

chemistry

November 2014

in Australia
for family and friends

PUBLIC EDITION

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world of molecules**



**Tatts: a novelty that
won't wear off**



**Chemistry at the
movies**





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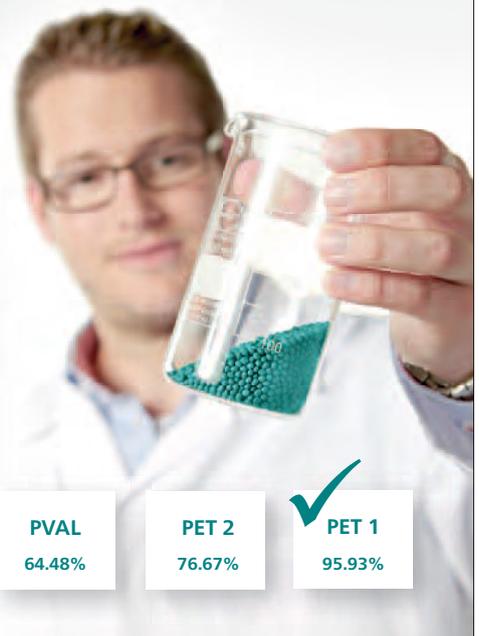
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public edition for family and friends

Chemistry is everywhere, and this month we're sharing it with everyone. Enjoy this special edition, which has news, opinion, feature stories, book reviews and some fun kitchen chemistry for all to understand and enjoy.

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The colour of chemistry

Next year is the UN International Year of Light and light-based instruments. Many institutions and professional organisations around the world will be taking advantage of the year to raise the profile of the work they do, and its value to the community. Not surprisingly, many physical scientists and technologists, from astronomers to quantum computer scientists, are thinking about what they might do during the year.

Surprisingly to some, the year is also being embraced by art galleries, through special exhibitions and interactive installations, accentuating the roles of light and colour, perspective and vision as part of the experience of art.

What might the year mean for chemistry, and chemists?

For me, chemistry and light have always been linked. And in retrospect it seems that light and colour have provided not only me, but also many students and researchers past and present, with a pathway to some level of chemical understanding. A reaction that transforms two colourless ingredients into a brightly coloured solution has always seemed slightly more alchemical, more real, and more essential. The colours, as well as the light, of fireworks draws people's attention. The colours of opals, and the rainbows refracted in even the clearest diamonds, are in large part responsible for the popular interest in these and other gemstones.

Colours and changes of colour have always caught our eye, and focused our attention. The history of chemistry is rich with serendipitous discoveries, many only recognised by the presence or emergence of colours. The story of William Perkin, and the initial discovery of mauve dye, is a case in point. Before the innovation of aniline-based dyes, natural dyes and colorants had been developed and enhanced, often through experimentation, trial and error. The recipes for their extraction, application and fixation were often highly valuable trade secrets. Perkin was in part



(Stockphoto/ross1248)

experimenting with these raw ingredients in a quest to synthesise quinine, then as now a valuable compound for the treatment of malaria. The interest in the area of chemistry, the synthesis and elaboration of aniline dyes and related organic compounds, did much to advance our understanding of organic chemistry. It is sobering to reflect that the original quest to synthesise quinine to help save lives led to a dye-manufacturing industry that in the early days was responsible for many chemically induced cancers.

The bright colours of fireworks were often in the minds of many students who had the chance to vaporise various metal salts in Bunsen burners. These simple experiments were for many of us the first step in the direction of analytical chemistry. We were given an unknown white crystalline compound, and with the dip and whip of a wire we could divine some part of its make-up. Yet while all of my time at school was spent in the science labs and reading widely, I was not aware of the work of Bunsen of the burner fame. I thought his contribution was simply the design of the ubiquitous gas burner, and was unaware that this was just a spin-off from his work in spectroscopy.

In high school, I used small handheld spectrosopes to view the flame tests that I had for many years found

fascinating (and conducted in secret in the garage at home, profiling any and all materials that came to hand). It was during these years of covert chemical exploration that I invented a new paint for the drenches I slapped and split my chemicals over. By adding universal pH indicators into a white ceiling paint, I ended up with a bench top, which through its various coloured blobs could tell me which areas I had split acid on, and which were caustic. Colours can be so informative. Watching the colours creep over the apparently tie-dyed bench top reminded me of the simple paper chromatography I had been doing for years. I am undoubtedly a slow learner – it is only now that I see the obvious link between the term *chromo*-tography and separation of coloured materials. These principles would probably not have been discovered and applied so soon if all materials were homogenous clear solutions. Colour is so often the clue.

These early experiences sharpened my appetite for analytical chemistry. As a keen 15 year old, I talked my way into the chemistry department at the university, and convinced one of the lecturers to train me how to use the atomic absorption spectrophotometers they had for use by second- and third-year students. The excuse was to use the equipment to assay water and waterways

The history of chemistry is rich with serendipitous discoveries, many only recognised by the presence or emergence of colours.

in Canberra for heavy metals, in particular lead, for a school project. After some training, I was allowed free access on days when the lab was not being used for classes. And water samples were only some of the things I put through the machine. The principles of the machine were clear to me, as indeed were the working parts. It made me feel instantly like a real scientist.

When years later I entered university, it was with the intent to become an analytical chemist. I found ways to get access to every analytical tool and instrument they had. Before I was done, half of the hours I spent at the university were in front of one type of chromatograph or spectrograph or another. While doing my formal studies, I also volunteered at Questacon – then a community science centre – now Australia's national science centre. The founding Director of Questacon – Professor Michael Gore has always had great skill in scientific demonstrations. Simple but profound (the demos *and* the professor). Despite having worked closely with Professor Gore for over 35 years, it was only in the last year or so that I saw him do a demonstration on chemistry. As he set up, I thought I knew what I would see. He had some Bunsen burners and some salts. Nice, I thought, but not new. He started the two burners, the dark room softly

illuminated by the blue glow. He introduced some salt – sodium chloride – into one, and a great yellow blaze lit up the room. He drew our attention to the other burner, and its shadow on the wall nearby. The stem of the burner was there, but its flame was not. He then introduced some of the table salt into the second flame – now two bright yellow lights brightened the space. But unmistakably there on the wall was the clear shadow of the second bright yellow flame. He took the sodium-impregnated wire out; the shadow disappeared. He introduced some copper salt. Its bright distinctive colour sprang up. But of its shadow – nothing. The sodium in the second flame was absorbing its twin's yellow light, and casting a shadow. The copper, having a different absorption spectrum, didn't. To see such clear manifestations of the science and the practice that took up so many of my years was not only incredibly special, but really enriched my understanding. It would be a shame to let the year of light pass without chemistry's special relationship with light and colour go unmarked. Chemistry is colourful.

Stuart Kohlhagen has worked at Questacon – Australia's National Science and Technology Centre – for over 35 years. He was part of the original group that established Science Circus, and worked on the transformation of the original Questacon into the National Science and Technology Centre.

From the editor

The future is looking bright, with an entire spectrum to be in the spotlight during our International Year of Light in 2015. With some citizen science such as the Globe at Night campaign (globeatnight.org) among the events, IYL2015 is bound to attract attention outside the science community.

Every month, *Chemistry in Australia* highlights the diverse people and activities that characterise chemistry. This issue is different: it's written for everyone, not just for chemists. So share the magazine, go to the open access version at raci.org.au/chemaust, then round up some kids for the Smarties test – discuss, enjoy and comment! I'd love to hear from you.



Sally Woollett
(wools@westnet.com.au)

International Year of Light

For more information on the International Year of Light, visit www.light2015.org/Home.html. To find out what is happening in Australia, or how to run or register activities, visit www.light2015.org/Home/About/Country/Australia.html.

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ISSN 0314-4240 e-ISSN 1839-2539



From the President

I trust that general readers find this month's edition of *Chemistry in Australia* interesting and accessible. I applaud the initiative of our editor, Sally Woollett, and her editorial team to produce an edition that showcases the relevance of chemistry to society in such an accessible way.

In September I participated as a discussion panel member at a Smart Science symposium at Parliament House in Canberra, organised by Australia's Chief Scientist, Professor Ian Chubb. I contributed to a discussion on how to make science more relevant in our modern society. In response to the discussion, the Federal Industry Minister, the Hon. Ian Macfarlane MP, adopted a challenging tone by gently berating science (and scientists) for making themselves largely irrelevant in Australian society. Minister Macfarlane was clear in his rhetoric regarding who he thinks is in control of increasing the awareness of science to Australian business and our citizens – we scientists. Minister Macfarlane's comments at the Smart Science symposium, together with the contributions of all participants, can be viewed at www.youtube.com/watch?v=hLQY0VJ7JQ4. The entire video is approximately 100 minutes long, with the Minister's speech beginning just after the first hour.

This brings me back to applauding the *Chemistry in Australia* editors for conceiving and producing this issue. If chemistry is to make itself understandable to, and appreciated by, the general population, we, the practising chemists, must communicate to the broadest possible audience in a clear and accessible manner. Producing publications such as this edition of *Chemistry in Australia* is a tangible example of chemists accepting the challenge laid down by Minister Macfarlane.

My term as President of the Royal Australian Chemical Institute concludes later this month. I acknowledge and thank a number of people who have helped me as President-Elect, then President, over the past four years. First, I thank my predecessor, Professor David Wood. David encouraged me to nominate for the roles I have undertaken and has been truly supportive of me over the past four years. I joined the Board in late 2010 as last-minute planning was underway for the RACI's celebrations for the International Year of Chemistry. Talk about a baptism of fire! David was generous with his time and advice in bringing me up to speed as we began the IYC celebrations. We have become firm friends.

Arguably, the only real job the RACI President-Elect is tasked with is finding his or her successor – or at least a colleague crazy enough to accept nomination for election to the role. I was extremely fortunate in being able to convince Professor Paul Bernhardt to follow me. Paul and I met when we both served on the RACI Assembly last decade and found that we worked well together. That positive working relationship has continued over the past two years on the Board. Paul tempers my energetic enthusiasm with a calm, considered, demeanour. I know that the RACI is in good hands as Paul takes over the reins as our next President.

Roger Stapleford, our CEO, has been a tremendously supportive colleague. Roger joined the RACI just a few months before I assumed office on the Board. One of Roger's last acts before leaving Perth to become our CEO based in Melbourne was to meet me in my office at Curtin. He wanted to meet the incoming President-Elect to see what was about to befall him. That meeting prepared Roger for my full-on approach. Importantly, Roger and I were in complete agreement that the CEO is responsible for the day-to-day operations of the RACI, while the Board oversees matters at the strategic level. I leave the Board satisfied that our steady progression towards achieving this corporate governance objective (commenced before my time) is firmly rooted.

It has been my pleasure to work with a number of outstanding RACI colleagues on the Board over the past four years. Apart from those already mentioned, I have served on Boards with Sam Adelejo, Tatiana Anesbury, Adam Cawley, David Edmonds, Vicki Gardiner, Scott Kable, George Koutsantonis, Ashok Muthupandian, Roger Read, Martina Stenzel and Curt Wentrup. This outstanding group of committed RACI members has brought extensive experience and broad-based perspectives to Board deliberations.

The RACI cannot function without the hard work and commitment of the dedicated team of employees in the National Office and Regional Coordinators around the country. I particularly acknowledge the support, advice and friendship offered by Robyn Taylor. Between the two of us, we seemed to muddle through! The RACI is blessed to have such a talented and committed office leader and all-rounder.

My time on the Board has seen a number of important achievements come to fruition. I am particularly proud of the new financial model adopted just over 18 months ago – after much consultation and debate. The RACI is already on a stronger financial footing, with an enhanced capacity to invest in member benefit, as a result of the changes implemented. I am also extremely pleased to see the new university accreditation paradigm becoming a reality. As I leave office, a debate is underway on possible ways to improve further the corporate governance capability of the Board. We have worked hard to develop a new national congress model, with the first meeting to be held next month in Adelaide.

As I retire from the Presidency and the Board, I remain as strong a fan of the RACI as I have ever been. Next month, with the support of the Board, I will focus my energy on the 2017 RACI Centenary Congress as the Chair of the Organising Committee. This is an exciting, yet daunting, challenge that I embrace. Thank you for your support over the past four years.



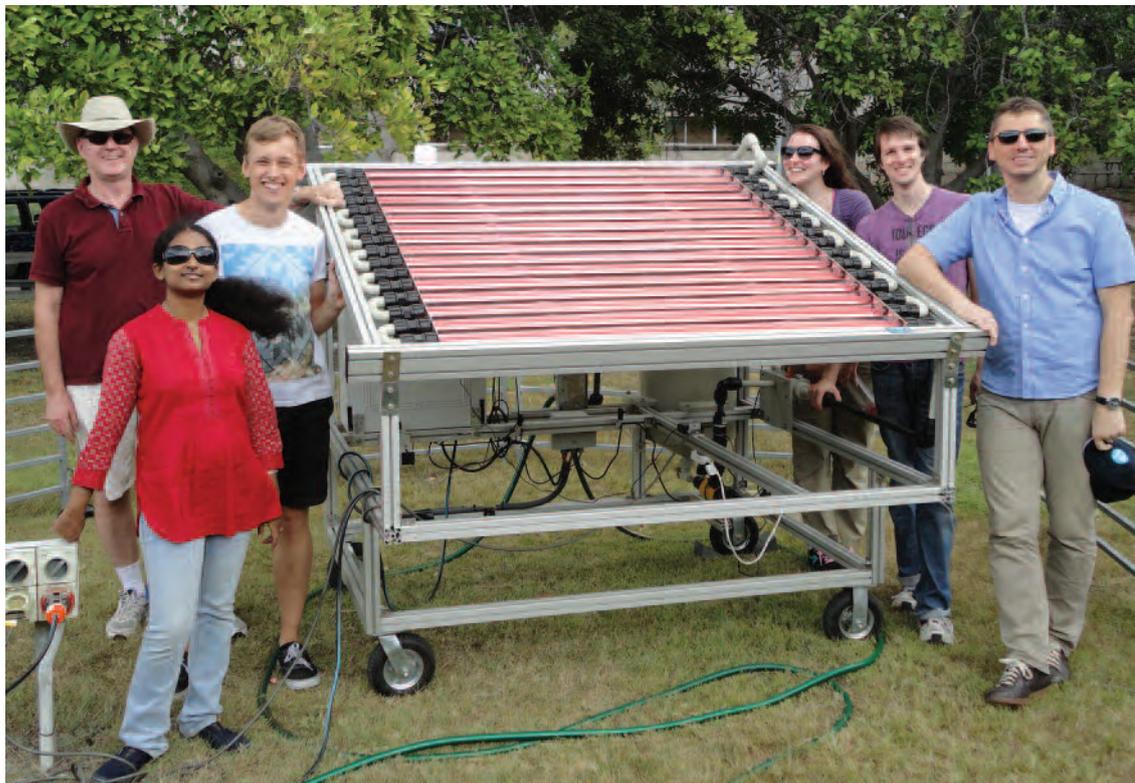
Mark Buntine FRACI CChem (president@raci.org.au) is RACI President.

The sunny side of chemistry at James Cook Uni

Crescente luce – ‘light ever increasing’ – is the motto of James Cook University (JCU) in Tropical North Queensland, and this is exactly what the members of the Applied and Green Photochemistry group in Townsville are aiming for. With more than 300 days of sunshine, Townsville receives plenty of solar radiation that can be harvested to drive chemical reactions. JCU’s location offers vast tropical biomass resources and attractive opportunities with local industries. The solar research activities of the group take advantage of these resources and span from the solar synthesis of valuable commodity chemicals and pharmaceuticals to the solar degradation of priority pollutants, for example pharmaceutical residues in hospital wastewater, pesticides in agriculture run-off water and aquaculture effluents.

The team is led by Associate Professor Michael Oelgemöller, an internationally recognised leader in solar and flow photochemistry (Oelgemöller *M. J. Chin. Chem. Soc.* 2014, vol. 61, pp. 743–8), the branches of chemistry concerned with the chemical effects of radiation. The group comprises graduate, undergraduate and internship students and research volunteers from within JCU and across the world. The research group at JCU operates with a variety of solar reactors that range from a few hundred millilitres to dozens of litres in size. Larger reactions are conducted in a compound parabolic collector (CPC). The reactor is similar to a domestic solar water heating system and the reaction mixture is pumped through a series of clear glass pipes that rest on round W-shaped reflectors. So far, this device has been successfully used to make valuable fragrances, platform chemicals and potent herbicides.

The team at JCU is especially interested in oxygen-transfer reactions (photo-oxygenations) that are industrially relevant in the fragrance and flavour industry. These transformations are highly suitable for solar applications as they are driven by organic dyes, which give the reaction mixtures their distinct colours. When hit by sunlight, the dye generates an activated



Associate Professor Michael Oelgemöller (far right) with some members of the solar research team and their demonstration-scale solar CPC-reactor for demonstration-scale reactions

oxygen species known as singlet oxygen (1O_2). This short-lived species can react with a variety of chemical groups within a chemical entity.

The ‘Solar Chemicals from and for the Tropics’ activities of the group offer a range of new and ‘green’ products for the local economy in North Queensland. The sugar industry, for example, provides a steady access to sugarcane bagasse-derived compounds. Solar exposure of these materials yielded a potent herbicide and pharmaceutical building block on kilogram scales. Likewise, the solar conversion of essential oils enables the local industry to diversify its product portfolio. As an example, the important three-step synthesis of the fragrance rose oxide was conducted successfully within a week. The amount of final product covered the annual demand of a small perfume manufacturer. The group also helps to prevent or cure tropical diseases such as dengue and malaria by synthesising insect repellents or antimalarials with sunlight.

The Applied and Green Photochemistry group has embraced the abundant natural resources of Tropical North Queensland: sunlight and biomass. Together with other solar research activities at JCU, solar photochemistry can help to create new future green chemical industries in the region.

Associate Professor Michael Oelgemöller, Applied and Green Photochemistry research group, James Cook University

Anti-tank missile detector joins fight against malaria

State-of-the-art military hardware could soon fight malaria, one of the most deadly diseases on the planet.

Researchers at Monash University and the University of Melbourne have used an anti-tank Javelin missile detector, more commonly used in warfare to detect the enemy, in a new test to rapidly identify malaria parasites in blood.

Scientists say the novel idea, published in the journal *Analysis*, could set a new gold standard for malaria testing.

The technique is based on Fourier transform infrared (FTIR) spectroscopy, which provides information on how molecules vibrate. In this study the researchers utilised a special detector known as a focal plane array (FPA) to detect malaria-infected red blood cells. Originally developed for Javelin anti-tank heat-seeking missiles, the FPA gives highly detailed information on a sample area in minutes. The heat-seeking detector, which is coupled to an infrared-imaging microscope enabled the team to detect the earliest stages of the malaria parasite in just a single red blood cell.

The infrared signature from the fatty

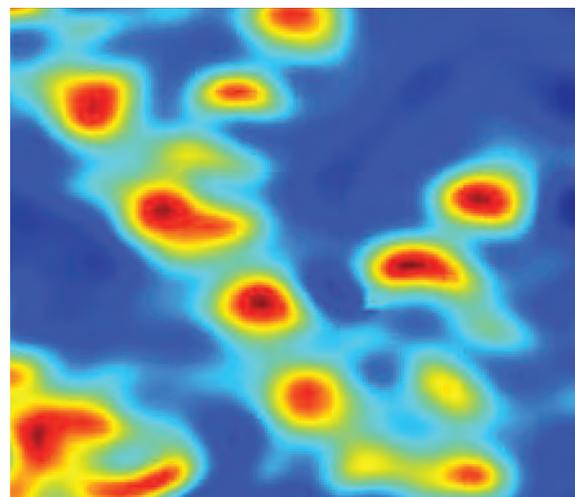
acids of the parasites enabled the scientists to detect the parasite at an earlier stage, and crucially determine the number of parasites in a blood smear.

Lead researcher Associate Professor Bayden Wood said to reduce mortality and prevent the overuse of antimalarial drugs, a test that can catch malaria at its early stages is critical.

‘Our test detects malaria at its very early stages, so that doctors can stop the disease in its tracks before it takes hold and kills. We believe this sets the gold standard for malaria testing.’

As well as being highly sensitive, the new test has a number of advantages – it gives an automatic diagnosis within four minutes, doesn’t require a specialist technician and is so advanced it can detect the parasite in a single blood cell.

The disease, which is caused by the malaria parasite, kills 1.2 million people every year. Existing tests look for the parasite in a blood sample. However the parasites can be difficult to detect in the early stages of infection. As a result the disease is often spotted only in the later stages when the parasites have developed and multiplied in the body.



An infrared image of malaria-infected red blood cells recorded using a Javelin anti-tank missile detector on an infrared microscope coupled to a synchrotron light source. The image is generated by integrating the C-H bond stretching region ($3100\text{--}2800\text{ cm}^{-1}$), which is dominated by strong fatty acid bands from the malaria-infected red blood cells (red in the image).

Co-author Professor Leann Tilley said the test could also have an impact in cases where patients do not present the classical fever-type symptoms associated with the disease.

The next phase of research will see Associate Professor Wood’s team work with Professor Patcharee Jearanaikoon from the Kohn Kaen University in Thailand to test the new technology in hospital clinics.

Article compiled by **Lucy Handford**, Monash University Media, and **Bayden Wood** FRACI CChem

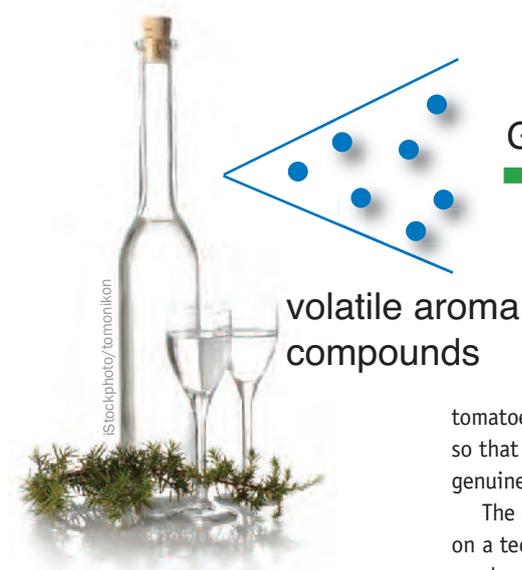
Northernmost chemists in the southern hemisphere



Telling someone you work at Charles Darwin University (CDU) often meets with the reply, ‘Where is that?’ CDU is the Northern Territory’s only university. Although many of the research projects that the chemistry group handles start at the remote campuses in Alice Springs, Katherine and at Jabiru in the Kakadu National Park, the main centre for chemistry is the Casuarina campus in Darwin. A small but diverse chemistry group is involved in research and teaching within the engineering, environment, pharmacy and medical laboratory science themes.

Dr Martin Boland MRACI CChem, Dr Yasmin Antwertinger and Dr Vinuthaa Murthy MRACI CChem from Charles Darwin University

Chemistry creating consumer certainty



volatile aroma compounds



✓ right ratio = genuine grappa



✗ wrong ratio = fraud!



tomatoes, and beverages such as grappa, so that consumers can be assured of genuine products.

The methods being developed are based on a technique called gas chromatography combustion isotope ratio mass spectrometry (GC-C-IRMS). While this is indeed a mouthful, the technique can be broken down into three parts. First, gas chromatography (GC) separates components in a mixture. For example, in the aroma of grappa are volatile molecules that give grappa its characteristic smell. This complex mixture can be separated by GC so that the individual components can be identified.

Second, the aroma components are literally burned in a combustion chamber, producing carbon dioxide (CO_2). The CO_2 is then further analysed by isotope ratio

mass spectrometry (IRMS). There are similarities between this technique and carbon dating in archaeology. In carbon dating, radioactive ^{14}C is detected and its abundance is used to date an object. In IRMS, the ratio of ^{12}C to ^{13}C (other isotopes of carbon) is measured. This ratio can be used to identify the origin (geographical or botanical) of the compound. For example, if grappa has been adulterated with a cheap substitute from another country or another plant source, the carbon isotope ratio may be used to detect this substitution.

The project is being led by PhD student Katryna van Leeuwen, a former employee of the Edmund Mach Foundation and now based in Auckland. Katryna's work is investigating fatty acids in lamb, linked to the possibility of enhancing the nutritional value of lamb by increasing the polyunsaturated fats. In order to do this, a better understanding of sheep metabolism is required, including how polyunsaturated fats can be incorporated into meat through diet. The project on tomatoes is aimed at differentiating between tomatoes grown conventionally and those grown organically. In this case, organic tomatoes can be identified by measuring nitrogen isotopes from organic fertilisers and those in amino acids from tomatoes.

The outcome of Katryna's project will be a set of methods that can be used on various foods to ensure consumers are getting what they pay for.

Katryna van Leeuwen, Danielle Ryan MRACI, **Paul Prenzler** FRACI CChem, Charles Sturt University, and **Federica Camin**, Edmund Mach Foundation of San Michele all'adige, Italy

Consumers are demanding more certainty over where their food and beverages originate from and the genuineness of ingredients. In order to provide this assurance and catch instances of fraudulent activity, there is a need to develop ways of testing food, beverages and their ingredients to ensure traceability, authenticity and origin. Researchers from Charles Sturt University, Wagga Wagga, and Edmund Mach Foundation of San Michele all'adige, Italy, are collaborating to develop methods for testing diverse foods such as lamb and

Over the last year, chemistry at CDU has begun something of a renaissance with the appointment of two new lecturers: Dr Yasmin Antwertinger, covering environmental and analytical, and UK import Dr Martin Boland, covering pharmaceutical and medicinal chemistry. They join long-time CDU staff member, computational chemist Dr Vinuthaa Murthy.

Most research programs are focused on the unique issues of the Top End. These can be NT-focused, such as stability of pharmaceuticals in tropical climates and developing bio-monitors of water quality and food safety using corals, oysters and other important marine and estuarine species. Other investigations aim to

further develop materials used to combat wear and corrosion in mineral, oil and gas industries – important to many local economies in the NT.

Martin Boland MRACI CChem, Senior Lecturer, Medicinal and Pharmaceutical Chemistry, Charles Darwin University

Chemistry by computer

Chemistry is traditionally an experimental science. However, recent advances in computer technology and the development of highly efficient computer algorithms have opened the way for a viable alternative approach to chemistry: chemistry by computer. The cost of carrying out such computations has decreased by the remarkable factor of 1 trillion (10^{12}) in the past 50 years, making the computational approach to studying chemistry highly attractive! Nobel Prizes were awarded to computational chemists in 1998 and 2013.

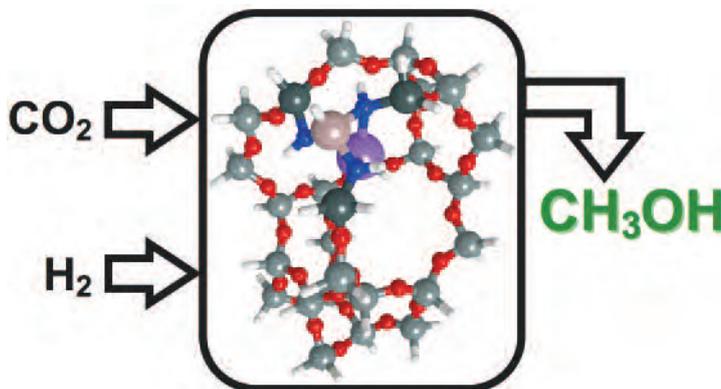
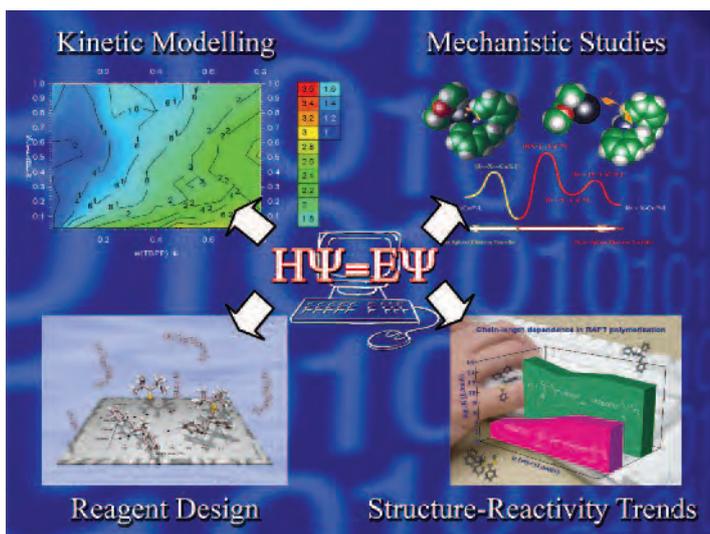
The computer calculations are based on the laws of quantum mechanics and, remarkably, they make chemistry predictions without using any experimental information. The calculations may be used to determine the structures of molecules and to help understand how molecules react with one another. The unique mechanistic insights offered by computational quantum chemistry are helping to transform our understanding of chemical reactivity, and replace trial and error experimentation with computer-aided chemical design. Of course, computers will never replace the experimental chemical laboratory, because ultimately chemicals and materials need to be synthesised for practical applications, but the computer calculations are increasingly playing a valuable role in guiding experiment.

As an example of recent research, scientists at the Australian National University, led by Professor Michelle Coote, have successfully used computational quantum chemistry to design improved reagents for catalysing and controlling radical polymerisation, and redox mediators that can improve the efficiency of dye-sensitised solar cells. They are also working with industry to help improve the thermal and photostability of paints and other plastics, and to help design materials that undergo self-healing at some specified temperature.

At the University of Sydney, the group led by Professor Leo Radom has used the computer calculations, also carried out at the National Computational Infrastructure National Facility, to design catalysts that might efficiently convert the waste material carbon dioxide to the valuable chemical feedstock methanol. Another example of their research is the computational design of bioinspired antioxidants. On the mechanistic front, they have used computer calculations to probe the intimate details of how an analogue of vitamin B₁₂ facilitates certain types of enzyme-catalysed reactions, and to help understand how free radicals can damage amino acids and peptides.



Raijin supercomputer at National Computational Infrastructure (NCI National Facility), Canberra, ACT

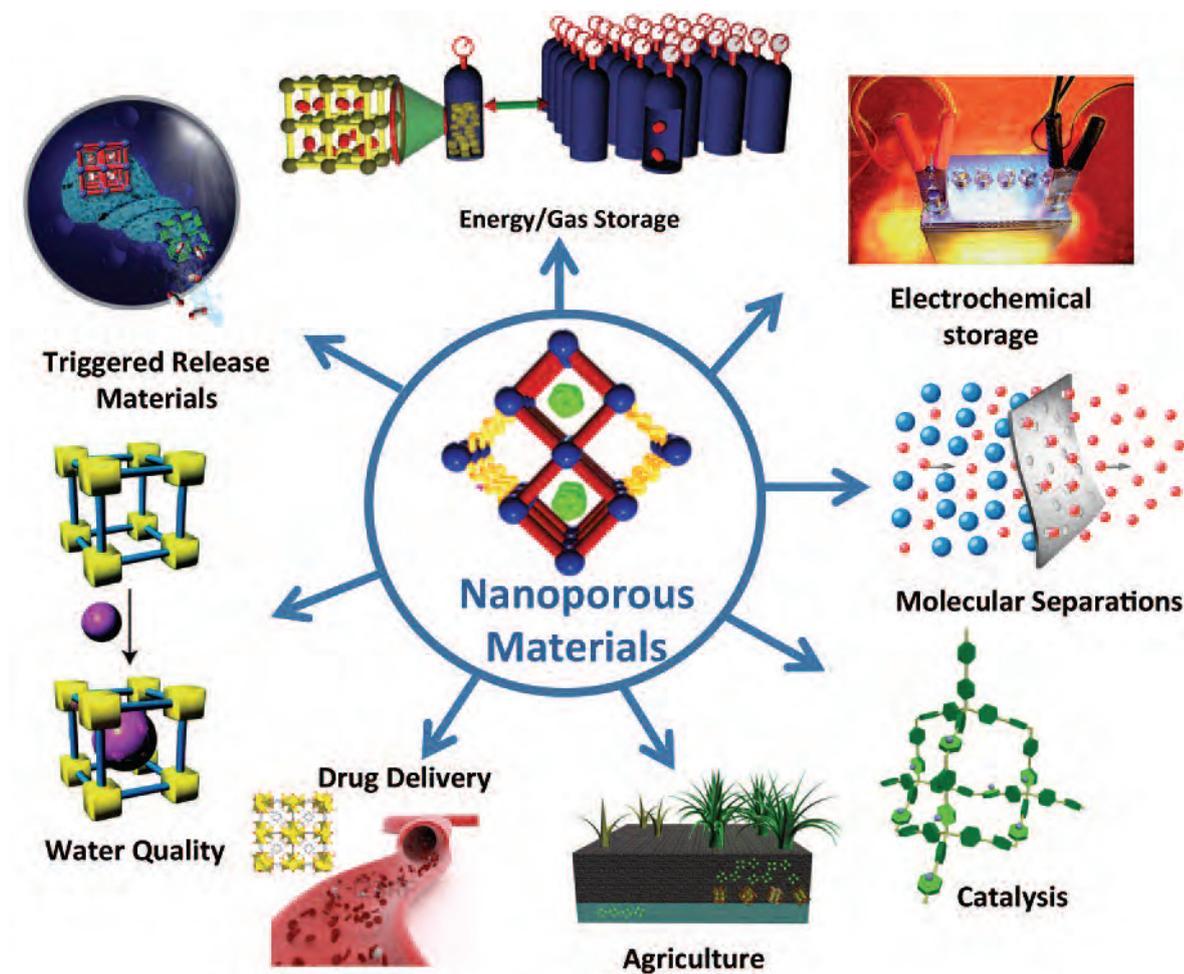


Supersponges

Improved efficiency and sustainability in the way we use our limited resources are crucial factors across many Australian industry sectors. As a means to address these challenges, CSIRO Integrated Nanoporous Materials (INAM), led by Dr Matthew Hill, has developed new technology in materials known as metal organic frameworks (MOFs). MOFs, made by joining metal ions with organic linkers to form a three-dimensional array similar to a building scaffold, are the most porous materials known – they are almost entirely made of holes. One teaspoon of MOF may have as much surface area as an entire football field hidden inside it. Like a sponge, the pore surfaces can store and release substances on demand, such as fertilisers or fuels, or, like a sieve, the uniform pore sizes can be used to separate one

substance from another, such as natural gas from impurities, or carbon dioxide from an exhaust stream.

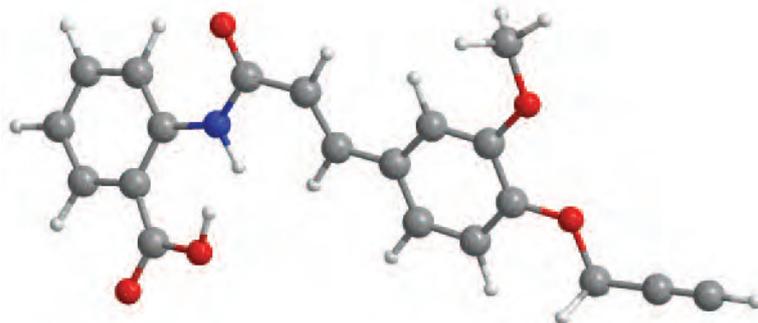
For example, INAM has developed a MOF that can capture carbon dioxide like a sponge, later releasing it when simply exposed to concentrated sunlight, so that no extra energy is needed to regenerate the sponge. Also, INAM developed an ageless gas separation membrane. Currently, the most attractive polymers for use in these membranes suffer from ageing; that is, they lose most of their performance over time. The CSIRO MOF membrane is unaffected after two years of testing, making it useful for application in remote locations. MOFs developed at CSIRO are finding use in situations where higher performance from less material is crucial.



Small molecules excite big pharma

Associate Professor Spencer Williams (School of Chemistry and Bio21 Institute) and Professor Darren Kelly (Department of Medicine) at the University of Melbourne have discovered a new class of drugs to treat fibrosis, an unmet clinical need that is associated with up to 45% of all mortality. Commencing 2006, their laboratories collaborated to establish a medicinal chemistry program to develop targeted therapies to act on the pathological fibrosis occurring in chronic kidney disease as the primary therapeutic indication. Their research led to the discovery of FT011, an antifibrotic drug that prevents the deposition of extracellular matrix into major organs that is the hallmark of the pathology of diabetes.

The researchers established Fibrotech Therapeutics to commercialise their family of antifibrotic compounds, including FT011. FT011 completed a phase 1b clinical trial in 2014 in patients with diabetic nephropathy and showed excellent safety and tolerability. In May 2014, Shire Plc, a major global pharmaceutical company, announced the acquisition of Fibrotech for a \$75 million upfront payment and significant additional payments contingent on development and regulatory milestones. Acquisition by Shire (itself subsequently acquired by AbbVie) will provide the capital and expertise needed to bring this innovative therapy to the market.



FT011 – an antifibrotic drug that is being trialled in patients with diabetes



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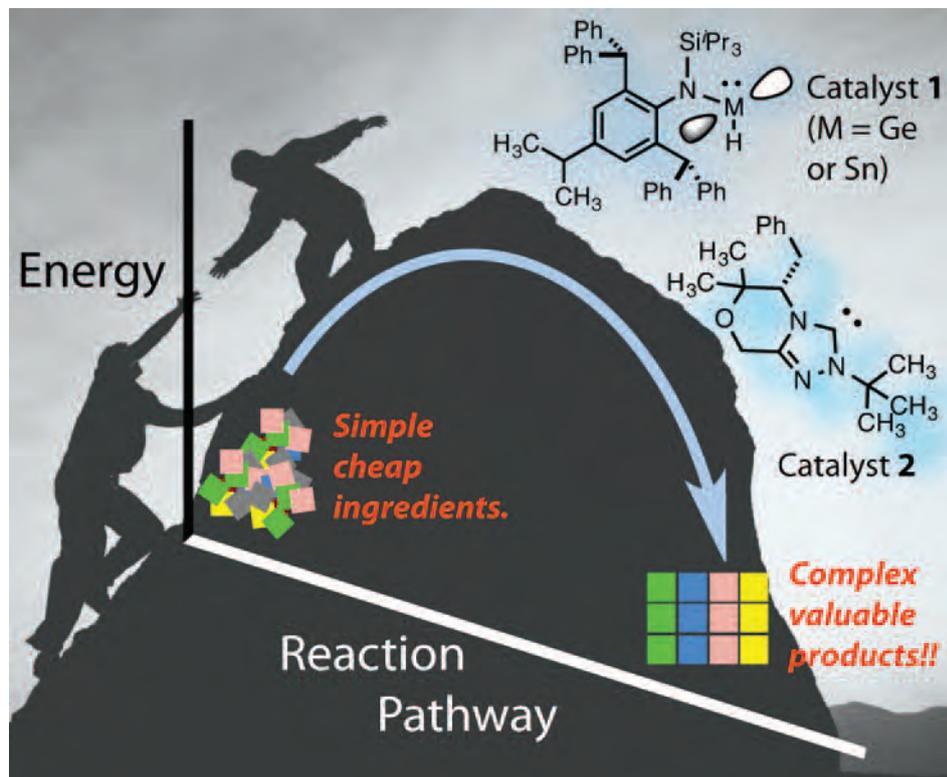
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Earth-abundant elements take on noble roles in catalysis

Catalysts are helper compounds that accelerate chemical reactions, but aren't consumed in the process. This property allows valuable materials to be made while minimising the creation of waste. These facts have been greatly exploited by industry, with catalysts now used in the production of innumerable chemicals (global market greater than US\$10 trillion per year), indispensable to almost every aspect of everyday life. However, a problem is looming. Many catalysts exploit noble transition metals, e.g. rhodium, palladium or platinum, that can be prohibitively expensive, are derived from dwindling mineral deposits, are toxic, and require removal from chemical products, which is often very costly. As a result of these limitations, there is a global drive towards the development of sustainable alternatives to precious metal catalysis that exploits cheap, non-toxic, earth-abundant and renewable elements.

In Australia, studies carried out by Professor Cameron Jones and Dr David Lupton at Monash University are leading the way in this challenging and rapidly emerging field. Although their respective research programs take different approaches, investigations in both groups are connected by a desire to provide useful alternatives to traditional transition metal-based, homogeneous (i.e. single phase) catalysts. The attainment of this goal will soon be facilitated by the establishment, by Jones and Lupton, of a centre for catalysis at Monash.

Jones' background lies with the development of very low oxidation state s- and p-block metal (e.g. magnesium, gallium and germanium) complexes, previously thought incapable of existence



under ambient conditions (e.g. *Angew. Chem. Int. Ed.* 2013, **52**, 10199). Although these are of significant fundamental interest, it has recently been demonstrated that their electronic properties and reactivity patterns can be very similar to those of noble transition metal complexes.

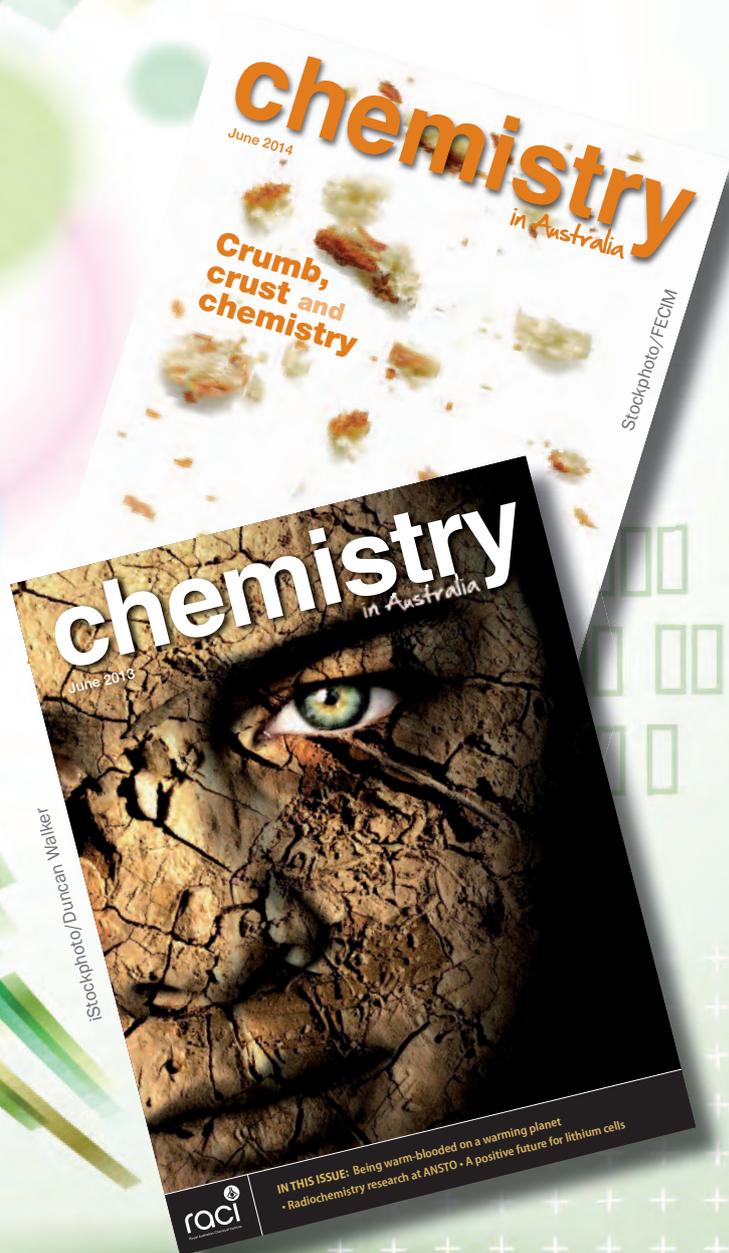
Jones' team is systematically channelling these attributes into the application of main group complexes (e.g. **1**) as highly efficient and selective 'transition metal-like' catalysts in a variety of synthetic transformations (e.g. *J. Am. Chem. Soc.* 2014, **136**, 3028).

Lupton's approach to catalysis, on the other hand, completely dispenses with

metals. His group has focused on the use of low-valent metal-free catalysts (e.g. carbene **2**) that display reactivity seldom achieved with related catalyst types. Specifically, these catalysts are particularly useful for the generation of molecules that have very high levels of a type of shape purity known as chirality (e.g. *J. Am. Chem. Soc.* 2013, **135**, 58; *Angew. Chem. Int. Ed.* 2013, **52**, 9149). This property is found in many natural materials, and as a consequence is becoming increasingly important when making materials capable of becoming medicines of the future.

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

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Chemistry publishing

The role of scientific journals is clearly to publish scientific research. Not so long ago, scientists published in whichever journal they deemed most relevant for their work; that would often mean a journal close to home. For Australian chemists, that would be the *Australian Journal of Chemistry*, which was established in 1948 – at first as the multidisciplinary *Australian Journal of Scientific Research*, which soon split up into subject-specific journals. Nobody cared about impact factors and citation rates.

***Aust. J. Chem.* is an international journal, but through the agreement with the Academy it has an obligation to publish research in the national interest.**

National journals such as *Acta Chemica Scandinavica*, *Australian Journal of Chemistry*, *Bulletin de la Societe Chimique de France*, *Bulletin of the Chemical Society of Japan*, *Canadian Journal of Chemistry*, *Helvetica Chimica Acta* and *Receuil des Travaux Chimiques des Pays-Bas (J. Roy. Netherlands Chem. Soc.)* were perfectly respectable 'national' journals. Meanwhile, everything has changed. Everybody everywhere is obsessed with journal impact factors (IF, which is a measure of the number of times over a two-year period papers published in a journal are cited in other journals) and personal *h*-indices (an *h*-index of *x* is when *x* papers have all been cited *x* times by others). This means that chemists all over the world want to publish in high-ranking journals such as the *Journal of the American Chemical Society*, *Angewandte Chemie*, *Nature Chemistry*, *Chemical Science* and so on (even though that does not guarantee high citation rates of individual papers). Some of the above-mentioned journals have ceased to exist, and others are

struggling to survive.

The obsession with impact factors is due in no small measure to the policies of publically funded research granting bodies and university promotion committees, who tend to judge the quality of people's research papers on the basis of the IF of the journals in which they are published and the author's personal *h*-index.

The *Australian Journal of Chemistry* is published by CSIRO Publishing in cooperation with the Australian Academy of Science. *Aust. J. Chem.* is an

international journal, but through the agreement with the Academy it has an obligation to publish research in the national interest. At present, a little less than half of all papers published in the Journal are from Australasia. Of the rest, the majority are from China and other Asia-Pacific nations, notably Singapore and Japan, followed by Europe and the Americas. The overall rejection rate is about 60% – and for uninvited papers it is about 80%. We have an excellent team of associate editors, who are active scientists in various areas of chemistry, and of course we use high-quality reviewers from all over the world to assess papers and guarantee high standards. The Journal will continue to negotiate the difficult path between national interest, internationalisation, and the fierce competition from high-IF international journals. Our prime objective must be to provide the best possible scientific publishing service to Australasian chemists.

Curt Wentrup FAA, FRACI CChem (wentrup@uq.edu.au), <http://researchers.uq.edu.au/researcher/3606>

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tattoo inks

Poison pigments ?

Humans have been tattooing themselves for as long as there have been humans, as far as we know. Ötze the Iceman, whose body was entombed in ice for around 5300 years, was tattooed with lines and crosses. Over the millennia, tattoos have wandered between being signs of royalty to being signs of criminality. Since Ötze's time tattoos have become more complex and colourful, with regional specialisation. In Sir Arthur Conan Doyle's *The red-headed league*, Sherlock Holmes was able to tell that a man had been in China from the shade of pink on the scales of a tattooed fish.

Tattoos are fashionable again, yet in many ways the chemistry of tattoos has advanced little. The commonest pigment for tattoos is still carbon black, although today it is applied with sophisticated needles, instead of cutting the skin and rubbing soot into the cuts, which is how Ötze's tattoos were made.

iStockphoto/Brainsil

BY **IAN MUSGRAVE**

Allergy and infection are two causes for caution when contemplating a tattoo. But are tattoo pigments toxic, and do they increase the risk of cancer?

Modern tattoos are made by injecting tattoo pigment by needle into the dermis, the layer of connective tissue that anchors the epidermis to the underlying tissue. The chemistry of the tattoo pigment has to ensure that the pigment does not migrate far from the injection site, and that the colour does not fade substantially over time.

For millennia, these conditions were largely met by carbon black and various metal compounds. Today, synthetic colours are part of the tattooist's armamentarium.

Traditionally, tattoo inks are seen as being biologically inert. However, significant health concerns have been raised over tattoo inks, and a recent ABC radio series (ab.co/1r75FTP) focused on the possibility of carcinogens being present in tattoo inks. What exactly are the risks of toxicity from tattoo inks?

Answering this question is rather difficult, as tattoo inks and tattooing are more complicated than it might seem.

First, we need to consider the types of toxicity – there is acute toxicity (occurring in a relatively short period of time) and chronic toxicity (over weeks to years), and there are also allergic reactions. As well, we need to consider not only the pigments, but the solutions the pigments are suspended in.

Then, we need to consider the tattooing process. The pigment is injected into the dermis, where it is initially distributed in the matrix of the connective tissue, or inside fibroblasts. Over time, macrophages – scavenger

cells – take up pigment. Some of the pigment may be transported by the macrophages into the lymphatic system and to the lymph nodes (bit.ly/1ARGANq).

In this way, the material in the tattoo pigments can be exposed to local tissue, and to the body at large. In contrast, the solvents in which the pigments are suspended can rapidly diffuse away, possibly causing more immediate problems.

Allergic reactions to both organic and inorganic pigments are quite common. Tattoo pigments based on metals such as cobalt, cadmium, dichromate and mercury have high risks of allergic reactions. Also, if the pigments are contaminated with nickel sulfate, then they can cause strong allergic reactions. Around 8% of the Australian population is allergic to nickel.

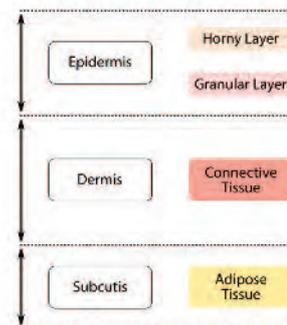
Heavy metal toxicity from metal-based pigments is also possible.



iStockphoto/PeterHermesFurian

Some of the most vibrant colours are associated with toxic heavy metals; the red pigments cinnabar (HgS) and cadmium red (CdSe) are both highly toxic, as is cadmium yellow (CdS , CdZnS) and chrome yellow (PbCrO_4).

While there are many reports of local reactions to toxic heavy metals, the degree of chronic exposure is hard to determine. It has been estimated that an 8 centimetre by 13 centimetre tattoo contains between 1–25 micrograms of lead (depending on the degree of lead in the various inks) (1.usa.gov/1tZWxCl). However, how much metal is released from the particles and over what time frame is uncertain. Heavy metal pigments have largely been replaced by organic pigments (e.g. naphthol-AS for metal-based reds), but as there is limited regulation of tattoo inks in Australia, it is unclear if Australian inks contain substantial amounts of heavy metals. Recent assays of tattoo inks in New Zealand showed that most of them had low levels of heavy metals, although 24% had levels of cadmium over 0.2 mg/kg ink and 22% had levels of lead over 2 mg/kg ink (ab.co/1qe1NLI). Tattoo inks in Australia probably have similar composition and similar heavy metal levels. The incidence of severe adverse reactions to the tattoo pigments is not clear, but one German study reported an overall adverse



Tattoos are made by injecting pigment into the dermis of the skin.

How tattoos are removed

You're probably familiar with how tattooing works: coloured ink is deposited via needles into the dermal layer of skin. But you're probably less familiar with the process for having it removed: laser therapy.

Lasers work by generating a beam of light of a specific frequency. The intensity of the beam can be varied, as can the frequency – which changes the colour of the laser – and the duration of the light pulse. The laser beam will release energy selectively when it hits a target of a specific colour.

Lasers are used to break down ink particles so that they can then be removed by the cells of the immune system. If the intensity of the laser energy is too high, there will be collateral damage to the surrounding skin that will produce a scar. If the intensity is too low the ink particles will not be disrupted.

The pulse duration is also important. When the tattoo pigment absorbs the laser energy it releases heat as the particle explodes. Rather than fire a single beam at the target, laser tattoo removal works best when multiple high-energy, millisecond or nanosecond pulses are fired repeatedly at the target. This allows any heat generated in the pigment explosion to dissipate before the next pulse hits. It reduces pain, and reduces scarring.

There are several different types of laser. Some lasers have a fixed frequency, while others are tuneable. Each will remove a different colour based on the frequency of light generated.

Person-to-person variation in skin colour and thickness and tattoo-to-tattoo variation in pigments, technique and depth mean it's impossible to predict how much laser is required to remove a particular tattoo. Trained operators err on the side of caution, preferring to under-treat the tattoo and risk the need to repeat the treatment rather than over-treat and risk causing permanent scarring.

Treatments are usually done without local anaesthetic, and are said to be only marginally more painful than having the tattoo. Devices to cool the skin prior to laser treatment reduce the discomfort.

So, how long does it take?

Multi-coloured tattoos often require multiple lasers or a single laser with a tuneable frequency. Each treatment takes 5–30 minutes, depending on the size of the tattoo.

Following treatment, the skin will immediately whiten and swell; this may be followed by weeping of the skin a few hours later and the formation of a scab. This should heal after seven to ten days.

The pigment will slowly fade over 3–6 weeks as the fractured ink particles are removed by the cells of the immune system. Repeat treatments are usually spaced six or seven weeks apart.

Most tattoos require 6–12 treatments to fade. But it's important to note that complete tattoo removal without scarring is rare. There will usually be a subtle silhouette indicating where the tattoo once was.

The skin also contains coloured structures that also absorb laser light, so complications are possible. Pigment irregularity – where skin looks blotchy and uneven – is the most frequent complication, especially in people of colour.

Laser tattoo removal is best done in well-equipped centres with a range of laser devices that mirror the colour complexity of the tattoo and best performed by trained technicians who understand the complexity of laser science and skin biology. Those working alongside dermatologists or plastic surgeons are possibly best placed to do this type of medical procedure.

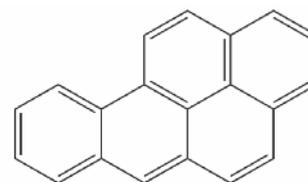
Rodney Sinclair, Professor of Dermatology, Honorary, is at the Epworth Hospital at University of Melbourne. First published at The Conversation (www.theconversation.com).

event rate (including bacterial infections) of 0.02% (bit.ly/1s7kHuH).

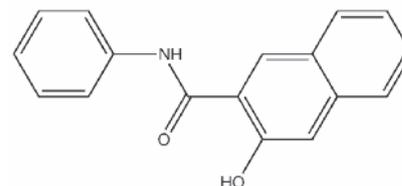
The more recent concerns are over the presence of possible carcinogens in tattoo inks. These can be due to the pigments themselves, or to the solvents the pigments are suspended in. It may surprise you that inks based on carbon black – some of the most common inks – are of greatest concern. Ironically, Ötze's carbon black tattoos may have been for medicinal purposes.

Pure carbon would seem to be a poor candidate for a carcinogen, but it is the chemicals formed during its production that are the main sources of worry. Carbon black is produced by combustion, and in many preparations some polyaromatic hydrocarbons are present. Some, such as benzo[a]pyrene, are known carcinogens; others are suspected of being carcinogens. While benzo[a]pyrene has been detected in some overseas inks (bit.ly/1oYDtxs), it has not been found in Australian inks. Phthalates – also of concern with regards human health – have been found in some of the ink solvents (bit.ly/1woUN3y).

A significant complication is that, as with the heavy metals, we have no clear idea of the level of exposure to these chemicals. Clearly, a large, detailed tattoo with lots of shading has



benzo[a]pyran



naphthol-AS



Regulation of tattoo inks in Australia

There is limited regulation of tattoo ink in Australia. The therapeutic goods administration does not regulate tattoo inks because they are not seen as therapeutic substances. The chemicals in tattoo ink are considered to be industrial chemicals, and are subject to the same requirements as other industrial chemicals under the Industrial Chemicals (Notification and Assessment) Act 1989 (the Act). If a chemical that is used in tattoo ink is in the Australian Inventory of Chemical Substances (AICS), then its importation is usually not regulated by the National Industrial Chemicals Notification and Assessment Scheme. For example, chromium red is listed on the AICS. It is unclear if there is any testing for contamination or adulteration of tattoo inks.

The European Society of Tattoo and Pigment Research was formed in 2013, and its website has some useful general information about tattoos, their risks and questions to ask, covering issues beyond those of chemistry toxicity outlined here. Visit www.estpresearch.org/tattoo-campaign.html.

more potential for carcinogen (or heavy metal) exposure than a small outline tattoo, but if the carcinogenic compounds are largely immobile in the ink particles, then the exposure will be low.

Removal of tattoos (see box p. 18) involves a wide range of issues unrelated to the actual toxicity of tattoo pigments themselves and is beyond the scope of this article.

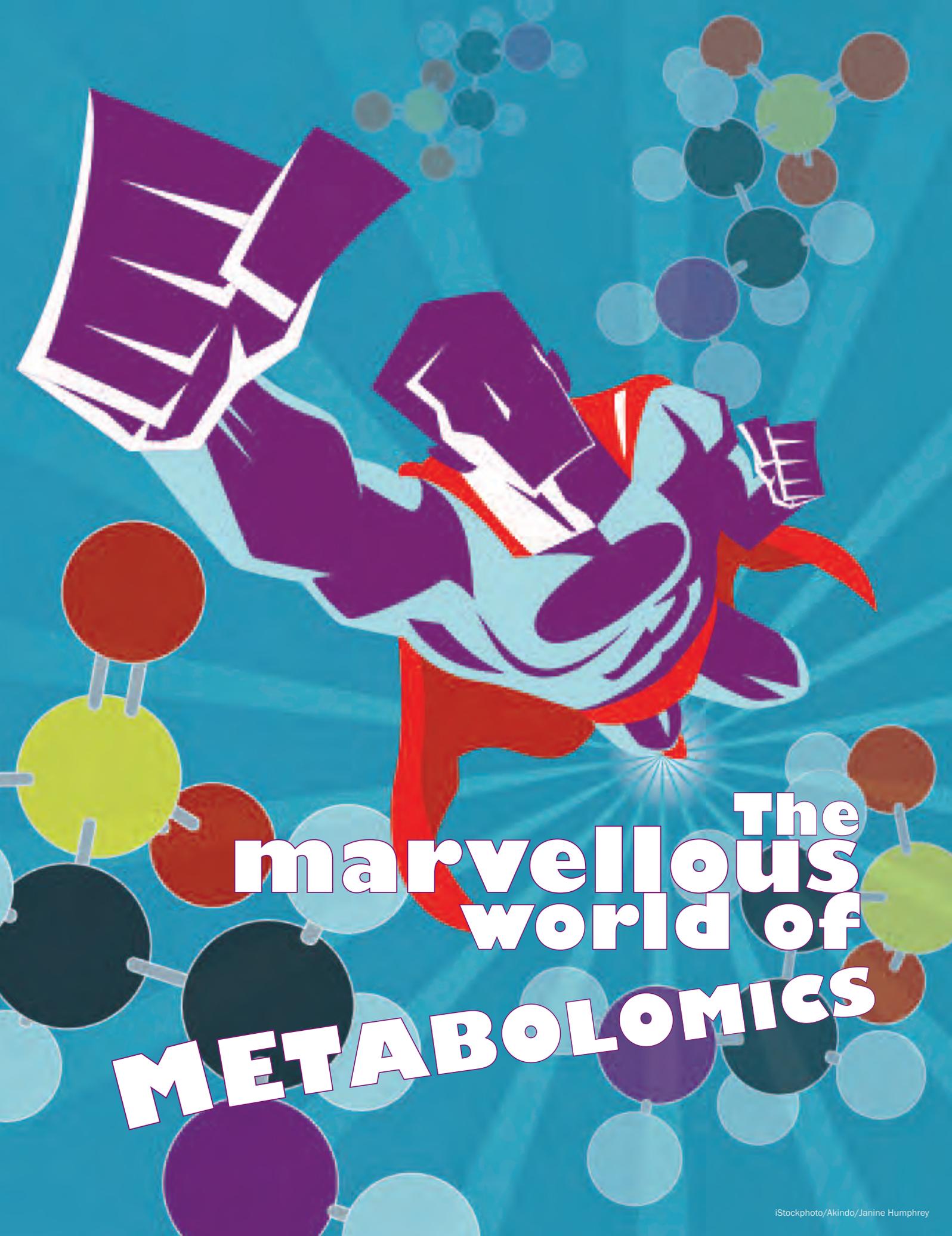
As a reality check, a recent review concluded that any association of skin cancer with tattoos was coincidental. As the highest concentration of potential carcinogens would be in the

skin itself, the likelihood that there is a significant general cancer risk is low (bit.ly/1woUN3y).

Tattoos have been part of human life since at least the last ice age, and are increasingly bringing colour into the lives of 21st century Australians. The very chemistry of the tattoo pigments that gives them their vibrant colours produces adverse reactions in some people, more than the average person contemplating a tattoo realises. However, the risk of cancer from tattoos seems very low.

Ian Musgrave is a molecular pharmacologist/toxicologist working at the University of Adelaide.

... inks based on carbon black – some of the most common inks – are of greatest concern. Ironically, Ötze's carbon black tattoos may have been for medicinal purposes.



**The
marvellous
world of
METABOLOMICS**



BY **OLIVER JONES**

A researcher keen on comic books delves into the marvels of investigating small molecules.

There is an unfair charge sometimes levelled at scientists (and reinforced by certain TV shows), namely that they are often nerdy, geeky types obsessed with comic books. Unfortunately, I am not going to do anything to dispel this myth here since (a) I am a scientist who is quite fond of comic books and (b) I intend to use said comic books to try and help explain some of the work that goes on in my lab.

There is a character in the Marvel comic universe who has changed his identity almost as often as his Spandex socks. Henry 'Hank' Pym is, like a large number of superheroes and supervillains, a scientist (think Tony Stark, Bruce Banner, Peter Parker and Reed Richards for the good guys and Mr Sinister, Norman Osborn and Drs Octopus and Doom for the dark side). Through the discovery of the mysterious Pym particles, Hank becomes Ant Man, with the ability to shrink down to the size of an ant. There is only so long you can keep kids interested in a character whose main power is to shrink, so, over the years, Hank has had a number of other costumed identities, including the size-

changing Giant-Man and Goliath and, more recently, the insect-themed Yellowjacket and the Wasp.

Like Hank Pym, I'm a scientist with an interest in biochemistry. Unlike him, I haven't (yet) discovered a way to give myself superpowers or been designated Earth's Scientist Supreme. Although exposure to substances commonly found in laboratories, such as radiation, chemicals and electricity (and various combinations of each), has given many superheroes, and indeed supervillains, their powers, I can't stress strongly enough how dim a view the Occupational Health and Safety people of Earth-1218 take of scientists trying to replicate such effects; radioactive spiders are especially frowned on from an animal rights point of view. So, for now, I am content with my day job, part of which involves doing research in a field known as metabolomics.

Metabolomics can be defined as the analysis of thousands of naturally occurring small molecules (metabolites) that are the products of cellular metabolism. These include things like sugars, fats and amino acids. The technique can be used to give a 'snapshot' of the physiology of a

cell or tissue and to assess how it has changed from normal as a response to everything from disease to exposure to cosmic rays. Indeed, if superheroes actually existed, the technique would probably be a very good way to show what features of their metabolism were responsible for their superpowers.

In fact, many of the powers demonstrated by superheroes would be impossible without the additional ability of a super metabolism. For example, it has been suggested that several characters in both the Marvel and DC Universes can move at a top speed of close to that of light, but how

Many of the powers demonstrated by superheroes would be impossible without the additional ability of a super metabolism.

much energy would this take? In his excellent book *The physics of superheroes* (bit.ly/XGGLPD), Dr James Kakalios calculated the metabolic requirements to generate the kinetic energy needed to accelerate a 70 kilogram human to a more conservative speed of 1% of the speed of light. The total comes to just under 75 billion calories, or roughly 136 million Big Macs (at 550 calories each (bit.ly/1nDISNV)). This means that any hero running that fast would have to eat almost constantly and at the same rate they were moving. To be fair, comic book writers are aware of such restrictions and often incorporate explanations into their stories. For example, in *The Marvel encyclopedia*, the speedster Quicksilver is described as having several extra physiological adaptations to deal with life at super speed – his cardiovascular and respiratory systems are apparently many times more efficient than those of a normal human being and his body is able to use about 95% of the caloric energy content of his food (normal humans use only about 25%). For comparison, *The DC Comics encyclopedia* reveals that DC took a slightly easier way out with their speediest character, the Flash. His powers allow him to tap into the 'Speed Force', which provides him with all the

energy he needs for his superfast adventures, although the cartoon version of this character is often seen eating huge amounts of food almost as fast as he does everything else.

Not all metabolic super powers would need billions of Big Macs' worth of energy to accomplish; some could be done with much less. For example, in the recent blockbuster *Iron Man 3* the Extremis-powered villains were capable of not only regenerating lost limbs but also of creating huge amounts of heat, in one case enough for lead bad guy Aldrich Killian to force Colonel Rhodes out of the Iron Patriot suit by heating it up. To be fair, all cellular metabolic processes lose some energy as heat, but could your metabolism generate that much of a temperature change, and if it could how much power would it take? Let's start by assuming that the metal of the suit gets close to its melting point before the safety release opens and that only a small portion of it, say about 20 kilograms, gets heated up. (Killian only heats the abdominal area of the suit in the film.) We can use the specific heat and melting point of the metal the suit is made of to calculate the approximate amount of energy



required to melt it. First, let's assume that the Colonel Rhodes' suit was made of titanium, rather than iron as the former is much stronger. Titanium has a specific heat of 0.125 kcal/kg/°C, which is how many calories are required to raise the temperature of 1 kilogram of titanium by 1°C. Now we can calculate that to raise the temperature of 20 kilograms of titanium from room temperature (~23°C) to its melting point (1668°C) would take 4112.5 calories *if* that heat transfer process were 100% efficient. While that is over double the calories most people consume in one day, used up in only a few minutes, it is less than many top athletes get through and Killian could make up for it with a supersized lunch of 'only' 7.5 Big Macs.

The metabolic processes involved in the feats outlined above would make interesting metabolomic studies for Hank Pym. Indeed, metabolomics has a lot in common with the good doctor. For instance, like him it is known by many different names. It is variously referred to as metabonomics, metabolic fingerprinting, metabolic footprinting and metabolic profiling. In addition, like Dr Pym, who was a founding member of 'Earth's Mightiest Heroes', the Avengers (along with the Hulk, Iron Man, Thor and the original Wasp), metabolomics is a member of a greater whole, namely the science of systems biology. Additionally, just as the Avengers had a rotating membership of heroes dedicated to fighting evil, systems biology has a wide membership of omic sciences, which all share a common aim – analysing the components of living



organisms in their entirety. Founding members include proteomics (the study of the complete set of proteins produced in a cell) and genomics (the study of the complete set of genes). Newer members include glycomics (the study of sugars) and lipidomics (the study of all the lipids/fats in a system). Genomics even has a sidekick known as epigenetics, which looks at all the methylation reactions that can occur within an organism's DNA and their effects on gene function. Not that epigenetics is your typical, non-descript sidekick; it is pretty powerful stuff and was recently utilised by Dr Sebastian Alvarado, a postdoctoral research fellow at Stanford University, to explain how Captain America and the Incredible Hulk may have come to possess and control their superpowers. Dr Alvarado speculates that in these two cases at least, superpowers might come via the reversible activation and/or modification of particular genes (see videos at bit.ly/1AG2tAZ and bit.ly/XnJ4GU).

This whole system approach is quite different from the kind of biochemistry that most of us studied in school, which traditionally studies the functions of genes, proteins and cells individually. That methodology yields a lot of information but gives relatively limited insights about the whole. It is as if we were studying Iron Man's armour, but only looking at individual components, such as the jet boots, gauntlets and repulsor rays, separately. We would be able to take a reasonable guess as to the specific purpose of each, but would have little to no idea of how the complete system worked. In the same way, systems biologists hope to develop detailed models of whole organisms by working out the relationships and interactions between their various parts.

Metabolomics is a relatively new player in this field of study but it has already had considerable success in a variety of areas. These include studies on drug toxicity, the identification of



... epigenetics ... was recently utilised ... to explain how Captain America and the Incredible Hulk may have come to possess and control their superpowers ... via the reversible activation and/or modification of particular genes.

so-called silent mutations (which do not have easily observed outward effects on an organism's phenotype) and even medical applications, such as the diagnosis of cancer or coronary heart disease – all by simply looking at changes in metabolite levels.

My own work looks at the effects of mixtures of pollutants; think of it as a bit like studying the behaviour of supervillains. If several bad guys band together, you might think that they could cause more trouble than if each worked alone. However, if their various superegos got in the way of actually doing evil, they might end up causing less trouble overall. In a similar way, if an organism is exposed to two or more pollutants, there can be an additive effect (the supervillains work together) but sometimes there is an antagonistic one (the supervillains fight among themselves). I use metabolomics for this work since it is very good at detecting these interactions at exceedingly low exposure levels.

This all points to an exciting future! But wait ... my science sense has

started to tingle. This tells me that either there has been an explosion in the lab (a distinct possibility) or that we have run out of space for this month. But join us next time, science fans, for more adventures in the marvellous world of metabolomics.

Metabolomics away!

Dr Oliver Jones MRACI CChem is a Lecturer in Analytical Chemistry at the School of Applied Sciences at RMIT University Melbourne and is not quite as comic obsessed as this article would seem to imply (honest). Oliver would like to thank his super awesome cousin, Janine Humphrey of Oyster Studios (UK), for all her help generating the images used in this article.

On-screen chemistry

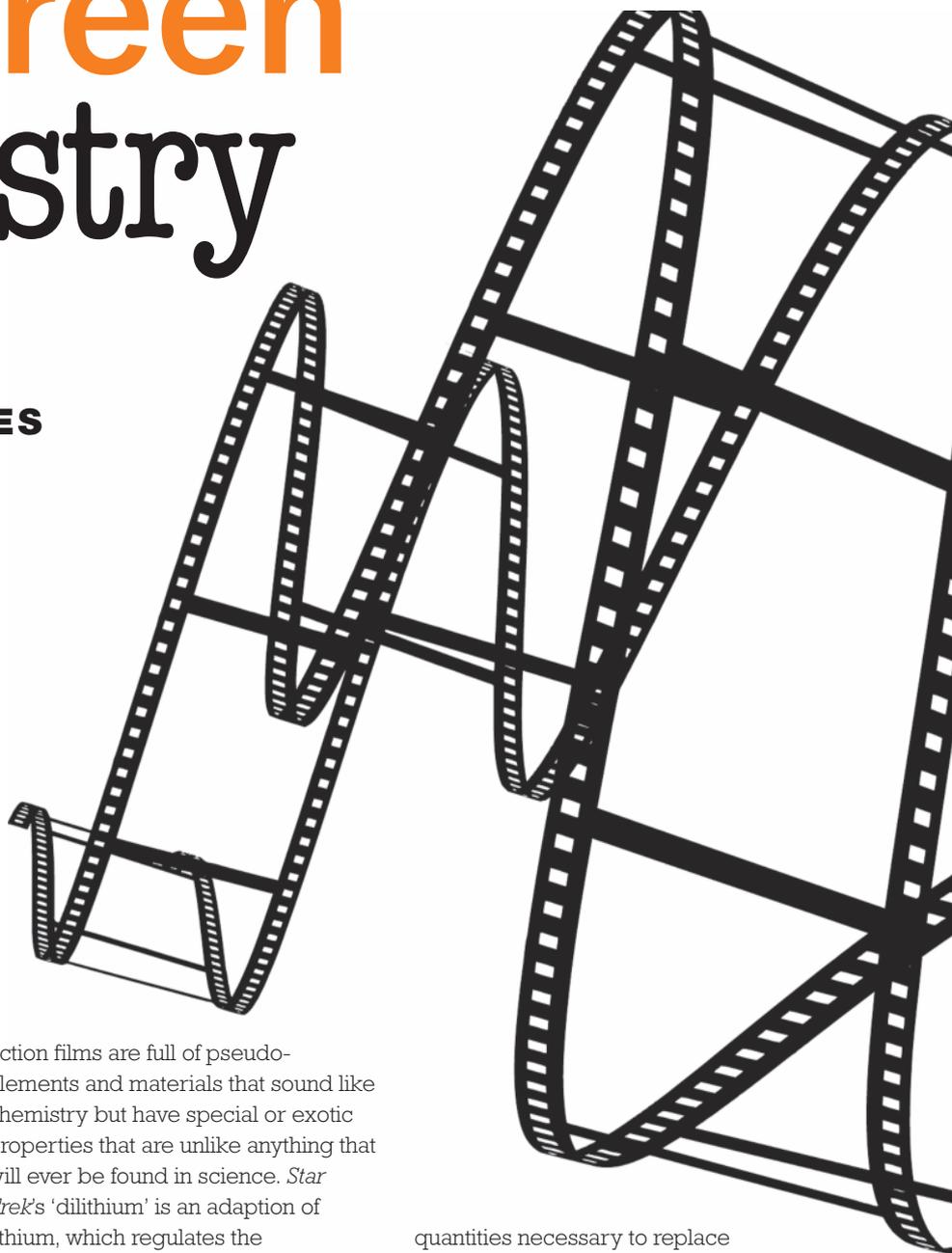
BY COLIN A. SCHOLES

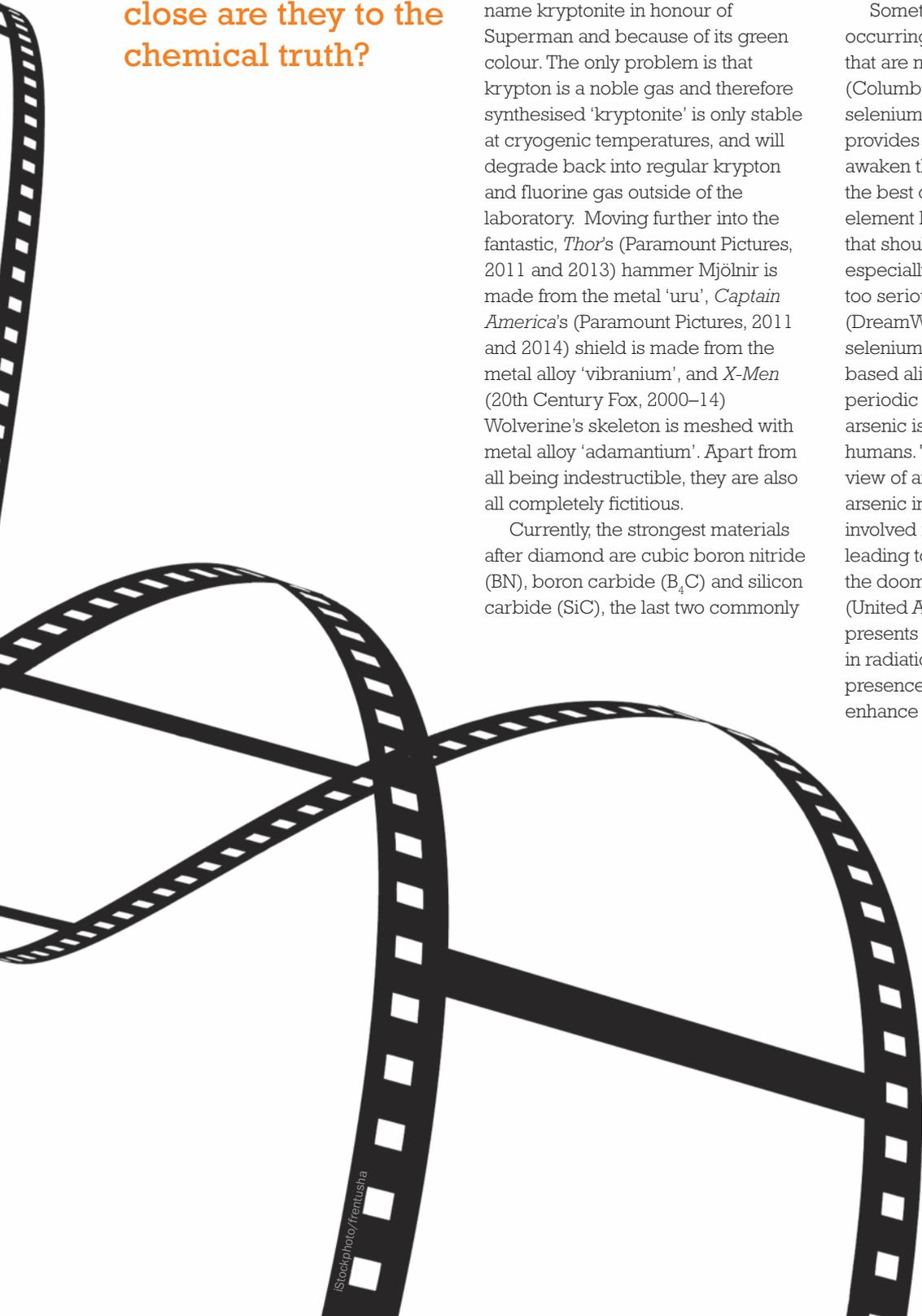
A *Avatar* (20th Century Fox, 2009), the highest grossing film of all time, has as the antagonist a mining corporation focused on extracting the metal 'unobtainium' from the fictional moon Pandora. In the film unobtainium, as the name suggests, is incredibly rare and does not exist on Earth, which is fortunate, because current chemistry does not place such a metal on the periodic table. What it does highlight is the use of chemistry, and in particular pseudo-chemistry, in cinema to drive key plot points.

Interestingly, unobtainium was originally coined in the aerospace industry to describe a perfect material that had all the theoretical properties needed for a specific function, but did not exist or was too rare to be viable. Its use appears in a number of science fiction films to denote exotic materials to enable technical barriers to be overcome. Another recent example is *The Core* (Paramount Pictures, 2003), where unobtainium has the unique property of becoming stronger the more pressure is applied, allowing the actors to journey into the Earth's molten mantle. Naturally, science

fiction films are full of pseudo-elements and materials that sound like chemistry but have special or exotic properties that are unlike anything that will ever be found in science. *Star Trek's* 'dilithium' is an adaption of lithium, which regulates the annihilation of antimatter with matter – a process that is currently scientifically impossible. *Star Trek IV* (Paramount Pictures, 1986) introduces us to 'transparent aluminium', a clear material that is stronger than steel. Surprisingly, sapphire (Al_2O_3) does meet these criteria, though is currently too expensive to fabricate in the

quantities necessary to replace existing plastics and glasses as building materials. The science fiction parody *Galaxy Quest* (DreamWorks Pictures, 1999) opts to use the real element beryllium as the power source for their spaceships. This isn't that big a fictitious stretch, given beryllium's role in the nuclear power industry as a neutron reflector.





Our blockbusters abound with elements, potions and fantastic substances. But how close are they to the chemical truth?

Movie adaptations of comic books are also littered with chemical potential. *Superman* (Warner Bros., 1978–2013) is susceptible to kryptonite, a green ore from Superman's fictional home planet of Krypton. Recently, krypton difluoride (KrF_2) was synthesised and given the name kryptonite in honour of Superman and because of its green colour. The only problem is that krypton is a noble gas and therefore synthesised 'kryptonite' is only stable at cryogenic temperatures, and will degrade back into regular krypton and fluorine gas outside of the laboratory. Moving further into the fantastic, *Thor's* (Paramount Pictures, 2011 and 2013) hammer Mjölfnir is made from the metal 'uru', *Captain America's* (Paramount Pictures, 2011 and 2014) shield is made from the metal alloy 'vibranium', and *X-Men* (20th Century Fox, 2000–14) Wolverine's skeleton is meshed with metal alloy 'adamantium'. Apart from all being indestructible, they are also all completely fictitious.

Currently, the strongest materials after diamond are cubic boron nitride (BN), boron carbide (B_4C) and silicon carbide (SiC), the last two commonly

used in tank armour and bulletproof vests because of their hardness. However, even these materials will fail with time and under the right pressure and temperature conditions, not to mention that no one has yet fabricated them as a hammer or shield or grafted them onto a skeleton.

Sometimes, cinema gives naturally occurring elements special properties that are not possible. *Ghostbusters* (Columbia Pictures, 1984) utilises selenium as a building material that provides the psychokinetic energy to awaken the Sumerian god Gozer. To the best of scientific knowledge, no element has psychokinetic power, but that shouldn't stop a good movie, especially when it doesn't take itself too seriously. Similarly, *Evolution* (DreamWorks Pictures, 2001) presents selenium as a poison for nitrogen-based alien life forms, based on the periodic table position correlation that arsenic is poisonous to carbon-based humans. This is a woefully simplistic view of arsenic's toxicity, given that arsenic inhibits an essential enzyme involved in the energy system of cells, leading to cellular death. Surprisingly, the doomsday classic *On the Beach* (United Artists, 1959) accurately presents the danger of cobalt isotopes in radiation poisoning and cobalt's presence in nuclear weapons to enhance the explosive yield.



...flubber – a fantastic rubbery substance that appears to have a life of its own, gains energy on striking a hard surface and, upon exposure to radiation, has the ability to fly.

The Absent Minded Professor (Walt Disney Productions, 1961) introduces the world to flubber – a fantastic rubbery substance that appears to have a life of its own, gains energy on striking a hard surface and, upon exposure to radiation, has the ability to fly. Such a compound naturally breaks the laws of thermodynamics, but to honour the movie, boron cross-linked polyvinyl alcohol has been given the name 'flubber'. This is because of its non-Newtonian viscous-elastic behaviour, which can more easily be characterised as slime, and it is often found in children's science shows where a green food dye is added to give it colour.

Sometimes, movies can be very instructive on chemistry, one of the most notable examples being *Fight Club* (20th Century Fox, 1999), where the character Tyler Durden introduces the audience to the process of saponification, the production of soap. Through his job collecting human fat from liposuction clinics, Durden demonstrates how the base-catalysed reaction of an ester forms the fatty acid and glycerol, and salt is used to precipitate the soap. Or in his words, 'As the fat renders, the tallow floats to the surface. Keep stirring. Once the tallow hardens, you skim off a layer of glycerine.' Durden also introduces the audience to the concept of chemical burns by applying sodium hydroxide (NaOH) to the narrator's hand, and informing him that the resulting burn will be more painful than any flame.

The Fast and Furious franchise (Universal Pictures, 2001–13) demonstrates to the audience how nitrous oxide (N_2O) as an additive to the engine provides the extra horsepower necessary to boost a car's

speed. This is true combustion chemistry, in that nitrous oxide will break down into nitrogen (N_2) and oxygen (O_2) within the piston chamber of the engine. This will provide additional oxygen for fuel combustion, increasing engine efficiency, while the nitrogen provides additional pressure within the piston chamber, enabling the engine to generate greater work energy.

In many movies, the abilities of chemicals are overemphasised. A good example of this is the use of truth serums on key characters to establish major plot points, such as in *Kill Bill Vol. 2* (Miramax Films, 2004), or for comical purposes such as *Meet the Fockers* (DreamWorks Pictures, 2004) and *True Lies* (20th Century Fox, 1994). Many of these cases refer directly to the chemicals sodium pentothal or sodium amytal. Both of these compounds are short-term anaesthetics, and have hypnotic effects that impair judgement and higher brain functions. Interestingly, they were trialled in the 1950s and 1960s by intelligence agencies as truth serums. Unfortunately, neither compound has the ability to force a person to tell the truth, and rely on the person being in a drugged state and not having the cognitive ability to fabricate a lie. However, given their sedative properties, the person under duress can easily confuse fact with fantasy and therefore these compounds are completely unreliable in the real world, but live on in Hollywood.

Chloroform ($CHCl_3$) is another chemical whose properties have been overemphasised in the movies, where a rag soaked in chloroform forced over the nose and mouth will

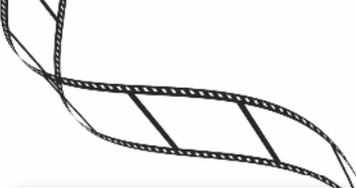
instantaneously render a person unconscious. It is true that chloroform has anaesthetic properties and was used by dentists in the 19th century for that purpose, but was delivered directly as a gas. It has been estimated that breathing in chloroform from a soaked rag will take 15–30 minutes to render a standard-sized man unconscious, more than enough time to fight off your assailant.

Going to a darker place, *The Life of David Gale* (Universal Pictures, 2003) accurately describes to the movie-going audience what constitutes a lethal injection – sodium penthonal, pancuronium bromide and potassium chloride. The first is sedative, the second is a neuron blocker that collapses the diaphragm and lungs, while the third floods the body with potassium ions, interrupting muscle control and stopping the heart.

Poisoning is where Hollywood often gets it right with chemistry. Darker still, *The Young Poisoner's Handbook* (C/FP Distribution, 1995) covers the real life story of chemist Graham Young, whose knowledge of chemistry, and in particular thallium, gained him the nickname the 'teacup murderer', because he poisoned his co-workers through their tea. *D.O.A.* (United Artists, 1950) is based on a similar premise, where an iridium-spiked drink is used to poison the protagonist, and allows the film to open with a surprising cinematic twist for the time, of a man reporting to the police his own murder. However, the only form of iridium that is soluble in water is iridium chloride, and then only partially, and a standard drink would never have the dose necessary to kill a man, let alone be able to mask the metallic taste.

In *Arsenic and Old Lace* (Warner Bros., 1944), the Brewster family murdered bachelors by serving them with elderberry wine spiked with the old favourites of arsenic, strychnine and cyanide. All three will kill a person, with strychnine an alkaloid, like morphine, that is a neurotoxin affecting the glycine receptors in muscles. This causes constant triggering of the neurons, resulting in uncontrollable muscle contractions. The main poison used in the movies, especially the spy and espionage genres, is cyanide, where a small vial of potassium cyanide (KCN), sometimes hidden in a false teeth, is consumed, leading to instant death. However, the recent James Bond film *Skyfall* (Metro-Goldwyn-Mayer Columbia Pictures, 2012) portrays cyanide in the completely wrong fashion, as a botched suicide attempt leaves the villain's jaw badly disfigured. While potassium cyanide is a Lewis base, the quantity required to dissolve flesh is orders of magnitude greater than the quantity required to kill a person. Sadly, the Oscar winner *Schindler's List* (Universal Pictures, 1993) accurately portrays the use of hydrogen cyanide (HCN) gas in the Holocaust.

The movies also provide us with antidotes to ward off the effects of poison. In *Crank* (Lionsgate, 2006), the main character must keep his adrenaline levels high to survive a toxic drug cocktail. This is achieved through natural or artificial stimuli, such as epinephrine. This approach is partly true, as increased adrenaline can limit the effects of a number of poisons and drugs, especially those of a sedative nature, and provide time for the body to break down the poison. Interestingly, 'crank' is slang for methamphetamine (*N*-methyl-1-phenylpropan-2-amine), a psychostimulant drug commonly used for recreational purposes and a key fixture in many drug-related productions, such as the television series *Breaking Bad* (AMC, 2008–13). The other main drugs depicted in



How 3D glasses work

Blockbuster movies are increasingly been shown in 3D – to provide depth perception and hopefully enhance the viewing experience. They are produced through a process known as stereoscopic photography, where the camera system records the image from two perspectives.

Ideally, two cameras, positioned so that the lenses are the same distance apart as the average pair of human eyes, record images of the action that the left and right eyes would perceive if you were on the movie set. Alternatively, computer software can take images from a standard camera and distort them into two distinct images corresponding to the different eyes. This allows films to be converted into 3D postproduction, but the viewing experience is poorer and generally criticised.

In screening the 3D film, the objective is to ensure that images for the left eye are only perceived by the left eye and vice versa for the right eye, since both camera images are superimposed upon the cinema screen. Old-fashioned 3D filming did this through colour – the left eye images were red filtered and the right eye images were blue filtered. Hence, the old red and blue glasses, which ensured only the correct colour image was received by the correct eye.

However, basing the 3D experience on colour selection limits the vibrancy of colour now expected in most modern movies. Current 3D technology overcomes this through polarised light. Polarised light is light that vibrates in only one plane, which means the electromagnetic oscillations are all parallel. Most light is unpolarised, or scrambled, and hence the electromagnetic oscillations occur in all planes. The clear glasses now worn by movie goers are polarising filters that have tiny parallel lines etched upon them that only allow light through that oscillates in the same orientation as the etched lines. Hence, instead of screening the two images in different colours, now 3D films screen the two images in two polarised images, orientated perpendicular to each other. The lens of one eye allows one polarised image to be seen and the other lens allows the perpendicular polarised image to be seen. The eye cannot differentiate polarised light and hence a 3D image is perceived. However, because the glasses only allow through one type of polarised light, the intensity of the light received by the eye is less than what would occur for a standard 2D film without the glasses. Most cinema projectors increase the intensity of the light emitted from the projectors to make up for this. However, mega-screen cinemas in modern megaplexes often cause eye strain, because standard projection systems cannot provide enough intensity to overcome both the polarised light filtering effect of the glasses and the larger screen area.

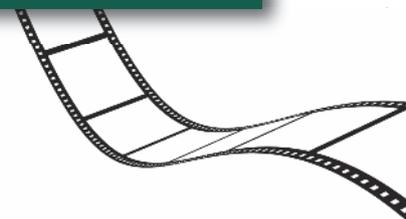


cinema are cocaine and heroin, which are more often associated with police versus cartel action movies, such as *Miami Vice* (Universal Pictures, 2006) and *Bad Boys* (Columbia Pictures, 1995). Interestingly, the effects of these illicit drugs are nearly always depicted accurately.

In the end, the cinematic world denotes 'Chemistry' to describe the sexual attraction between couples, and is used for romantic or comic, though sometime tragic, ends – because this is the main purpose of cinema, to

entertain or enlighten audiences. Delving too deep into the fictitious science underpinning the plot only breaks the illusion of some wonderful and at other times woeful story-telling.

Colin Scholes FRACI CChem is at the University of Melbourne.





Global industry drives



the dry cell

BY **DAVE SAMMUT**

The humble battery is an inspiring thing, embodying the grand scale of human endeavour.

Their technology is so elegant, so simple, and it would be hard to find a household anywhere in the country that didn't have a few batteries somewhere – in a drawer, or (if you want them to last longer) in the fridge. These compact cells are little charges of chemical energy just waiting to burst forth.

But how does a battery work? In simple terms, some materials 'want' electrons more than others. If you touch zinc to iron, then the zinc will

give up its electrons to the iron when some other factor comes calling. This is why galvanising steel with a coating of zinc protects it from corrosion. As the oxygen in the environment tries to take electrons away from the iron (causing it to rust), the iron in turn takes those electrons from the zinc. Bit by bit, the zinc gets eaten away; but as long as the zinc lasts, the steel shouldn't rust.

The same is true for boats. Most steel vessels have a magnesium, zinc or aluminium 'sacrificial anode' that

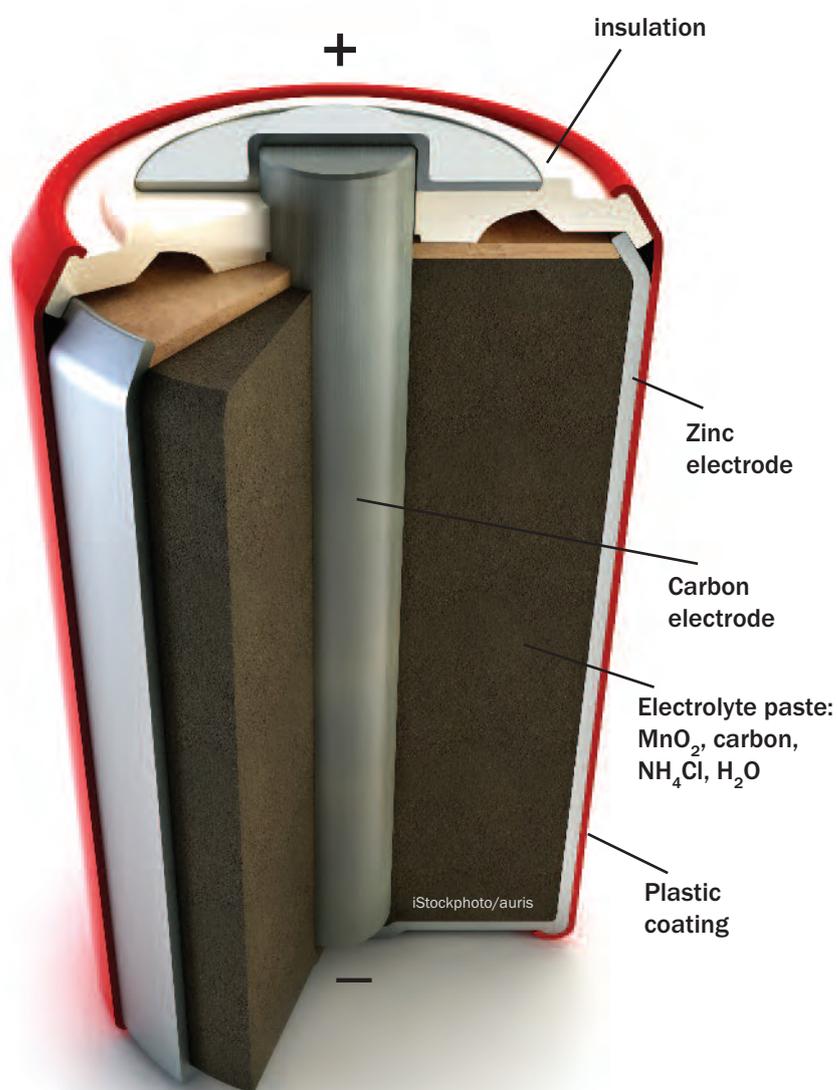
Just about every component of a battery – the metallic zinc and copper, the manganese dioxide, even the plastic coating on the outside – is a product from mining and minerals/petroleum processing.

helps protect them from corrosion. Sodium would do the job even better than these metals, except it reacts so violently with water it would explode, and ships with large holes just aren't that useful.

So, if the two metals are touching, the electrons flow from one to the other. If you separate them and put a conductor in between, then the flow of electrons is electricity. That's all a battery is – an incomplete circuit, with two electrodes and a conductor in between, and a driving force between two materials that have different attitudes to electrons.

Batteries are based on simple, straightforward principles, yet those principles have taken many generations of clever men and women working together to discover, share and build knowledge. The household 'dry cell' battery represents the perfection of a leap forward in science that started in the second half of the 18th century with such pioneers of electricity as Benjamin Franklin, Luigi Galvani and Alessandro Volta, yet it uses the same principles as were developed all those years ago.

Alessandro Volta's original 'voltaic pile' used discs of zinc and copper metal separated by brine-soaked cardboard. It worked, but it wasn't as efficient as it could be. The alkaline battery, a modern dry cell battery, is actually pretty similar. It still uses zinc as one of its electrodes, which wraps around the outside of the battery, just



Cutaway diagram of a type of dry cell battery. Dry cell batteries are named for their electrolyte (conducting medium), which is a paste rather than a solution. Alkaline, lithium, nickel-metal hydride and silver oxide ('button') cells are all types of dry cell.

under the plastic coating. The big difference from the original design is that the 'zinc-carbon dry cell' uses solid manganese dioxide and graphite as the other electrode instead of Volta's copper, and a paste of ammonium chloride as the internal conductor instead of the soggy cardboard. There are no messy liquids, which is why it is called 'dry'.

In simple terms, when a circuit is made from the negative to the positive terminal of your battery, the manganese dioxide 'sucks' the electrons around that circuit from the zinc anode to the carbon cathode with 1.5 volts of pulling power.

But as a chemist, here's the thing that truly inspires me. This elegant little battery is the product of a huge amount of science, and a huge global industry goes into its manufacture. Every day, tens of thousands of people work to produce the metals that are (quite literally) the framework of modern society.

Just about every component of a battery – the metallic zinc and copper, the manganese dioxide, even the plastic coating on the outside – is a product from mining and minerals/petroleum processing. Australia is the world's largest producer of zinc, and the equal second largest producer of manganese.

Although the chemistry of these two metals differs markedly, their production uses the same basic principles. You might remember a chemistry experiment from high school, in which two electrodes are put into a beaker of bright blue copper sulfate solution and wires are connected to a transformer. You would have 'plated' a thin layer of copper onto something metal, such as a coin.

Producing zinc or manganese dioxide is basically the same. In both cases, the ore is mined from the ground as a mixture of the metal and oxygen or sulfur (ZnS, ZnO or MnO₂). These ores are impure, so the target minerals are separated from all of the other rocks and minerals that are not wanted (called 'gangue'). Then, concentrated acid solutions dissolve the minerals into solution in huge stirred tanks, each tank about the size of a backyard swimming

pool. After filtering off the residual solids in filters the size of buses, we end up with concentrated, highly coloured liquids containing the dissolved metals dissolved. Think of it as cola – concentrated, acidic, and really not good to drink in excessive quantities.

In industry, this is jokingly called 'bucket chemistry'. At this huge scale we add a bucket of this, a bucket of that to get the desired product – sometimes quite literally. In my first job as a chemist, I spent many an hour hauling buckets of soupy mud from one place to another in an experimental plant for minerals processing.

Of course, the detail can get a bit more complicated than that, particularly when we get to the part about purifying the electrolytes. But generally, chemistry is on our side, and there are some truly clever tricks to efficiently separate one dissolved metal from another.

Then comes the modern part of the technology. By using electricity to force the electrons to flow in the desired direction, we can either push them into the dissolved zinc to make it plate out (just like you did at school) or forcibly strip extra electrons out of the dissolved manganese so that it precipitates in just the right form (called electrolytic manganese dioxide). For zinc, that leaves it ready to lose electrons again, and for manganese it makes it particularly hungry to get its electrons back. And that stored imbalance between the two is what makes a battery work so well.

We face many challenges, not least the overwhelming weight of the human population's dependence on limited resources. Yet how grand are those quintessential human characteristics that both create and solve these problems: ingenuity, curiosity, cooperation.

When a bad storm hits, or a fuse blows, or we just forget to pay the electricity bill, the lights go out and we reach for a torch. And that humble battery is standing by, ever ready, awaiting the day that we need it.

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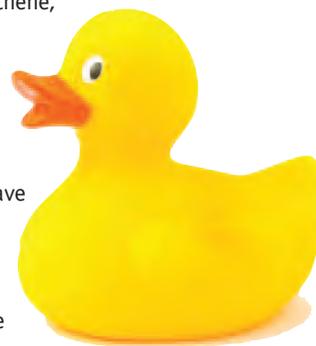
Plastic: the making of a synthetic century

Fenichel S. HarperCollins, 1997, 356 pp. ISBN 0887308629

This book sets out to show how plastics, and synthetic polymers generally, shaped 20th century society. Fenichel contends that 'Plastic has become the defining medium of our synthetic century precisely because it combines the ultimate twentieth century characteristics – artificiality, disposability and synthesis – all rolled into one.'

The book describes little chemistry, or other hard science, other than to detail the ingredients and mixtures on which a range of scientists worked. Where it makes a contribution to the lay person's understanding of science is in relating the stories of discovery, particularly the scientific approaches of the discoverers. It weaves a thread of history, characterised by curiosity, serendipity and skunkworks. The discoveries of all the major synthetic materials are addressed: including celluloid, cellophane, nylon, acetates, polythene, rubber and teflon.

The stories of discovery are well told. My personal favourites relate to polyethylene and teflon. In both cases, sealed cylinders of reactive gases were thought to have leaked, after the pressure gauges showed a loss of pressure in the cylinder. The experimenters weighed the cylinders to convince themselves that there had not been a leak, and then opened the cylinders to reveal powdery white plastics.



iStockphoto/Tsekhmister

There is a section on the importance of World War II on the development of synthetic materials. I knew that the Americans and Germans both pursued synthetic rubber, after they were isolated from the supplies of natural rubber in south-east Asia. However, I was unaware of polyethylene's role as a lightweight insulation material for airborne radar, and the use of teflon gaskets, because of teflon's corrosion-resistant properties, in the enrichment of uranium. Large-scale production for the war effort facilitated the availability of these materials for later, peaceful, purposes.

If there is a drawback to the book, it is that the improvements to the initial production processes are not discussed. The reader could be forgiven for thinking, for example, that all polyethylene is still produced by a high-pressure process. A major omission is the lack of any mention of Karl Ziegler and Giulio Natta, whose Nobel Prize-winning work on polymerisation catalysis enabled low-temperature/low-pressure production of several important polymers.

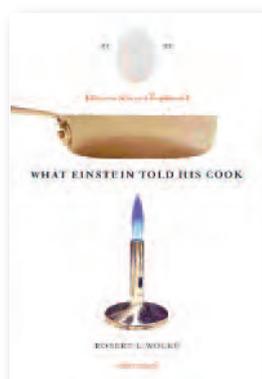
Overall, this book should appeal to individuals (scientists and non-scientists alike) with a bent for history and a curiosity about the things around them, and where they came from.

Paul Moritz MRACI CChem

Digestible chemistry

By the time you finish reading this sentence, the cells in your body will have completed about ten million little chemical reactions. Maybe more. It's hard to count that fast. Breathing, digestion, blood sugar level, electrolyte balance, even thinking, all boil down to chemistry. While you think about that, follow me to the kitchen and sit while I brew a pot of coffee and scramble an egg. Chemistry in action. Open the cleaning cupboard and we can make a list of chemicals a page long just by reading the list of ingredients. And the medicine cabinet? Make that another two pages. Chemistry is everywhere. Where then, should the general reader begin?

'For the general reader' was the main criterion I used in my search of titles to recommend. That means you, general reader, are much like me, someone with a keen interest in science, but no formal background. Basically, you haven't looked at chemistry since high school or maybe first year of college, but now, for whatever reason, you are interested, or you might be. Or perhaps your dad is, or your aunt, or your 12 year old, or a friend, and you're looking for a gift. Any of the titles here would do splendidly.



Kitchen chemistry

If you are a foodie, there is a whole buffet of books on 'the science of the kitchen'. As an entrée, you could try **Culinary reactions: the everyday chemistry of cooking** by Simon Quellen Field. Field is a fun guy. In the introduction is a photo of him using a tank of liquid nitrogen to make ice cream for a group of Nobel Prize winners. Neither your average kitchen appliance nor the usual crowd you might have to dinner, but it captures the spirit of the book. In Field's own words, 'When you're cooking, you're a chemist! Every time you follow or modify a recipe, you are experimenting with acids and bases, emulsions and suspensions, gels and foams.' By the time you finish Field's book, you will know what those and a dozen other terms actually mean, and your mayonnaise will be outstanding.

Along similar lines but in a Q&A format is Robert L. Wolke's **What Einstein told his cook: kitchen science explained**. Is there really a difference between supermarket salt and sea salt? How is sugar made? Should cooks avoid aluminium pans? The answers are mostly chemical, and your aluminium pots pose no danger to your health.

There are more titles dealing with kitchen science or, as some like to call it, 'molecular gastronomy'. The wonderful thing about Amazon and Kindle is that you can browse at least some of the content and read reviews from other readers and make up your own mind.

The human element

If none of the foodie titles whet your appetite for chemistry, you may prefer the more human touch. Who were these people, these chemists? What kind of lives did they live? What led them to their great discoveries?

A perfectly delightful introduction is Oliver Sacks's **Uncle Tungsten**. Sacks is a British-American neurologist and chemist, currently Professor of Neurology at New York University School of Medicine, and a prolific and talented writer. Uncle Tungsten was the family nickname for his Uncle Dave, who owned a lightbulb factory and introduced the young Sacks to chemistry. Sacks was obsessed with 'stinks and bangs' and was given a whole room in the family's rambling house as his laboratory where he experimented freely. We see the young Sacks, aged about 12, toddling off to the local chemical supply shop to purchase vials of hydrochloric acid and chemicals that today would require a license and clearance from Homeland Security. Once, when he nearly asphyxiated himself, his parents installed a hood to vent fumes. Hard to imagine modern parents taking such a casual attitude, but times change.

In a similar vein, **Periodic tales: the curious lives of the elements** by Hugh Aldersley-Williams is a pleasant ramble through the history, literature, science and art surrounding just some of the currently known 118 elements in the periodic table. This is the kind of book you can open anywhere and be both enthralled and enlightened.

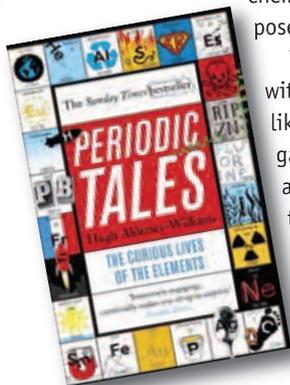
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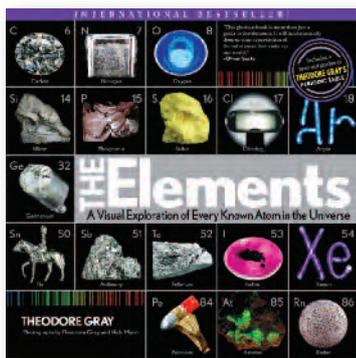
On food and cooking: the science and lore of the kitchen by Harold McGee (see Chem. Aust. July 2014, p. 32)

How baking works: exploring the fundamentals of baking science by Paula I. Figoni

Ratio: the simple codes behind the craft of everyday cooking by Michael Ruhlman

Molecular gastronomy: exploring the science of flavor by Hervé This





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30-second elements: the 50 most significant elements, each explained in half a minute by Eric Scerri (editor)

Mendeleev's dream: the quest for the elements by Paul Strathern (see Chem. Aust. December 2009, p. 42)

Molecules that changed the world: a brief history of the art and science of synthesis and its impact on society by K.C. Nicolaou and T. Montagnon (see Chem. Aust. June 2008, p. 31)

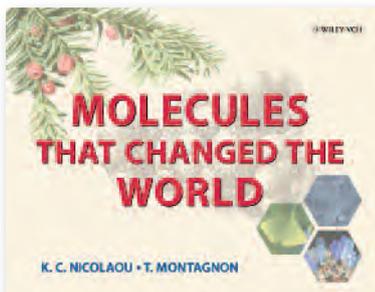
Salt: a world history by Mark Kurlansky

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An ocean of air: why the wind blows and other mysteries of the atmosphere by Gabrielle Walker

H₂O: a biography of water by Philip Ball



The periodic table

You can't wander very far into chemistry and not become acquainted with the periodic table, quite possibly one of the most outstanding achievements of modern science. After **Periodic tales**, you simply must have a look at **The elements: a visual exploration of every known atom in the universe**, by Theodore Gray (author) and Nick Mann (photographer) (see *Chem. Aust.* April 2014, p. 32). This is a visually stunning book. Each element gets a two-page spread. One side features a large colour image of the element in its true form, when possible. The facing side includes images of ways the element appears in the world and explanations of some of its compounds. If you are looking for something to wean your kids off their computer games, give them a copy of **The elements**. And start looking for chemistry sets, which surprisingly Homeland Security hasn't got around to banning yet.

With young readers in mind once again, have a look at **The mystery of the periodic table** (Benjamin D. Wiker, Jeanne Bendick and Theodore Schluenderfritz). This is a chemical version of 'the lives of the saints' in which you meet the colourful and often eccentric men who put chemistry on today's solid, scientific footing.

More 'serious' reading

By now you may be encouraged to tackle slightly more 'serious' titles. These are titles that do require a bit of work, but as Darwin says in *The origin of species*, '... no slight effort of reason and memory is left to the reader ...'. For those with a genuine interest in the world around them, this will pose no problem.

In **Oxygen: the molecule that made the world**, Nick Lane takes us back to a world where the air contained 'probably about one part in a million of oxygen'. Lane ranges widely across disciplines from environmental science to molecular biology and offers his speculations on the role of oxygen in ageing, a topic that will appeal to the baby boomers in the audience.

Online

Good reading is no longer confined to hardcopy books. For the chemically inclined, a good place to begin is **Ten Cool Sites** (<http://apps.exploratorium.edu/10cool>). My personal favourites are Chemsoc Timeline and What's that Stuff?, the latter about the chemistry of everything from road paint to wasabi. Be warned, you can spend hours on **Ten Cool Sites**. If my high school teachers had had access to sites like this, I might have done better than a C⁻ in chemistry. And physics. And biology.

Much later in life, my interest in science rekindled, I signed up for an online course on human physiology from **Coursera** (you can audit courses for free or pay a small fee and get a certificate). A lot of chemistry in physiology, and this time I got a B⁺, mainly with help from **Khan Academy**. Khan Academy is a not-for-profit, 'with the goal of changing education for the better by providing a free world-class education for anyone anywhere'. Worked for me. The 14-minute video clip on the sodium potassium pump is simply brilliant. High school teachers take heed.

Ready for some fun?

In the early stage of my search for interesting titles, I thought I would cast about and see what I could find on the chemistry of everyday things. I went to my browser and entered: 'chemistry of + [name of some everyday item]'. I couldn't find a term that didn't have something about 'the chemistry of'. There is chemistry of: toothpaste, nail polish, superglue, kitty litter, ink, lightbulbs, nappies, socks ... I still haven't found an everyday item that turned up an empty search. Why don't you try and let us know what you find. Or don't. In the meantime, have fun reading.

Terry Clayton www.redplough.com

A tale of ancient pharmacies

Years ago, the Royal Australian Chemical Institute worried about the confusion that was thought to exist in the public's mind between the chemistry profession and the local chemist's shop. Since then, chemistry has spread its influence from the environment to nuclear disarmament, and the high street chemist's shop is now called a pharmacy. Some readers may know either the National Trust 'Dow's Pharmacy' in Chiltern or the 'Savory and Moore' pharmacy at the Medical History Museum at the University of Melbourne. These give a sense of the old fashioned 'chemist's shop', but neither is truly ancient.

Ancient pharmacies have been preserved in various museums around the world, for example, in Dubrovnik and Florence. The internet sites of the Swiss pharmacy museum in Basel, or the National Library of Medicine in Bethesda, US, have many fascinating illustrations of pharmacies throughout the ages. The history of pharmacy has a considerable literature, and at least one journal (*Pharmacy in History*, the journal of the American Institute of the History of Pharmacy). To choose one lovely example, the *Illustrated history of pharmacy* by David Cowen (New York 1990) is a beautiful coffee table book packed with marvellous artwork, particularly the medieval woodcuts and paintings, a typical one being the 15th century miniature of 'The pharmacy' from the *Canon medicinae* of the 11th century Persian scholar Ibn Sina (Avicenna).

Although the history of pharmacy goes back to the civilisations of Mesopotamia and Egypt, the Greeks and the Romans (Dioscorides, Hippocrates and Galen) followed by the Arabs (the first identifiable pharmacy shop is attributed to Baghdad in CE 770–780) were responsible for the transmission of pharmaceutical knowledge, mostly in encyclopaedic form – those collections of remedies which became 'pharmacopoeias'. The name 'apothecary' was used in Galen's time for the store where the medicines were kept. 'Apotheke' is still used in Germany, but in France and Italy you look for a 'Pharmacie' or 'Pharmacia', easily identified by its flashing green cross!

In Western European culture, we know of Hippocrates and Galen, but the Persian scholar Ibn Sina is more obscure. He lived from 980 to 1037 (370–428 Islamic calendar). His interests covered astronomy, philology, philosophy, mathematics and metaphysics. He was often involved in the administration of the courts of the Persian sultans. He began dictating his *Canon medicinae* in 1012 in Jurjan and finished it in 1023 at the court of Ala al-Dawla in Isfahan. It was translated into Latin by Gerard of Cremona in 1150–87, when the author's name was changed to Avicenna. The *Canon* became the authoritative compendium of Greco-Roman medicine until the Renaissance and was still in use as a reference work in the 18th century.



Doctor and pharmacist, illustration from *Medicinarius* (1505) by Hieronymus Brunschwig

The old pharmacies of Dubrovnik and Florence date from the late medieval and Renaissance periods when pharmacies were founded by monastic orders such as the Benedictines, the Dominicans and the Franciscans. The Stara Ljekarna of the convent of the Franciscan Friars minor in Dubrovnik claims to be the oldest working pharmacy in the world, being founded in 1317 (see www.malabraca.wix.com). It has a working dispensary, which can be difficult to get at as it is visited by many tourists from cruise ships! It is easier to access the museum of the pharmacy of Santa Maria Novella in Florence, founded in 1612 by the Dominicans (see www.smnovella.com). Santa Maria Novella, in the Via delle Scale, not far from the main railway station in Florence, is no longer a dispensing pharmacy but operates as a purveyor of upmarket cosmetics. Its museum preserves much of the old fashioned apparatus for grinding, dissolving, extracting and distilling remedies from herbal sources ... all too familiar to those who did Organic Practical Class about 1960!



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Science online

People cite the 1970s and 1980s as the golden years of television. It was relatively new, with only a few channels. Much of it was novel, producers had original ideas for new shows while special effects and trick camera work were arresting, even if they had been seen before in the cinema. Unlike in the cinema, Australians began to see themselves on the TV screen. Even in slightly fuzzy black and white, familiar topics acquired a different allure on the 'idiot box'.

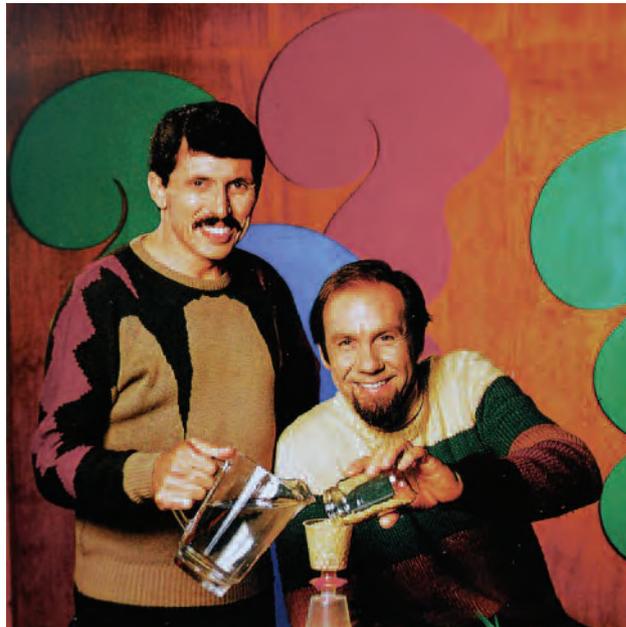
It was my good fortune, along with Dr Deane Hutton, to host a science program throughout those two decades. We were not the first. Our program, *Curiosity Show*, followed earlier work by Professor Julius Sumner Miller, of *Why is it So?* fame, but we had the luck to come to television just as it became widespread in Australian homes.

There were then few programs for children beyond their preschool years, and what existed was often overtly educational. Our audience was older children, so we were frequently lumped into that category. Educational television in those days tended to have a classroom look, with presenters in front of a blackboard behind a bench talking to 'boys and girls' as though facing an invisible class. Producers were still to learn that viewers, even in a group, watch as individuals and should be spoken to as such.

Sumner Miller is still remembered, not just for his interesting material, but also for his quirky belligerent delivery. He would poke his mildly protesting interviewer while demanding that he (it was usually he) solve some problem. While I can't prove it, I suspect that he realised that an ageing teacher in black and white in front of a blackboard might be less than compelling, but phony aggression lent his performances enough energy to overcome the limitations of early TV production.

We were luckier. Through those two decades, TV definition improved, video replaced film and introduced colour, the early versions of which could magically change trousers from brown to green and would not let you wear red as it bled over the screen. The magic of Chromakey allowed the superimposition of any footage over green or blue backgrounds so you could seem to be facing a charging bull, boating in Venice or presenting against any background you liked. Our *Curiosity Show* title sequence showed me with a third eye rolling in my forehead – achieved by pasting a piece of blue paper there and superimposing video of another eye from a second camera. We saw the introduction of powerful graphics and special effects software that greatly improved the scope of segments – no more blackboard by now.

But apart from technological advances, we did our bit to develop different ways of presenting science. Aware of the dominance of 'talking heads' in television, we got the camera off us and onto what we were doing or showing. The frequent use of extreme close-ups transformed commonplace material



Deane Hutton and Rob Morrison, hosts of the *Curiosity Show*

into something extraordinary. With a three-camera studio, we used one camera for a 'point of view' angle so that viewers saw what we saw.

Curiosity Show featured much to make and do, and we always used stuff from around the home to make activities widely accessible. We also showed our finished items working so that viewers knew what to expect. That meant making several versions at different stages of development, and Wikipedia attributes to us the origin of the phrase 'Here's one I prepared earlier'.

Many of the huge old studios I worked in, once cluttered with sets for a multitude of programs produced in them, are now used only for storage, their cameras and monitors gone, the collective expertise of their crews long since dispersed.

Paradoxically, the number of television channels has multiplied, many showing endless repeats from the 1970s and 1980s, reminding us if we needed it that television's golden age has gone. The internet has seen to that, and *Curiosity Show* has its own online channel now (youtube.com/curiosityshow). In some ways it is a better technology for making and doing as you can stop, rewind or replay segments at will, but I'll admit to a certain nostalgia for those two decades. They were more than fun while they lasted.



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Smoking is bad for fish, too

In July, the Australian Bureau of Statistics released data showing that the rate of smoking in Australia is at an all-time low. Less than 15% of the population over the age of 14 now smokes. The reduction in smoking rates can be attributed to public health-awareness campaigns and changing social attitudes. Many of the public health messages are accompanied by vivid images of the health impacts of smoking. Other government initiatives such as restrictions on advertising, even at point of sale, plain packaging and higher taxes have all played a part.

Smoking is now less socially acceptable in Australia, partly because of restrictions on where smoking is allowed. It is banned in most indoor public spaces, and many outdoor areas, too, including sporting stadia and railway station platforms. A greater awareness of environmental and public health has probably also played a part. Some of the restrictions, and changed behaviours, can also be attributed to business owners and employers responding to case law that holds them liable for workers' compensation claims arising from their employees' exposure to smoke-filled environments. Crowded bars were the first targets for restrictions.

With this change in behaviours and attitudes in Australian society, it can be easy to forget that other parts of the world have not followed Australia's example. This was brought home to me in a dramatic fashion earlier this year in Helsinki. I had acclimatised to the sight of smokers almost everywhere I looked, but the accepted habit of dropping cigarette butts (usually still lit) to the footpath was quite confronting. I was certainly not ready for a besuited businessman to fling a lit butt to the ground at my feet as I walked past!

Different Australian environmental authorities have conducted advertising campaigns aimed at reducing cigarette butt litter. One image that stays with me is of a swimmer in the ocean surrounded by cigarette butts. The EPA's campaigns have been targeted at the litter, waste and aesthetic aspects of discarded butts, often with an emphasis on stormwater quality. To the best of my knowledge, the environmental impacts of the smoke and tar residues on the used butts have not been considered an issue.

In June, an opinion piece appeared in *New Scientist*, written by Thomas Novotny, of the Cigarette Butt Pollution Project at the San Diego State University. Novotny and his team have undertaken research to show that the effects of cigarette butts on the environment are more insidious than we might think. The organic compounds present in cigarette smoke and residual tar (often on the filter) have been identified and characterised for some time. Some, such as polycyclic aromatic hydrocarbons, (PAHs) are known carcinogens, but only sparingly soluble in water. Novotny and his team completed a peer-reviewed study in which they applied standard tests endorsed by the US EPA (acute fish bioassays) to determine the toxicity of cigarette



butts to freshwater and marine fish (see tobaccocontrol.bmj.com/content/20/Suppl_1/i25.full). Cigarette butts were treated in a leaching solution, and fish were then exposed to the resulting leachate. This is intended to simulate the impact of pollutants leached from the cigarette butt on various water-living species. A number of different leachates were produced containing different amounts of cigarette butt materials. Acute toxicity was measured as LC₅₀ – the lethal concentration of cigarette butts in solution (number of butts per litre) that resulted in the death of half the test fish.

The most lethal solution was obtained when the smoked cigarette butts comprised the filter and some tobacco. The measured LC₅₀ was just one butt per litre of solution. The leachate from just the filter part of the smoked butt was less toxic, with LC₅₀ values of 1.8 and 4.3 butts per litre for the freshwater and marine test species, respectively. Alarming, even unsmoked filters with no tobacco were found to show toxicity, with LC₅₀ values of 5.1 and 13.5 butts per litre for the freshwater and marine test species.

In my work as a contaminated land auditor, I regularly encounter PAHs. They are formed during the combustion of organic matter and fossil fuels. Hence, it is no surprise that they are present in cigarette smoke. There are quite low allowable levels for PAHs in soil, because they are carcinogens, and because of the possibility of exposure of children and other sensitive individuals to contaminated soil. I've never understood why anyone would voluntarily expose themselves to carcinogens by smoking, and I've talked to enough fire fighters and rural residents to understand the hazard of discarded butts when still lit. This new information highlights that some smokers' individual actions can cause harm beyond their own health, and that there is more to be achieved by litter control than clear water at the beach for your summer swim.



Paul Moritz MRACI CChem (Paul.Moritz@douglaspartners.com.au) is a Principal Contaminated Land Consultant with Douglas Partners, and an EPA-appointed Environmental Auditor in Victoria and the Northern Territory. Field research for this article was, unfortunately, not sponsored by any organisation.

Wine tasting when flying high

Recently, an article by Cathy Gowdie in Fairfax Media's *Epicure* looked at why wine seems to taste different when flying (bit.ly/1sU5Lj7). A question indicated a preference for drinking Champagne on planes. Gowdie commented that perhaps the Champagne and other wine served at the pointy end of the plane differed in quality from that served at the back. But she also noted the body of research evidence underpinning why wine may taste different when flying high.

Normally, if I want to taste a wine, I pour a small amount into a glass, first checking the colour and making sure the wine is clear and free of debris, although I will accept some debris in aged reds. Then, I smell the wine, noting the aromas and checking that it is free of spoilage characters. I am not overly fazed by the need for fruity aromas that are all the rage in some wine-tasting notes – if I want the smell of fruit, I would rather have the fruit! When the wine is placed in the mouth, additional aromas may be sensed via what is known as 'retro-nasal olfaction' (bit.ly/1fMGXP8). The mouth is warmer than the temperature at which wine is normally served and so less volatile compounds are more apparent. Finally, I check the taste, looking for balance, length and firmness.

Overall, the results suggest that seeking subtlety in a wine's aroma and taste profiles is not a requirement of value when flying.

How then does this relate to tasting wine in a plane? First, it is unlikely that the serving temperature will be optimal. Even on the ground, many whites are served too cold and some reds may be too warm. Labels often show serving temperatures recommended for a better reflection of the wine's characters. Plastic glasses are not the best for observing wine colour and the cabin lighting does not help. For me, the physical environment is important when tasting and a crowded seat in the rear section of a plane is far from ideal. Astringency assessment is influenced by salivary flow, which is not helped by the dry atmosphere of the plane. Further, the olfactory mucosa, essential for aroma assessment, are significantly affected by the dry atmosphere.

The research into odour and taste perception in planes has been described by Andrea Burdack-Freitag and colleagues in the *Journal of Consumer Protection and Food Safety* (2011, vol. 6, pp. 95–109). Experiments were carried out under simulated flying conditions in the fuselage of an Airbus A310-200. This fuselage was placed in a metal tube that allowed adjustments to humidity, temperature and pressure. Sensory tests on food and wine were performed at a low pressure corresponding to

that experienced at cruising altitude and at normal atmospheric pressure; the humidity and temperature were the same at both pressure levels. Two panels of 24–30 tasters, one more experienced and the other 'naïve', comprising both sexes and mixed age groups, were used in the sensory analysis. Lufthansa funded the study as it wished to have 'hard data' to underscore anecdotal comments from its customers regarding likes/dislikes of food and beverages on its flights. 'As Germans, we love science' said the head of wine selection for Lufthansa (<http://on.wsj.com/VMMIbN>). Oh, for a similar attitude in Australia!

The white wines studied were a Pinot Blanc, a Chardonnay Icewine (made from frozen grapes and very sweet) and a Riesling. One red wine came from Bordeaux and one from Italy. The Italian Amarone wine was made in part from dried grapes that tend to intensify the aroma and taste, especially astringency. The Icewine and Amarone are curios and not styles that are part of a general consumer focus in wine selection.

The 'on-plane' experiments were performed at a commonly used cabin pressure, some 25% lower than that used for the normal pressure experiments in a laboratory. Perhaps surprisingly, the perception of odours and tastes changed in different ways. For example, the two fruity white wines (Pinot Blanc and Riesling) showed a loss of aromatic or fruity characters and an enhanced perception of alcohol to the extent that it was considered offensive. The acid taste of these wines was enhanced at low pressure, 'sourness' being a common descriptor. The aroma profile of the Chardonnay Icewine was regarded as independent of the change in pressure. The Icewine was selected as the 'most popular' wine, although (from my biased opinion) this may reflect cultural issues in determining preferred wine styles. For the two red wines, the aroma and taste profiles of the Bordeaux were essentially independent of pressure, while the authors commented that the Amarone's assessment depended on whether the taster appreciated the style or not. Overall, the results suggest that seeking subtlety in a wine's aroma and taste profiles is not a requirement of value when flying.

There is much more to the study by Burdack-Freitag et al. than I can describe here. There is a detailed account of the sensory trials and results as well as physical chemistry data on the influence of pressure change on volatility and on modelling solubility in the olfactory mucosa. Champagne was not studied, but my guess is that bubbles will constantly bring aroma compounds to the surface to be sensed. Or maybe, after two or three glasses, one simply falls asleep for the remainder of the flight!



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Your kitchen is full of chemicals. This includes everything you eat and drink – even water. Chemists have worked out that its formula is H_2O .

Although many chemicals are very dangerous, you can do many fun, safe experiments on your food.

Smarties test

Lollies like Smarties have coloured dyes on the outside to make them bright and attractive. But what happens when they get wet?

You need

- 2 small packets of Smarties
(Hint: Smarties work best!)
- small jug of water
- small jug of milk at room temperature
- 2 white saucers or shallow glass dishes

What do you think?

Can you suggest why you get different colours and patterns?

Which liquid did you think worked best – the water or the milk? Why do you suppose they behave differently?

What to do

- 1 Pour a small amount of water into one saucer and milk into the other, so the liquid just half-covers the Smarties when they are placed in it.
- 2 Take four of the darkest coloured Smarties and place them as far apart as possible on the edge of the water in the saucer containing water. Then repeat with the same colours in the saucer of milk. Watch and compare what happens over the next 10 minutes.
- 3 What do you think will happen if you repeat this but also place a Smartie in the middle of each saucer? Try it and see! Did your prediction come true?
- 4 Try other arrangements. What patterns can you make?



Some Smarties in water, after a few minutes

Red cabbage test

Red cabbages, despite their name, look dark purple, and they're great for making purple dye. What happens when you add the dye to food and drink, or create mixtures? Make some predictions and see if they come true!

You need

- 1½ cups of diced red cabbage
- small amounts of colourless or pale lemon foods and drinks, such as freshly squeezed lemon juice, vinegar, egg white, milk, lemonade, bicarb soda and a crushed calcium tablet
- 2 cups of water
- small saucepan
- strainer
- small bowl
- white ice-block tray (or egg tray or art palette)
- small teaspoons
- dropper
- paper towel
- camera to take photos of your experiment (optional)
- T-shirt so your clothes don't get stained

What to do

Making the purple dye

- 1 Place the cabbage and water in the saucepan and simmer for about 10 minutes. Then allow it to cool.
- 2 When the liquid is cold, strain it into the bowl.

Testing the foods and drinks

- 1 Place paper towel on the bench and sit the tray on it. Line up the foods and drinks and teaspoons ready, near the tray.
- 2 Using a fresh, clean dry teaspoon each time, place 1 teaspoon of each food in a different section of the tray, in the same order as your samples, so you can remember what is in each section.



One kitchen test

- 3 Using the dropper, add the same amount of purple juice to each sample. As you start, see whether you can predict what other colours you will see. Did you guess any correctly?
- 4 In another section, just add 2 teaspoons of the purple dye, to keep as a comparison.

Making mixtures

- 1 In a fresh section of the tray, add a teaspoon of vinegar and a teaspoon of the purple dye. Then add half a teaspoon of bicarb of soda. What happens? What colours do you see?
- 2 Predict what will happen if you do the same with the other foods and drinks. Then try it and see. Did your predictions come true? What patterns did you notice?
- 3 You can try other mixtures too, such as vinegar and the calcium tablet.
- 4 Where a lot of fizzing happens, you might like to try larger amounts in glasses – but over the sink! Watch the whole time for all the colour changes.

What do you think?

Why do you suppose you were told to test foods that are not coloured?

Chemists classify many of the substances you would have tested as acidic or basic. Vinegar is acidic and bicarb soda is basic. With that clue, how would you classify the foods and drinks you tested, and what else did you discover? What other experiment do you think you might try with them? For example, do you think you could get the bubbles to blow up a balloon? Work out how you might do that!

This photo shows some foods that were tested. They were (not in their order) dairy milk, tap water, vinegar, soy milk, lemon juice, egg white, bicarb soda and a partially crushed calcium tablet. (The calcium tablet is the same chemical as chalk.) On the other side of the tray, two liquids were tested with bicarb soda. Can you guess what is in each section?

Acknowledgement

A big thank you to my grandson Liam, who helped me with these experiments, made predictions and had lots of good ideas. And to Liam's dad, who took the photos.

Jenny Sharwood MRACI CChem

In defence of the lab coat

Dotted around the bulletin boards of my alma mater, the University of Sydney, were posters boldly proclaiming 'Not all chemists wear white coats'. Those posters always used to bug me. To support their claims, they showed chemists collecting samples in Antarctica and off the Great Barrier Reef. And while it's true that a lab coat would be rather superfluous when you're equipped with an aqualung, it really isn't a reflection of how the vast majority of chemists go about their work without breathing apparatus or surrounded by penguins.

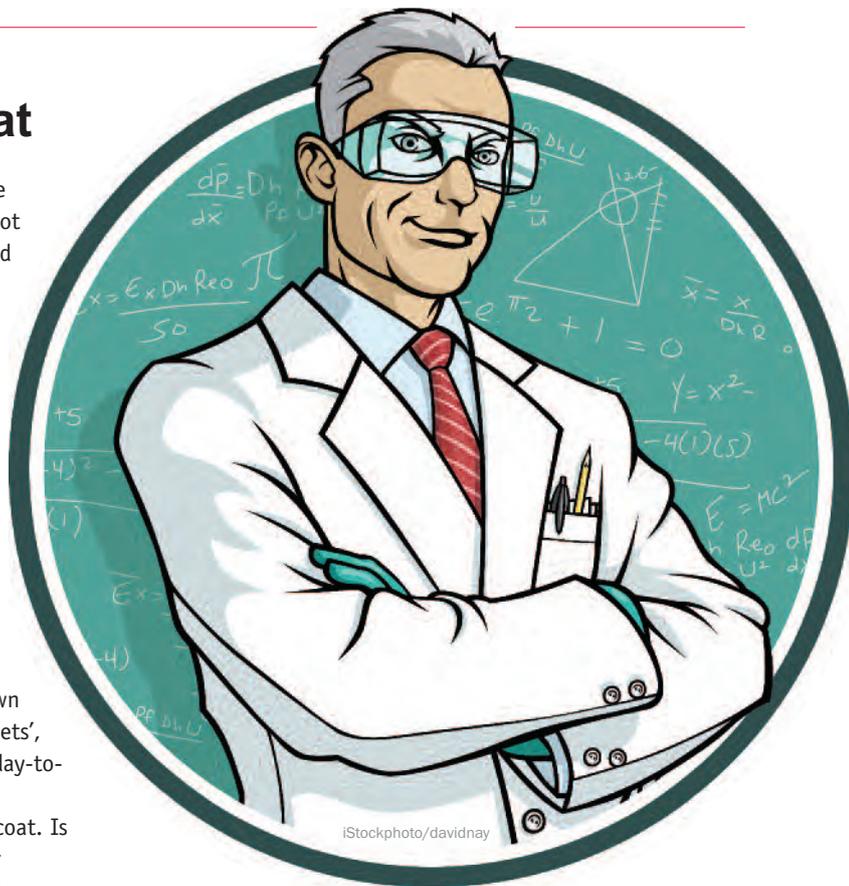
I guess what the posters are trying to do is entice would-be chemists to the diverse world of chemistry, but using the 1% of chemists in picturesque locations seems to be a little disingenuous. Wouldn't you find a poster with Richard Branson skydiving off the coast of Maui or abseiling down the Iguacu Falls proclaiming 'Not all CEOs use spreadsheets', as taking too much artistic license when depicting the day-to-day life of an average business person?

Perhaps there is a stigma attached to wearing a lab coat. Is it perceived that lab coat wearers are somehow nerdy or engaged in uninteresting work? If so, this attitude baffles me. Sure, there are times when I've been a bit bored in my job. Who hasn't? But for the vast majority of the time that I spend as a chemist (lab coat or not), I feel motivated, enthusiastic, privileged and, yes, excited to do what I'm doing. So instead of talking about the 1% who don't wear lab coats, I'd like to share a bit of my experience – one of the poor downtrodden souls whose day-to-day chemistry work doesn't involve braving sub-zero temperatures or fending off manatees.

Just so there is no hint of sugar-coating my experience, I'll be honest and say my first job wasn't so glamorous. I worked on a waste product of paper recycling called de-inking 'sludge'. The sludge looked horrible and smelled worse. It is something that is produced by the tonne every year and then promptly landfilled. My research project was to take this malodorous slurry and transform it into a pristine white powder (calcium carbonate and kaolinite clay) that could then be re-used for making new paper. While the project involved very little scuba diving, I was proud to be working on a project to improve the environmental benefits of paper recycling.

Next, for my Masters project I worked on conducting polymers, a field that was just-burgeoning at the time and netted its discoverers the Nobel Prize in Chemistry in 2000. I was steadfastly Wellingtonian at the time and had the opportunity to meet and discuss my project with one of the Nobel Laureates (only the third New Zealand recipient of the prize). It was cool to see just how far a local Wellingtonian could go in his humble lab coat.

During my PhD, I worked on polymers of a different sort, using 'living radical polymerisation' (a process invented in



Australia) to make a variety of nanoparticles. Not only was it great to rub shoulders with some of the greatest living Australian chemists (who among other things have introduced the world to plastic banknotes), but I also got the opportunity to talk about my 'Made in Australia' research all over the world in such exotic locations as Okayama, Denver, Coventry and even Cairns! I also collaborated with groups from Göttingen, Cyprus, Paris and Kyoto. Being a Kiwi proselytising Aussie science made me feel like an oddly benign Cold War double agent, more suited to a trenchcoat than a lab coat.

Now I'm in an academic research position in Switzerland and my day couldn't be more varied from all that I've done before. My major project focuses on using bacteria-eating viruses to find small protein fragments to combat amyotrophic lateral sclerosis. I also work on using polymers to deliver drugs to cells and study fundamental properties of polymers. Recently, I've begun looking at how we can use a combination of living radical polymerisation (once again, introducing the Swiss to some Aussie chemistry) and nanoparticle synthesis to improve the performance of solar cells.

From de-inking sludge to conducting polymers to nanoparticles to amyotrophic lateral sclerosis to solar cells, I've had very little time to get complacent about the doors that chemistry has opened for me. There is plenty you can do with a lab coat on and with a bit of luck you can end up wearing a lab coat for a job that doesn't even seem like work.

The author's lab coat has been hung on hooks in New Zealand, Australia, Japan and Switzerland, and has saved the rest of the author's wardrobe from many a mishap.

Which way is best?

When I'm writing, I often have trouble choosing between *that* and *which*. Perhaps as a consequence, editors with a preference for one or the other, and claiming superior knowledge, are inclined to change my text. From such rough usage, I gained the impression that *which* was a genteelism and to use it was an affectation, when plain ordinary *that* was perfectly adequate to express what I wanted to say. One editor even recommended submitting my late drafts to a 'which hunt'. He claimed that this recommendation came from Sir Ernest Gowers' *The complete plain words* (1954), which I bought many years ago for 8/6, the UK price on the cover being 5s. I could not find the pithy advice there so I widened my search to Bob Schoenfeld's *The Chemist's English* (1985). He dealt with these terrible twins in a chapter entitled 'On the Training of Old Dogs for Which-Hunting' and there referred to 'which-hunting editors'. Bob set out the rules of correct usage and he wrote that complying with them needs a fine ear but 'if you slip up, do not suffer agonies of guilt'.

Gowers says 'on the whole it makes for smoothness of writing not to use either if a sentence makes sense and runs pleasantly without'. He does admit that there are exceptions, and goes on to say '*that* is an awkward word because it can be one of three parts of speech – a conjunction, a relative pronoun, and a demonstrative pronoun'. Schoenfeld provided some helpful examples of the latter two.

Another of my word books describes them as 'two of the most misused words in the English language', so ... writer beware! There is less verbiage in my final reference work, which simply says 'that refers to a person or thing' while 'which refers exclusively to things; *who* to persons'. This source is the *Authors' & printers' dictionary* of F. Howard Collins (1857–1910). First published in 1905, the *Dictionary* was frequently updated and appeared in successive editions, reaching the 11th in 1973 before it was rewritten and retitled *The Oxford dictionary for writers and editors* in 1981. Collins' work lived on for years after his death in the way that some chemistry textbooks have done, morphing from, say, *Chemistry* by Henry Bloggs, to *Bloggs' Chemistry* as time went by.

My copy of *Collins* is the eighth impression of the seventh edition, published in 1933, although its originator had died in 1910 at age 43. Successive editions provided advice on such things as correct names, dates and professions of prominent people; hyphenation and capitalisation; punctuation (seven pages on this); chemical symbols for elements; and words and phrases in languages other than English. Once I would have taken the high imperial ground and written 'foreign languages', for which Collins suggests the abbreviations 'for.' and 'lang.'. Some chemical matters are included: for example, Liebig (Justus, baron von), 1803–73, chemist; Lavoisier (A.L.), 1743–94, Fr. chemist; and one I have never heard of, Lewes (Vivian B.), chemist. Then there is advice on distil, *not* -ill; desiccate, *not* dess-; dialise (chem.) *not* -ize, but neutralize and oxidize, *not* -ise; kilometre, *not* -er, with abbreviation Km, *not* kilo.

which that

My copy was formerly owned by the Australian Institute of Mining and Metallurgy, who stamped it '1939', presumably the date of purchase. I was interested to see what had been written on the blank pages that Collins had thoughtfully left at the end of each alphabetical section, for users to add their own special guidelines. In the D section, I found 'dispatch', which was the advice that Collins gave (*not* des-); disk (*not* disc), which again accords with Collins' advice; and a rhetorical question about a hyphen for de-watering, something that Collins had perhaps never encountered.

Collins' information was 'accumulated over the years as an extended card index' and he encouraged users, among whom were major publishing houses and learned societies, to contribute suggestions for future revisions. The editions of his book appeared in parallel with those of Horace Hart, who had been compiling guidance for printers at Oxford University Press since 1893. It was first made available to the public in 1904 as *Hart's rules*, and went into many editions, the last (the 39th) appearing in 1983 with a final revision in 1989. Both formed part of the OUP work to advise on – some would say enforce – their house style. They also published *The Oxford spelling dictionary* (1983), which makes up a trio of good works.

I could not find obituaries or full biographical details for Collins and Lewes. Vivian Byam Lewes (1852–1915) was professor of chemistry at the Royal Naval College, Greenwich, and an expert on fuels. He published several books on applied chemistry, delivered lectures and wrote articles on such subjects as gaslight mantles. His death was noticed by the aircraft industry and announced in *Flight* magazine.

I did find ~~that~~ there was more to Collins than his *Dictionary*. In 1891, he published a little book entitled *The diminution of the jaw in the civilized races: an effect of disuse*, which suggests that he was a neo-Darwinist.



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.



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American Chemical Society

www.acs.org/content/acs/en/education.html

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www.science.org.au/events/building-world%E2%80%99s-biggest-telescope

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www.csiro.au/Portals/Education/Programs/Do-it-yourself-science/Chemical-sciences-activities.aspx

The CSIRO Lectures

www.csiro.au/Portals/Events/The-CSIRO-Lectures.aspx

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www.raci.org.au/events/event/the-raci-nyholm-youth-lecture-series-2014

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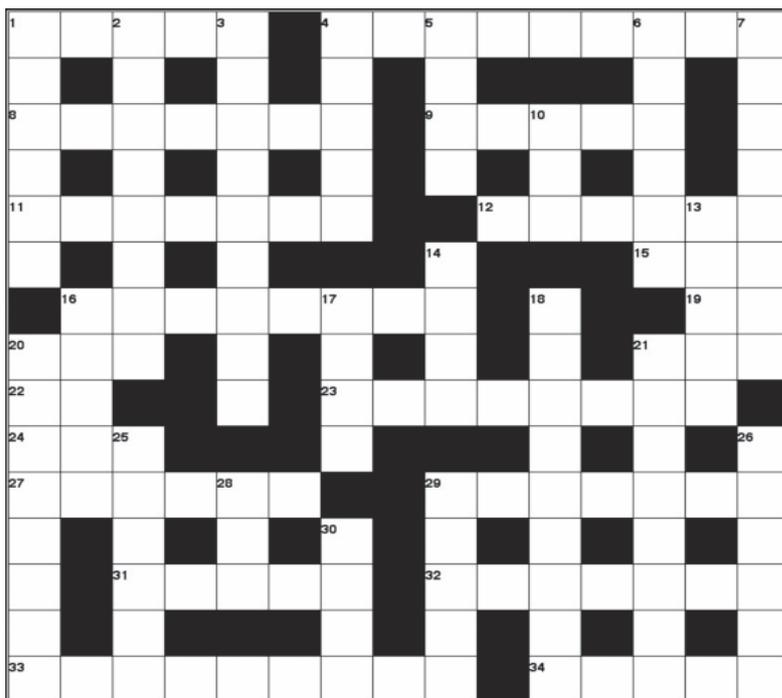


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cryptic chemistry



Across

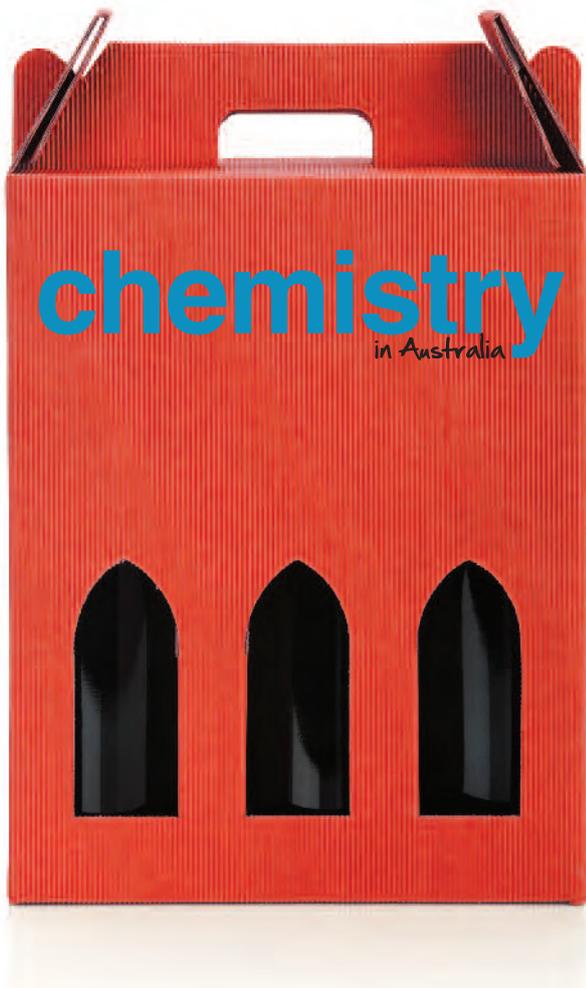
- 1 Visual twitch follows operation. (5)
- 4 First manufacture in plant of substance important as a component of optical fibres and as a semiconductor. (9)
- 8 Fights lab test changes. (7)
- 9 No robber comes back with what makes the Hope Diamond blue. (5)
- 11 Languages of mouth organs. (7)
- 12 His hidden talents include something to do with teeth. (6)
- 15 13 Down loses sodium and goes back a long time. (3)
- 16 & 14 Down Strange circus: a fluid used in the manufacture of a wide range of products. (8,4)
- 19 Use the element with hesitation. (2)
- 20 Fringe at last for bikini bottom. (3)
- 21 Gene carrier returned in addition. (3)
- 22 Return this element as an example. (2)
- 23 A mixture of chemicals used to remove carbon dioxide from breathing gases made oils mucky. (4,4)
- 24 Poor aim, French friend. (3)
- 27 Tent made from tin, vanadium and arsenic. (6)
- 29 See 2 Down.
- 31 Logo I adapt for shelter. (5)
- 32 Arresting and fixing. (7)
- 33 You mind me! It's used to make super strength magnets widely used in wind turbines and electric cars. (9)
- 34 Zero time for nine. (5)

Down

- 1 Paths or pieces. (6)
- 2 & 29 Across Exit audition mid change to what makes Correction Fluid white. (8,7)
- 3 Bright and interesting. (9)
- 4 Perhaps carbon dioxide and carbon monoxide confuse sages. (5)
- 5 New buyer lost first ever gemstone constituted of aluminium oxide with chromium. (4)
- 6 Back part of set in giving light. (6)
- 7 & 20 Down Read rational claim dismissing a strange explanation for what makes meat change colour during cooking. (8,8)
- 10 New buyers miss bus to find grain. (3)
- 13 Toluene is one, and naphthalene is another, wife of Aphaeus! (5)
- 14 See 16 Across.
- 16 Eighteenth Greek magic trick changing carbon into sulfur. (5)
- 17 Corrode iron oxide. (4)
- 18 Cool! Lid on application as a liquid bandage spray and by movie make-up artists to make fake scars and bruises. (9)
- 20 See 7 Down.
- 21 24 Across holds bit on purpose. (8)
- 25 Doing over after I made your blue jeans blue. (6)
- 26 How heavy sounds pause. (6)
- 28 Everyone is a 50:50. (3)
- 29 Dug going up to make blue jeans. (5)
- 30 Centres where oxygen, iodine, fluorine and carbon are mixed. (4)

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

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RACI National Congress

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

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



Congress Venue – Adelaide

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

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

To register please visit the website:
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