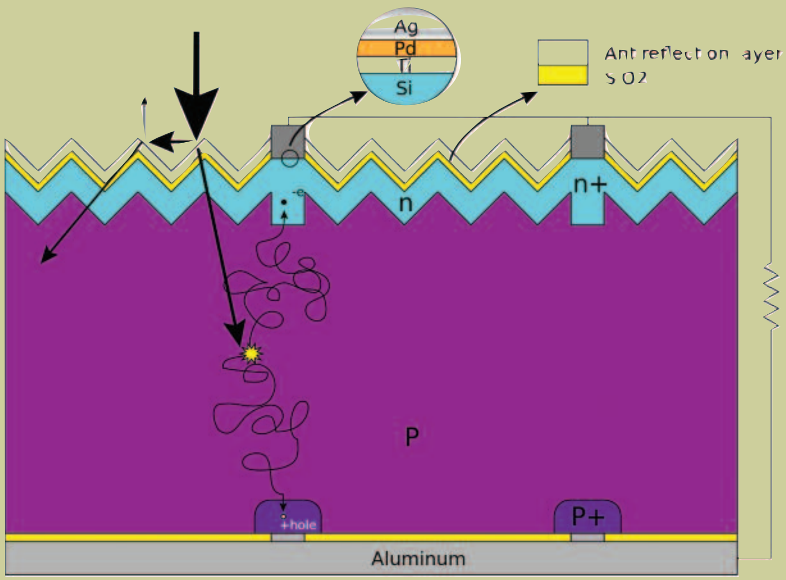
When you fire up the backyard barbie, you are a chemist. Holding a match to the starter initiates a chemical reaction in which your fuel reacts with the 20% oxygen in the air and releases carbon dioxide, water vapour and heat. In oxy-fuel combustion, coal (the fuel) is burned using oxygen adjusted to 95% purity with recycled flue gas. Burning the recycled mixture produces approximately 75% less flue gas than normal air-fuelled combustion. The carbon dioxide is extracted from the remaining flue gas using any one of several chemical processes. The resulting carbon-rich fluid is stored deep underground (sequestered) by pumping it into saline aquifers. The big challenges for chemists and engineers are reducing the cost of producing 95% pure oxygen, reducing the cost of extracting the carbon dioxide from the flue gas, improving the injection technology for storing the carbon, and scaling up the process to 500–700-megawatt plants.

The way big science works these days, researchers have to justify their work in terms of practical applications or they don't get funding, so they have to say things like: '… our theoretical work could help guide future experimental research into xyz and

**Without basic research, no country can hope to be more than a market for products based on research done in other countries.**

## What is a solar cell?

A solar, or photovoltaic, cell converts the energy of light directly into electricity through the photovoltaic effect, which is a physical and chemical phenomenon. The chemical bonds in the semiconductor are vital for the process to work. Pure silicon is a poor conductor of electricity because none of its electrons are free to move about, unlike the electrons in metals like copper. To get around this limitation, the silicon in a solar cell has impurities mixed in with the silicon atoms. The process of adding impurities is called doping. When doped with phosphorus, the resulting silicon is called n-type ('n' for negative). N-type doped silicon is a much better conductor than pure silicon. The other part of a typical solar cell is doped with boron and is called p-type silicon ('p' for positive). It has free openings and carries the opposite (positive) charge.




**Another issue is a widespread lack of awareness in society and among politicians of what chemistry is and how reliant we have been on chemistry innovation for our health and material wellbeing.**

ultimately aid the development of new technologies'.

The key words are 'could' and 'ultimately'. There is no guarantee that basic research will pay off. That's why we call it research. That's why it is vital to ensure our government provides an adequate share of the national budget to basic research. Without basic research, no country can hope to be more than a market for products based on research done in other countries. The top ten countries for chemistry research are the US, Japan, Germany, the UK, France, China, Italy, Spain, Canada and India. Australia ranks 14 on the list. Compared to these leaders, Australia allocates a reasonable portion of the national budget to research and development, so it's not all down to lack of funding.

Pause here for outcries of protest from university and national research agency researchers. PowerPoint may be involved.

In the 2014–2015 budget, the Australian government allocated $9.2 billion to research and development. That's 2.39% of the GDP. On the list of top ten chemistry countries, Canada, Italy, France, Spain and the UK spend less than 2%. So if it isn't a funding problem, what is holding us back from joining the ranks of the top ten?

It's not for lack of trying. Twenty-nine of Australia's 43 universities have dedicated chemistry departments. Six are among the top 100 in the world. Research in chemistry at Australian universities is at or above world-class standard as evident from the Excellence for Research in Australia assessments in 2010 and 2012. Australian research in chemistry accounts for 2% of high-impact research publications. In non-academic terms, that's like your rugby team being near the top of the National League ladder. In non-rugby terms it means – brilliant.

Nor is it down to lack of need or opportunity. Chemicals and plastics supply 109 of Australia's 111 industries and there are 60 000 people employed in the chemical industry, our second largest manufacturing sector. The sector contributes $11.6 billion annually to the Australian economy. The average starting salary for chemists is around $50 000 per year.

Perhaps what we are lacking is a little direction. Perhaps what we need is a plan, a roadmap for our chemical future.

That is precisely what the Australian Academy of Science's National Committee of Chemistry in partnership with the RACI has been working on over the past year, a ten-year or 'decadal' plan for chemistry. Several messages have emerged from the 26 open town hall meetings all over

## Biomimicry and innovation

One pathway to a sustainable future is biomimicry – imitating nature's best ideas, designs and processes to solve human problems. We do it all the time. Velcro mimics multiple-hooked structures such as burs. A passive cooling model inspired by termite mounds keeps the Eastgate Centre, a mid-rise office complex in Harare, Zimbabwe, comfortably cool without air conditioning and uses only 10% of the energy of a conventional building its size. Bacteria are super chemists. We can use the enzymatic system of aerobic bacteria to detoxify highly polluting compounds. We can use bacteria to mine the ocean floor without harm. We can make vaccines that survive without refrigeration based on Africa's resurrection plant, and create friction-free surfaces suitable for modern electrical devices from the chemistry of the skin of the Arabian sandfish lizard (pictured). The list goes on and is limited only by our imagination. At the heart of all these innovations you will find chemistry.

FinnHK/Wikimedia Commons9

## Be part of the chemical future

- Find out more about the Decadal Plan for Chemistry: bit.ly/1VK5cUK
- Learn more about biomimicry at Nature's 100 Best Initiative: Biomimicry Design: bit.ly/1IVcBHw
- You don't need a university degree in chemistry to understand the basics. Try some of these fun links to get started:
  - Science of fireworks: bit.ly/1K2USyC
  - Basic chemistry explained: bit.ly/1QlgN9C
- Learn more about 'accidental' discoveries at Xperimania (bit.ly/1g6DmSd) and Popular Mechanics (bit.ly/1LgBBux)
- Read about chemistry. Start with some of the books reviewed in Digestible Chemistry (November 2014 issue, pp. 32–3.
- Look around you, at home or at work. When you have a free moment, do a Google search on 'the chemistry of [fill in the blank]'. Make it a challenge. Can you find something for which there is no chemistry? Would you believe there is chemistry of cat litter (bit.ly/1NYwRjm)?
- Date a chemist: abt.cm/1UxVuHU

Australia and the scores of interviews with industry, government and educators.

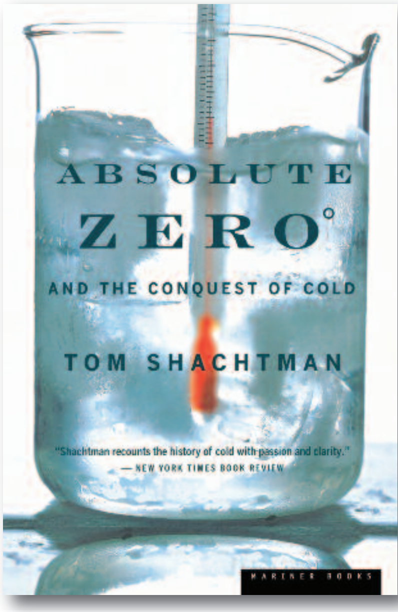
Among the clearest messages are the disconnect between academia and industry, and the secondary and tertiary education interface. Ask kids in primary school if they know what a chemical is and the answer is likely to be 'something dangerous'. Not a great indicator those kids will go on to study chemistry.

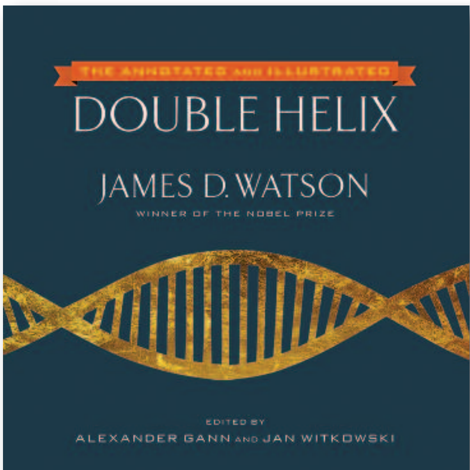
Another issue is a widespread lack of awareness in society and among politicians of what chemistry is and how reliant we have been on chemistry innovation for our health and material wellbeing. Hence, one of the aims of the Decadal Plan is to find ways chemists can better communicate the tremendous advances and contributions of chemistry to the community.

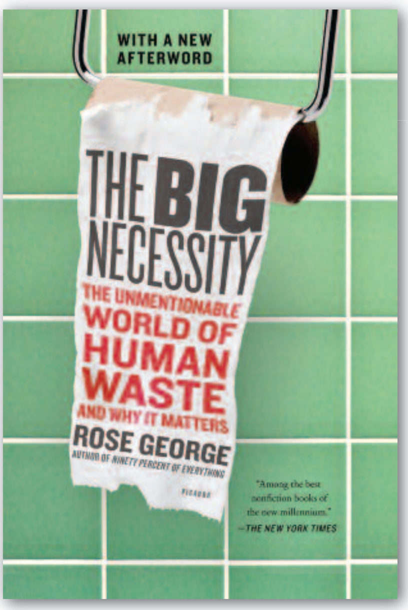
When it is submitted to the government later this year, the Plan will provide the information and knowledge needed to help direct future investment in chemistry; help us predict where the new jobs are and what skills are needed for chemistry graduates; and help determine how to improve interaction between industry, universities and government and maintain workforce numbers and how multidisciplinary research impacts on chemistry. The Plan also offers recommendations for improving chemistry education to increase the numbers of students studying chemistry, science and maths at secondary schools.

Any ten-year plan will last longer than several future terms of government (we can hope not more than several). What the Decadal Plan needs to succeed is a bipartisan agreement between the major political parties on how chemistry, science and maths relate to our education system, to innovation and our economic and material wellbeing. If new governments keep reversing policies governing science and education, we are surely going to fall to the bottom of the league ladder, because the future is chemical.

**Terry Clayton** is a freelance commercial writer, blogger and educator with a wide range of interests in the physical sciences and humanities. See more of Terry's work at www.redplough.com. Terry would like to thank Professor Paul Mulvaney FRACI CChem for taking time to talk about the Decadal Plan for Chemistry. Professor Mulvaney is Chair of the National Committee for Chemistry and ARC Laureate Fellow at the School of Chemistry & Bio21 Institute, University of Melbourne.




# Remarkable science reads

Books are a major influence in my life. I am a life-long bibliophile, information geek and proselytiser of the printed word, as well as a serial-escapist into the world of fiction. Some of my inspiration comes from a 1960 address by Werner von Braun, when he said to me (and 150 of my 15-year-old peers): 'Boys and girls, we have one thing in common: we are both still learning.' Life itself is a process of learning and there are few adjuncts more valuable to its course than books.

Science, broadly defined as seeking logical and coherent explanation for how and why 'things' work, has been a second great driver of my life. No wonder, then, I'm interested in books about science and in particular books that might pique broad interest, excitement and intrigue in science. Does it really matter whether people are scientifically literate or even interested in science? Well, yes, you bet it does! Recently, Australia's Chief Scientist Ian Chubb appealed for more science in the primary school curriculum if children are to thrive (*The Age*, 20 May 2015, p. 18) and nationally we have debate on issues including climate change, renewable energy and fracking being driven and decided by, essentially, scientific luddites. We need to do everything we can to encourage everybody (but particularly children) to read, think and be informed about science. And Christmas is a great time to give this a kick along. Here are some ideas.

Fairy stories for children came to life with the Grimm Brothers' tales, published in 1812. However, it was not until 1887 that Lucy Rider Meyer melded chemistry and fairies in her book *Fairy-land of chemistry*, subtitled *Real fairy folks: explorations in the world of atoms*. Lucy Jane Rider was a very remarkable woman (try Googling her!). Alas, her book is well and truly out of print. If you come across it, then grab it with both hands. (Well with one, actually, because the other will be digging for the substantial price you can expect to pay!) It would be a good investment. Meantime, you can download a (free) scanned version at https://dds.crl.edu/crldelivery/18956.

Arabella Buckley (1840–1929), another remarkable woman who was long time secretary to lawyer and founding geologist Charles Lyell, published *The fairy-land of science* in1879. I've just come across an 1882 original, but reproduced versions are readily obtainable and inexpensive. A recent book *Science in wonderland* (see September issue, p. 29) explores the relationships between science and 'fairy-land' in Victorian times. Looney stuff? Well, no, it is a really interesting book, a serious scholarly work! Well worth buying. Maybe science needs more fairy stories to excite and inspire little people?

Interestingly, there is a resurgence of something-like-fairydom in chemistry with the 'Basher' series. *The periodic table: elements with style* and *Chemistry: getting a big reaction*, aimed at a 10–14-year-old market are great little books, based around cartoon characters. Kids of this age may also enjoy DK Eyewitness Books', *Chemistry*. Another gift to consider for this group is a subscription to the *Double Helix Club* (https://doublehelixshop.csiro.au), rated as 'great!' by several young folk I know. Unfortunately, chemistry seems to lack a Theoni Pappas, author of *The adventures of Penrose, the mathematical cat* and *The further adventures of Penrose the mathematical cat.* These are to swoon over and a cheap and painless way to boost enthusiasm in neophyte, or indeed neophobic, mathematicians.

For the older teens (and adults) you would be hard pressed to do better than Theodore Gray's books. *The elements* (also available as an app for iPad, and as a calendar) and *Molecules* (see March issue, p. 35) are splendid books, brim-full of good chemistry clothed in spectacular wrapping. *Mad science (experiments you can do at home but probably shouldn't)* and its sequel *Mad science 2 (experiments you can do at home but* ***still*** *probably shouldn't)* … Well, what else could you call it? … are similarly engaging. The whole family will love them.

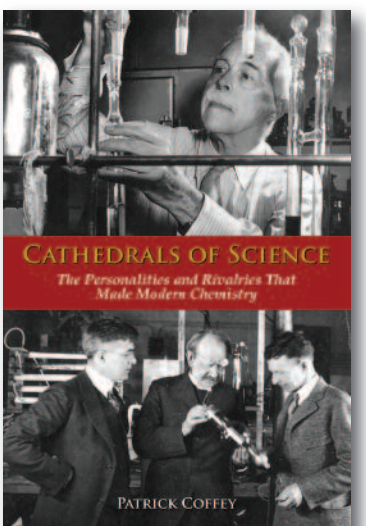
You might also consider a subscription to *New Scientist*. It is a tad expensive at $250 per year, but always engaging. And, it keeps on coming! *New Scientist* also publishes a great series of books of questions and answers on all manner of scientific topics, based on its column The Last Word. These are cheap, readily available and always full of intriguing Q&A. Another great way to have some fun with your teenagers would be to buy yourself a copy of *Open-source lab* (see August issue, p. 29), getting into Arduino interface boards and, maybe, even building your own 3D printer. Don't worry, I'm sure the kids already know the words you let slip when things don't quite go to plan!

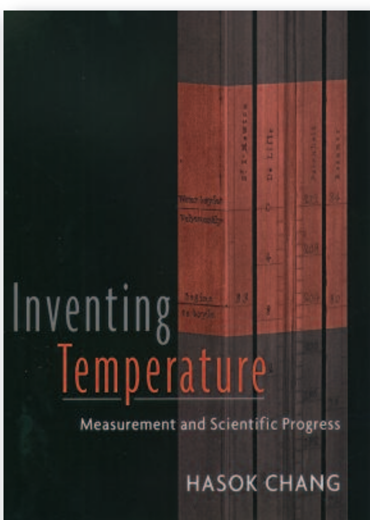
What about for 'grown-up'? If you haven't read *Uncle Tungsten – memories of a chemical boyhood*, then you absolutely *must*. You'll love it. Author Oliver Sacks, the neurologist, describes growing up in pre World War 2 London in a fairly laid-back and indulgent family that more-or-less let him do his own (chemistry) thing. (They did eventually draw the line at young Oliver's smelly shenanigans, but solved the problem by building him a fume cupboard in the garden!) Sacks' subsequent autobiography, *On the move* has appeared very recently. If you haven't read either, then you might be able to negotiate a good deal! Me? I've got *On the move* on order!

Other interesting 'adult' science books worthy of consideration include *The science of good cooking* (you can learn not only how to do it, but why it works. Good stuff, but be careful! Giving your partner a cookbook for Christmas requires detailed consideration of the possible consequences.); *The annotated and illustrated double helix* (a hyped-up version of Watson's original book on the elucidation of the structure of DNA); *The science of cheese* (see February issue, p. 29); *The big necessity* (this is not so much an excrement of a book as a book about human excrement! Really eye-opening or, perhaps, buttock-clenching); *Absolute zero and the conquest of cold* and *Inventing temperature* (these make an educative pair if, like me, you find the concept of temperature exciting ... *You* don't? Ah, well!); *Scientific babel* (this utterly fascinating book traces the language of communication in science from its origins to the present) (see October issue, p. 4); and finally, *Cathedrals of science* (a history of the emergence of physical chemistry, warts and all).

Finally, if absolutely none of this appeals, and the last thing you ever want to do is read another book about science, escape to *The whites*. It's supposed to be the best crime novel of the year!

**R. John Casey** FRACI CChem




## Suggested reading

*Fairy land of chemistry: real fairy folks: explorations in the world of atoms*, Lucy Rider Meyer (Lucy J. Rider), D. Lothrup and Co., 1887

*The fairy-land of science*, Arabella B. Buckley, Echo Library, 2006 (1882 edition published by Edward Stanford)

*Science in wonderland – the scientific fairy tales of Victorian Britain*, Melanie Keene, OUP, 2015

*The periodic table: elements with style*, Basher and Adrian Dingle, Kingfisher, 2007

*Chemistry: getting a big reaction*, Basher Science, Kingfisher, 2010

*DK eyewitness books: chemistry*, DK Children, 2005

*The adventures of Penrose, the mathematical cat*,Theoni Pappas, Wide World Publishing/Tetra, 1997

*The further adventures of Penrose the mathematical cat*, Theoni Pappas, Wide World Publishing/Tetra, 2004

*The elements: a visual exploration of every known atom in the universe*, Theodore Gray, Black Dog and Leventhal, 2009

*Molecules: the elements and the architecture of everything*, Theodore Gray, Black Dog and Leventhal, 2014

*Mad science: experiments you can do at home but probably shouldn't*, Theodore Gray, Black Dog and Leventhal, 2009

*Mad science 2: experiments you can do at home but still probably shouldn't*, Theodore Gray, Black Dog and Leventhal, 2013

*Open-source lab: how to build your own hardware and reduce research costs*, Joshua M. Pearce, Elsevier, 2014

*Uncle Tungsten: memories of a chemical boyhood*, Oliver Sacks, Picador, 2001

*On the move: a life*, Oliver Sacks, Macmillan, 2015

*The science of good cooking*, edited and published by America's Test Kitchen, 2012

*The annotated and illustrated double helix*, James D. Watson (Eds Alexander Gann and Jan Witkowski), Simon and Schuster, 2012

*The science of cheese*, Michael H. Tunick, OUP, 2014

*The big necessity: the unmentionable world of human waste and why it matters*, Rose George, Metropolitan Books, 2008

*Absolute zero and the conquest of cold*, Tom Shachtman, Houghton Mifflin, 1999

*Inventing temperature*, Hasok Chang, OUP, 2007

*Scientific babel: how science was done before and after global English*, Michael D. Gordin, University of Chicago Press, 2015

*Cathedrals of science: the personalities and rivalries that made modern chemistry*, Patrick Coffey, OUP, 2008

*The whites*, Richard Price writing as Harry Brandt, Henry Holt and Co, 2015

# Poloxamers: from dishwasher tablets to treating cancer

What would you say if the same polymer would be used for cleaning products and as a cancer drug delivery system? You may think it is a crazy idea, but it is true!

Once you go through the labels of your household cleaning products, for example dishwasher tablets or contact lens solutions, you will see that different poloxamers are listed as ingredients. What is more, poloxamers are also studied as promising delivery systems for anticancer drugs and some formulations are currently undergoing clinical trials.

## So what are those poloxamers?

Poloxamers, known under their trade names Pluronics, Synperonics and Kolliphors, represent a class of non-ionic surfactants and have the general structure ABA (ABA triblock copolymer). The word 'poloxamer' was introduced by the inventor, Irving Schmolka, who received the patent for these materials in 1973.

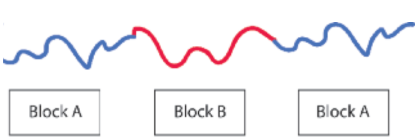
As you probably know, surfactants are the most important part of any cleaning agent. The word 'surfactant' refers to 'Surface Active Agent'. In general, they are chemicals that, when dissolved in water or another solvent, orient themselves at the interface between a liquid and a solid or between two liquids and change the properties of the interface (e.g. by lowering the surface tension). Surfactants may act as detergents, wetting agents, emulsifiers, foaming agents or dispersants.

All surfactants have a common structure. One part of the molecule has a long non-polar chain that is attracted to oil, grease and/or dirt; this is the hydrophobic part, also known as the tail. The head, or the hydrophilic part of the molecule, is attracted to water. When we talk about compounds that exhibit both hydrophilic and hydrophobic properties, we say that they have an amphiphilic character.

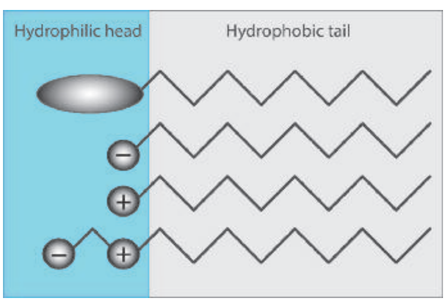
In the case of poloxamers, the poly(ethylene oxide) (PEO) block serves as the hydrophilic part and the poly(propylene oxide) (PPO) block as the hydrophobic part. The difference between those blocks is minimal, with only an additional methyl group being present in the PPO block compared with the PEO block. Although this is a small difference, the extra carbon atom induces a more hydrophobic character of the PPO, making it the hydrophobic tail and the PEO block the hydrophilic head.

## And how does the surfactant work again?

The surfactant lines up at the interface between either two liquids or liquid and solid. The hydrophobic part of the molecule gets away from the water and the hydrophilic part stays close to the water. When dirt or grease is present (hydrophobic in nature), the surfactants surround it (forming micelles) until it is disconnected from the surface. The dirt molecules are actually

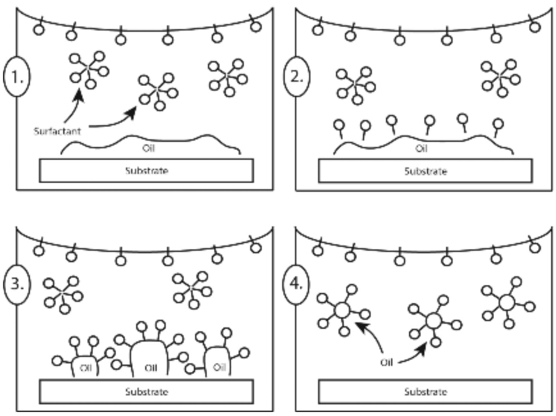



Structure of ABA triblock copolymer.

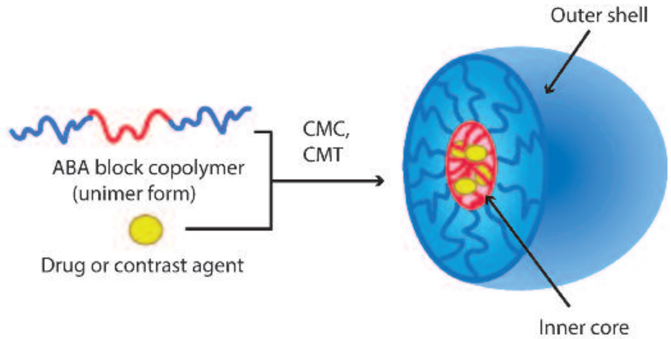



Surfactants classification according to the composition of their head: (top to bottom) non-ionic, anionic, cationic, amphoteric.


Chemical structure of poloxamers: PEO serves as the hydrophilic part and PPO as hydrophobic part of the molecule.



Surfactant mode of action: 1. Substrate covered with oil. 2. Surfactant surrounding oil. 3. Formation of surfactant's micelles. 4. Oil is surrounded, lifted, suspended and dispersed in the solution, leaving the substrate's surface clean.



Micelle formation and drug encapsulation.

suspended in solution. Now, simply by washing off the detergent we obtain a clean surface.

## How do poloxamers work?

Poloxamers also organise themselves in the solution, forming micelles, multimolecular spherical aggregates that consist of a hydrophobic core and a hydrophilic corona. Micellisation (the process of micelle formation) occurs above the so-called critical micelle concentration (CMC) or critical micelle temperature (CMT). At low temperature and concentration, poloxamers are dissolved in water as unimers or single units, if the concentration and/or the temperature rises, then an association of the hydrophobic blocks occurs, leading to the formation of micelles. The diameter of Pluronic micelles typically varies from about 10 nm to 100 nm.

## Poloxamers for dishwasher tablets

Due to the surfactant properties of poloxamers, they were soon recognised as perfect candidates for automatic dishwasher tablet formulations. They not only lower the surface tension and help water to sheet off the dishes' surface, minimising the appearance of water spots, but they also form little or no foam that would inhibit the washing action. Other applications where foaming must be significantly depressed include laundry detergents and rinse aids.

Because of their mildness, poloxamers are also commonly used in cosmetic products for personal care like mouthwashes, lens cleaning solutions, skin cleansers, shampoos and conditioners.

## How do we cross the gap between cleaning and patient treatment?

The answer is hidden in the amphiphilic nature of the poloxamers. Oil and grease are chemicals of highly hydrophobic nature. It just happens that most of anticancer drugs exhibit the same characteristics. As a consequence, they are poorly soluble in water. To enable their successful delivery to the tumour tissue, special platforms are needed, called delivery carriers. They increase drug solubility and stability, as well as their pharmacokinetics and biodistribution.

Looking for an ideal delivery system, researchers noticed that Pluronic micelles have very appealing properties. The hydrophobic core of the micelles is perfectly suited for the encapsulation of highly hydrophobic drugs, while the hydrophilic shell provides stealth properties to the micelle. The latter ensures the maintenance of the micelles in a dispersed state and minimises any undesirable drug interactions with the surrounding environment (e.g. cells and proteins). As a result, micelles can circulate in the bloodstream for a longer period of time, increasing chances for accumulation in the tumour.

Cancer patients are administrated the drug-loaded poloxamer micelles via intravenous injection. Travelling through the bloodstream, the micelles reach the cancer cells in two ways:

- *Via passive targeting:* Pluronic micelles easily escape from the leaky capillary beds and accumulate in pathological tissue having poor lymphatic drainage. This mechanism of tumour targeting is called passive targeting and is possible because of the enhanced permeability and retention (EPR) effect.
- *Via active targeting:* Poloxamer micelles can also be engineered for active targeting by coupling ligands or addition of pH-sensitive moieties. Various ligands such as different sugars, transferrin, folate residues, and peptides were thus attached to Pluronic micelles.

## Take-home message

I hope you are all convinced by now how versatile poloxamers can be. It is probably not a crazy idea any more to find the very same poloxamer on the labels of the cleaning products in your house and think of them also as a potential delivery carrier for treatment of cancer patients.

**Karolina Morawska** is at the Polymer Chemistry & Biomaterials Group, Ghent University, Belgium. Reused, with permission, from www.yourformula.eu/internalposts/poloxamers-chemistry-cancer. References available online.

# E-cigarettes – more than a health issue

E-cigarettes are often considered as battery-powered substitutes for cigarettes. They are designed to deliver nicotine and/or other substances as an aerosol that is then inhaled. The e-cigarette is argued by some to be an important weapon in the arsenal of people attempting to quit smoking.

However, in Australia there is currently a hidden mini-battle being waged between health and epidemiology experts: those for and those against e-cigarettes. While this battle is raging, one cannot legally buy e-cigarette liquids containing nicotine.

Laws covering e-cigarettes vary quite confusingly between the states. While possession or use of nicotine in e-cigarette liquids without approval is illegal across the whole country, the sale of non-nicotine e-cigarettes is only illegal in some states. Despite this confusion, the use of e-cigarettes by Australians has increased remarkably over recent years. There are virtually no controls for the purchase of nicotine-containing e-cigarette liquids via the internet.

Those arguing for e-cigarettes make the following case: if an individual wants to stop smoking and the e-cigarette helps them to do so, then that is a good thing from a health point of view. The medical risks associated with e-cigarettes, they argue, are almost certainly substantially lower than those associated with smoking cigarettes because of the absence of any number of the carcinogens that are prevalent in cigarette smoke. This conclusion is based on all sorts of technical work, which of course cannot be conclusively correlated with any epidemiological data related to health risks – this would take decades. Indeed, if there are no, or even low, risks, then the absence of a correlation between e-cigarettes and health risks could at some point be falsely attributed to a failure of the testing regime and not a lack of health risks.

The arguments against e-cigarettes are varied. One cohort argue that e-cigarettes may act to introduce nicotine to users (usually children according to press releases) that may later convert to the real thing. This reminds me of the old joke where an individual takes up smoking to wean him- or her-self off nicotine patches. Another argument uses the unknown risks of passive inhalation of toxins resulting from 'vaping' (the verb associated with the use of an e-cigarette). And yet another position is the untested toxicological impact of e-cigarettes to users. Some work has been done in this area, and e-cigarettes look far less harmful than cigarettes. And yet, opponents of e-cigarettes have suggested that we wait for more definitive data.

There is also an underlying ethical debate in this battle for the hearts and minds of our lawmakers. Those in favour of a ban do not want to see any new forms of potentially harmful drugs or drug delivery platforms being made lawful – their ultimate goal is to have all such drugs and delivery methods banned by law. The more practical specialists in the area note the relative harmfulness of e-cigarettes and cigarettes and punt for the lesser of the two evils. They also note the failure of any current laws that ban drugs to do anything other than to drive up costs and increase the risks of low quality control by manufacturers and distributors.

At a deeper ethical level, we as a community have seceded many of our personal freedoms to our various governments, their administrations and key advisors. This triumvirate weighs up the public health cost-benefits of a new drug delivery platform such as e-cigarettes, and then adds in a risk assessment for personal health risks, and then further spices the calculation with their own self-interests associated with avoiding negative publicity from those opposed to e-cigarettes. Currently, they refer to an absence of definitive data in order to defer making any decisions on the matter. Wise or weak, I cannot say.

The percentage of people smoking cigarettes in Australia has dropped from


**This e-cigarette comprises a mouthpiece; a refillable reservoir for the e-liquid (which may contain propylene glycol, nicotine, glycerin and flavouring substances), which is vapourised by the heating element below it; and a battery/circuitry.**

a peak of over 40% of the population in the 1950s to around 15%. Key influences in this dramatic drop have been consistently negative health messages, increased personal insurance rates, increased cigarette prices, a ban on marketing, plain packaging, the creation of certain social stigmas, and a ban on smoking in various physical environments.

The rate of people taking up smoking

**Some proponents for e-cigarettes fear that the proportion of smokers in the population will plateau due to a lack of further restrictions that can be made without an outright ban on cigarettes.**

for the first time has continued to decrease over the years. But just as importantly, the relative rate of existing smokers who have quit has also been maintained over time. Physical aids such as nicotine gum and nicotine patches have been quite instrumental for those giving up the habit.

Some proponents for e-cigarettes fear that the proportion of smokers in the population will plateau due to a lack of further restrictions that can be made without an outright ban on cigarettes. Indeed, the e-cigarette is now considered by some to be a next key tool for weaning people off cigarettes. Others are promoting further price increases, a license to smoke or a prescription to smoke.

One risk that we all have is that there are campaigners who make a good living off this cause. No matter how successful they are in reducing the degree of cigarette usage in our country, they will fervently chase the remaining few smokers with determination, ignoring the Pareto rule, which implicitly underpins all matters of public health cost-benefits. Once nicotine has been vanquished, these campaigners won't just go away; they are incredibly organised and they need to eat. They will then target other habits of our daily lives that they find offensive. They scare me a little and there may come a day when we have to ban them as well.

## Australian regulation of e-cigarettes*

- As a recreational product, nicotine is classed under Schedule 7 of the Commonwealth Standard for the Uniform Scheduling of Medicines and Poisons (Dangerous Poison).
- It is illegal to sell e-cigarettes that contain nicotine.
- It is illegal to use nicotine in e-cigarettes without a prescription or other authority.
- In Queensland, it is legal to sell e-cigarettes that do not contain nicotine under the same conditions as for tobacco products. In some other states, it may be illegal to sell e-cigarettes even if they do not contain nicotine.
- No e-cigarettes (with or without nicotine) have been registered with the Therapeutic Goods Administration.

* This is a general overview and not intended as specific legal information. Information is current at July 2015.

## Further reading

https://theconversation.com/viewpoints-should-australia-lift-its-ban-on-e-cigarettes-28410
apps.who.int/gb/fctc/PDF/cop6/FCTC_COP6_10-en.pdf?ua=1
http://cen.acs.org/articles/92/i10/Controversy-Clouds-E-Cigarettes.html
https://www.tga.gov.au/community-qa/electronic-cigarettes
http://otru.org/wp-content/uploads/2013/11/e_cigarettes.pdf

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

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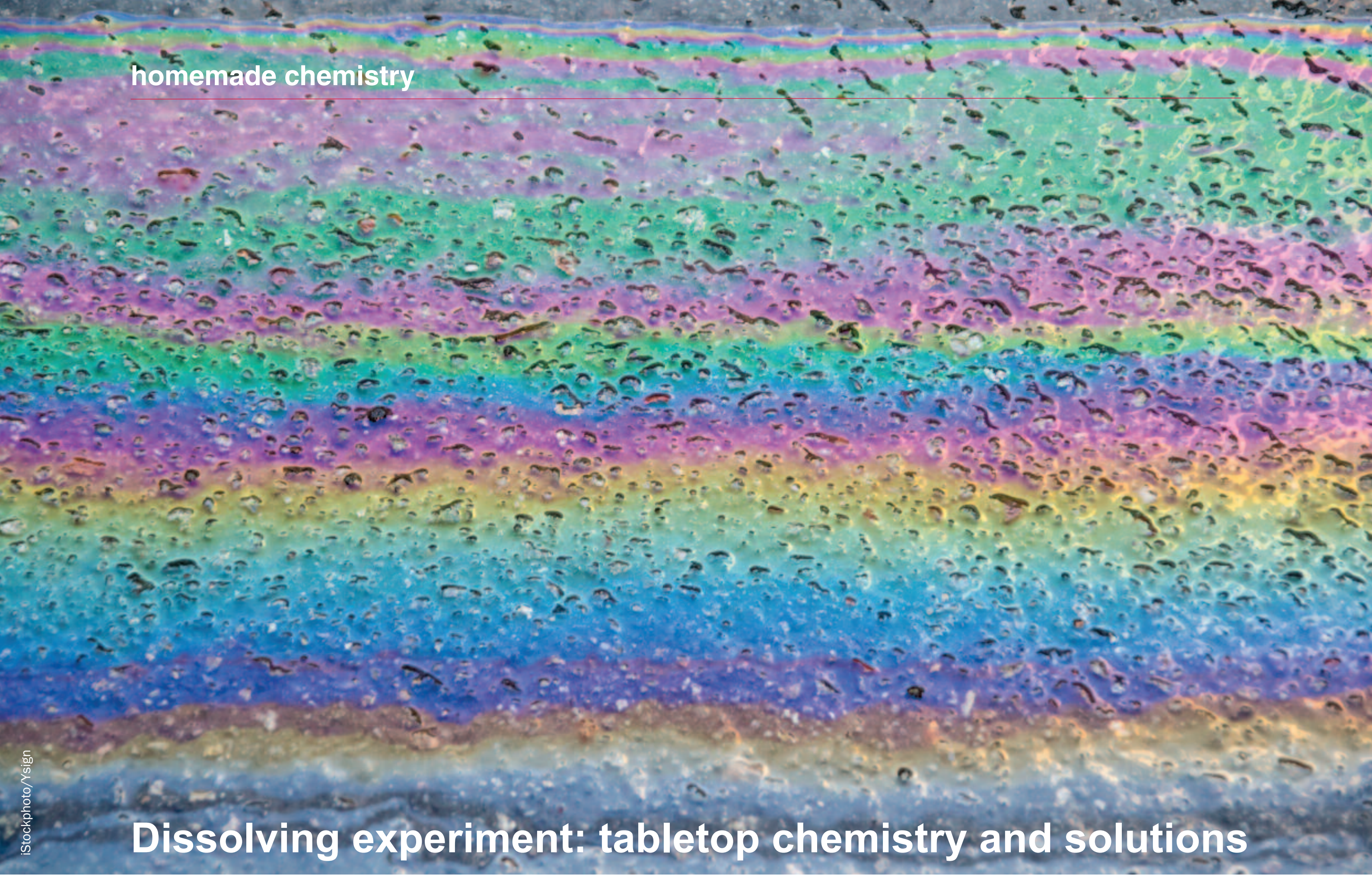
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# Dissolving experiment: tabletop chemistry and solutions

## You can conduct a simple kitchen experiment using tea and some honey to teach children how to observe the basic chemistry rule 'like dissolves like'.

On a rainy day, oil slicks appear on the road. Cars and other combustion vehicles leave their calling card in the wake of start–stop traffic.

Certain oils from cars will not dissolve in water – this leaves the rainbow-hued oil patch you see on the road.

Is there a teachable moment here? The obvious statement that oil and water will not mix may lead you and your kids to speculate on gradients of oil and water mixing.

### Unlike solutions will not mix

Place three glasses of water side by side, each with a drop or two of food colouring added so that they're all different colours.

Dissolve salt into the water of one glass. Try to add the briny solution (a drop at a time) into one of the other glasses of coloured water. The brine will sit atop of the water coloured solution (it will not dissolve).

This instance, similar to the original gasoline and water phenomenon, further illustrates how one substance cannot dissolve in another.

How can two such different substances mix?

### Chemistry in the moment: a kitchen table experiment

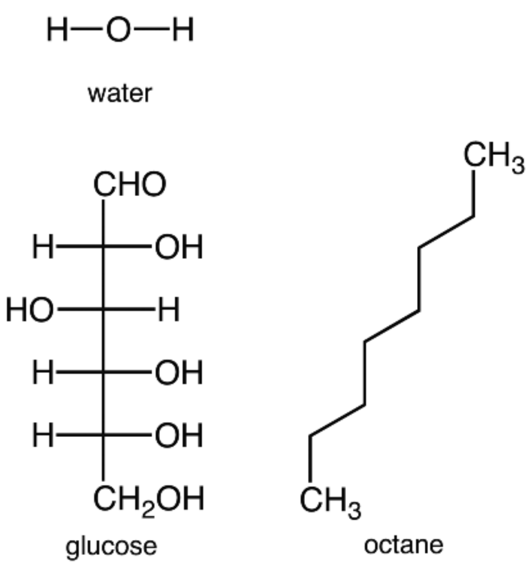
There's a proven concept in chemistry that states: like dissolves like. If you're trying to dissolve two substances – watery substances will readily dissolve other watery substances.

A set of three glasses contain three solutions – each a different colour (or substance). The first contains black tea, the second contains green tea and the last vessel contains honey. The black and green teas dissolve together easily.

Pouring green tea into the glass containing honey, however, produces a watery mixture that will stand atop of the honey. Adding sugar to the green tea first will force the mixture to dissolve readily when you add it to the honey.

### How does 'like dissolve like'?

The chemist's adage of 'like dissolving like' is where the teachable moment comes into play. Although the oil and water will never naturally mix, quick experimentation allows for further exploration of the concept. Scientists term water the 'universal solvent'; it may be manipulated to suit a variety of different situations.



Dissimilar molecules: water, glucose and octane.

Cold water dissolves salt, but not sugar. Heating the water allows the sugar to dissolve and (more) rapidly dissolves the salt. Sugar is a molecule that is part carbon and part oxygen/hydrogen. The molecule half resembles grease. Water is a tightly packed group of $H_2O$ molecules – it is packed tightly because of its size, and contains no other atoms (there are no carbon atoms).

Water dissolves molecules similar to it. Sugar will dissolve in hot water for several reasons: (1) molecules of hot water are not tightly packed (as in the colder alternative); (2) the warming sugar molecules also lose cohesion with one another; (3) the molecules can make room for one another – and allow for solvation.

Perhaps the best illustration would be to attempt to dissolve sugar into solid water (ice?) – it doesn't work that way, does it? Thus, pure gasoline, termed octane, is all carbon and hydrogen (with no oxygen) atoms. Water, as illustrated, is dissimilar to octane and will not dissolve it.

## Where does that leave us?

Bringing experimentation to a familiar setting – the kitchen table – allows a more relaxed conversation to occur. Avoid chemistry 'jargon' at first, and then add in the correct terms as your child becomes interested.

All too often, we grope in the dark to find the appropriate response to questions that seem beyond our reach, and base our answers on an intuitive gut instinct. However, as is the case with all hard science, chemistry is an experimental endeavour.

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**John Jaksich** holds a BA in chemistry from California State University East Bay. He writes for Decoded Science, Decoded Plants and Decoded Everything, covering various chemistry topics. This article republished, with permission, from decodedparenting.com.

# It takes a community to raise a chemist

Once upon a time in the 1980s, a teacher at my children's primary school suggested that I help her with interactive science lessons for year 5. As I was asking questions of the students, she was able to observe the children, and was often amazed at their inventiveness when they explained, in their very own words, 'why' something had happened.

Another teacher at the school 'used the children as her resource'. She encouraged her year 1 students to bring in interesting items for the science table – everything from a rock to a feather or flower to a dead lizard – then involved the whole class in researching them. I encouraged her to write up her methodology and enter a science teachers' competition. She was Highly Commended; named in the top 12 in the nation along with high school teachers.

Two decades later, I was delighted to be offered a Scientists and Mathematicians in Schools (SMiS) partnership with this school, and to find the award-winning teacher still there – now teaching environmental science to every class.

Scientists and Mathematicians in Schools (www.scientistsinschools.edu.au) is funded by the Australian Government Department of Education and Training and CSIRO Education. They employ coordinators in each state who match scientists and schools, provide online resources and face-to-face workshops, organise the Working with Children certificates and give personal advice and moral support. The scientists are all volunteers, and the schools provide teacher support from their own budgets.

Each partnership (= scientist + school) develops its own programs. A relative of mine who is active in the scheme (and persuaded me to register) attends different schools on an occasional basis. He gives talks on his professional topic, or supervises senior projects, or sets up in-class demonstrations. I prefer a close association with one class in one school for a whole term, mentoring the teachers as well as the students.

There is now a second SMiS (a chemist-parent) at the school I attend, and together we supervise a group of years 4–6 students undertaking projects of their choice, often using the environmental science garden. We are fortunate to have had two supportive, enthusiastic principals over several years.

Despite the headline, we go gently on the chemistry. Our real aim is to instil some basic scientific thinking, practice and reporting. Following guidelines from many resources, we insist on the following: dating all entries and writing in ink on numbered pages; accurately recording measurements and observations; using replicates and controls where time permits; changing only one variable at a time; and writing down references and personal acknowledgements. We help our Superior Scientists analyse their results, suggest appropriate graphs and diagrams and encourage them to make conclusions that refer back to their predictions. Most importantly, we push them to ask themselves and each other 'why'.

At the beginning, I ask them to see if there is a hobby that contains no science. After 30 years we have never found one. The children become engaged in thinking of an interesting project topic, and it establishes a culture of interactive discussions where nothing is right or wrong.

Having analysed our own results, we are pleased to report that all 35 students over three years have produced posters of their work for display in science week. Each child has developed new skills in learning independently and managing his or her time, and their parents have been amazingly supportive.

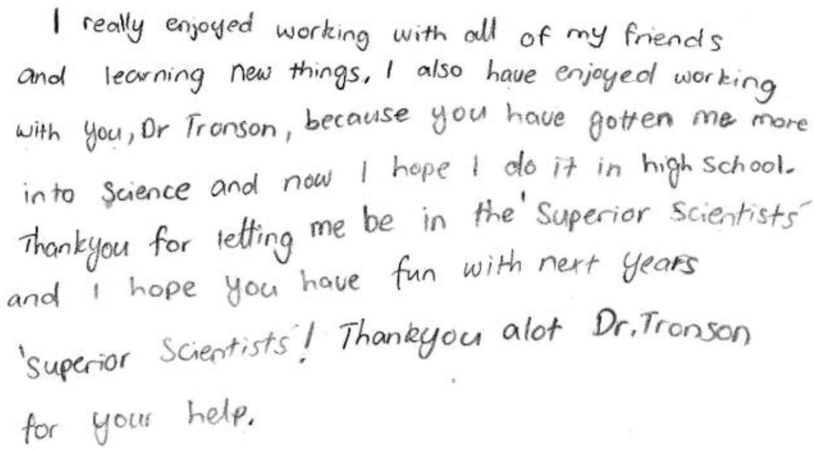
One of our conclusions is that entering competitions is not for us. The school is a busy one and the children have competing interests (their talents are not confined to science). The competition requirements don't suit our timeframe. Some students will learn more science by doing a literature-type search and developing associated demonstrations, as shown by posters on 'rainbows' and 'polarised light' (celebrating the Year of Light). The boy investigating the workings of fluorescent lights was interested to talk about tungsten, mercury, the periodic table and spectra, but he didn't investigate these ideas further. I know that he will understand these concepts when he hears of them again. Another student comparing the hardness of minerals ('The Ore Wars') wondered why the pictures of different materials all looked like diamond. Using a molecular model kit, he had an 'Aha' moment when he recognised that diamond and boron nitride had similar tetrahedral structures, but with different atoms inside.

Some kids do prefer the activity of experiments in the garden, and the results are a revelation to them, if not new enough to science for a competition entry. Two year 4 girls (wearing gloves) thoroughly enjoyed mucking about with different manure slurries in order to compare their effects on growing plants (see photo). One boy compared various methods of trying to kill stinging-nettles (following all safety directions). A photo entitled 'Why is D watering the weeds?' was published in the school newsletter with an explanation of the importance of a 'control'. His analytical thinking skills blossomed and he won the year 6 science prize that year.

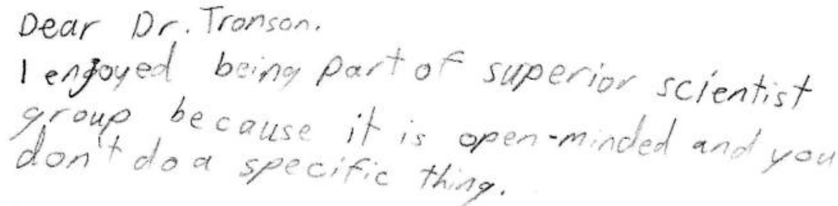
This year, we have added a science fair to our poster day, and our Superior Scientists are developing activities to illustrate their projects. During the panic of the final preparations, two year 4 boys were setting up the matchstick race (you dip a finger in detergent and place it behind your own floating matchstick, which then scoots along). When asked 'why', one of them told me that the detergent spread the water out. They confirmed that they knew about molecules (!), so we discussed the concept of a 'skin' on the water due to attraction of water molecules. Then the other boy's eyes lit up as he said 'so that's how the matches get pushed along'. They wrote a beautifully worded paragraph for their poster, in their own year 4 level plain English (yes, yes!).

I find it stimulating to listen to kids' ideas. I particularly like taking classes with the uninhibited littlies, but I was chuffed when one high school science teacher thanked me for working with year 6 because she said those students were well prepared for year 7. My philosophy is that it is important to learn to ask 'why' and be introduced to a variety of ways that help you to find the answer. We all get a kick out of the sense of wonder when children discover something, and the pride they get in what they have achieved.

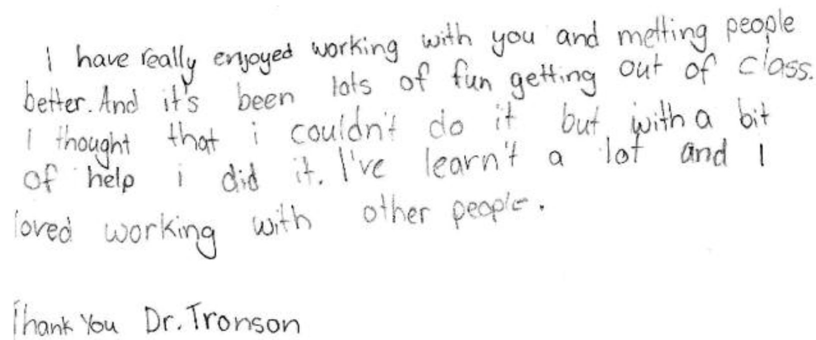
If you are involved in a school community, wouldn't you love a professional scientist to come to your school to help the children? If you are a scientist, wouldn't you love to share your passion with our young future scientists? If you are inspired to join SMiS, please develop your own thing (you can find out more on the website). But remember: if you are a scientist, you have to respectfully fit into the school's culture and timetable; if you are a teacher, please ensure you continually communicate with 'your' scientist (using dates, not numbered weeks). Finally, from our experience of a teacher and two scientists, we suggest you give the children two notebooks to work with – and one of them stays at school and never leaves the classroom. While not a perfect solution to the 'dog ate my science book' syndrome, it is the best solution we have found so far.


I really enjoyed working with all of my friends and learning new things, I also have enjoyed working with you, Dr Tronson, because you have gotten me more into Science and now I hope I do it in high school. Thankyou for letting me be in the 'Superior Scientists' and I hope you have fun with next years 'Superior Scientists'! Thankyou alot Dr. Tronson for your help.

From a year 6 girl who successfully (after discussion) managed her time during the year to fit in the project as well as some high-level sporting commitments. Her final poster had little flaps with extra information underneath.


Dear Dr. Tronson.
I enjoyed being part of superior scientist group because it is open-minded and you don't do a specific thing.

From a year 6 boy who has a natural understanding of gears and could explain their workings (and made models of them).


I have really enjoyed working with you and melting people better. And it's been lots of fun getting out of class. I thought that i couldn't do it but with a bit of help i did it. I've learn't a lot and I loved working with other people.

Thank You Dr. Tronson

From a very shy year 4 girl who was taken under the wing of one of the year 6 girls. She learnt some amazing things about the physiology of a ballerina's foot (and how to prevent injury).


**Dr Deidre Tronson** FRACI CChem used to be a mad scientist, but is now the Good Little Banksia Lady who, in retirement, is an enthusiastic member of Scientists and Mathematicians in Schools at a local primary school. She has proudly raised three science graduates. She has had separate careers in research and teaching, culminating in a position as part-time senior lecturer at the University of Western Sydney, Hawkesbury campus.

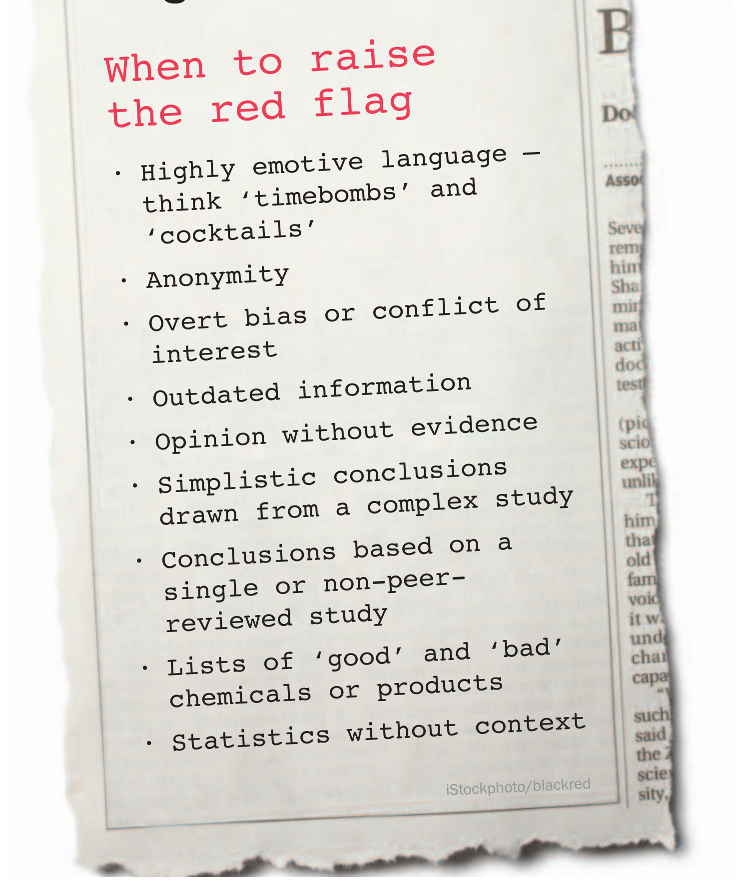
# Thinking twice about media coverage of chemicals

We are surrounded by media – whether it be traditional print, online sources including websites and blogs, product packaging, film, television or radio.

Do you believe everything you read? Or hear? Or see? Of course not. As a unique individual, you bring an individual set of values to every media text you encounter, which helps determine whether you accept a message at face value, reject it completely, or engage in further negotiation to determine whether you will accept or reject it.

The formulated chemical products industry – think cleaning, hygiene, cosmetics and personal care – faces some texts that perpetuate misinformation about our industry. Most relate to concerns with the safety of everyday products and ingredients via claims that are not upheld by scientific evidence.

It is important to be able to critically evaluate the texts we encounter every day. This is because media texts are not neutral and natural, they are value-embedded constructs of reality: a product of authors making choices and manipulating creative tools to target a particular audience. And they have a particular purpose – often to sell a product, service or ideology. Key questions need to be asked: Who constructed this? For what purpose? What are the author's credentials? What values and points of views are represented, or omitted? Are they providing opinion or fact? Are they qualified to provide this information? Could they be misinformed or misunderstand an issue? Do they back up claims and can information be verified via other reliable sources? And – ultimately – should I take action as a result?



iStockphoto/blackred

Lipstick is often in the firing line. 'Chemicals in lipstick and cleaning products linked to early menopause' was an early 2015 headline in *The Australian*. 'Poisonous puckers' did the rounds in the US a couple of years ago. Search for 'lead in lipstick' and your browser will return many pages listing lipsticks by their lead levels or identifying lead-free lipsticks ('safe, non-toxic make-up') – this is despite regulators in Australia, the European Union, the US, and Canada agreeing that the levels of lead in lipstick pose no risk.

When texts like these are amplified via online news sources, blogs and websites, they can generate unwarranted alarm in the community. Another example, covered in the July 2014 issue of *Chemistry in Australia* (p. 35), is where sunscreen 'nanophobia' was resulting in some Australians not using sunscreen because of unfounded safety fears.

To combat unfounded fears about chemicals and everyday chemical products, Accord developed the www.furphies.org.au website. As well as providing information on some of the more persistent myths, Furphies also provides guidance on critical evaluation of media on chemical-related issues: how to work out if an issue is worth your concern, or is simply a 'beat-up'.

For example, Furphies cautions people to be wary of:

- phrases such as 'associated with' or 'linked to'; these do not mean that a causal connection has been established
- the phrase 'found in'; just because a substance is present, whether in a product or in the human body, doesn't mean that it has an adverse effect – any substance can be harmful in certain quantities, or in the wrong place, or if used in the wrong way
- comparisons of humans and animals; animal studies where high doses of a substance cause adverse effects do not necessarily mean that humans will show similar adverse effects when metabolising very low doses of the same substance.

Be especially wary of online media. Anyone can post information or broadcast their opinion – but how can we know that what we are reading is accurate and unbiased, or even current? For example, Wikipedia is written and edited by anonymous authors, making it 'the source where you can be an authority even if you don't know what the hell you're talking about' (Steve Colbert, referred to at bit.ly/1Ll9qKR).

Of course, Furphies itself is not agenda-free. The goal of Furphies is to erode misconceptions about chemicals and everyday chemical products through careful presentation of evidence and by encouraging critical evaluation of media. It aims to promote more balanced thinking when encountering media texts and avoid undue public alarm.

Please check it out and spread the word!

**Jennifer Semple** MRACI CChem is Education and Sustainability Manager at Accord.

# Wine and sensory stimulation

Sensorial analysis of wine is now a well-established science. The skills of the taster include developing a meaningful vocabulary to maintaining a consistent ability to recognise and describe the aroma and taste sensations. While this is all great science, wine is meant for consumption and pleasure, to simulate the senses. This column addresses some factors that assist in sensory stimulation when drinking wine.

## Serving temperature

Serving wine at its optimum temperature is essential for the most effective sensory stimulation. White wine is often served too cold, which does not allow the subtle aromas to be sensed when nosing the wine, and if the wine has been aged in oak, the oak aromas can dominate the wine characters. Here, I can be critical of myself as I tend to place the white wine in the refrigerator and then forget to get the bottle out until just before I open it. In reality, for most white wines, just 1–2 hours in the refrigerator before serving is sufficient and unless the dining area is warm or outside, an ice bucket is hardly necessary.

If a wine is too warm, the aromas will be readily lost when the bottle is opened. The palate may be dominated by alcohol and there is a loss in palate structure: the terms 'flabby' or 'fat' are sometimes used. In summer, there is an advantage in refrigerating a red wine for 15–20 minutes before serving. The idea of serving red wine at 'room temperature' developed from bringing wines from the cellars of chateaus to the dining room before a meal so that they could come to room temperature.

Many wines now have a suggested serving temperature on the label, which is obviously a good guide. For me, a stronger white wine such as Chardonnay or Viogner should be served around 15°C, while 10°C is more appropriate for delicate whites such as Riesling, with Sauvignon Blanc being somewhere in between. Sparkling wines are better when cooler, perhaps around 7°C, although the richer, high-quality sparkling wines are better closer to 10°C. Red wines seem best between 16°C and 18°C, with the richer reds at the upper end of this range. Lighter reds and rosés can be served at a lower temperature. It is trial and error really, until you are satisfied with the outcome that is best for you. I find it helpful to take notes as a memory guide.

## Wine and food

Harmony in taste between wine and food can bring about a stimulation of the senses. There are no hard and fast rules, although I grew up thinking that red wine and fish do not mix and a Japanese study in 2009 seems to support this (bit.ly/1fupVeG). On the other hand, I have had a very pleasant fish meal in Porto with a red wine from the Douro Valley. In reality, I suspect that tradition in both wine and food in a region is often the dominating feature in selecting wine to match a dish. In the Jurançon region of France, a sweeter white wine is often paired with goose to help cut through the fat and in Bordeaux, oysters may be paired with a Sauternes.


iStockphoto/AndreaAstes

Increasingly, wine labels have suggestions for food pairing. To some extent, this is an outcome of supermarket pressure, but winemakers, who spend a considerable amount of emotional energy in creating a wine, would prefer that their creation is not swamped by inappropriate food. In a restaurant, a sommelier is responsible for proposing wines to match individual dishes. Once in Montpellier, we asked for a Picpoul, a regional dry white, to pair with our entrée. The sommelier recommended against this choice, and on tasting the entrée, we accepted his proposal for an alternative wine. On another occasion, the chef appeared at our table and complimented our host for the wine he had selected to pair with her main dish. Seeing the chef appear at the table momentarily brought images of the Monty Python 'dirty fork' clip to mind!

## Wine and passion

Wine has long been associated with passion, as expressed in art, literature and music. Opera, especially Italian opera, is no exception. In Verdi's *La Traviata*, there is a beautiful brindisi (*Libiamo ne' lieti calici*) in the first act. A brindisi is a toast or drinking song and here Alfredo sings '… let's drink from the joyous cups, that beauty so truly enhances … Let's drink for the ecstatic feeling that love arouses … Let's drink, my love, and the love among the chalices will make the kisses warmer'. Violetta replies '… everything in life which is not pleasure is foolish. Let's enjoy ourselves for the delight of love is fleeting and quick …' And so on it goes. Check out the flash mob performance at bit.ly/1vq64ox. There are several other examples of wine in opera at bit.ly/1hSEc6A.

The brindisi from *La Traviata* and other arias and duets by Puccini, Cardillo, de Curtis and Leoncavallo were sung at the opening social event at the *In Vino Analytica Scientia* conference held in July this year at Trento in northern Italy. It was undoubtedly a great way to start the conference, although the only difference from so much opera is that the lead singers were not killed or did not die of a broken heart at the end! Rather, the tenor and soprano with their accompanist joined us for the matching wine, cheese and bread tasting. It was the first time for me that I have encountered bread specifically baked, using traditional recipes and local ingredients, to enhance the characters of the local cheese and wines. Overall, it was a rather stimulating experience.

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

# Peering into peer review

A large part of a scientist's life (especially an academic scientist's) revolves around publishing research results. So if you overhear a group of scientists talking about a 'paper' they just read or published, it is fairly unlikely they are referring to the *Sydney Morning Herald* or *New York Times*, but rather to a peer-reviewed publication.

I sometimes find it hard to explain to my non-scientist friends or family just what a big deal a publication (or paper) is to a scientist. After all, in this era of digital domination by the twittering blogosphere, publishing something either online or off hardly seems like something to be brag about. So perhaps I can explain what makes me so proud every time I have a paper published and bring a better understanding of what it takes for a fledgling researcher to have a paper these days.


iStockphoto/Ellagrin

Every paper starts with an idea; often it is a grand one requiring interdisciplinary collaboration, but sometimes it is a simple one that a single student can work on. The one intractable requirement, however, is that it is a unique one: researching something that has already been done is, after all, an anachronism.

Once you come up with an idea, you go into the lab (or clean room, or synchrotron or whatever) and do a bunch of experiments that test your hypothesis and see if what you envisioned sinks or floats. The lab is where many good ideas meet their match in the face of undeniable scientific evidence. But a good researcher can work around many obstacles in creative and innovative ways to germinate the seed of an idea into a plant of a result. And when you do, there is that great 'Eureka' moment. Fists are punched in the air, whoops of cheer are enjoined and high-fives proffered and accepted (but thankfully, due to health and safety regulations, very few aged Greek men are noted running down corridors dripping bathwater). This, as it turns out, is often the easy part.

Next you harvest your result and analyse it in as many ways as you can think of. The only reliable result is one that stands up to intense scrutiny. The scrutiny is important for what will come next because then you have to convince the world that your result is a true, reproducible, original and important one. It is then that you refine your result, telling all who will care to read why you did what you did, how you did it and what you discovered. This story then goes through a first round of scrutiny where all of your collaborators check and criticise it to make sure the story is solid and an accurate representation of what actually happened (minus the high-fives). This is usually the least harrowing part.

Now that your story has been read, edited and approved by those who had a hand in its creation, it is time to see how it survives in the wild. So you send the manuscript to an editor of a scientific journal. The editor then makes a decision: is your story right for her journal? If so, she sends it on to a few more scientists to ask for their opinions.

Sometimes the reviewers will love your paper. Sometimes they will disagree entirely with your results. Sometimes they will fail to see the point. Sometimes they will offer insightful suggestions that really strengthen your paper. In the end, you hope that the editor has sent it to your peers who will review the work with a critical but fair eye.

The reviewers send their comments back to the editor who either decides your paper will not be published in her journal or green-lights it (with or without changes). This is the true vindication stage. You know that what you have accomplished has met with the approval of your peers after a lot of inspiration, perspiration and determination, and it is one of the greatest feelings in the world. It's especially true of the first paper your publish – there is so much pride in seeing something you've worked so hard on go through so many critical eyes before being a tangible, eternal commodity. It is certainly not a feeling that can readily be replicated using Facebook, Instagram, Tumblr or Twitter.

But there is something else that I find incredible and incredibly satisfying about seeing my publication in print. It is that every single person who viewed and reviewed it after I sent it to the editor did so absolutely for free! It is pure love of the game that keeps everyone playing and somehow that makes the victory even sweeter to think that your peers are people as enthusiastic and engaged as you and that they read your work and granted you the highest honour in the land: a scientific publication.

The author both peer-reviews and is peer-reviewed in Lausanne, Switzerland.

# Aussie chemistry in times of war

The centenary of World War I is a boon to the 'looking back' industry. Media coverage and recently published books concentrate on the military and on social impacts of the war. There was a lot of chemistry going on, too, but chemical stories of the period are usually drowned out by the attention paid to the ill-fated invasion of Gallipoli. The stories do cover the use of poison gases by both sides, new explosives like Lyddite (picric acid), and the process developed by chemist Fritz Haber and engineer Carl Bosch to take nitrogen from the air and convert it into ammonia. A further step converted ammonia into nitric acid, paving the way for explosives and fertilisers.

All this chemistry happened in the northern hemisphere, but something just as interesting (at least to a chemist with an interest in history) was taking place in Melbourne. At the time war broke out, the pharmaceutical industry in Australia relied almost entirely on Britain and Germany for the supply of drugs. British drugs continued to be available here, albeit in limited quantities because of increased need for them 'at home' and limitations on the availability of transport ships, but also because marine warfare meant that not all ships made it to their intended destinations.

Drugs manufactured in Germany were, for obvious reasons, unavailable, but there were glimmers of hope that the necessary substances could be manufactured locally. That glimmer brightened when the Australian government suspended the patent and trademark rights of German inventors. This meant that Australian companies were free to manufacture drugs that had formerly been protected by patents that gave inventors sole rights for periods like 20 years.

Several hurdles confronted prospective manufacturers in Australia. First, they had to have access to raw materials and learn how to use them to manufacture the drugs. Second, the government required proof that the Australian company really could make chemical substances identical to the imported ones. And third, there was opposition in the profession to the use of German trade names because using them would be valuable marketing tools for successful manufacturers – something their competitors were to fight hard against.

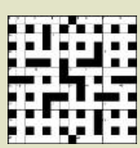
You might have guessed by now that I am writing about Aspirin (a trade name of the Bayer company) and the Australian look-alike Aspro, manufactured by the Nicholas Company. The chemical name for this mild analgesic (pain-relieving) drug is acetylsalicylic acid, so you can see that a producer would shy away from such a mouthful towards some snappy marketing name. The starting material for the production of acetylsalicylic acid is, unsurprisingly, salicylic acid. Salicylic acid occurs naturally in the bark of the willow tree (*Salix alba*), and folk medicine had recognised its analgesic (pain-killing) properties but also the fact that it is rather corrosive. A paste of salicylic acid applied to a skin excrescence like a wart or a whitlow eats it away more-or-less painlessly but it's not the sort of substance you want in your mouth or your gut. Aspirin (acetylsalicylic acid) is a less irritating but still effective drug, formed from salicylic acid with acetic anhydride as described in the British patent (No. 27 088), granted to the German company Bayer in 1899, and in its 1900 US patent (No. 644 077).

Part of the art of composing a patent is to give enough detail to convince the government patent examiner that something novel has been, or could be, done by the inventor but not enough detail to make it easy for an imitator to repeat the process. This was the dilemma faced by Harry Shmith and George Nicholas who set out to manufacture the drug, knowing only the basics but not the fine detail. They took advantage of the fact that the purity of a solid organic substance can be checked by measuring its melting point and comparing it with that of the authentic substance as described in a patent or in the research literature. The presence of an impurity lowers the melting point so a good melting point is an indicator of purity. The starting material, salicylic acid, and the desired product acetylsalicylic acid, are white solids, with melting points 159°C and 135°C respectively. Acetic anhydride is a liquid, as is the by-product of the reaction, acetic acid. After the chemical reaction, the acetic acid and any unconsumed anhydride must be removed and the product purified. Getting a pure product, free of the two liquids and unconverted salicylic acid, is the tricky part and the local manufacturers struggled with it.

Eventually they got there, and presented their results to the Commonwealth government, seeking approval for manufacture of the product that was soon to be named Aspro. The government had their chemists on the job, too, and despite the new product having a good melting point, they subjected it to a further test. Salicylic acid mixed with iron chloride solution gives a bright purple colour, but acetylsalicylic acid does not, so this is a sensitive test for the obvious impurity. The local product passed, and permission to market it was granted in September 1915. Modern spectroscopic methods have largely replaced colour tests such as this but the older literature is full of them, often based on esoteric chemistry that is forgotten today.

Shmith and Nicholas never had a purple patch but their aspirin was the genuine article.

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



**November crossword**

For our regular readers, the November edition of the crossword is available at www.chemaust.raci.org.au.

# Science Alive in South Australia

The tenth annual South Australian Science Alive event was held on 7–9 August at the Adelaide Showgrounds to coincide with National Science Week activities. The event is designed to showcase sciences to the masses and foster imagination and enthusiasm. It has grown to occupy more than 17 000 $m^2$ of the showgrounds and includes over 50 display booths/exhibits from universities, professional societies, industries and local inventors. The public event is held on the weekend and the Friday is devoted to secondary school students and their teachers as a career day. This year more than 25 000 people attended over the three days, a 30% increase on 2014.

Making sherbet.

The show ended with a big bang with the explosion of hydrogen-filled balloons. Metal salts were added into the balloons to produce firework colours. Here copper(II) chloride has produced green light.

The RACI South Australian Branch has been actively involved in Science Alive for five years, with a mission to present our science with an enthusiastic and friendly face to the young and not so young. Our members run a booth, focusing on hands-on chemistry activities, and support a Chemistry Show held in the main stage area.

The Chemistry Show organised by RACI members and supported by the South Australian Branch is a key feature of Science Alive. Our first show in 2011 was presented by Sci-World, supported by the University of South Australia, and subsequent shows have been organised and presented by chemists from the Universities of Adelaide and South Australia, and this year by Flinders University. This year's show was organised by Dr Justin Chalker, Dr Sue Pyke and Mr Michael Wilson, and celebrated the International Year of Light by demonstrating how molecules interact with and emit light in different ways. Ten shows were presented over three days, with audiences of up to 2000 attending each show. With Justin compering and ten Flinders' students conducting the experiments, the 'traffic light' reaction featured, as did a spectacular trail of luminescence and production of a massive quantity of fluorescent slime. In an attention-grabbing conclusion, not content to explode the usual balloons of hydrogen, the demonstrators used balloons lined with metal salt solutions to produce quite colourful *booms*. The audience participated enthusiastically, answering questions, predicting colour changes and counting down for explosions. The fluorescent slime was later made available at the RACI booth for hands-on investigation by attendees, building our surrounding crowd somewhat. These shows demand much time in preparation and presentation, but the three South Australian universities now rotate the process. The Chemistry Shows have become a highlight of the whole event, generating deafening applause and prompting many subsequent 'how' and 'why' queries.

Beyond the Chemistry Shows, the Branch operates a large booth, powered by volunteers from the Institute, including our newly formed Young Chemists' Group. The RACI booth remains very popular because of the hands-on involvement on offer. In contrast to the 'don't try this at home' chemistry of the Chemistry Shows, we provide an opportunity for the public to safely engage in our science. It's all quite simple stuff, but we endeavour to explain why and how things work in simple terms and always send the youngsters away eager to try simple experiments in the home kitchen 'laboratory'. This year, we had paper chromatography of marking pen ink and we had kids of all ages (from 3 to 80) six deep around six operating stations at all times. We used 1100 filter papers over three days; none was wasted and most people went home as proud chromatographers – all their own work. The next bay was DIY sherbet – similar enthusiasm, but slightly more messy; many kilograms of raw materials disappeared over the weekend to reappear all over the event as a sticky, coloured dust.

The RACI 2011 International Year of Chemistry Periodic Table was on display and explained to many. If there are any of you who have not seen this resource, please look it up on the RACI website – under Periodic Table. It is a real hit with the school students (and some of the oldies!). This year we supplied blank element 'tiles' for the public to present their individual artistic impressions and colours. Finished tiles were then mounted to


One of the completed periodic tables created during a colouring competition.

produce our own artistic periodic tables. Two long tables with chairs were occupied at all times by aspiring artists, producing almost four complete periodic tables. The best efforts were judged and rewarded with a prize (copies of *Let's Experiment* and A3 periodic table posters, courtesy of National Office).

To acknowledge the 2015 International Year of Light, we had a couple of plasma balls and a fibre-optic lamp on display (to touch and feel) and a brilliant display of images generated in the Laser Spectroscopy and Molecular Dynamics Laboratory of Flinders University, titled 'Quantum Conversations – Art of Fluorescence'. Few had any inkling of the scientific work that produced these, but most were enthralled by the intricate patterns generated. Share this experience and look up www.quantumconversations.net for some inspiring images.

Including the Thursday set-up and the long event days, this is a busy time for our South Australian chemistry community, but those we spoke to felt rewarded by the excitement of the crowd, and enriched by the experience. No one yet knows if we have inspired many youngsters to pursue science, but the interest and enthusiasm shown would suggest that we have helped demystify science and create a positive impact on a large cross-section of the community.

**John Mason** FRACI CChem, **Sue Pyke** MRACI CChem and **Greg Metha** FRACI CChem

Colours revealed from felt tip pens by water and filter paper.

chemaust.raci.org.au