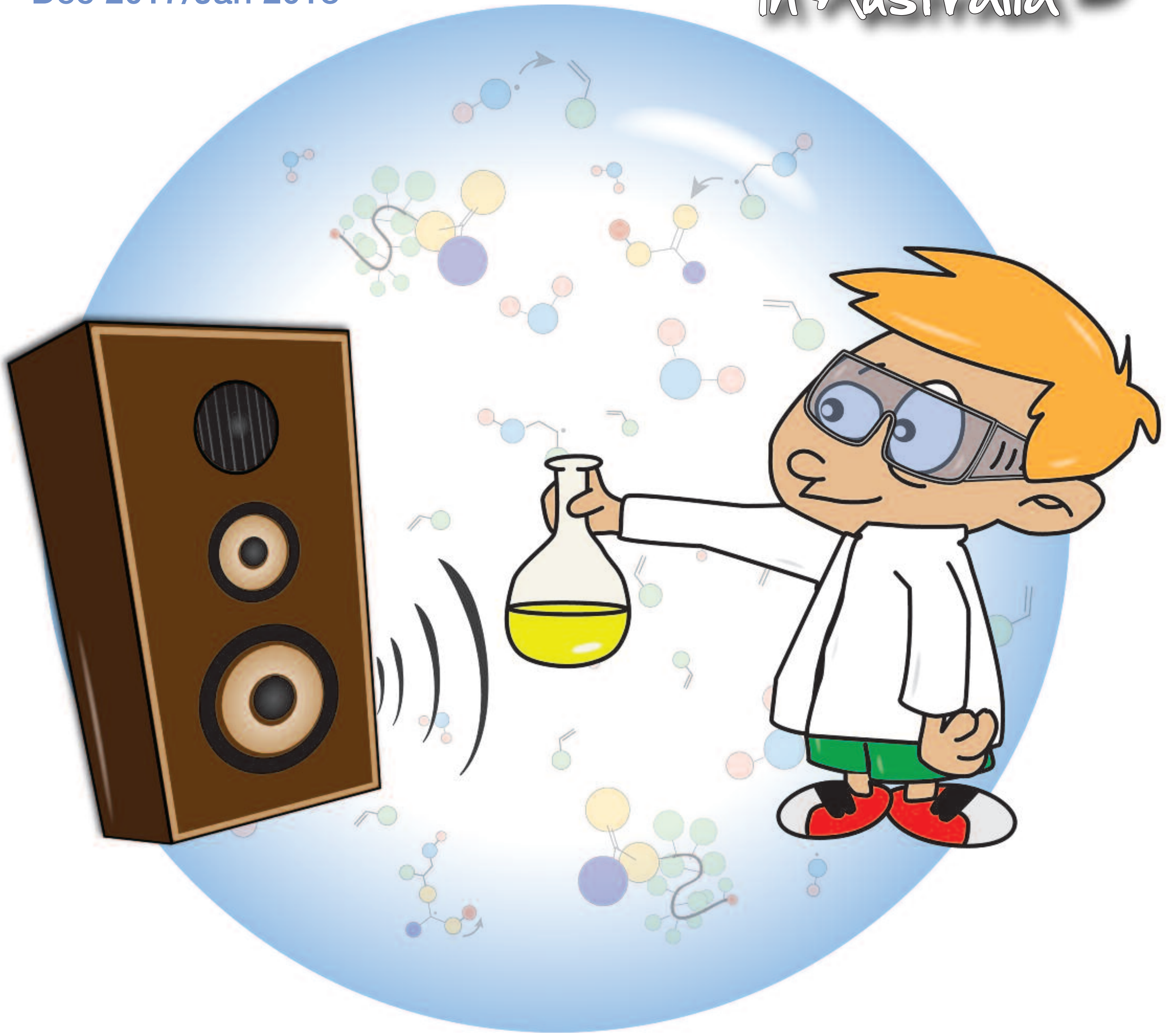
chemistry in Australia

Dec 2017/Jan 2018



Sound polymerisation

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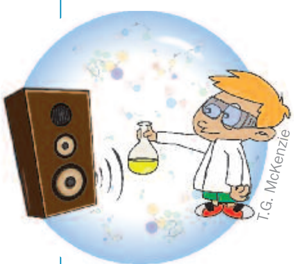

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From the President

This column and issue of *Chemistry in Australia* brings to an end the year of 2017. It has been an extremely eventful year from many points of view – politics, international relations, national votes/surveys, the year of the rejuvenation of the Tigers and, most importantly, the 100th birthday of the RACI.

Many events took place across the nation to celebrate our birthday, the pinnacle being the RACI Centenary Congress held in July in Melbourne. With so many people involved in the organisation and success of the Congress, it is not possible to name individuals. However, special thanks go to the CEO of the RACI Roger Stapleford, the Chair of the Congress Professor Mark Buntine, RACI staff and all the people involved on the organising committees of the multitude of conferences that were a part of the Congress. It would not have been the success it was without the involvement of many RACI members. Encouraged by this success, the Board is considering the future of these congresses – frequency, locations, involvement of other conferences, structure etc. – and we welcome any input from members. If you have any ideas, please get in touch with the Board or your local Branch or Division and let them know your opinion.

As with all previous years, 2017 was a busy year for the Board. There were many achievements, with some of the more significant including:

23-28 July 2017 | Melbourne

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Centenary Congress

Many events took place across the nation to celebrate our birthday, the pinnacle being the RACI Centenary Congress held in July in Melbourne.

- implementation of the inclusion and diversity policy that sets out forward planning for the Institute with respect to diversity across all areas, and sets guidelines for committees and conferences along with several new awards/prizes for women
- a new strategic plan that will set out the future of the Institute to ensure a bright success into the next century
- other policies, including a statement on chemical weapons
- RACI's involvement and leading of the establishment and integration of the Chemistry Decadal plan. This is a very important plan for the future of chemistry and the RACI Board felt we needed to lead this, being the voice of chemistry in Australia.

This is a time to thank all members for their contributions to the success of our birthday year. The events that I attended over the year were excellent and I met many new and old members. It makes me think that we should not wait for 'special years' for us to hold as many functions as we had this year – this should aid in the RACI's success and great future if we continue in this vein.

I wish all members a Merry Christmas, and a prosperous New Year. Let's see what 2018 brings for us. Who knows, maybe the Demons can break their drought! Now we're dreaming!

Peter Junk FRACI CChem (president@raci.org.au) is RACI President.

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

ISSN 0314-4240 e-ISSN 1839-2539

Reminiscing on Australian chemistry

I enjoyed the article in October (p. 22) on the 70-year history of the *Australian Journal of Chemistry*. It brought back many happy memories of my life in scientific research and my association with the RACI and its publications.

I am probably one of the few people still around who has published a paper in the *Australian Journal of Scientific Research, Series A Physical Sciences* (1951, vol. 4(2), pp. 172–80). It was titled 'The influence of slit-width on the shape and intensity of infra-red absorption bands'.

Let me reminisce a little.

It happened because I was a member of Dr A.L.G. (Lloyd) Rees's Chemical Physics Section, which was part of the CSIRO Division of Industrial Chemistry, headed by Dr Ian Wark. Both Wark and Rees worked enthusiastically for the RACI, and each became its President, Wark in 1958 and Rees in 1967–8. Both were strong protagonists of the idea that Australia should have its own journals for publishing scientific research. Lloyd was Editor of the Institute's publications from 1948 to 1956, and was the first Editor of *Reviews of Pure and Applied Chemistry* when it was established in 1950, with Dr J.R. (later Sir Robert) Price as Assistant Editor. Price was later Chairman of CSIRO, and President of the Institute in 1962–4.

In the late 1940s, we at Chemical Physics had the only operating infrared spectrometer in Australia, and were in great demand by organic chemists to help in determining the structures of their compounds.

I am probably one of the few people still around who has published a paper in the *Australian Journal of Scientific Research, Series A Physical Sciences*

The year after the publication of my paper in *Aust. J. Sci. Res.*, a paper by D.A. Ramsay, of the National Research Council of Canada, appeared on a similar topic, though with a slightly different approach. It was published in the widely read *Journal of the American Chemical Society* (1952, vol. 74, p. 72). There is no prize for guessing which paper was referred to in almost all the later literature on the subject!

Both Wark and Rees strongly opposed the Institute's decision in 1972 to discontinue publication of *Reviews*.

John Willis FRACI CChem

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

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

2017 science Nobel prizes

Physics: observation of gravitational waves

The Nobel Prize in Physics 2017 was divided, one half awarded to Rainer Weiss, the other half jointly to Barry C. Barish and Kip S. Thorne ‘for decisive contributions to the LIGO detector and the observation of gravitational waves’.

On 14 September 2015, the universe’s gravitational waves were observed for the first time. The waves, which were predicted by Albert Einstein 100 years ago, came from a collision between two black holes. It took 1.3 billion years for the waves to arrive at the LIGO detector in the USA.

The signal was extremely weak when it reached Earth, but is already promising a revolution in astrophysics. Gravitational waves are an entirely new way of observing the most violent events in space and testing the limits of our knowledge.

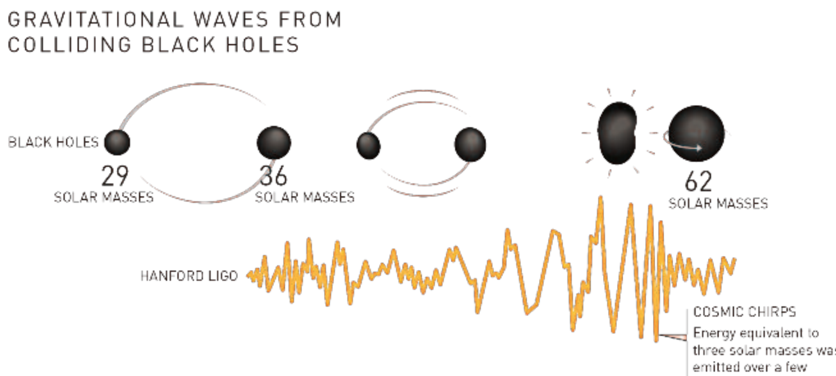


Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences

LIGO, the Laser Interferometer Gravitational-Wave Observatory, is a collaborative project with over 1000 researchers from more than 20 countries. Together, they have realised a vision that is almost 50 years old. The 2017 Nobel laureates have, with their enthusiasm and determination, each been invaluable to the success of LIGO. Pioneers Weiss and Thorne, together with Barish, the scientist and leader who brought the project to completion, ensured that four decades of effort led to gravitational waves finally being observed.

In the mid-1970s, Weiss had already analysed possible sources of background noise that would disturb measurements, and had also designed a detector, a laser-based interferometer, which would overcome this noise. Early on, both Thorne and Weiss were firmly convinced that gravitational waves could be detected and would bring about a revolution in our knowledge of the universe.

Gravitational waves spread at the speed of light, filling the universe, as Einstein described in his general theory of relativity. They are always created when a mass accelerates, like when an ice-skater pirouettes or a pair of black holes rotate around each other. Einstein was convinced it would never be possible to measure them. The LIGO project’s achievement was using a pair of gigantic laser interferometers to measure a change thousands of times smaller than an atomic nucleus, as the gravitational wave passed Earth.

So far all sorts of electromagnetic radiation and particles, such as cosmic rays or neutrinos, have been used to explore the universe. However, gravitational waves are direct testimony to disruptions in spacetime itself. This is something completely new and different, opening up unseen worlds. A wealth of discoveries awaits those who succeed in capturing the waves and interpreting their message.

Nobel Media

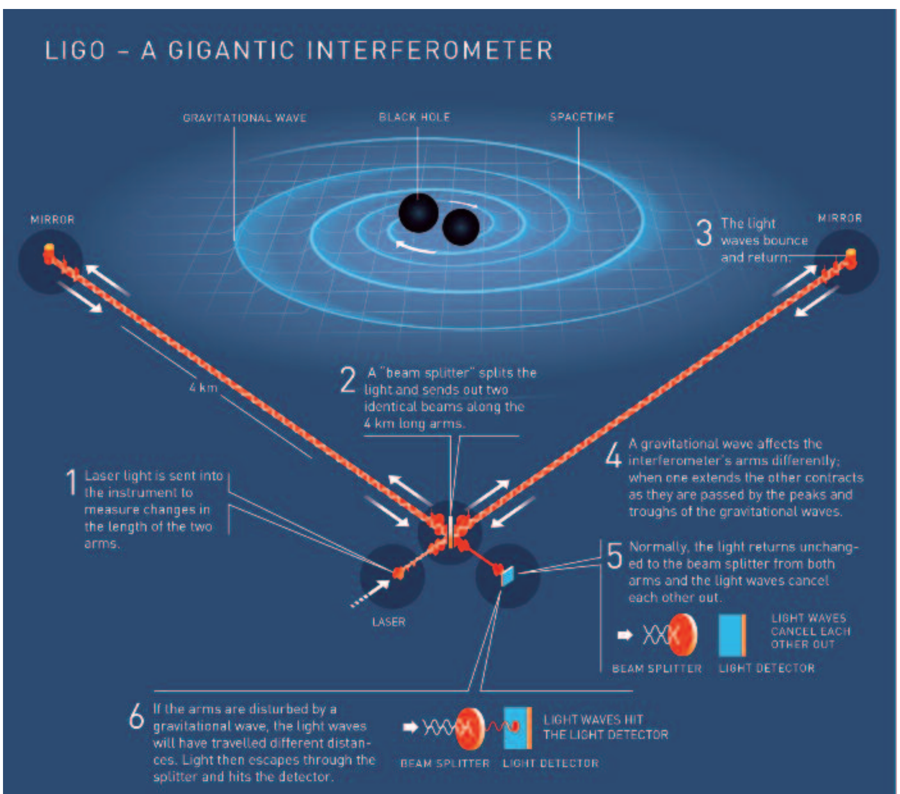


Illustration: ©Johan Jarnestad/The Royal Swedish Academy of Sciences

Physiology or Medicine: molecular mechanisms of circadian rhythm

The Nobel Prize in Physiology or Medicine 2017 was awarded jointly to Jeffrey C. Hall, Michael Rosbash and Michael W. Young 'for their discoveries of molecular mechanisms controlling the circadian rhythm'.

Life on Earth is adapted to the rotation of our planet. For many years we have known that living organisms, including humans, have an internal biological clock that helps them anticipate and adapt to the regular rhythm of the day. But how does this clock actually work? Hall, Rosbash and Young were able to peek inside our biological clock and elucidate its inner workings. Their discoveries explain how plants, animals and humans adapt their biological rhythm so that it is synchronised with Earth's revolutions.

Using fruit flies as a model organism, this year's Nobel laureates isolated a gene that controls the normal daily biological rhythm. They showed that this gene encodes a protein that accumulates in the cell during the night, and is then degraded during the day. Subsequently, they identified additional protein components of this machinery, exposing the mechanism governing the self-sustaining clockwork inside the cell. We now recognise that biological clocks function by the same principles in cells of other multicellular organisms, including humans.

With exquisite precision, our inner clock adapts our physiology to the dramatically different phases of the day. The clock regulates critical functions such as behaviour, hormone levels, sleep, body temperature and metabolism. Our wellbeing is affected when there is a temporary mismatch between our external environment and this internal biological clock, for example when we travel across several time zones and experience jet lag. There are also indications that chronic misalignment between our lifestyle and the rhythm dictated by our inner timekeeper is associated with increased risk for various diseases.

Our inner clock

Most living organisms anticipate and adapt to daily changes in the environment. During the 18th century, the astronomer Jean Jacques d'Ortous de Mairan studied mimosa plants, and found that the leaves opened towards the sun during the day and closed at dusk. He wondered what would happen if the plant was placed in constant darkness. He found that independent of daily sunlight the leaves continued to follow their normal daily oscillation. Plants seemed to have their own biological clock.

Other researchers found that not only plants, but also animals and humans have a biological clock that helps to prepare our physiology for the fluctuations of the day. This regular adaptation is referred to as the circadian rhythm, originating from the Latin words *circa* meaning 'around' and *dies* meaning 'day'. But just how our internal circadian biological clock worked remained a mystery.

Identification of a clock gene

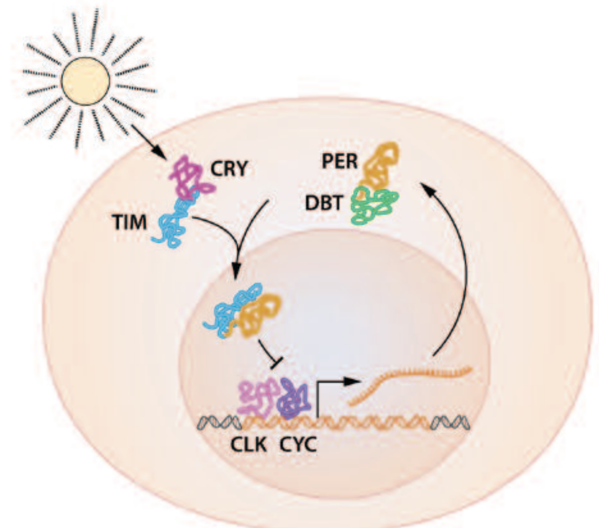
During the 1970s, Seymour Benzer and his student Ronald Konopka asked whether it would be possible to identify genes that control the circadian rhythm in fruit flies. They demonstrated that mutations in an unknown gene disrupted the circadian clock of flies. They named this gene 'period'. But how could this gene influence the circadian rhythm?

This year's Nobel laureates, who were also studying fruit flies, aimed to discover how the clock actually works. In 1984, Hall and Rosbash, working in close collaboration at Brandeis University in Boston, and Young at the Rockefeller University in New York, succeeded in isolating the period gene. Hall and Rosbash then went on to discover that PER, the protein encoded by period, accumulated during the night and was degraded during the day. Thus, PER protein levels oscillate over a 24-hour cycle, in synchrony with the circadian rhythm.

A self-regulating clockwork mechanism

The next key goal was to understand how such circadian oscillations could be generated and sustained. Hall and Rosbash hypothesised that the PER protein blocked the activity of the period gene. They reasoned that by an inhibitory feedback loop, PER protein could prevent its own synthesis and thereby regulate its own level in a continuous, cyclic rhythm.

The model was tantalising, but a few pieces of the puzzle were missing. To block the activity of the period gene, PER protein, which is produced in the cytoplasm, would have to reach the cell nucleus, where the genetic material is located. Hall and Rosbash had shown that PER protein builds up in the nucleus during night, but how did it get there? In 1994, Young discovered a second clock gene, 'timeless', encoding the TIM protein that was required for a normal circadian rhythm. In elegant work, he showed that when TIM bound to PER, the two proteins were able to enter the cell nucleus where they blocked period gene activity to close the inhibitory feedback loop.



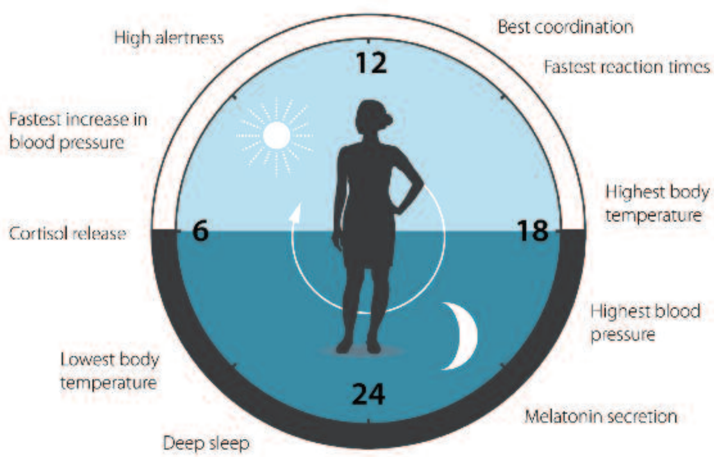
A simplified illustration of the molecular components of the circadian clock. Mattias Karlén /© The Nobel Committee for Physiology or Medicine

Such a regulatory feedback mechanism explained how this oscillation of cellular protein levels emerged, but questions lingered. What controlled the frequency of the oscillations? Young identified yet another gene, 'doubletime', encoding the DBT protein that delayed the accumulation of the PER protein. This provided insight into how an oscillation is adjusted to more closely match a 24-hour cycle.

The paradigm-shifting discoveries by the laureates established key mechanistic principles for the biological clock. During the following years, other molecular components of the clockwork mechanism were elucidated, explaining its stability and function. For example, this year's laureates identified additional proteins required for the activation of the period gene, as well as for the mechanism by which light can synchronise the clock.

Keeping time on our human physiology

The biological clock is involved in many aspects of our complex physiology. We now know that all multicellular organisms, including humans, utilise a similar mechanism to control circadian rhythms. A large proportion of our genes are regulated by the biological clock and, consequently, a carefully calibrated circadian rhythm adapts our physiology to the different phases of the day. Since the seminal discoveries by the three laureates, circadian biology has developed into a vast and highly dynamic research field, with implications for our health and wellbeing.



The circadian clock anticipates and adapts our physiology to the different phases of the day. Our biological clock helps to regulate sleep patterns, feeding behaviour, hormone release, blood pressure and body temperature. Mattias Karlén/© The Nobel Committee for Physiology or Medicine

About the Nobel laureates

Jeffrey C. Hall was born in 1945 in New York, USA. He received his doctoral degree in 1971 from the University of Washington in Seattle and was a postdoctoral fellow at the California Institute of Technology in Pasadena from 1971 to 1973. He joined the faculty at Brandeis University in Waltham in 1974. In 2002, he became associated with the University of Maine.

Michael Rosbash was born in 1944 in Kansas City, USA. He received his doctoral degree in 1970 from Massachusetts Institute of Technology in Cambridge. During the following three years, he was a postdoctoral fellow at the University of Edinburgh in Scotland. Since 1974, he has been on faculty at Brandeis University in Waltham, USA.

Michael W. Young was born in 1949 in Miami, USA. He received his doctoral degree from the University of Texas in Austin in 1975. Between 1975 and 1977, he was a postdoctoral fellow at Stanford University in Palo Alto. From 1978, he has been on faculty at the Rockefeller University in New York.

Rainer Weiss was born in 1932 in Berlin, Germany. He received his doctoral degree in 1962 from Massachusetts Institute of Technology, Cambridge, Massachusetts, USA. He is Professor of Physics, Massachusetts Institute of Technology.

Barry C. Barish was born in 1936 in Omaha, Nebraska, USA. He received his doctoral degree in 1962 from the University of California, Berkeley, California, USA. He is Linde Professor of Physics, California Institute of Technology, Pasadena.

Kip S. Thorne was born in 1940 in Logan, Utah, USA. He received his doctoral degree in 1965 from Princeton University, New Jersey, USA. He is Feynman Professor of Theoretical Physics, California Institute of Technology, Pasadena, California, USA

Chemistry: development of cryo-electron microscopy

The Nobel Prize in Chemistry 2017 was awarded jointly to Jacques Dubochet, Joachim Frank and Richard Henderson 'for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution'. These laureates and their work will be featured in *Chemistry in Australia* early in 2018.

The fog of champagne

The temperature at which a bottle of champagne is stored affects the formation of the grey-white cloud of fog normally formed on opening, according to a study in *Scientific Reports* (doi: 10.1038/s41598-017-10702-6).

On popping open a champagne bottle, the gas mixture gushing from the bottleneck experiences adiabatic expansion (an expansion of the gas that causes a drop in temperature), and therefore cools adjacent air packages, thus causing condensation of water vapour found in the ambient air in the form of a characteristic grey-white cloud of fog. However, this process may be more complex than previously thought.

Gérard Liger-Belair and colleagues used high-speed video imaging to visualise cork popping and the condensation process in the bottlenecks of transparent champagne bottles stored at different temperatures (6, 12 and 20°C). The authors found that the temperature of the bottle played a role in the condensation process, leading to the formation of the grey-white cloud. For the bottles stored at 20°C, the characteristic cloud disappeared and was replaced by a more evanescent blue plume, starting from inside the bottleneck. The authors propose that after adiabatic expansion of the gas mixture following the cork popping, clusters of ice-water appear in the bottlenecks of the bottles at all storage temperatures. However, at higher temperatures, freezing of gas-phase CO_2 occurs on ice-water clusters, resulting in the blue phase observed at 20°C.

Springer Nature

Estimating Earth's composition

Scientists at the Australian National University (ANU) have produced the best estimate of Earth's elemental composition, which will help them understand how Earth formed 4.6 billion years ago.

The solar system began as a dense blob in a molecular cloud of hydrogen gas and dust that collapsed under its own gravity, forming the early sun, and Earth and other planets. Co-researcher Associate Professor Charley Lineweaver, from the Research School of Earth Sciences and the Research School of Astronomy and Astrophysics at ANU, said Earth's chemical composition was set at that early stage of formation.

'The four most abundant elements – iron, oxygen, silicon and magnesium – make up more than 90% of the Earth's mass, but working out exactly what the Earth is made of is tricky', said Lineweaver

'Seismological studies of earthquakes inform us about the Earth's core, mantle and crust, but it's hard to convert this information into an elemental composition.'

Lead author, ANU Research School of Astronomy and Astrophysics PhD scholar Haiyang Wang, said the team made the most comprehensive estimates of Earth's composition based on a meta-analysis of previous estimates of the mantle and core, and a new estimate of the core's mass.

'Our work focused on getting realistic uncertainties so that our reference model can be used in future comparisons of the Earth with the sun, or with Mars or with any other body in the solar system', said Wang.

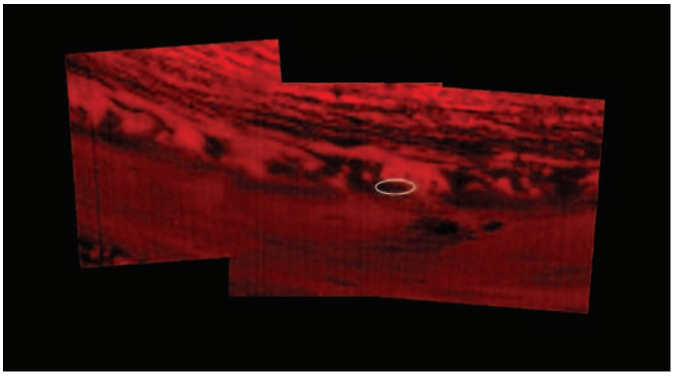
The research is published in *Icarus* (doi: 10.1016/j.icarus.2017.08.024).

Australian National University

Our deepest drilling has only scratched the surface … Rocks at the surface only come from as deep as the upper mantle.

Charley Lineweaver, Research School of Earth Sciences and Research School of Astronomy and Astrophysics, ANU

End of Cassini's Saturn exploration



This montage of images, made from data obtained by Cassini's visual and infrared mapping spectrometer, shows the location on Saturn where the NASA spacecraft entered Saturn's atmosphere on 15 September. The spacecraft entered the atmosphere at 9.4° north latitude, 53° west longitude. NASA/JPL-Caltech/University of Arizona

A thrilling epoch in the exploration of our solar system has come to a close, as NASA's Cassini spacecraft made a fateful plunge into the atmosphere of Saturn, ending its 13-year tour of the ringed planet.

Telemetry received during the plunge indicates that, as expected, Cassini entered Saturn's atmosphere with its thrusters firing to maintain stability, as it sent back a unique final set of science observations. Loss of contact with the Cassini spacecraft occurred on 15 September, with the signal received by NASA's Deep Space Network antenna complex in Canberra.

Cassini's plunge brings to a close a series of 22 weekly 'Grand Finale' dives between Saturn and its rings, a feat never before attempted by any spacecraft.

As planned, data from eight of Cassini's science instruments was beamed back to Earth. Mission scientists will examine the spacecraft's final observations for new insights about Saturn, including hints about the planet's formation and evolution, and processes occurring in its atmosphere.

Cassini launched in 1997 from Cape Canaveral Air Force Station in Florida and arrived at Saturn in 2004. NASA extended its mission twice – first for two years, and then for seven more. The second mission extension provided dozens of fly-bys of the planet's icy moons, using the spacecraft's remaining rocket propellant along the way. Cassini finished its tour of the Saturn system with its Grand Finale, capped by the intentional plunge into the planet to ensure Saturn's moons – particularly Enceladus, with its subsurface ocean and signs of hydrothermal activity – remain pristine for future exploration.

While the Cassini spacecraft is gone, its enormous collection of data about Saturn – the giant planet, its magnetosphere, rings and moons – will continue to yield new discoveries for decades to come.

NASA

Science boosts skills of young people with intellectual disabilities

A new science program for people with intellectual disabilities has delivered great educational, social and economic benefits to students.

The program, developed by a PhD scholar at the Australian National University (ANU), uses science to engage students with intellectual disabilities, help them observe what is happening around them, evaluate what it means, and then help them provide a reasoned response.

It has been implemented in three schools over the past 10 years, with about 60 students going through the program in the past two years.

Program developer Vanessa de Kauwe said specialist schools that had implemented the program had reported overwhelmingly positive results.

'The results have been overwhelmingly positive. Some students even go on to work, adult education, or both', said de Kauwe from the ANU Australian National Centre for the Public Awareness of Science.

'Students begin building working models, creating controlled chemical reactions, and tracking processes in nature such as plant growth.

Some reports show that students who previously did not interact with others started talking at home and school.

'Some reports show that students who previously did not interact with others started talking at home and school. Others started communicating with notes and drawings.

'Participants are always in a situation where they are learning to communicate with others and share ideas, which helps with their daily living skills.'

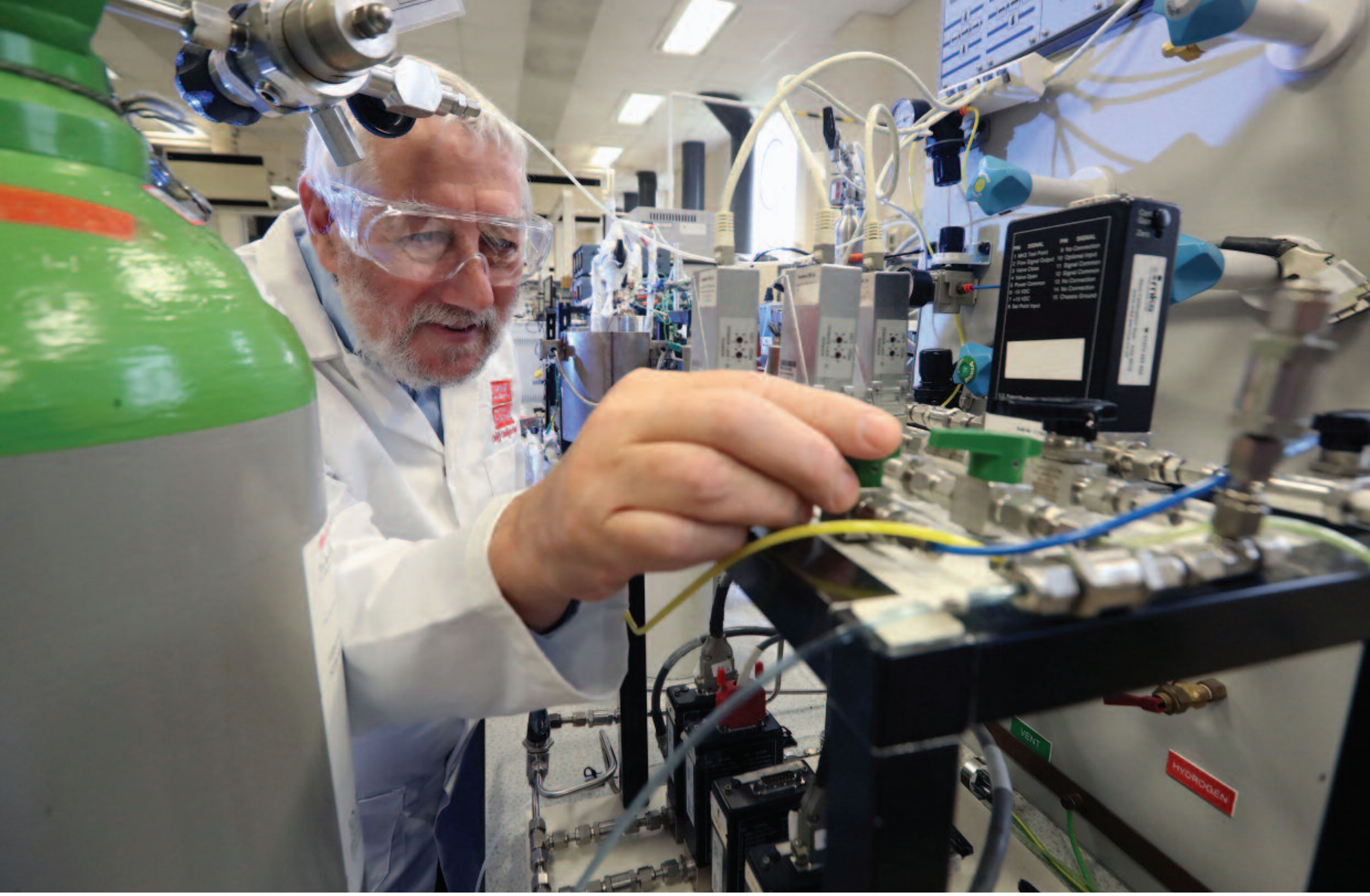
de Kauwe said feedback from schools and parents showed that students became more independent in daily life.

She said people with disabilities were the greatest experts in their own experience. She said radical changes were needed for educational practices and policies for students with an intellectual disability.

'I have spent more than 20 years working in disability and education in Australia and overseas and they are one of the most undervalued groups in society, something I wanted to see change', said de Kauwe.

'A number of young adults with intellectual disabilities are now assisting me to explain more empowering teaching techniques to science educators from all around the world, and this is how it should be.'

ANU Australian National Centre for the Public Awareness of Science



Methanol from methane, using air around us

Scientists in the UK have created methanol from methane by using oxygen from the air.

Methanol is currently produced by breaking down natural gas at high temperatures into hydrogen gas and carbon monoxide before reassembling them – expensive and energy-intensive processes known as 'steam reforming' and 'methanol synthesis'.

But researchers at Cardiff Catalysis Institute have discovered they can produce methanol from methane through simple catalysis that allows methanol production at low temperatures using oxygen and hydrogen peroxide.

The findings, published in *Science* (doi: 10.1126/science.aan6515), have major implications for cleaner, greener industrial processes worldwide.

Professor Graham Hutchings (pictured), Director of Cardiff Catalysis Institute, said: 'The quest to find a more efficient way of producing methanol is 100 years old. Our process uses oxygen – effectively a "free" product in the air around us – and combines it with hydrogen peroxide at mild temperatures, which require less energy.'

'We have already shown that gold nanoparticles supported by titanium oxide could convert methane to methanol, but we simplified the chemistry further and took away the titanium oxide powder. The results have been outstanding.

'Commercialisation will take time, but our science has major implications for the preservation of natural gas reserves as fossil fuel stocks dwindle across the world.

'At present, global natural gas production is about 2.4 billion tons per annum and 4% of this is flared into the atmosphere – roughly 100 million tons. Cardiff Catalysis Institute's approach to using natural gas could use this "waste" gas, saving CO_2 emissions. In the US, there is now a switch to shale gas, and our approach is well suited to using this gas as it can enable it to be liquefied so it can be readily transported.'

Dr James J. Spivey, Professor of Chemical Engineering at Louisiana State University and Editor-in-Chief of *Catalysis Today*, said: 'This research is of significant value to the scientific and industrial communities. The conversion of our shale resources into higher value intermediates like methanol provides new routes for chemical intermediates.'

Cardiff University

New laboratory to help countries fight insect pests

In conjunction with other methods of control, the sterile insect technique has successfully controlled insect pests such as the Mexican fruit fly (*Anastrepha ludens*).

Jack Dykina, USDA Agricultural Research Service

The International Atomic Energy Agency (IAEA) has opened the doors of a new laboratory to help countries use a nuclear technique to combat insect pests such as mosquitoes and fruit flies that spread disease and damage crops.

With over 1700 m^2 of laboratory space, the modern Insect Pest Control Laboratory (IPCL) will substantially increase the Agency's ability to assist Member States in applying the sterile insect technique (SIT). This form of insect birth control uses radiation to sterilise male insects, which are reared in large numbers and released in a target area to mate with wild females. Since they do not produce any offspring, the pest population is reduced over time.

The inauguration marks a milestone in the IAEA's initiative to modernise its eight nuclear applications laboratories built in Seibersdorf in 1962, a project known as ReNuAL and its follow-up ReNuAL+. The new laboratory will replace the old IPCL at the same site.

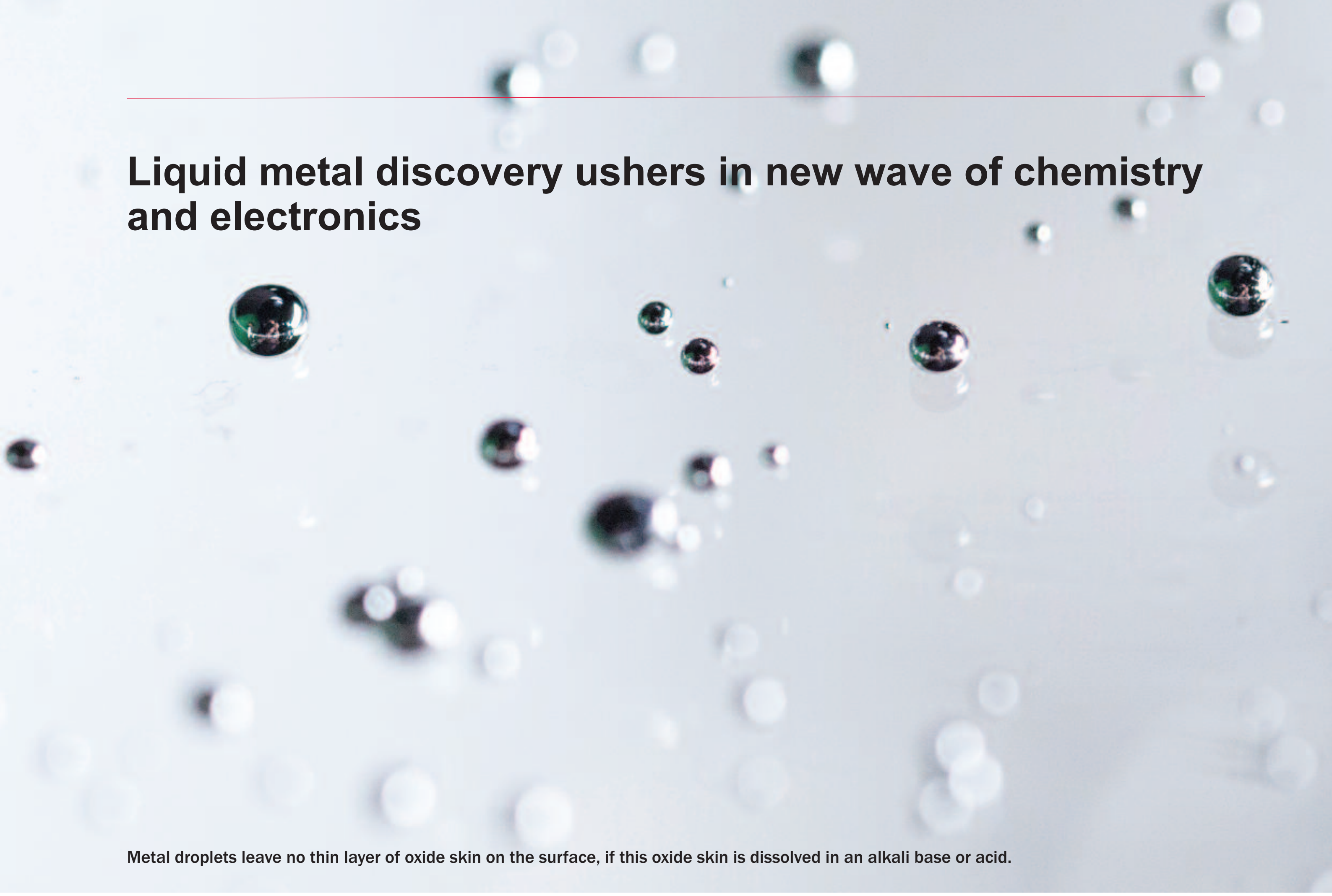
The environmentally friendly SIT is widely used around the world to keep harmful insects at bay, such as the Mediterranean fruit fly and the screw-worm fly.

Along with additional space to train experts to support the transfer of SIT to countries, the new IPCL will facilitate research on the application of the technique for different insects, including mosquitoes that transmit malaria, Zika and other diseases.

Earlier this year, the IAEA, in partnership with the Food and Agriculture Organization of the United Nations, provided assistance to the Dominican Republic to use SIT to eradicate an outbreak of the Mediterranean fruit fly – one of the most damaging agricultural pests in the world, which attacks several types of fruit and vegetable. Through the assistance, the Latin American country was able to eradicate the fly within two years, and regain access to export markets worth US$42 million a year.

International Atomic Energy Agency

Liquid metal discovery ushers in new wave of chemistry and electronics



Metal droplets leave no thin layer of oxide skin on the surface, if this oxide skin is dissolved in an alkali base or acid.

Researchers from RMIT University have used liquid metal to create 2D materials no thicker than a few atoms that have never before been seen in nature. The research will not only revolutionise the way scientists do chemistry but could be applied to enhance data storage and make faster electronics.

The researchers dissolve metals in liquid metal to create very thin oxide layers, which previously did not exist as layered structures and which are easily peeled away.

Once extracted, these oxide layers can be used as transistor components in modern electronics. The thinner the oxide layer, the faster the electronics are. Thinner oxide layers also mean the electronics need less power. Among other things, oxide layers are used to make smartphone touch screens.

The research is led by Professor Kourosh Kalantar-zadeh and Dr Torben Daeneke from RMIT's School of Engineering, who with students have been experimenting with the method for the last 18 months.

'When you write with a pencil, the graphite leaves very thin flakes called graphene, that can be easily extracted because they are naturally occurring layered structures', said Daeneke. 'But what happens if these materials don't exist naturally?'

'Here we found an extraordinary, yet very simple, method to create atomically thin flakes of materials that don't naturally exist as layered structures.

'We use non-toxic alloys of gallium (a metal similar to aluminium) as a reaction medium to cover the surface of the liquid metal with atomically thin oxide layers of the added metal rather than the naturally occurring gallium oxide.

'This oxide layer can then be exfoliated by simply touching the liquid metal with a smooth surface. Larger quantities of these atomically thin layers can be produced by injecting air into the liquid metal, in a process that is similar to frothing milk when making a cappuccino.'

Kalantar-zadeh said that the discovery now places previously unseen thin oxide materials into everyday reach, with profound implications for future technologies.

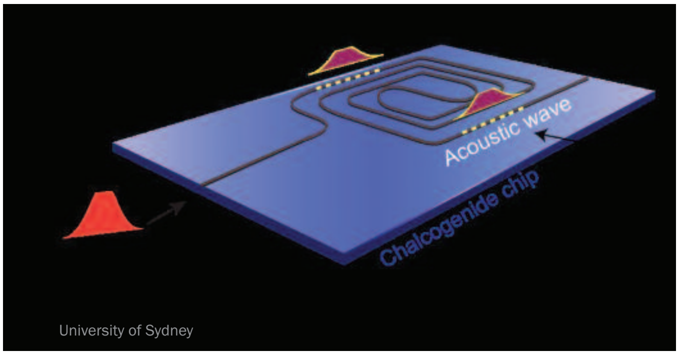
'We predict that the developed technology applies to approximately one-third of the periodic table. Many of these atomically thin oxides are semiconducting or dielectric materials.'

The breakthrough could also be applied to catalysis, reshaping how we make medicines, fertilisers and plastics.

The findings have been published in *Science* (doi: 10.1126/science.aao4249).

RMIT University

From optical data to readable sound waves



University of Sydney

Researchers at the University of Sydney have dramatically slowed digital information carried as light waves by transferring the data into sound waves in an integrated circuit, or microchip. It is the first time this has been achieved.

Transferring information from the optical to acoustic domain and back again inside a chip is critical for the development of photonic integrated circuits: microchips that use light instead of electrons to manage data.

These chips are being developed for use in telecommunications, optical fibre networks and cloud computing data centres where traditional electronic devices are susceptible to electromagnetic interference, produce too much heat or use too much energy.

'The information in our chip in acoustic form travels at a velocity five orders of magnitude slower than in the optical domain', said Dr Birgit Stiller, research fellow at the University of Sydney and supervisor of the project.

This delay allows for the data to be briefly stored and managed inside the chip for processing, retrieval and further transmission as light waves.

Light is an excellent carrier of information and is useful for taking data over long distances between continents through fibre-optic cables. But this speed advantage can become a nuisance when information is being processed in computers and telecommunication systems.

To help solve these problems, lead authors Moritz Merklein and Stiller, both from the ARC Centre of Excellence for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), have now demonstrated a memory for digital information that coherently transfers between light and sound waves on a photonic microchip.

The chip was fabricated at the Australian National University's Laser Physics Centre, also part of the CUDOS Centre of Excellence. Their research is published in *Nature Communications* (doi: 10.1038/s41467-017-00717-y).

Stiller said, 'Our system is not limited to a narrow bandwidth. So unlike previous systems, this allows us to store and retrieve information at multiple wavelengths simultaneously, vastly increasing the efficiency of the device.'

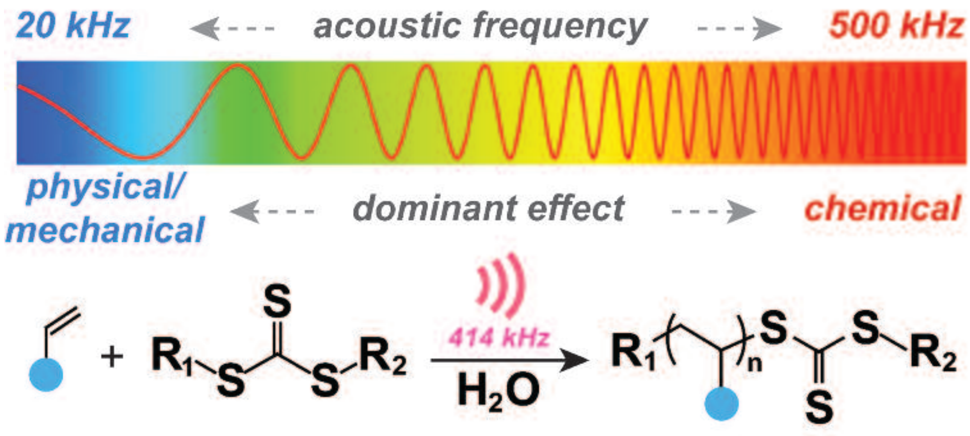
Fibre optics and the associated photonic information – data delivered by light – have huge advantages over electronic information: bandwidth is increased, data travels at the speed of light and there is no heat associated with electronic resistance. Photons, unlike electrons, are also immune to interference from electromagnetic radiation. However, the advantages of light-speed data have their own in-built problem: you need to slow things down on a computer chip so that you can do something useful with the information.

In traditional microchips this is done using electronics. But as computers and telecommunication systems become bigger and faster, the associated heat is making some systems unmanageable. The use of photonic chips – bypassing electronics is one solution to this problem being pursued by large companies such as IBM and Intel.

Merklein said, 'For this to become a commercial reality, photonic data on the chip needs to be slowed down so that they can be processed, routed, stored and accessed.'

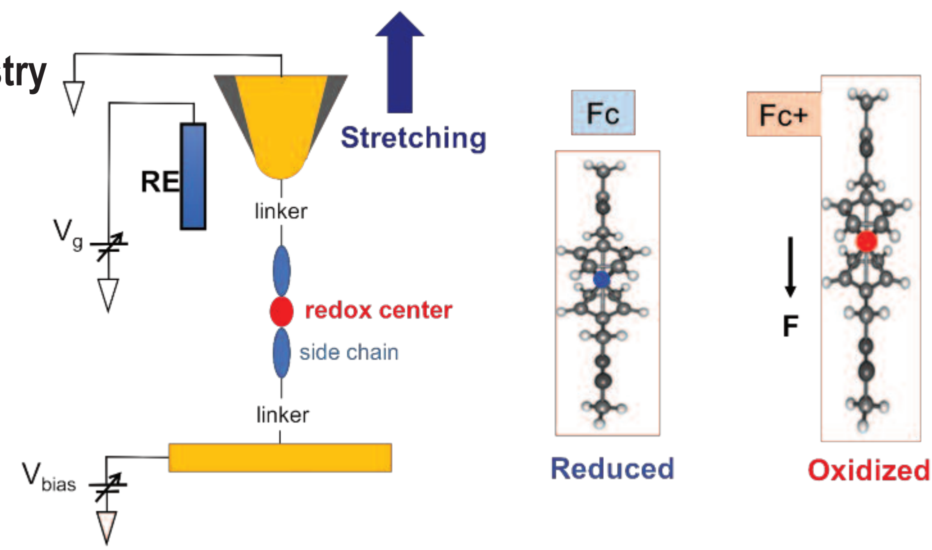
University of Sydney

Sound polymerisation



The application of ultrasound to a liquid medium results in the spontaneous formation, growth, and collapse of bubbles – a phenomenon known as acoustic cavitation. Recently, Professors Greg Qiao and Muthupandian Ashokkumar and co-workers at the University of Melbourne have harnessed the reactive radicals generated by these sonochemical events for the controlled synthesis of linear polymers from vinyl monomers (McKenzie T.G., Colombo E., Fu Q., Ashokkumar M., Qiao G.G. *Angew. Chem. Int. Ed.* 2017, **56**, 12 302–6). They demonstrated that, when water is used as a solvent, water-derived radicals (primarily HO•) can act as initiating species for a polymerisation; when conducted in the presence of a highly efficient chain transfer agent, such as a thiocarbonylthio-containing compound, chain propagation can be controlled via a reversible addition–fragmentation chain transfer (RAFT) mechanism to furnish 'living' polymers with controllable chain lengths and good end-group fidelity. This technique offers a novel method to control RAFT polymerisations externally, with rapid temporal switchability by simply turning the ultrasound on or off. Work is currently ongoing to expand these systems to non-aqueous solvents and different operating ultrasonic frequencies.

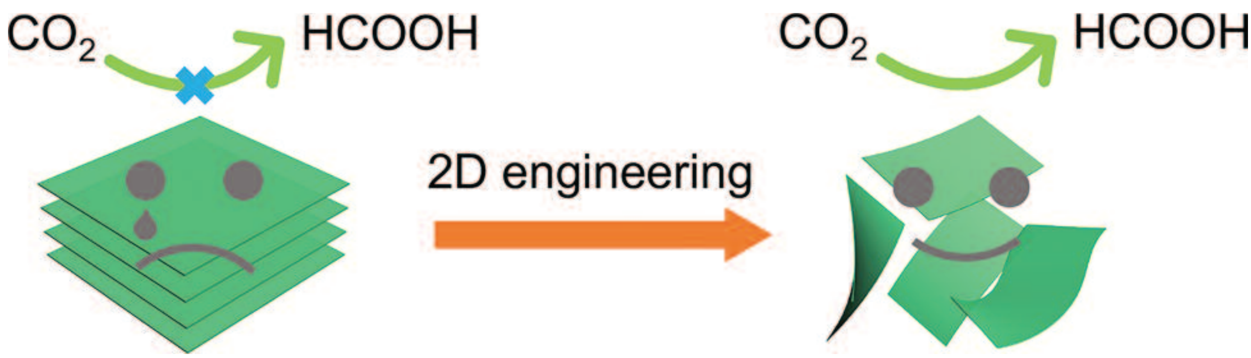
Electrical mechanochemistry



Normally, the redox potential of a molecule is assumed to be a unique property of the molecule, its solvent environment and the temperature. But researchers from the Arizona State University, the Australian National University and Curtin University have now demonstrated that mechanical force can also be used to manipulate electron-transfer reactions (Li Y., Haworth N.L., Xiang L., Ciampi S., Coote M.L., Tao N.J. *J. Am. Chem. Soc.* 2017, **139**, 14 699–706). Using scanning tunnelling microscopy, the researchers showed that, on stretching, a single molecule of a ferrocene (Cp) derivative undergoes spontaneous oxidation. The oxidation is associated with changes in its single-molecule conductivity, which could be tracked experimentally. Calculations confirmed the result and showed that the process is driven by the tendency of the Fe–Cp bond to stretch upon oxidation because of removal of an electron from its bonding orbital. The observation that mechanical stretching can control the redox states and conductance of a single molecule provides a way to mechanically switch its electronic properties, with potential applications in electromechanical molecular machines.

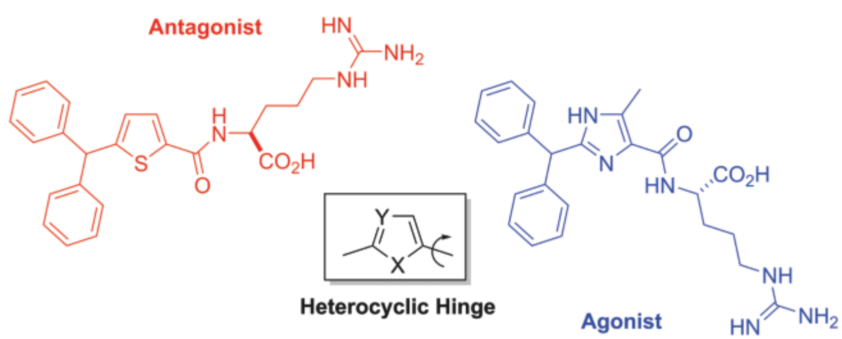
Thinner is better

The electrocatalytic CO_2 reduction reaction has drawn considerable interest because of its potential for the sustainable storage of intermittent, renewable wind and solar energy in the form of value-added fuels and chemicals. But this reaction suffers from the drawbacks of poor product selectivity, energy efficiency and catalyst durability, calling for significant advances in the development of effective catalysts. Recently, two-dimensional (2D) engineering of materials has emerged as an effective approach to enhance catalytic activity that is essentially absent or considerably inferior in the bulk forms of the materials. With this strategy in mind, the groups of Dr Jie Zhang and Professor Douglas MacFarlane in the Australian Centre of Excellence for Electromaterials Science at Monash University employed a simple, environmentally friendly and efficient electrochemical exfoliation approach to thin down bulk antimony (Sb) to a 2D form consisting on average of only four atomic layers of Sb (Li F., Xue M., Li J., Ma X., Chen L., Zhang X., MacFarlane D.R., Zhang J. *Angew. Chem., Int. Ed.* 2017, https://doi.org/10.1002/anie.201710038). By this 2D engineering strategy, the researchers transformed the catalytically inactive bulk Sb to an active catalyst for the electro-reduction of CO_2 to formic acid, a liquid fuel with a high energy density for fuel cell applications. Compositing with graphene further enhanced the performance by strong electronic interaction between Sb and graphene.



Switching inflammation on and off

Complement system protein C3a is a mediator of immunity that binds to the C3a receptor on the surface of cells, but its exact roles in inflammation remain unclear due to its metabolic instability. Now scientists in the Institute for Molecular Biosciences at The University of Queensland have developed highly potent, metabolically stable and C3a-receptor-selective small-molecule modulators to unequivocally characterise C3a-induced inflammation (Lohman R.-J., Hamidon J.K., Reid R.C., Rowley J.A., Yau M.-K., Halili M.A., Nielsen D.S., Lim J., Wu K.-C., Loh Z., Do A., Suen J.Y., Iyer A., Fairlie D.P. *Nat. Commun.* 2017, **8**, 351). The compounds contain a heterocyclic 'hinge' region that switch the pharmacology of the molecules from agonist to antagonist. The researchers used in vitro assays on human inflammatory cells and an acute inflammation model in rats. The team discovered that the C3a receptor-selective agonist induced substantial paw swelling, beginning with mast-cell degranulation and subsequent recruitment of macrophages and neutrophils. The C3a receptor antagonist inhibited the agonist-induced mast-cell degranulation, blocking macrophage and neutrophil activation and the resulting inflammation. The scientists suggest that these compounds could be used as tools to interrogate the mechanism of C3a in inflammation. C3a antagonists may be useful for treating mast-cell-related allergic and acute inflammatory responses, such as asthma, hives and responses to insect bites.



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

Special issue: RACI awards

Since 2013, *Aust. J. Chem*. has published an annual issue of invited papers showcasing the winners of awards, prizes and medals from RACI and the Australian Academy of Science. In the November issue, we are pleased to publish ten such papers from the 2016–2017 awardees.

Mark Buntine (Curtin University), a past president of the RACI, was awarded the prestigious Leighton Memorial Medal. In a paper with co-workers at Curtin, including Max Massi, the winner of the Organometallic Chemistry Award, the laser-based formation of copper nanoparticles (CuNPs) is described. The presence of N-donor ligands results in changes in the nanoparticle optical properties and particle size distributions, depending upon the nature of the donor ligands. The kinetics of formation of the CuNPs are found to be independent of the nature of the donor ligand.

Joe Shapter (Flinders University) received the Fensham Medal for Outstanding Contribution to Chemical Education and reports with co-workers at Flinders and at QUT on application of new hole transporting materials as the interlayer in graphene oxide/single-wall carbon nanotube heterojunction solar cells to yield better performance.

W. Alexander Donald (University of New South Wales), recipient of the 2016 RACI Physical Chemistry Division Lectureship and the 2016 RACI Analytical and Environmental Chemistry Division Peter W. Alexander Medal, reports with colleagues at the University of Melbourne and Accurate Mass Scientific, Victoria, that internal energy deposition in dielectric barrier discharge ionisation is significantly lower than in direct analysis in real-time mass spectrometry. Portable dielectric barrier discharge ionisation is a plasma-based ion source for mass spectrometry that is significantly ‘softer’ than the two most widely used plasma-based ionisation sources. This is important for the detection of intact molecules with thermolabile bonds, such as many explosives, and some chemical weapons and organic pollutants.

Jason L. Dutton (La Trobe University) was the recipient of the Inorganic Division’s 2016 Alan Sargeson Lectureship. With M. Albayer he describes reactions of classic iridium and rhodium complexes with iodine(III) oxidants, which result in two-electron oxidation. Ligand exchange and anion scrambling was observed in monodentate ligand-containing complexes, but I^{III} reagents reacted with chelating ligand-containing complexes without scrambling, so well-defined complexes could be isolated.

Deanne D’Alessandro (University of Sydney) is the recipient of the 2017 Australian Academy of Science Le Fèvre Memorial Prize as well as the Inorganic Chemistry Division’s 2017 Alan Sargeson Lectureship. for her work on photoactive and physical properties of an azobenzene-containing coordination framework. A new porous three-dimensional coordination framework containing the novel photoactive ligand 5-((4-*t*-butyl)phenylazo)isophthalic acid displays light-dependent spectroscopic properties.

Carol Hua, formerly a PhD student at the University of Sydney and now a postdoc at Northwestern University, USA, won the RACI 2016 Cornforth Award for the best PhD thesis. The paper on redox-state dependent spectral properties of porous organic polymers containing furan, thiophene and selenophene is based on her PhD work with Deanne D’Allessandro. Redox-active porous organic polymers with heterocyclic linkers (furan, thiophene and selenophene) were synthesised, and their electronic and spectral properties investigated as a function of redox state. Through the use of EPR spectro-electrochemistry, it was found that the distinct redox states in these polymers could be accessed reversibly.

Tom Davis (Monash and Warwick Universities) was awarded the Polymer Division’s Batteard–Jordan Australian Polymer Medal for his work on the synthesis of star polymers by RAFT polymerisation as versatile nanoparticles for biomedical applications. He discusses recent advances made in his laboratory focused on star polymer research ranging from improvements in synthesis through to novel applications of the product materials with an emphasis on biomedical applications.

David StC. Black (University of New South Wales) is the 2017 winner of the David Craig Medal of the Australian Academy of Science and contributes two research papers, the first on 3-hydroxymethylindoles, which undergo acid-catalysed reactions involving *ipso*-electrophilic substitution with the extrusion of formaldehyde and the formation of diindolylmethanes. Both inter- and intra-molecular processes lead to macrocyclic compounds. The second paper describes the construction of 21-membered macro-heterocycles containing three indole units linked through imine and amine moieties.

Michela Mitchel (Monash University) won an early career investigator award and best student oration at the RACI Peptide User Group Winter Symposium. Together with co-workers at Monash, University of Queensland and the Walter & Eliza Hall Institute of Research she contributes a Focus article on a new technique, the use of imaging mass spectrometry to study peptide toxin distribution in Australian sea anemones.

This collection of papers reflects the calibre of research in the authors’ laboratories and at the same time represents a good cross-section of Australian chemistry.

Curt Wentrup FAA, FRACI CChem

Cyber security for travelling researchers

Losing digital research data when travelling is much more than an inconvenience. There are many compelling reasons to protect your data.

BY **DANIEL WINSON**

When a laptop owned by the University of Sydney containing information about students – including names, dates of birth, contact details and medical details – was lost in 2016, the outcry was understandably significant. The university declined to comment on whether the files or the disk were encrypted. A message sent to the students said the computer was password-protected, and that 'this does not absolutely guarantee the security of the information [stored on the device]'. The importance of protecting research data from cyber-attacks cannot be overstated. Ethical obligations, organisational policy and privacy laws all compel researchers to take this issue seriously. Also, researchers should be motivated by self-interest to avoid the hassle that comes with losing research data and the exposure that comes with research data falling into the wrong hands.

While working from the relative security of a campus or other location managed by your organisation's IT department, it is easy to forget about these obligations. Although researchers still have a role to play in securing data at home, it's when travelling that their behaviour has the biggest impact.

Researchers who are travelling need to be particularly aware of the relevant threats and take steps to avoid being the victim of a cyber security breach.

In February 2018, the Privacy Amendment (Notifiable Data Breaches) Bill 2016 is expected to come into operation. This new law will apply to all entities that are currently subject to the Australian Privacy Principles under the Privacy Act 1988. Under this law, organisations must notify eligible data breaches to the Office of the Australian Information Commissioner and affected individuals as soon as practicable after the applicable entity becomes aware that 'there are reasonable grounds to believe that there has been an eligible data breach of the entity' (section 26WK of the Bill).

Research data stored on any type of portable device is at risk of being lost or stolen. While many organisations do an excellent job of securing their corporate notebook computers, the same is not always true for employee-supplied devices or for tablets, phones and USB storage devices. If an unsecured device containing research data is lost or stolen, it is at risk of being accessed by unauthorised people and there may be an obligation under new mandatory reporting legislation to report the loss to any person whose privacy may have been affected.

Lost or stolen devices aren't the only threat to research data – government officials in several countries, including the US, have the right to demand travellers unlock digital devices for examination (see box p. 20). Travelling researchers are not exempt from this. If you have research data on a device you are bringing into another country, that device may be legally examined and you can be forced to hand over passwords so data can be examined and even copied by officials of that country.

The root cause of these problems is the same: any data stored on any device in the possession of a researcher is at risk of loss or disclosure to unauthorised people.

Digital data: a multilayered security approach

- Enable **full disk encryption** on all devices that contain research data. If you lose or someone steals your computer and you aren't using full disk encryption, anyone can steal all your files. Unfortunately your password won't help – an attacker who has physical access to the device can easily bypass your password or they can simply remove your hard disk and put it in a different computer to get access to your files. High-quality full-disk encryption options are available for Windows, MacOS, IOS and Android – the exact steps needed to enable full disk encryption are different for each device, but there are plenty of good guides available to walk you through the process.
- Use **file level encryption** on all sensitive files. In addition to encrypting your full disk, you should consider individually encrypting files. A good starting point is making use of the encryption options built into Microsoft Office. Simply navigate to File/Info/Protect Document and select 'Encrypt with Password'. Once you've finished encrypting the files, you should run the Disk Cleanup tool to ensure unencrypted temporary files have been removed.
- Use **remote management software** to remotely wipe a device if it is lost or stolen. If you use an iPhone or iPad and your device is lost or stolen, you should use iCloud.com to remotely wipe your device to ensure data can't be accessed. A similar tool is available through Android Device manager for Android devices. A range of third-party applications offer the same feature on Windows and MacOS.
- **Patch** your devices. Malware with the potential to steal, delete or encrypt your data generally makes use of known vulnerabilities. Software vendors are constantly releasing patches to fix these bugs and you should ensure you take an active approach to applying these patches. At your organisiation, this is usually managed by your IT department; if you're travelling, you need to make sure that the patches still get applied.
- A **virtual private network (VPN)** should be used to create an encrypted tunnel to a secure location before accessing any corporate resources or the internet. (Note: President Putin has recently passed legislation that makes the use of VPNs in Russia illegal). While there is a range of low-cost consumer-oriented VPN services you could use, a better option would be working with your IT department to create a private tunnel back to your organisation – not only will this provide you with increased security and privacy while browsing, it will provide you with access to files and programs hosted on the corporate network, which should reduce the need to store sensitive information on your local device.
- Make **secure back-ups** of all data that is created or modified while travelling. Ideally these will be back-ups to a secure remote location via a VPN. If the only option available is USB back-ups, these should be encrypted and stored in a separate location to the primary device. If you are using cloud-based storage services such as Google Drive or Dropbox, you rely on their encryption, but you should take the extra steps needed to enable two-step verification, which requires an extra code that is texted to your phone to access the account.

While travelling, your device may need to connect to third-party networks; these networks may not be secured to an adequate standard and there is additional risk of data sent or received using these networks being intercepted or modified.

The root cause of these problems is the same: any data stored on any device in the possession of a researcher is at risk of loss or disclosure to unauthorised people. In solving this problem, the first option that must be considered is leaving the data at home. Do you really need a copy of the whole project folder? If not, leave it on the department share drive where it belongs.

If you need a computer at all, ideally it should be a 'burner' device that contains no sensitive information. This device can be used to securely access your organisation's network remotely as and when research data needs to be accessed or updated. This should be the default solution whenever possible and researchers should encourage their IT departments to explore options for secure remote access via virtual private networks (VPNs) to remote desktop or virtual applications that leave no data cached on the remote device.

If you need a computer at all, ideally it should be a 'burner' device that contains no sensitive information.

How to protect your private data when you travel to the United States

On 30 January 2017 – three days after US President Donald Trump signed an executive order restricting immigration from several predominantly Muslim countries – an American scientist employed by NASA was detained at the US border until he relinquished his phone and PIN to border agents. Travellers are also reporting border agents reviewing their Facebook feeds, while the Department of Homeland Security considers requiring social media passwords as a condition of entry.

Intimidating travellers into revealing passwords is a much greater invasion of privacy than inspecting their belongings for contraband.

Technology pundits have already recommended steps to prevent privacy intrusion at the US border, including leaving your phone at home, encrypting your hard drive and enabling two-factor authentication. However, these steps only apply to US citizens. Visitors need a totally different strategy to protect their private information.

The problem

Giving border agents access to your devices and accounts is problematic for three reasons.

1. It violates the privacy of not only you but also your friends, family, colleagues and anyone else who has shared private messages, pictures, videos or data with you.
2. Doctors, lawyers, scientists, government officials and many business people's devices contain sensitive data. For example, your lawyer might be carrying documents subject to attorney–client privilege. Providing such privileged information to border agents may be illegal.
3. In the wake of revelations from Chelsea Manning and Edward Snowden, we have good reason to distrust the US government's intentions for our data.

This problem cannot be solved through normal cybersecurity countermeasures.

Encryption, passwords and two-factor authentication are useless if someone intimidates you into revealing your passwords. Leaving your devices at home or securely wiping them before travelling is ineffective if all of your data is in the cloud and accessible from any device. What do you do if border agents simply ask for your Facebook password?

And leaving your phone at home, wiping your devices and deactivating your social media will only increase suspicion.

iStockphoto/arinahabich

What you can do

First, recognise that lying to a border agent (including giving them fake accounts) or obstructing their investigation will land you in serious trouble, and that agents have sweeping power to deny entry to the US. So you need a strategy where you can fully cooperate without disclosing private data or acting suspicious.

Second, recognise that there are two distinct threats:

1. border agents extracting private or sensitive data from devices (phone, tablet, laptop, camera, USB drive, SIM card etc.) that you are carrying
2. border agents compelling you to disclose your passwords, or extracting your passwords from your devices.

Protecting your devices

To protect your privacy when travelling, here's what you can do.

First, use a cloud-based service such as Dropbox, Google Drive, OneDrive or Box.com to back up all of your data. Use another service like Boxcryptor, Cryptomator or Sookasa to protect your data so that neither the storage provider nor government agencies can read it. While these services are not foolproof, they significantly increase the difficulty of accessing your data.

Next, cross the border with no or clean devices. Legally purchased entertainment should be fine, but do not sync your contacts, calendar, email, social media apps or anything that requires a password.

If a border agent asks you to unlock your device, simply do so and hand it over. There should be nothing for them to find. You can access your data from the cloud at your destination.

Protecting your cloud data

However, border agents do not need your device to access your online accounts. What happens if they simply demand your login credentials? Protecting your cloud data requires a more sophisticated strategy.

First, add all of your passwords to a password manager such as LastPass, KeePass or Dashlane. While you're at it, change any passwords that are easy to guess, easy to remember or duplicates.

Before leaving home, generate a new master password for your password manager that is difficult to guess and difficult to remember. Give the password to a trusted third party such as your spouse or IT manager. Instruct him or her not to provide the password until you call from your destination. (Don't forget to memorise their phone number!)

If asked, you can now honestly say that you don't know or have access to any of your passwords. If pressed, you can explain that your passwords are stored in a password vault precisely so that you cannot be compelled to divulge them, if, for example, you were abducted while travelling.

This may sound pretty suspicious, but we're not done.

Raise the issue at your workplace. Emphasise the risks of leaking trade secrets or sensitive, protected or legally privileged data about customers, employees, strategy or research while travelling.

Encourage your organisation to develop a policy of holding passwords for travelling employees and lending out secure travel-only devices. Make the policy official, print it and bring it with you when you travel.

Now if border agents demand passwords, you don't know them, and if they demand you explain how you cannot know your own passwords, you can show them your organisation's policy.

This may all seem like an instruction manual for criminals, but actual criminals will likely just create fake accounts. Rather, I believe it's important to provide this advice to those who have done nothing illegal but who value their privacy in the face of intrusive government security measures.

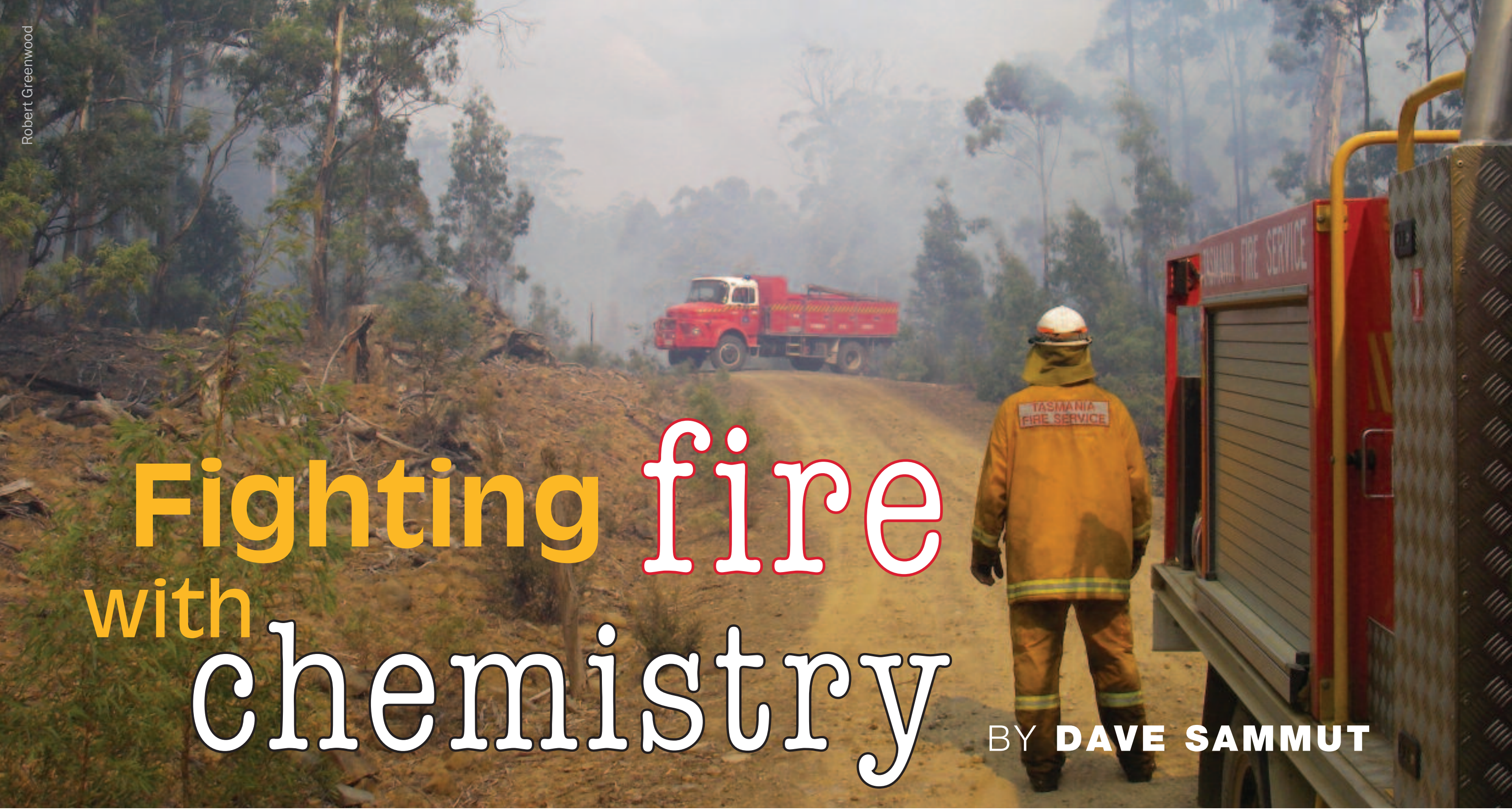
Paul Ralph, Senior Lecturer in Computer Science, University of Auckland. First published at www.theconversation.com.

If remote access to your organisation's network is impossible, you can take steps to provide a multilayer approach to security (see box). It reduces but cannot eliminate risk.

In addition to these technical controls, researchers must take all possible steps to ensure the physical security of their devices. Keeping your devices with you or locking them in a safe is a good idea. If you are travelling to a country where border officials have the legal right to access your data, you are left with a real problem. Again, the best solution is not having the data on your device at all. Even if you can't manage this as a permanent solution while travelling, you may be able to cross the border without the data on your device and then copy it via your VPN to the device from your destination. If this isn't possible, the only alternative is using a courier service to transport the device.

Too hard? Maybe … and even with all the controls we've listed here, there is a risk that you'll have your data stolen. Talk to your IT department – if they can set up a secure remote access solution for you, it will save everyone a lot of grief.

Daniel Winson is a cyber-security specialist at Think Technology, www.thinktechnology.com.au.

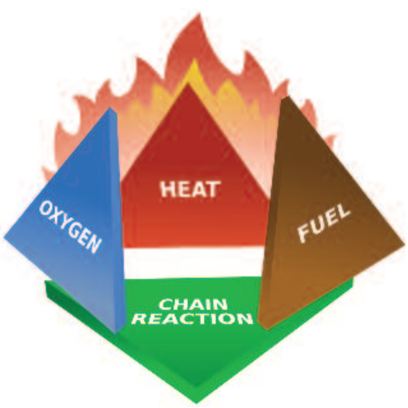


Robert Greenwood

Fighting fire with chemistry

BY **DAVE SAMMUT**

After a dry winter, much of Australia's east coast is likely to be on high alert this bushfire season. An understanding of the science of fire informs both fire alert and firefighting systems.



The fire triangle has been expanded to include chain reactions. Gustavb

Although the chemistry of exothermic reactions is pretty straightforward, the science of fire can be surprisingly complex. A great deal of study has gone into understanding fire, its propagation, prevention and mitigation.

Fire 101

Standard textbooks on fire refer to the 'fire triangle' of heat, fuel and oxygen. More recent texts update this to the 'fire tetrahedron', in which oxygen is replaced with an oxidising agent (typically air) and uninhibited chain reactions.

The basic reactions are simple: an organic molecule reacts with oxygen to form carbon dioxide and water. Where oxygen is limited, a portion of the combustion products will be intermediates, such as carbon monoxide or soot. Heat energy overcomes the initial activation energy, and the overall combustion is exothermic. In simple terms, the reaction is self-propagating until either the fuel or the oxygen runs out, or the heat is removed.

However, there are interesting nuances. The reactions primarily occur in the vapour phase, so other physical and chemical reactions must occur prior to combustion where the fuel is liquid or solid.

Liquid organics first volatilise to form a combustible gas-phase mixture. The classic example is kerosene in a lamp. The liquid fuel is volatilised via a wick (to increase the surface area), and combustion occurs in the gas phase immediately adjacent to the wick. Due to limitations in oxygen mass transfer, the zone closest to the wick is oxygen deficient, and the blue flame observed is due to the secondary oxidation of carbon monoxide from initially incomplete reaction.

For solids to burn, they must first undergo pyrolysis – thermochemical decomposition of solid-phase large molecules into vapour-phase smaller molecules and free radicals, typically leaving solid-phase carbon residues. In established fires, the residual char may then combust directly from the solid phase via flameless 'glowing' or 'smouldering'.

It is also noteworthy that the rate of reaction is temperature related, so the hotter the fire is, the faster it burns. This is an important issue in firefighting.

Fuel load, terrain and atmosphere

In the science of bushfire prediction and control, the rate and mode of spread of fires is determined by a complex interplay of factors – the type and density of biota, including the 'fuel load' of readily combustible (dehydrated) dead material, terrain, fire intensity and atmospheric conditions.

Growing up, I used to dread the summer days with the hottest, driest westerly winds. They swept across our area with the dead hand of foreboding. On bad fire days, they carried embers far ahead of the fire front to start new spot fires.

From a more scientific perspective, most of the effect of bushfires is associated with the convection (such as into the soil) and radiation of heat from flames. Substantive heat is also lost with the combustion gases in the convection column.

Plant cells die at around 60°C, while the charring of plant tissues starts at around 300°C and ash forms above about 500°C. With high surface area and being poorly insulated, leaves are easily subject to hot, dry conditions. They burn quickly, and generate a lot of flaming embers.

Bark tends to protect active tree tissues through reduced thermal diffusivity. The period that the plant surface remains at 100°C is critical to predicting the extent of tissue death. Once the water in the tissues has been exposed long enough to boil away, then the temperatures can rise rapidly and sensitive inner tissues can be irreparably damaged.

The overall fire hazard from fuel is measured by assessing the type of bark on the trees ('Bark Hazard'), the amount of elevated fuel such as grasses and ferns ('Elevated Fuel Hazard') and the ground detritus ('Surface Fine Fuel Hazard'). The accumulation of fine fuel depends on how much the local vegetation sheds dead litter, how quickly it rots, and the frequency of fires.

While many plant species in Australia have evolved in the presence of fire, developing adaptations to improve their survival, our country has many varied ecosystems. Not all of our ecosystems have evolved for frequent or intensive fire regimes (see box p. 25). For example, New South Wales contains large areas of wet sclerophyll rainforest and wetlands, which in some cases could take hundreds of years to recover from a substantive fire. Prescribed burning protocols for hazard reduction therefore need to consider the ecosystems affected, and the influence that they may have on the diversity of species in a given area (such as through replacement with more fire-resistant species).

More than just the fact that fires burn more easily uphill, topography can have a significant influence on fire behaviour. The NSW Department of Environment and Heritage notes 'Aspect will influence the type of vegetation and fuel moisture. In NSW west facing slopes are usually hotter and dryer and support more fire tolerant (therefore more flammable) vegetation. South facing slopes however, are usually cooler and wetter and support more fire intolerant (less flammable) vegetation.' (bit.ly/2yEoMzF)

For the survival of the plants, fire intensity is important. Described as the heat released per metre of fire front, fire intensity is a multiple of the heat yield of the fuel (J/g), fuel load (kg/m^2) and velocity of the fire front (m/s). Low-intensity fires generate up to around 500 kW/m (the limit recommended for fuel-reduction burning), producing flames up to 1.5 metres high. High-intensity fires can generate more than 3000 kW/m, with flames up to 15 metres high and spotting up to two kilometres away.

At the extreme, 'fire storm' or 'crown fire' bushfires can generate up to 100 000 kW/m. Over a fire front of just one kilometre, that's substantially greater than all of the power station capacity in NSW.

Just as importantly, even a fire of moderate intensity (2500 kW/m) can heat the soil to a depth of six centimetres and increase surface temperatures to more than 250°C. This can kill microorganisms, seeds and plant tissues, and can cause changes in soil chemistry. In turn, this can result in long-term changes that affect the recovery of particular ecosystems.

Excluding, absorbing and retarding

The science of firefighting comes back to the fire triangle – the removal of fuel, oxygen and/or heat. The use of water remains the bedrock of firefighting through the simple thermal capacity of water (with its heat of vaporisation of 2257 kJ/kg). However, this is not nearly as effective in bushfire fighting, where the transport of water to the fire is a major challenge. In intense fires, even water-bombing can prove ineffective, because the water simply evaporates in the radiant heat above the fire.

Similarly, the removal of oxygen is much more difficult in bushfire fighting. Smaller, contained spaces (such as high-value IT hardware centres) can use gas-based systems

Fire activity looking south-west towards Dargo from Swifts Creek, Victoria, 11 January 2007.
Fir0002/Flagstaffotos

Single-engine airtanker dropping retardant at Mudgee, NSW. Phos-Chek Australia

At the extreme, 'fire storm' or 'crown fire' bushfires can generate up to 100 000 kW/m. Over a fire front of just one kilometre, that's substantially greater than all of the power station capacity in NSW.

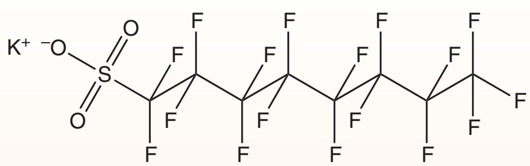
that both starve the fire of oxygen and minimise water damage. And most household and industrial fire extinguishers are either carbon dioxide, foams or suppressant powders.

Bushfire fighting may use chemical foams or gels. The foams are made of a combination of wetting and foaming agents mixed with water, while gels use polymers such as potassium polyacrylate that can absorb a multiple of their mass of water. As long as they remain wet, the foams can help exclude air directly at the fire site, while the gels can absorb heat. However, the CSIRO noted that these tend to dry out quickly and can be ineffective for higher intensity fires.

Fire retardants are designed to directly inhibit the fire. The NSW Rural Fire Service (RFS) declares the use of three variations – PHOS-CHeK, BlazeTamer and Thermo-Gel – the safety data sheets for which are spectacularly unhelpful in elucidating their chemistry. Other sources cite the use of ammonium and diammonium sulfate and ammonium phosphate, guar gum as a thickener, and corrosion inhibitors (to protect the aircraft used for delivery). The RFS states that the PFOS class of chemicals, now notorious for contamination at sites around Australia (see box), is not used in bush firefighting.

The fire retardants are mixed with water, and are commonly highly coloured with pigment (often iron oxides) to make it easier to see where they have been delivered. After the water has evaporated, the remaining residue continues to inhibit ignition of vegetation via heat adsorption and endothermic decomposition (for example, to sulfuric and phosphoric acid and ammonia). However, as noted by the CSIRO in 2010: 'The ability of retardant lines [0.5–1.0-kilometre long from a single air drop] to halt fire spread in eucalypt forests is limited to low fire intensity conditions (<2 MW/m) because of the spotting potential associated with higher-intensity fires. Retardant lines require

Investigating PFOS contamination



Potassium salt of PFOS.

PFOS (perfluorooctane sulfonic acid, its salts and perfluorooctane sulfinyl fluoride) have gained a lot of attention of late. Part of a group of chemicals termed POPs (persistent organic pollutants) under the UNEP Stockholm Convention, they are used in a wide range of products. It is their use (or misuse) as surfactants in firefighting foams and the subsequent potential for contamination of areas surrounding particular facilities – airports, firefighting training facilities and some industrial sites – that has become contentious.

The Royal Australian Air Force has more than 20 sites under investigation for potential PFOS contamination. Its air base at Williamtown, near Newcastle, is a case in point. Nearby residents were alarmed to discover that the RAAF had in 2012 become aware and failed to report the presence of PFOS in groundwater leaving the site. The residents have now been advised not to shower, bathe or fill pools with groundwater, nor to consume products from livestock grown within the area.

While a government-initiated report found the contamination to have a 'low and acceptable' risk, it is being criticised as seeking to downplay the seriousness of the situation. By contrast, a 2006 UNEP report (bit.ly/2yXlFij) concluded 'that PFOS is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects, such that global action is warranted'.

The Department of Defence is now providing water to more than 70 properties, as part of a $55 million nationwide project to address PFOS contamination concerns. At another affected site, residents of Oakey, Queensland (near the Army Aviation Centre), are preparing a class action for compensation on claimed health effects and loss of property values.

A UNEP study (bit.ly/2i2kP0q) into effective alternative foaming agents showed that fluorine-free alternatives, expected to not persist in the environment or bio-accumulate, would cost just 5–10% more, and that this would decrease as the non-PFOS market grew.

support from ground firefighting resources to be effective.' (http://bit.ly/2gtOOKW)

The last line of defence

The CSIRO's conclusion points to the fundamental aspect of fighting bushfires in Australia. For those at the front lines, the strategy most often centres on removing the fuel – creating fire breaks with dozers or graders, preparing controlled burns, and fighting the fires hand-to-hand with packs and shovels.

It comes down to the hardworking men and women, significantly including large numbers of volunteers, who give their time and risk their safety under the worst of conditions. This article can only conclude with a solemn salute to their effort, to the generosity of spirit, and the sacrifice made on behalf of us all. Let the weather this summer be kind, and let each of us do our part by preparing our homes, our properties and our fire plans.

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

Improving bushfire behaviour models for Tasmanian wet forests

The 2016 Tasmanian bushfires have been described as the worst crisis in decades for world heritage forests. Seventy fires that started by a severe dry lightning storm on 13 January burnt more than 124 000 hectares over a month and a half – affecting about 2% of the Tasmanian Wilderness World Heritage area – and have been linked to human-induced climate change by recent research. As the maps on the news portrayed, fires burnt across western Tasmania affecting a range of vegetation types including tall wet forests such as those at the Terrestrial Ecosystem Research Network Warra Tall Eucalypt SuperSite.

Even while the fires were still burning in other parts of Tassie, University of Tasmania Biological Sciences PhD student James Furlaud was camped among the tall eucalypts at the Warra SuperSite collecting post-fire data on forest fuel loads.

'The goal of my project is to improve current and future bushfire behaviour models and calibrate them specifically for Tasmanian wet forests', says James. 'Current bushfire behaviour models used in Tasmania are calibrated for fuel loads in Victoria, so a field-based assessment of Tasmanian fuel loads is critical.'

James, who is partly supported by the Bushfire and Natural Hazard CRC, has done fuel load surveys at eight monitoring plots located at the Warra SuperSite – part of TERN's Australian SuperSite Network – using a methodology based off of the TERN AusPlots Forests methodology that's openly available via the TERN website.

'The sampling is designed primarily to estimate the surface, elevated, and bark fuel loads, but also makes a number of qualitative measures that are commonly used by fire managers. I can then model these fuel loads as a function of time since previous fire. This will create fuel accumulation curves that are compatible with current and future fire behaviour prediction models.'

'Behaviour models predict fuel load as a function of time since previous fire. This is why the TERN chronosequence plots at the Warra long-term ecological research site are so valuable: they allow me to simultaneously sample fuel loads across a range of differently aged forests and quantify how fuel loads increase as a forest ages.'

Four of the eight plots James surveyed overlap with AusPlots. By sampling at these sites James is able to use nationwide AusPlots data to compare how fuel loads vary across both chronological and ecological gradients. Such comparison will allow James to examine how fuel accumulation rates might change with climate change.

The ultimate goal of this project is to develop improved bushfire behaviour prediction models. This will allow for updated risk assessments, an improved ability to evaluate fuel management regimes, and better fire suppression decisions.

James' supervisor, Professor David Bowman, says 'Given that such destructive fires are likely to become more common in

James collects data on fuel load at a monitoring plot located at the Warra SuperSite – part of TERN's Australian SuperSite Network – that will be used to estimate the surface, elevated, and bark fuel loads, and a number of qualitative measures that are commonly used by fire managers. Forestry Tasmania

Tasmania under a warming and drying climate, James's research will form an important part of improving our fire risk assessments, fuel management regimes and increasing the capacity to attack fires quickly and efficiently. It is research like this that will help better manage future fire crises in Tasmania and in other forest environments around Australia.'

First published in TERN newsletter April 2016. Reproduced with permission.

The Lindau Nobel Laureate Meeting – a once-in-a-lifetime opportunity

The 67th Lindau Nobel Laureate Meeting opening ceremony.
Julia Nimke/Lindau Nobel Laureate Meetings

Situated about 200 kilometres south-west of Munich, the city of Lindau on Lake Constance borders Austria's and Switzerland's mountains. Lindau is the place where the concept of the Nobel Laureate Meeting began. With a vision to reconnect German scientists to researchers around the globe, two Lindau physicians, Franz Jarl Hein and Gustav Wilhelm Parade, and Count Lennart Bernadotte af Wisborg organised the first Lindau Nobel Laureate Meeting in 1951. Over the past 67 years the meeting has thrived to educate, inspire and connect more than 32 000 young researchers.

This year's June meeting gathered 28 Nobel laureates and 420 young scientists from more than 70 countries. I was lucky to be one of the nine early career researchers in chemistry selected by the Australian Academy of Science, the Science and Industry Endowment Fund and the Lindau Council to represent Australia and discuss and develop ideas addressing pressing worldwide issues. Unlike other conferences that I have attended, the Lindau Meeting was set so as to maximise the interactions of young researchers with each other as well as with Nobel laureates. At the registration, I received my personalised one-week agenda packed with science breakfasts, lectures, discussion sessions, master classes, panel discussions and academic dinners.

The extraordinary week started off with the inspiring keynote address of Professor Steven Chu (James H. Clark Center, Stanford University) (delivered by Professor William Moerner, Department of Chemistry, Stanford University) on the effects of climate change and the need for scientists to work together as well as with the general public, the private sector and policymakers to remedy the aftermath of cumulative human-made carbon dioxide levels. The importance of uniting skills from diverse backgrounds to form an intergenerational network of multidisciplinary collaborators without borders was a recurring theme and the Lindau Nobel Laureate Meeting provided a perfect platform to do so.

Among the educative discussions addressing current research findings were opportunities to interact with industry researchers. On 28 June, I was invited to the Mars Incorporated sponsored Science Breakfast 'The chemistry of food: flavor and beyond' and the Academic Dinner 'The chemistry of the gut microbiome' – both key aspects of my research. The talk from Dr Anita Zaidi (director of Enteric and Diarrheal Diseases (EDD) program at the Bill and Melinda Gates Foundation) was a particular eye-opener. As a recent PhD graduate, I found being exposed to the process of transitioning from laboratory research to its implementation in larger societies, in Anita's case working on eliminating children's mortality from diarrhoeal diseases in low–middle income counties, inspiring and it demonstrated a real-world application with positive societal impact.

My favourite memorable experience of the meeting was during the Gala dinner organised by Mexico. I was seated next to Professor Johann Deisenhofer (Green Center for Systems Biology, Biophysics, University of Texas Southwestern Medical Center), who received the Nobel Prize in Chemistry in 1988 for the determination of the three-dimensional structure of a photosynthetic reaction centre. The conversation flowed smoothly, we shared insightful perspectives of secondary and tertiary STEM education and research across continents, equity, the increase in nationalism around the planet and (his observations on) how far we have come compared to 60 years ago. Johann's lifelong experience was invaluable and although I didn't realise it at that time, the conversation enhanced my knowledge of international research and encouraged me to think about present-day trends in mobility, collaboration and transparency in science.

When asked for advice, the Nobel laureates generously shared their experience through their scientific/life challenges, their

Inauguration of the 67th Lindau Nobel Laureate Meeting with an appeal for climate protection

The 67th Lindau Nobel Laureate Meeting was inaugurated in June in Lindau on the banks of Lake Constance in Germany. The guests, who hailed from approximately 80 countries, were welcomed by the President of the Council, Countess Bettina Bernadotte af Wisborg. In total, 28 Nobel laureates and 420 young scientists from around the world participated in this year's meeting, which was dedicated to chemistry.

In her opening address, Countess Bernadotte exhorted scientists to be more politically active in this 'post-truth era'. 'Scientists cannot ignore what is happening in the world. Some rulers, and people, seem to feel threatened by progress and the fact-oriented power of science.' With its focus on open and constructive dialogue, the Lindau meetings can act as the necessary antithesis of this ideology by encouraging young scientists to network with each other and to stand up for science.

The keynote speech by Steven Chu, Nobel Laureate and former US Secretary of Energy (2009–13) under Barack Obama, was read by Nobel Laureate William E. Moerner, because Chu had to cancel his attendance at short notice. The speech was dedicated to the devastating consequences of climate change, which cannot be ignored, and stressed the importance of evidence-based research for global climate policies. Chu criticised the proposed funding cuts to the budgets for both climate and clean energy research under US President Trump and made an impassioned plea for a rethink of humanity's attitude to the clear dangers of climate change. 'A changing climate does not respect national boundaries', he stressed. Chu closed his speech with an appeal to the next generation of scientists in the audience: 'I close my remarks by asking the young students gathering this week at the Lindau Nobel Laureate Meeting to consider joining the effort to combat climate change.'

Steven Chu and William Moerner were among the co-initiators of the Mainau Declaration on Climate Change during the 2015 Lindau Meeting. In addition to climate change and the role of science in a post-truth age, molecular machines are another of the core topics of the 67th Lindau Nobel Laureate Meeting. For the development of these microscopic structures, two of the participants at the Meeting, Bernard Feringa and Jean-Pierre Sauvage, received the Nobel Prize in Chemistry 2016 together with Sir Fraser Stoddart.

Federal Minister Johanna Wanka represented Germany at the inauguration – the Federal Ministry of Education and Research is among the biggest supporters of the Lindau Meetings. In her speech, the minister highlighted the special character of the meeting: 'Above all, the discussions and the exchange between the generations – the laureates, the young researchers and students from many countries of the world – are what make this event unique', said Wanka. She further stressed: 'We need bright minds that foster advancement. That's why we put special emphasis on strengthening science in Germany.'

The meeting ran until Friday, 30 June, giving the participating Nobel laureates and young scientists ample opportunity for lively, intellectual exchange. Numerous talks, discussions, master classes and, for the first time, so-called poster flashes, at which selected young scientists present their research in short talks, are on the program.

The meeting came to a close with a panel discussion on the theme of ethics in science. The panellists included Ahmet Üzümcü, Director-General of the Organisation for the Prohibition of Chemical Weapons (OPCW), who accepted the Nobel Peace Prize 2013 on behalf of the organisation.

Council for the Lindau Nobel Laureate Meetings/Foundation Lindau Nobel Laureate Meetings

The author (left) with the Australian delegation, accompanied by Professor Martin Chalfie (Columbia University Biological Sciences) for lunch.

boldness to try a project highly important but almost impossible to achieve and their perseverance to explain unexpected results. One of the most impactful take-home messages was Sir John Walker's anecdote about the importance of mentors in the career development of a young scientist:

> [Sanger] encouraged me, gave me space, he simply supported me, he didn't tell me what to do, he didn't suggest that I work in this particular area but through his interest in mitochondrial DNA I got interested in bio-energetics. It can be advantageous and helpful to have brilliant, helpful and sympathetic mentors. So do your best to find one.

The trip to the 67th Lindau Nobel Laureate Meeting was a rich experience that contributed to my career aspirations, research and personal life. Hearing firsthand from the Nobel laureates' experience in science, the way they learned from their mistakes and their advice to young scientists were unique experiences and I encourage other young scientists to apply for and attend future Lindau Nobel Laureate meetings.

Acknowledgements

I would like to thank the Australian Academy of Science, the Science and Industry and Endowment Fund, the Robert Bosch Foundation and the Lindau Council for sponsoring my attendance to the 67th Lindau Nobel Laureate Meeting. A huge thank you to Maria Forsyth (our delegation leader), Michael Taylor, Siddulu Talapaneni, Vini Gautam, Andrew Giltrap, Joy Jiang, Matthew Norris, Joseph Richardson and Andrew White for making this journey a fun and memorable one.

Dr Jessica Pandohee MRACI CChem is a postdoctoral research fellow, at the Centre for Integrative Metabolomics and Computational Biology, Edith Cowan University, Western Australia. To find out how to apply for future Lindau Nobel Laureate meetings, visit www.lindau-nobel.org/meeting.

About the Lindau Nobel Laureate meetings

Aerial view of Lindau Island.
Edda Praefcke/CC BY 2.5

The Lindau Nobel Laureate Meetings have been hosted on the banks of Lake Constance every year since 1951. Owing to the ongoing renovation of the local conference hall, this year's meeting again took place in Lindau's city theatre. The number of participants was therefore reduced from the usual 600 to 450.

Once every year, about 30 Nobel Laureates convene at Lindau to meet the next generation of leading scientists: 400–500 undergraduates, PhD students, and postdoc researchers from all over the world. The Lindau Nobel Laureate Meetings foster the exchange among scientists of different generations, cultures, and disciplines.

The meetings focus alternately on physiology and medicine, on physics, and on chemistry – the three natural science Nobel Prize disciplines. An interdisciplinary meeting revolving around all three natural sciences is held every five years. In addition, the Lindau Meeting on Economic Sciences is held every three years.

The scientific program of each Lindau Meeting is based on the principle of dialogue. The different sessions – lectures, discussions, master classes and panel discussions – are designed to activate the exchange of knowledge, ideas, and experience between and among Nobel laureates and young scientists.

Council for the Lindau Nobel Laureate Meetings/Foundation Lindau Nobel Laureate Meetings

Gordon Wallace named 2017 NSW Scientist of the Year

Professor Gordon Wallace FRACI CChem, Director of the ARC Centre of Excellence for Electromaterials Science (ACES) at the University of Wollongong, has been named 2017 New South Wales Scientist of the Year.

Wallace is an internationally renowned researcher in the field of electromaterials science for his innovative use of nanotechnology in conjunction with organic conductors to create new materials for energy conversion and storage, as well as medical bionics.

As Director of Australian National Fabrication Facility, Materials Node, Wallace has led the development of innovative approaches to materials processing and fabrication tools that enable advanced materials to be integrated into practical devices for use in energy and medical bionics. This has facilitated a number of commercial opportunities in both areas.

He has established a national clinical research network to develop customised printing solutions (hardware, software and bioinks) targeted at a range of clinical challenges. His research vision is to develop fully functional implantable 3D printed structures containing living cells, to regenerate damaged cartilage in knees, the ears of children suffering from microtia, bone and even organs.

This fusing of human biology with engineering and robotics has the potential to fix a patient's specific medical condition – from cancer to diabetes and neural diseases – by printing a functional 3D structure containing living cells and surgically inserting it into their body. This can only be achieved by interdisciplinary and collaborative research teams that involve end users throughout the research and development process.

ACES research into energy conversion and the formation of hydrogen from water into important fuels, hydrogen and oxygen, has led to the successful formation of an ACES spin-off company, Aquahydrex, now in its fifth year of operation.

'It is a great honour to have a fantastic team to captain and for our research to be recognised in this way', Wallace said.

'We will continue to strive to ensure that our most fundamental discoveries are translated into real applications to the benefit of our communities in the most effective way possible.'

ARC Centre of Excellence for Electromaterials Science

New Fellows

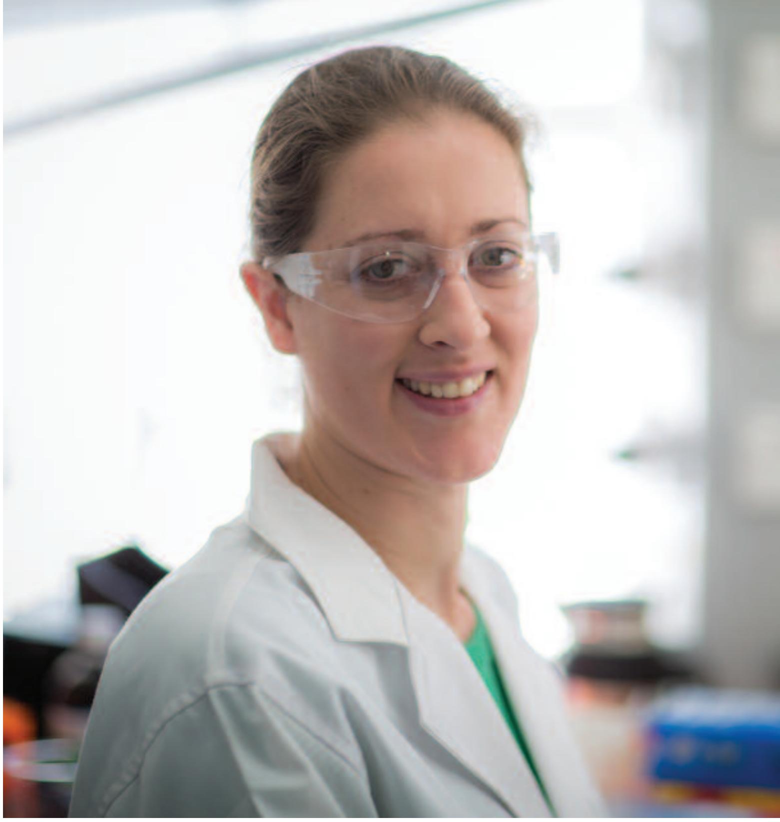
Frances Separovic is a biophysical chemist based at the Bio21 Institute, University of Melbourne. Separovic grew up in Broken Hill and, after the birth of her son, did a BA at Macquarie University and a PhD at the University of New South Wales while working full-time at CSIRO, Sydney. Following a postdoctoral fellowship at National Institutes of Health (USA), Separovic joined the University of Melbourne in 1996, where she became the first woman professor of chemistry (2005) and head of school (2010). Separovic has developed solid-state NMR techniques to determine the structure and dynamics of molecules in biological membranes with a focus on peptide antibiotics and toxins within phospholipid membranes.

While teaching chemistry, Separovic has served as assistant dean (EO) (2001–02) and associate dean (2009–10) of the Science Faculty. She is currently Secretary of the Biophysical Society (USA) and is an editorial board member of *Accounts of Chemical Research* and *Chemical Reviews* and editor of *Biochimica Biophysica Acta* and *European Biophysics Journal*. Separovic was elected President of Australian New Zealand Society for Magnetic Resonance, ANZMAG (2011–13); General Treasurer of the RACI (2008–10); Council of the Biophysical Society (2007–10); Treasurer of Lorne Protein Conference (2006–09), Council of International Union of Pure and Applied Biophysics, IUPAB (2002–05); and President of Australian Society for Biophysics, ASB (1999–2001, 2012–14). Separovic has organised 40 major scientific conferences and published more than 220 papers in international journals. She was awarded the ASB Robertson Medal (2009) and ANZMAG Medal (2011) and elected Fellow of the Biophysical Society (USA) and ISMAR Fellow (2012). Separovic was the first female chemist elected to the Australian Academy of Science (2012) and is a recipient of a IUPAC Distinguished Women of Chemistry/Chemical Engineering and UNSW Alumni Award: Science & Technology (2017).

Chris Ling completed his undergraduate studies in science at the University of Melbourne and PhD in solid-state chemistry at ANU. After graduating in 1999, he moved to Argonne National Laboratory in Chicago, USA, as a postdoc for two years; then the Institut Laue-Langevin in Grenoble, France, as a neutron instrument scientist for three years. He was appointed to an academic position in the School of Chemistry at the University of Sydney in 2004, where he is currently Associate Head of School (Research) and holds a Sydney Research Accelerator (SOAR) Fellowship.

Ling's research area is solid-state materials chemistry, within which his interests can be divided into two main areas: applied energy materials and fundamental magnetism. In the energy materials space, he focuses on new solid-state ionic conductors for applications in fuel-cell membranes and solid-state lithium/sodium ion batteries. His work in the magnetic materials space addresses fundamental questions about the physics and chemistry of low-dimensional and geometrically frustrated topologies, which give rise to exotic low-temperature ground states. A distinguishing feature of Ling's research program across all projects is an extensive use of powerful neutron and synchrotron X-ray scattering instruments at major facilities.

Ling has chaired a number of significant conferences, notably the 2nd Asia–Oceania Conference on Neutron Scattering (AOCNS-2015), and been elected to leadership roles of professional societies. He is currently Secretary of the Asia Oceania Neutron Scattering Association (AONSA, representing more than 2000 neutron scientists in the region), Vice-President of the Society of Crystallographers in Australia and New Zealand (SCANZ), and Consultant to the Commission on Inorganic and Mineral Structures of the International Union of Crystallography (IUCr). He has previously been Chair of the Materials Division of the RACI, President of the Australian Neutron Beam Users' Group (ANBUG), Chair of the NSW Synchrotron Consortium, and Chair of the Specialist Committee on Materials Structure and Dynamics of the Australian Institute of Nuclear Science and Engineering (AINSE).



Elizabeth (Liz) New undertook her undergraduate and masters studies at the University of Sydney with Professor Trevor Hambley before completing her PhD studies in 2010 at the University of Durham (UK) with Professor David Parker. New was then a Royal Commission for the Exhibition of 1851 Research Fellow at the University of California, Berkeley with Professor Chris Chang.

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

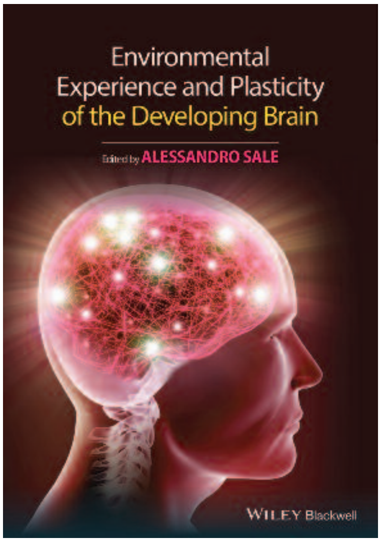
New was the 2014–15 RACI NSW Nyholm Lecturer and the 2017 RACI Tasmania Youth Lecturer, and currently serves on the executive of the Australian Academy of Science's Early-Mid Career Researcher Forum. She is also passionate about teaching, for which she has received awards, including the RACI Educator of the Year Award (2016).

Ron Clarke is a biophysical chemist at the School of Chemistry, University of Sydney, where he holds the position of associate professor. He grew up at Henley Beach, Adelaide, and studied at the University of Adelaide. He completed his BSc(Hons) (first class) in 1980 within the then Department of Physical and Inorganic Chemistry, at the time led by D.O. Jordan, a major player in solving the structure of DNA. During honours, Clarke researched the mechanism of cyclodextrin inclusion complex formation, which he studied on the microsecond timescale via the temperature-jump relaxation method. He continued on this topic for his PhD under the supervision of John Coates, a former student of Jordan's.

In 1987, he obtained a Humboldt postdoctoral fellowship and moved to Germany to work with Peter Läuger in the Membrane Biophysics Department of the University of Konstanz on the kinetics of the sodium–potassium pump. In Konstanz, Clarke was so fascinated with the field of membrane biophysics and so inspired scientifically and personally by Peter Läuger that he has devoted the rest of his career to this field. In 1989, he spent a year as a Leverhulme Fellow at the University of East Anglia, Norwich, England, but then returned to Germany for a further nine years to work within the Max Planck Society, first at the Fritz Haber Institute in Berlin (1990–5), where he experienced first-hand the changes accompanying the fall of the Berlin Wall and German reunification, and subsequently at the Max Planck Institute of Biophysics in Frankfurt/Main (1995–9) within the department of Ernst Bamberg, also a former student and postdoc of Peter Läuger. In 1999, Clarke moved back to Australia to the then Division of Physical and Theoretical Chemistry (now School of Chemistry) at the University of Sydney.

In 2010, Clarke received the McAulay–Hope Prize for Original Biophysics from the Australian Society for Biophysics (ASB), and in 2015 he received the Archibald Ollé Prize from the RACI for the book *Pumps, channels, and transporters: methods of functional analysis*. Since 2013, he has been national treasurer of the ASB.

Apart from biophysical chemistry, one of Clarke's chief passions is French horn playing, which he even manages to weave into his chemistry lectures, specifically on quantum chemistry, where the horn's harmonics serve as perfect analogies to electronic energy levels. In spite of his horn playing, Clarke is married to Binh Pham and they have three children – Milly (15), Nam (12) and Violetta (6).



Environmental experience and plasticity of the developing brain

Sale A. (Ed.), Wiley-Blackwell, 2016, hardcover, ISBN 9781118931653, 240 pp., $185.95

Alessandro Sale (Neuroscience Institute of CNR, National Research Council, Pisa, Italy) is the editor and co-author of *Environmental experience and plasticity of the developing brain*'s first chapter. He is also co-author of about 30 Medline-indexed papers that have been cited slightly less than 3000 times so far (including one groundbreaking paper with original data that has to date 542 citations (*Science*, 2008, vol. 320, pp. 385–8) and another seven papers with more than 100 citations each). Sale most recently published in January 2017 (*Oncotarget*, vol. 8(4), pp. 5682–3), about the possibility of reversing conditions characterised by intellectual disability or dementia such as neurodevelopmental disorders, including autism, Rett syndrome and Down syndrome, and age-dependent neurodegenerative diseases such as Alzheimer's disease. The other chapter authors are likewise impressive in terms of their backgrounds and thus there is a reasonable expectation that the reader should come away from the reading experience well informed, with new insights and understanding.

The subject matter is an immensely important one and each chapter heading of this book teases with potential practical applications. This is more than ample to make the most staid and stoic reader drool in anticipation of eye-opening advances.

Sadly, sometimes it's all sizzle and no steak.

The book is in essence a compendium of well-researched and well-written literature reviews in the areas of the respective chapter title headings that look at various aspects of the interplay of environmental experience (of a myriad of differing types) and the effects on the changing wiring within the developing brain as a consequence of such.

However, there is scant new data and very little (if any) in the way of original, meaningful, insightful discussion not found elsewhere in the literature. Thus, for those who could follow and understand it (who are very likely to be well read and informed in this area), there is hardly any compelling reason to do so.

Rather than tackle new paradigm-changing elements, it's simply a case of 'more of the same' and inconsequential minor advances if any. Often it's the same data that is already known being rehashed and republished.

The subject matter itself is potentially of interest to an exceedingly wide audience, yet the academic style and technical language adopted would likely exclude their participation, not least of which due to the prerequisite background knowledge vital to understand what is written.

As a result, this book's appeal falls into no-man's land: neither accessible by the general public and professionals from other disciplines by virtue of its language and prerequisite requirements nor having the content likely to inspire, enthral and satisfy the needs of those skilled in the art who take interest in the subject matter.

A notable feature is that half the chapters make prominent acknowledgements to funding agencies yet these chapters seem to omit the original and novel data of any significant nature that one would presume this funding was provided for. The remaining chapters likewise are barren of any reports of original previously unpublished consequential findings or novel explorations of the subject matter.

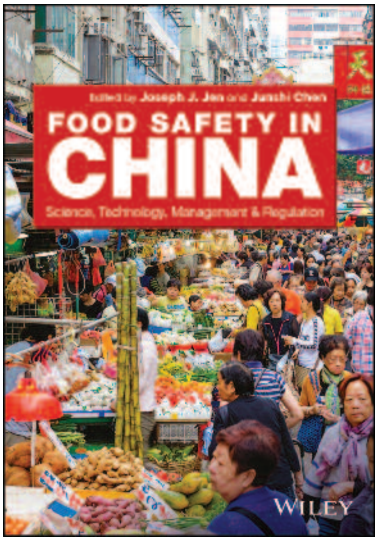
The now disheartened reader is left wondering whether this book is just another sad reflection of Academia's obsession with 'publish or perish'. Rather than concentrate and produce high-quality, meaningful, insightful and compelling reports of groundbreaking discovery, the seeming primary purpose of this work is to opportunistically inflate the various authors' publication statistics and to placate funding agencies.

This is a book that promises so much yet other than delivering a very credible and good-quality series of literature reviews, it will likely sadly disappoint the narrow band of potential readers because it does not provide anything novel that could not be found elsewhere in the literature. It likely serves its seemingly intended purpose but in a very real sense it has failed its readers.

This topic thoroughly deserves to be written both in accessible plain language in an open style (with technical concepts explained to a wider audience) to make it widely readable by the general public and professionals from disciplines not familiar with the technical details, and equally in full academic style with new groundbreaking data and meaningful and insightful discussions for technically minded audiences.

I could only in good conscience, at most, commend this book to perhaps graduate students about to embark on areas addressed in the individual chapters as a good starting point, but I find the book to be of otherwise limited additional general appeal.

Motty Sobol FRACI CChem



Food safety in China: science, technology, management and regulation

Jwu-Shan Jen J., Junshi Chen J. (Eds), Wiley, 2017, hardback, ISBN 9781119237969, 696 pp., $392.95

Recent publicity regarding a new system for certification of those baby formula food manufacturers who want to export to China has made the publication of this book very timely. *Food safety: science, technology, management and education* is a compendium of 36 chapters: a wide-ranging review of the subject with remarkably frank accounts of problems in China and how they have been, and continue to be, addressed. It is well presented in a very readable typeface (Warnock) with a sturdy binding and an eye-catching cover. There are very few typographical errors, making it a very readable text, the latter commendable as 70 of the 99 authors are Chinese. Twenty-four of the authors are from the US, indicating strong links with the universities and FDA. Minor detractions are overlap, which in places makes for tiresome reading, and the indiscriminate addition of acronyms. On the plus side, however, all chapters have subheadings to assist the reader. References are adequate, the most recent dated 2015. In some chapters, however, the majority are in Chinese.

The opening nine chapters cover food safety in China, first generally, then in detail, from the perspectives of bacteria, fungi, viruses and parasites. The sections on mycotoxins are of particular interest; here the authors compare the incidence and standard-setting measures with those of other countries. Mycotoxin from maize is of particular concern because this is a major Chinese crop; increasing fungal contamination is attributed chiefly to higher temperature and humidity from climate change. *Cryptosporidium* and *Giardia* can be common in China's surface waters, which will remind Sydney-siders of a scare some years ago when these parasites were briefly found in our drinking water, though it took filtration of 10 litres of test water to find one.

These chapters are only the beginning of an examination of every imaginable kind of safety issue. Some of these arise from the usual pressures for yield in both animal husbandry and crop-growing activities, as well as an almost universal belief in the value of antibiotics for every condition or disease. Antibiotic resistance acquired from the overuse of antibiotics in food animals is detailed for the seven most common species of bacteria, a good example of the level of detail throughout. Detective work is now facilitated by genotyping.

Additives, residues and food fraud form another group. Usage of food additives has overtaken regulatory control so badly that the whole class of chemical is now 'demonised' in the public mind. The use of pesticides and veterinary medicines has followed the familiar path of indiscriminate application followed by increasing restriction and regulation, but controls are hampered by production from 230 million smallholdings! Heavy metal residues are a special problem caused by pre-contamination of arable land. This makes an interesting comparison with Australia, where most land was initially 'clean'.

Various unsavoury practices are next discussed under the umbrella of 'food fraud', including milk so 'built' as to lack nutrition and the addition of melamine to increase nitrogen content. Very aggressive domestic regulation has sought to correct this sensitive class of food processing, resulting in a requirement even for foreign milk powder producers to be certified for export to China from January 2018. Local penalties are now among the most severe in the world. There is a parallel with slimming aids where the Australian TGA still regularly deregisters Chinese 'complementary medicine' products containing dangerous additives.

The final ten chapters cover specific food classes, traceability, testing for genetically modified organisms, safety of food-contact materials and cutting-edge methods to detect microorganisms and other substances. Traceability now includes some identification methods for proteins, which can often take identity to the source, often-important information for the consumer: think of vintage French wines!

A good deal of the general text is concerned with details of the regulatory, standard-setting and educational measures taken in China to overcome problems and bring the country into line with international standards. References to analytical procedures are given throughout, though for recent techniques, Australian readers would probably prefer to consult *Food safety: innovative tools for safety assessment* (see August issue, p. 30).

Besides its general interest, this book will be a valuable resource for anyone who needs to be familiar with the status of any aspect of food safety, especially in China. China can be commended for its 'crop-to-table' approach, evidenced by the systematic corrective actions presented in this text.

Bruce Graham FRACI CChem

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Printing with concrete: how I spent my summer vacation

Since they came out a few years ago, the capabilities of commercially available 3D printers have radically expanded. At first, they could only print little things out of plastic, but now people have begun to print working cars and even bridges. People are actively experimenting with how to print with more materials like metals, and, more recently, concrete.

This summer,* I participated in the Summer Undergraduate Research Fellowship (SURF) program at NIST. Upon being accepted, I was assigned to a project titled 'Additive manufacturing of cement'. I was intrigued by the title alone, as I had experience with 3D printing – but I had not, however, worked with cement or concrete. I found this project to be a good opportunity for expanding my knowledge of materials and their applications in manufacturing. My advisor, Scott Jones, told me that he had not even studied cementitious materials until he started his PhD, which was reassuring to me.

Because 3D printing of cement is becoming more widespread, Scott and his team at NIST want to study the process and make recommendations about how to improve it.

We had two primary areas of concern. First, we wanted to find out which cement formulations work best for printing. Second, we wanted to determine the optimal program settings for the printer itself so we can print the best quality structures.

Perfecting the mix, cracking the code

The additive manufacturing approach that we used is known as fused filament modelling or 'material extrusion'. In this process, a material is pushed through a nozzle and laid down to build up a structure layer by layer. Typical 3D printers use a plastic filament that looks a lot like the kind you might load into a weed whacker. The filament is forced through a heated nozzle to make it malleable and soft enough to stick to the previous layer. 3D printing with cement works essentially the same way, except the cement isn't heated and the nozzle is bigger.

Scott and his past SURF students modified a commercially available conventional 3D printer to deposit cement paste. They also experimented with different paste mixes to see how easily they can be pumped and how well they form standing structures rather than puddles. This summer, I furthered this research by not only optimising the cement paste for printing but also experimenting with how to introduce reinforcements – here in the form of a printed plastic mesh – to the concrete.

(Reinforcing concrete to make it more resistant to being pulled apart is standard when building conventional structures, but the practice has not yet been incorporated into cement-based additive manufacturing, so this is a first step towards that.)

To do this, I had to reprogram our printer so that it would alternately deposit layers of cement paste and reinforcing plastic mesh for the paste to diffuse into. Because I wanted something a little stronger than conventional plastic, I decided to use a carbon fibre-infused filament. This seemed like the best option because carbon fibre materials are already used to reinforce concrete for some applications.

We spent the better part of June tweaking the 3D printer's code. Thankfully, because the software that runs the printer's CPU and the software that processes 3D models for printing are both open source, I could modify the code anyway I needed to – very handy when you're trying to force a cement-shaped peg through a plastic-shaped hole. Despite the flexibility of the code, the process was still pretty frustrating, but I eventually figured out how to get the printer to deposit layers of cement paste with its pump, switch over to its plastic extruder, and then switch back to the pump. With that done, I began to print samples to see if the carbon fibre-infused plastic reinforcements had any noticeable effect on the material's strength and durability.

Printed concrete bricks, carbon-fibre straw

I printed several rectangular, brick-like artefacts and observed not only the behaviour of slightly different mixes but also how their properties changed over time. Soon after we prepare the mix, the concrete has the consistency of melted ice cream. In this state, it flows very easily through the pump and nozzle, but it cannot support its own weight very well and collapses into a puddle. If we let too much time pass after mixing, however, the material takes on the consistency of clay, which, while it can support itself, is very difficult to move through the pump. We found that the ideal consistency was more like a thick custard, which seems to develop anywhere between 35 and 80 minutes after mixing. This behaviour lined up with the data we collected, but you could only fully appreciate it by seeing it in action. After cleaning up puddle after puddle of brownish-grey goo, it's amazing how satisfying it was to see the cement come out of the nozzle in a smooth bead and behave the way I wanted it to.

Printing the reinforcing mesh was another finicky, yet ultimately rewarding, process. Lots of failures in the form of stringy, bird's-nest-like messes of melted plastic finally led to the production of excellent final specimens. They were still ugly, but I've learned that creating prototypes often requires prioritising function over aesthetics.

Over the course of running print after print after print, I picked up several other helpful habits. One of the most important was being excessively careful in preparing the cement and labelling every specimen with as much information as possible. Cement paste formulations are very sensitive to small changes in the proportions of the ingredients, and no matter how good my memory is, all the vaguely rectangular blobs I produced tended to look the same. Documenting made all the difference.

*In the US in 2017.

Reaching the breaking point

It wasn't until towards the end of my time at NIST that I got the opportunity to physically put the printed specimens to the test. First, I tested some specimens that were cast in a mould and not printed at all. One was pure cement and the other had layers of carbon-fibre mesh inside. We needed some confirmation that, additive manufacturing aside, the mesh would actually reinforce the brick. With our fingers crossed, we subjected the specimens to a three-point bend test until they broke. Our preliminary results showed that the reinforced bricks were truly a fair bit stronger than the ones without reinforcement.

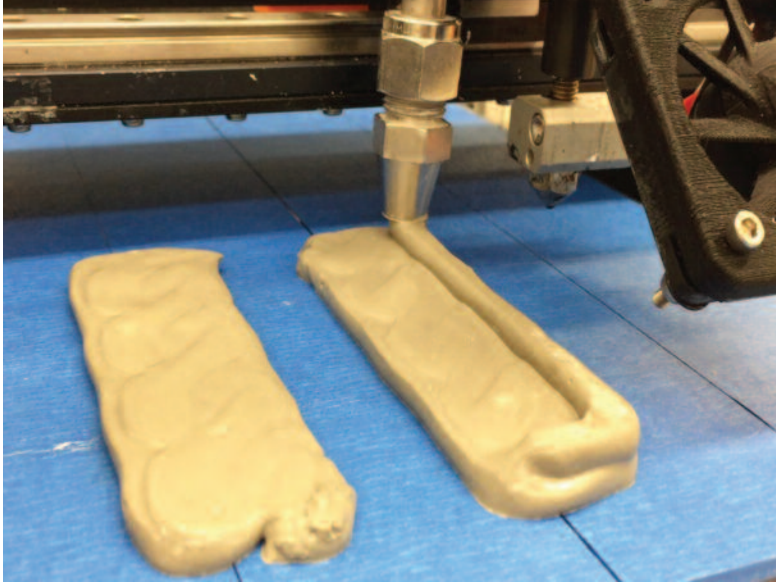
Whew! My efforts had not been in vain.

I then tested specimens that we had printed, some of which had reinforcement, some without. Again, the data seemed to suggest that the ones we had reinforced with the carbon-fibre mesh required more force to break. Seeing the results of our preliminary tests going in this direction was really great. There is, of course, still lots more testing to be done. One of the drawbacks of doing undergraduate research for only 10 weeks is that you don't have time to do the work necessary to draw significant conclusions.

Maybe next year!

Putting it all together

Overall, the SURF experience was very valuable to me. I had done research before at my university, but the scope of it was narrow and my advisor was the only accessible expert on the topic. Here at NIST, I worked in a department full of experts working in specialised labs studying the behaviour of cementitious material, so I had access to all the knowledge and instrumentation that I needed. With my project in particular, I was pleased with how my time was divided. True, I spent much

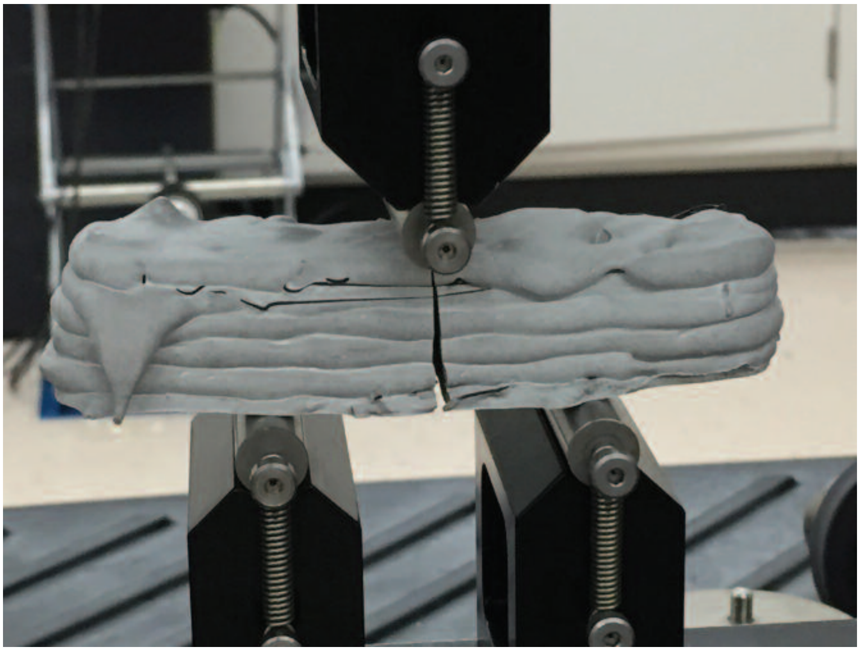


Here, the printer is printing layers of cement paste. This is the ideal custard-like consistency needed for additive manufacturing. A. Thomas/NIST

of it just tweaking the 3D printer, but I was also taught different ways to characterise cement-based material and ended up producing and testing real specimens. I liked being able to see so many facets of this research instead of being limited to looking at this topic through a keyhole.

What is especially valuable about the research I did is that it allowed me to apply my existing knowledge of 3D printing and manufacturing technology while gaining knowledge in materials characterisation and cementitious materials in general – topics that would not be covered in any of my classes. I'm excited to see how the field of concrete additive manufacturing will develop in the future, and I'm proud of the small contribution I made to optimising the process.

Austin Thomas is going into his third year studying mechanical engineering at the University of New Haven. He is particularly interested in the manipulation of materials through manufacturing and is intrigued by how engineers can make use of interesting material properties to serve the greater good. This article reprinted from NIST blogs, with permission.



Our preliminary results showed that the reinforced bricks were truly a fair bit stronger than the ones without reinforcement.

Here, a composite specimen is being broken on a load frame. Notice it is holding together after fracture due to the carbon fibre filament reinforcement. A. Thomas/NIST

Removing CO_2 from flue gas

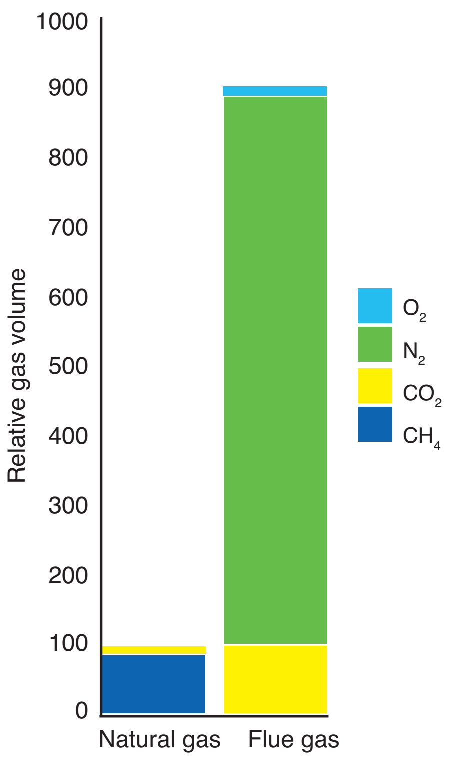
In the November issue (p. 36), I outlined the operation and issues for process plant designed to remove carbon dioxide from industrial gases. In essence, the key method is the absorption of the gas at pressure against a descending stream of liquid absorbent, which is subsequently regenerated by stripping out the absorbed gas. From this basic process, there are many variants used to strip carbon dioxide out of a wide variety of industrial gases.

One of the main concerns of greenhouse gas mitigation is the removal of carbon dioxide from flue gases, which are the result of combustion of fossil fuels. These range in scale from industrial heaters and boiler stacks, to gas turbine exhaust for gas-fired power generation to large coal-fired power stations. If successful, the captured carbon dioxide would be geo-sequestrated in appropriate deep geological structures.

Most natural gas contains some carbon dioxide, and process plant for this operation is widespread and relatively cheap. These processes often use alkanolamines as the absorbent, which form a weak complex with carbon dioxide that is easily reversed in a regeneration process. Applying this technology to flue gas illustrates several problems with the current technology.

Suppose we start with 100 parts of natural gas. If this is burned in a boiler, the ideal equation approximates to:

$$CH_4 + \text{air } (2O_2 + 8N_2) \rightarrow CO_2 + 2H_2O + 8N_2$$



Relative volumes of natural gas and resulting flue gas (10% excess air).

On a dry basis, the percentage of carbon dioxide in the in the flue gas is 11.1% (vol.). This is broadly similar to many natural gases where methane (and some higher hydrocarbons) substitute for the nitrogen. However, in practice the flue gas is far more complicated. First, it is common practice to conduct combustion with at least 10% excess air; this ensures minimum soot (particulate emissions), which means the flue gases contain significant volumes of oxygen. Second, the fuels used often contain sulfur, leading to SO_x gases. Furthermore, high temperature (generally more efficient combustion) and natural gas combustion, which has a high flame temperature, leads to nitrogen oxides (NO_x) in the flue gases.

The graph illustrates in volumetric terms a natural gas (containing 10% carbon dioxide) combustion and resulting flue gases to be treated. Striking is the volume increase of flue gas over the input gas. Furthermore, the input natural gas in an industrial operation is at high pressure (typically 20 bar or higher) so that process plant aimed at removing the carbon dioxide in the feed gas is quite compact. Not so for flue gas, where not only is there considerably more volume to process, but the flue gas pressure is near 1 atmosphere, meaning process plant will be considerably larger. The alternative is to compress the flue gas, which requires a considerable drain on electricity production.

Turning to process: the flue gases contain oxygen, NO_x and SO_x. In theory, NO_x and SO_x can be reduced prior to carbon dioxide removal but there is a practical limit. The main concern is the oxygen in the gas, which leads to oxidation and degradation of preferred absorbents, considerably increasing the cost of operation.

For gas turbines and coal boilers, the flue gas composition is quite different, as shown in the following table. The table shows a wide range of values but it is useful to note that modern gas turbine generators have a high level of air by-pass, resulting in low carbon dioxide and high oxygen content of the flue gas, whereas modern coal generators tend to have higher carbon dioxide and low oxygen content in the flue gas. In other words, prima facie, it would be easier to treat coal flue gas than that from a gas plant.

Typical flue gas compositions of gas turbines and coal-fired boilers

Flue gas composition	Gas turbine exhaust (%)	Coal boiler exhaust (%)
CO_2	2.75	9–15
H_2O	9–10	6–16
N_2	72–73	70
O_2	4.4–18	21.5–23

Saxena and Flintoff (*Hydrocarbon Processing*, December 2006, p. 57) have presented modelling data for treating flue gas using methylethanolamine (MEA, a commonly used absorbent) and another proprietary amine (SH amine). The data usefully gives estimates of typical flows through a flue gas treatment system (see the following table).

Typical utility usage for a standard absorbent (MEA) and an amine developed for flue gas treatment (SH amine)

	MEA	SH amine
Steam for solvent boiling (t/t CO_2)	1.95–3.0	1.2
Regeneration heat (GJ/t CO_2)	4.2–6.5	2.6
Solvent flow (m^3/t CO_2)	17–25	11
Power for pumps (KWh/t CO_2)	150–300	19.8
Cooling water (m^3/t CO_2)	75–165	150
Solvent consumption (kg/t CO_2)	0.45 to 2.0	0.35
SO_2 tolerance (ppm)	10 to 100	<10

... the capture of carbon dioxide from the flue gas of electricity generators is very costly in terms of power required and consumption of absorbent.

In interpreting this data, it is useful to note the amount of carbon dioxide in flue gas. This is shown for typical systems in the next table.

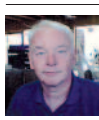
Typical annual CO_2 emissions from generating plant

	Thermal efficiency (%)	Capacity (MW)	Load factor (%)	Mt CO_2/year
Gas turbine/combined cycle	48	500	80	1.348
Gas turbine	35	500	80	1.849
Black coal	39	1300	80	7.569
Lignite	30	1300	80	10.384
Gas reciprocating engine (often used in banks of >100)	42	4	98	0.015

Using typical realised thermal efficiencies, gas generation for a 500 M station producing 400 MW with load factor of 80% emits 1.35 $MtCO_2$/year with the most efficient gas turbine/combined cycle plant and 1.85 $MtCO_2$/year for gas turbine alone (this is the most common in Australia). For large coal generators generating approximately 1 GW of power (nominal capacity 1300 MW with 80% load factor), the emission is about 7.6 $MtCO_2$/year for a black coal generator and over 10 $MtCO_2$/year using lignite. It is interesting to note that a gas turbine generator (not very efficient) producing 1 GW of electricity would emit 4.62 $MtCO_2$/year at the generator plus large amounts of CO_2 during gas production and transmission to the generator site – not much different from an efficient coal generator.

Using these values as guide and applying them to the values in the second table, it is quite clear that the capture of carbon dioxide from the flue gas of electricity generators is very costly in terms of power required and consumption of absorbent. Estimates for power demand lie in the range 25–40% of the total power generated.

Over the past decade, there have been many attempts to devise an efficient method of removing carbon dioxide from flue gas. There is still extensive research into finding an efficient absorbent that is robust to oxygen, NO_x and SO_x. One of the main problems is that demonstration is very expensive (well over $100 million and up to $500 million for a commercial operation on an existing generator). To date, none has been successful in demonstrating an economically viable process for extracting carbon dioxide from flue gas.



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iStockphoto/Onur Döngel

Seeing the unseeable: the 2017 Nobel Prize in Chemistry

The 2017 Nobel Prize in Chemistry has been recently announced, and was awarded to Jacques Dubochet, Joachim Frank and Richard Henderson for their work in cryo-electron microscopy (bit.ly/2yXXCR1).

In science and medicine, huge advances in knowledge were gained through the development of the microscope. The history of the microscope is not a simple one, with dispute over the original inventor. There exists an entire website devoted to the history of the microscope, for those so inclined (bit.ly/2yMhlXb)

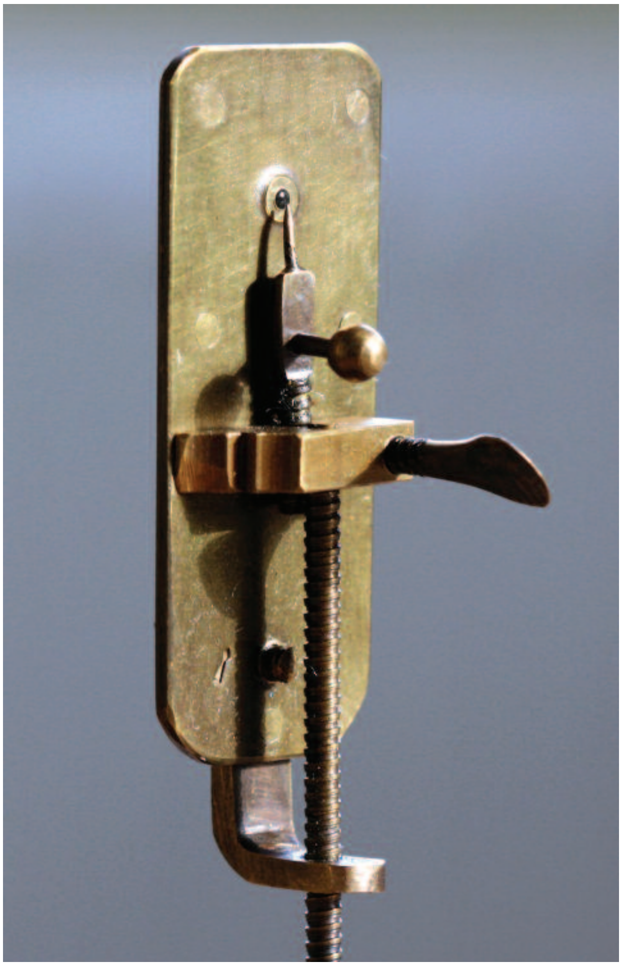
Microscopes were so important because they allowed people to see for the first time things otherwise invisible to the naked eye. The use of microscopes to discover single-celled organisms such as bacteria that cause illness led to huge advances in public health and treatments for infection.

So common are microscopes now that a student couldn't possibly get through school without looking down a microscope to investigate the structure of a plant cell in a life sciences class. One man credited with significantly advancing simple microscopes is Antonie van Leeuwenhoek. Van Leeuwenhoek was an apprentice to a cloth merchant in the late 1600s, and during this time sought to improve on the magnifying lenses available for determining the quality of thread. These were made of glass, but in even earlier times, droplets of water were used for their magnifying properties. With many obvious drawbacks!

In spite of not having an academic background, van Leeuwenhoek was then inspired to investigate the scientific applications of his newly created microscopes. Over a 50-year period from the late 1600s into the early 1700s, he published a significant body of work in microscopy through writing letters to the Royal Society. His light microscopes looked nothing like they do today.

Much about the world has changed since then, but never have things been moving at such a pace as they are today. The advancement in scientific knowledge and technology in my lifetime is mind boggling. At only 28 years old, I grew up through the rise of household internet and mobile phones. Sure, these things existed in some form before I was born, but they

A portrait of Antonie van Leeuwenhoek (1632–1723) by Jan Verkolje. CC01.0/Rijksmuseum Collection

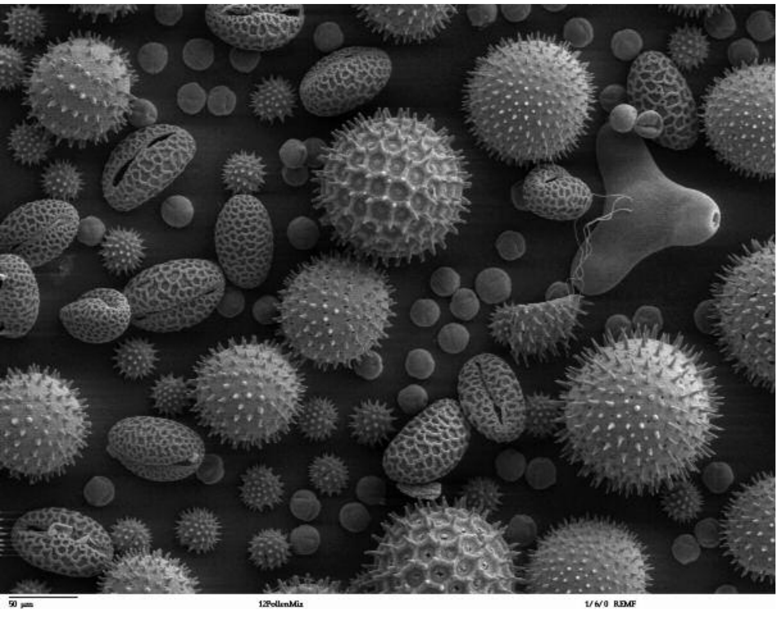


A replica of a microscope crafted by Antonie van Leeuwenhoek. A sample was mounted on a small pin, and then a set of screws was used for focus and positioning. The lens was then held very close to the eye and aimed towards one of the best light sources of the time, the sun. Jeroen Rouwkema/CC BY-SA 3.0

really didn't become commonplace until the last couple of decades.

So too has science and technology evolved, which brings us back to the 2017 Nobel Prize in Chemistry.

One of the difficulties faced by chemists is the inability to directly see the molecules that we create or isolate. To be able to directly see the atoms in any molecule and how they are put together in 3D space would make some of our currently used analytical technology redundant. There is a fundamental physical reason that we have so much trouble seeing molecules though – visible light is just too big to be able to resolve the image. As people wanted to see smaller and smaller things, different approaches had to be discovered.



A scanning electron microscopy image of pollen grains from the Dartmouth College Electron Microscope Facility. This and many more can be viewed at bit.ly/2cYWqUy. Dartmouth College Electron Microscope Facility

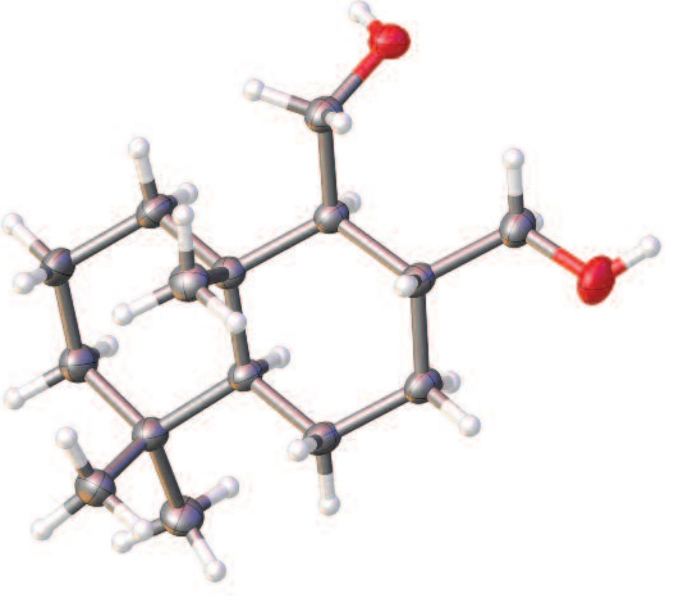
The absolute limit of a visible light microscope is around 0.5 micrometres, or 0.000 0005 metres. A technique commonly used to go smaller than that is electron microscopy. Electrons have a much smaller wavelength than visible light, and therefore are capable of a much higher resolution. Electron microscopy is well known for the stunning detail that can be seen, such as the image above of various pollen grains.

There are some added complexities in working with samples so small, however, such as preparing the sample and pointing the microscope at the right spot. This year's Nobel Prize in Chemistry was for work in this field, where the sample preparation and techniques allowed a resolution closer to 0.1 nanometres, or 0.000 000 000 1 metres! This technique is now applied to the analysis of single molecules, particularly large molecules such as proteins, allowing a clearer than ever picture of what they actually look like. This work has potentially huge implications in the study of diseases and developing specific treatments with fewer side-effects.

The specific area of achievement for this prize is in cryo-electron microscopy, where 'cryo' refers to the analysis being undertaken at around −200°C. This presents unique challenges in sample preparation and handling. You can read a full description of these challenges and accomplishments at bit.ly/2y8zInm.

Unfortunately, as yet this doesn't apply so much to my own work. The equipment would be prohibitively expensive for the average research group, and the analysis of small molecules is still a long way off. To go smaller, where electron microscopy won't cut it, one of the best ways we have of 'looking' at molecules is the indirect imaging technique of X-ray crystallography. In this method, intense beams of X-rays are directed at crystals of the molecule. As the X-rays pass through the crystal, they are bounced and deflected from their path before hitting a detector. The pattern of the X-rays on the detector can then be used to determine the 3D structure of the molecule through some incredibly complex mathematics that I won't even pretend to understand.

This is something I use in my own research. The 3D structure shown here is of a molecule I synthesised in the lab. Grey balls are carbon atoms, white are hydrogen atoms and red are oxygen atoms.



3D structure of a molecule determined by X-ray analysis. Grey = carbon atoms, white = hydrogen atoms, red = oxygen atoms.

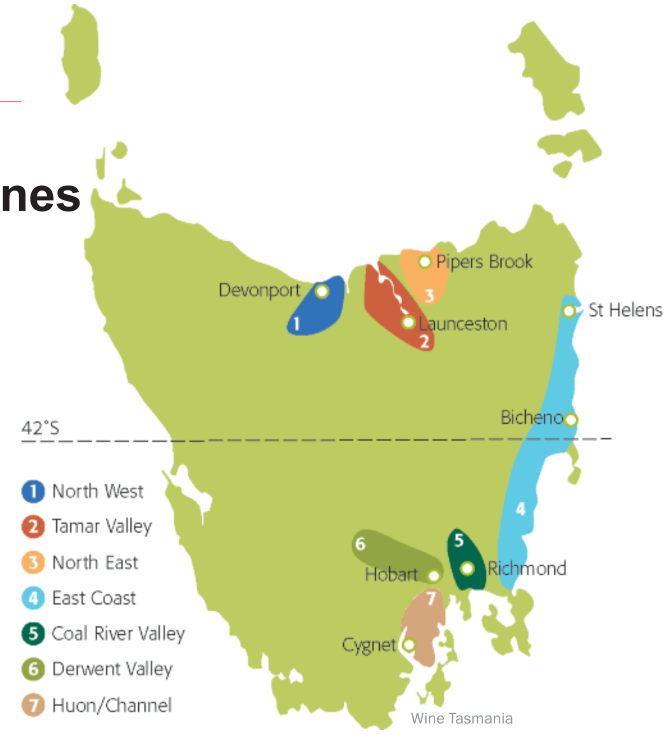
So congratulations to Dubochet, Frank and Henderson, and here's to higher resolution microscopy into the future!

Jeremy Just MRACI is a Hobart-based PhD candidate in organic chemistry and a passionate science communicator, specialising in chemistry shows and demonstrations. Jeremy writes these columns for members to share with or demonstrate to friends and family without formal chemistry knowledge.

Tasmania: a cool place for wines

Fiona Beckett, writing on wine in *The Guardian* in June this year, headlined her article with 'Tasmania has more in common with Burgundy than with the Barossa' (bit.ly/2yq4x7m). Fighting words perhaps, but certainly an idea to consider.

Wine production in Tasmania is relatively new, at least in terms of gaining national and international recognition. Data taken from the 'infographic' on Wine Tasmania's website (bit.ly/2xfcKIm) indicates that total production in 2016 was just over 15 000 tonnes, around 0.8% of total Australian production. Total sales of wine from Tasmania are above the $15 price point, compared to 7% above this point in the overall Australian market, which requires creative marketing campaigns.



There are seven major wine-producing regions (see image). These regions are classified as cool, an appropriate classification given the latitude of Piper's Brook (41.1°S) and Cygnet (43.5°S). The Barossa Valley is around 34.5°S, so on latitude alone, it is a much warmer region. Cultivars in Tasmania are Pinot Noir and Chardonnay, along with Pinot Gris, Sauvignon Blanc, Riesling and Cabernet Sauvignon. Sparkling wine from Pinot Noir and Chardonnay is a great success.

The two cultivars for which Burgundy has developed its reputation are Pinot Noir and Chardonnay. The region extends broadly from around Dijon (latitude 47.3°N) in the north through Beaune to Mâcon (46.3°N) in the south, at a somewhat longer latitude than the Tasmanian regions. While latitude influences sunlight and daylight hours, the climate is also affected by land mass. The Tasmanian regions are coastal, with little land mass to the south, while Burgundy is inland, with the Alps a short distance to the east. The Alps play a major role in controlling the climate in the winegrowing regions.

Irrigation of vineyards in Tasmania is common and regarded as essential in the low rainfall regions of the south and east, whereas irrigation is not permitted in Burgundy, although the changing climate is placing pressure on vine growth. Organic and biodynamic grapegrowing practices are common in Burgundy but rare in Tasmania, reflecting perhaps the differences in the market place.

You can read more about the wines of Tasmania in an article by Huon Hooke (bit.ly/2zGKhNf) and in the November 2017 issue of *Decanter*. With this outstanding wine success, maybe Tasmania should be now known as 'the wine isle'!

What to try

I will focus on Chardonnay here because it can express a range of styles, including aroma and mouthfeel expression. The styles reflect the origin of the grapes (terroir perhaps) as well as winemaking approaches.

The Tolpuddle 2015 Chardonnay from the Coal River Valley receives rave reviews. It can be difficult to find and might set you back $70. Bay of Fires Chardonnay ($34) is a more robust style with natural yeast fermentation in French oak barrels. The Dawson James Chardonnay is a rising star and the 2013 vintage ($60) is exceptional while the Brown Brothers Devil's Corner 2016 Chardonnay ($17) is a snappy young wine.

The Mâcon Villages classification in Burgundy provides a wide selection of wines in the $15–25 price bracket. Three that I enjoy are the Quinson Les Abbatiales 2015 ($22) and the 2015 Cave de Lugny Mâcon Villages at $12. The next level up is Cave de Lugny Bourgogne Blanc at $17. These wines are commonly prepared in stainless steel with natural yeast fermentation. Saint Véran wines can be found in the $28–40 price bracket. For something over the top, go to Montrachet and get the 2008 Bouchard Père et Fils Grand Cru at around $1800 per bottle. It is both budget blowing and mind blowing.

Sparkling wines from Tasmania have had major national and international success, and rightly so. Arras Grand Vintage 2008 ($60) is regarded by some as the 'pinnacle of Australian sparkling wine'. There is a range of other Arras wines in the $23–35 price bracket, all of which are very enjoyable. There are many other sparkling wines from Tasmania made in the traditional method to try. Two that I enjoy are Clover Hill NV ($30) and Jansz vintage ($35).

In Burgundy, the sparkling wines are known as Crémant de Bourgogne. The traditional production process that is used in Champagne is also used with these wines. Two that will not break the bank are the Simonnet-Febre Brut (60% Chardonnay, 40% Pinot Noir) at $22 and Cave de Lugny Crémant Blanc de Blanc at $18. Both are great as an aperitif or when mixed with crème de cassis to give a Kir Royale.

Obviously, there is a wide range of wines from both regions. Perhaps the ideal solution is to visit Tasmania and Burgundy for a month or two each and explore the regions.

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Toulouse and the colour blue

Regular readers will know that I keep my eye out for matters chemical, even when I'm on holiday. The latest 'find' was a blue dye known as 'pastel' that is enjoying a revival in the city of Toulouse, in south-west France. Toulouse is the most important city in the old French region of Occitanie and the old language (Occitane) is still to be found there.

Wandering the streets of the old town, I came across a small shop where items dyed with the pastel were for sale and where it was possible to sign up for a workshop on the art of dyeing with this ancient substance. It's a plant product derived from *Isatis tinctoria*, and perhaps better known to English speakers as woad. Shades of ancient Brits, Boadicea and all that. The leaves of the plant were washed and dried in the sun before being crushed. Producers used their feet to 'puddle' the resulting paste for one or two months while it fermented, after which it was dried out, remoistened with urine and fermented again. The blue dye was rolled into balls and packaged for transport and sale. Pastel, aka woad, is identical with indigo but the mystery of pastel is preserved in Toulouse by never mentioning either the *i*-word or the *w*-word.

A bag made of pastel-dyed cotton.

In the 15th and 16th centuries, Toulouse was a centre of production of pastel and some merchants grew very rich from producing and marketing the blue dye. One of them was Jean de Bernuy, who was rich enough by 1533 to build a grand house, 'l'Hotel de Bernuy', which still stands in old Toulouse. I should mention that 'hotel' doesn't mean quite the same thing in French as it does in English. The merchant's house was what is known as a 'hotel particular' – that is, a private house; and the 'Hotel de Ville' is the city hall.

The doorway to de Bernuy's old house.

The de Bernuy building passed from family hands in the 17th century and was for a long time the site of a Jesuit college. Its educational role continues today as the Collège Pierre de Fermat. The eponymous Fermat, a mathematician (1661–5), was born not far from Toulouse, and he represented the city in its parliament. His name is familiar to us because it is enshrined in 'Fermat's last theorem', although most of us would struggle to remember what that's all about. Fermat was interested in solutions to the equation $a^n + b^n = c^n$ for various values of n. He proposed that the only whole-number value of n for which numbers could be found that satisfied the equation was $n=2$, but – ever in a hurry – he did not have time before he died to provide the simple proof that he claimed to have found. Most chemists will remember the a, b, c values that fit the equation, because they are those of the sides of right-angled triangles – 3,4,5 and 5,12,13, for example. One feels intrinsically that there ought to be other values of n that would work, but Fermat says 'no' (or, maybe, 'non'). Despite many attempts to rediscover his proof, and the offer by a rich German in 1908 of a substantial reward for doing so, it was not until the early 1990s that a proof was published and (unlike many previous proposals) found to be watertight. In keeping with the right-angled-triangle motif, the proof was based on geometry, the field of mathematics in which Fermat specialised.

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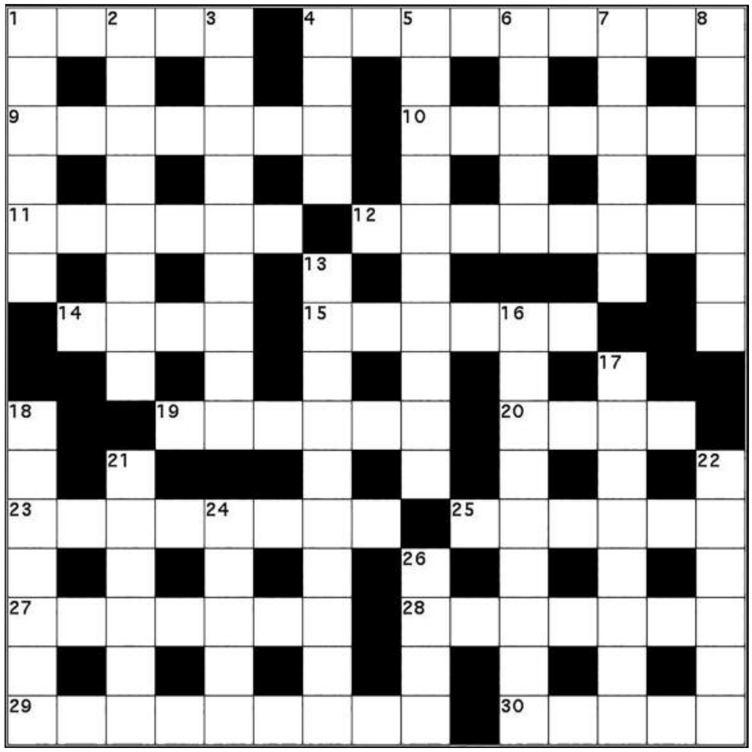
sudoku

^{132}Xe					^{130}Xe		^{124}Xe	
^{134}Xe		^{124}Xe	^{129}Xe		^{131}Xe	^{136}Xe	^{132}Xe	
				^{128}Xe			^{134}Xe	^{131}Xe
	^{124}Xe			^{134}Xe				
^{128}Xe								^{134}Xe
				^{131}Xe			^{129}Xe	
^{130}Xe	^{126}Xe			^{124}Xe				
	^{136}Xe	^{128}Xe	^{132}Xe		^{134}Xe	^{126}Xe		^{124}Xe
	^{134}Xe		^{136}Xe					^{129}Xe

Difficulty rating: moderate.
The symbols for the nine naturally occurring isotopes of xenon are used. Your challenge is to complete the grid so that each 3×3 box as well as each column and each row contains all nine isotopes.

cryptic chemistry



Across

1 Presents fellow over at NASA incorporation. (5)
4 So green to use hormone. (9)
9 Senses allow you and me to be green. (7)
10 Bird diatribe: what's in the burette??!! (7)
11 Dreamworld: initiating unifying theories of programming in accounting. (6)
12 Goal laid out as favoured by Everage. (8)
14 Iodine used with still humanoid. (4)
15 Rock rich with aluminium is non-superposable. (6)
19 Current French physicist. (6)
20 Case held in perpetuity. (4)
23 More port drunk helps to speed things up. (8)
25 Colour change? Love it! (6)
27 Corundum yields iodine: manual. (7)
28 One of ours providing phone coverage via 5 Down. (7)
29 Always leaves; never 25 Across. (9)
30 Better take in second code. (5)

Down

1 One of ours made useful radical removing an electron. (6)
2 Strange ring tone for one of ours! (8)
3 One of ours reduced 27 Across. (9)
4 Finished 30 Across with loss of sulfur. (4)
5 Subsidiaries took the chair and let lies break loose. (10)
6 Graded tread pattern. (5)
7 Bang or bust hold. (4,2)
8 Heard there's a reward for overtime? Negative! (7)
13 Re-elect ACA detail to speed things up. (10)
16 Bummer! CaI$_2$ reacted removing boron for one of ours. (9)
17 Regulating I$_2$ (with no gain) making cell entry more likely. (8)
18 Broke the pane to the compound. (7)
21 Book to capacity. (6)
22 Give the run around in hasty Mie scattering. (6)
24 Outstanding oxygen branch. (5)
26 Endorse evidence. (4)

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Solution available online at Other resources.

events

Christmas HLM Awards and Retirees Lunch
11 December 2017, Graduate House, Carlton, Vic.
raci.org.au/events/event/christmas-hlm-awards-and-retirees-lunch

6th International Conference and Exhibition on Materials Science and Chemistry
17–18 May 2018, Rome, Italy
materialschemistry.conferenceseries.com

ALTA 2018 – Nickel-Cobalt-Copper, Uranium-REE & Gold-PM Conference & Exhibition
19–26 May 2018, Perth, WA
altamet.com.au/conferences/alta-2018

AOCRP-5 – 5th Asian & Ocean Regional Congress on Radiation Protection
20–23 May 2018, Melbourne Vic.
aocrp-5.org

Macro 18 – World Polymer Congress
1–5 July 2018, Cairns, Qld
macro18.org

8th International Conference on Environmental Chemistry and Engineering
20–22 September 2018, Berlin, Germany
environmentalchemistry.conferenceseries.com

RACI events are shown in blue.

Fifty years of the Research School of Chemistry at ANU

This year marks the 50th anniversary of the founding of the Research School of Chemistry (RSC), Australian National University (ANU). Prior to 1967, teaching and research in chemistry at the ANU were conducted in the Department of Chemistry, which had been established in 1959 as part of the School of General Studies. Its head for many years was Arthur Hambly.

At the time of the RSC's establishment, the federal government's vision was that ANU should enhance Australia's profile and abilities in high-level and long-term research. To this end, the ANU Institute of Advanced Studies (IAS) was formed and in 1965, three internationally renowned British-based, Australian chemists, Arthur Birch, David Craig and Ronald Nyholm, agreed to establish the RSC as part of the IAS. Nyholm's involvement did not eventuate, with his position being taken by Ray Martin.

The RSC in 1968, soon after completion of the Birch building.

The original and iconic RSC building, later named the Birch building, opened in 1968. Birch, Craig and Martin became the foundation directors (then called deans) of the School. They established and promoted a non-departmental structure and encouraged collaborations as well as the development of new and 'non-standard' research areas within the School. The School prospered under the leadership of Lew Mander, Alan Sargeson, Athel Beckwith, John White, Denis Evans and Martin Banwell. The RSC undertook long-term and sometimes speculative research projects, driven by the group leaders, a few graduate students but mostly IAS-funded postdoctoral fellows and research fellows. These positions were unique in the Australian context and provided an opportunity for researchers to 'come home' from overseas and look for permanent positions within and outside academia. An extra and new RSC building, named the Craig building, was completed in 1994. In 2009, the RSC merged with the Department of Chemistry. Prior to the merger, the RSC had only limited interaction with undergraduate students. Undergraduate teaching is now an integral component of RSC activities.

The RSC in 2017.

In 2013, the RSC entered a new era by moving from the old Chemistry Department and Birch and Craig buildings to new and distinctive buildings within the Science precinct. The move coincided with the arrival of the current director, John Carver, and a significant reconfiguration of the School. With recent appointments, the RSC now comprises 24 research groups spanning the spectrum of chemistry, including emerging areas such as materials chemistry.

The founding deans set a vision for the RSC that, over the past 50 years, has led to a proud record of achievement by the many RSC students, staff and visitors. The RSC looks forward to continuing its major contributions to the advancement of Australian chemistry.

Professor John Carver FRACI CChem, Director, Research School of Chemistry, Australian National University


Best wishes
for the festive season and the new year.
chemistry in Australia
raci
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