IMPACT

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A picture of health

How health technology is transforming our lives

Annual Academy Oration & New Fellows Welcome

Friday 29 November 2019

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as we welcome more than two dozen leaders from across industry, government and academia as Fellows of the Academy.

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Cover photo of Dr Erica Smyth AO FTSE by Frances Andrijich

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PUBLISHER
Australian Academy of Technology and Engineering

ADDRESS
Level 6, 436 St Kilda Road
Melbourne VIC 3004

POSTAL ADDRESS
GPO Box 4055
Melbourne VIC 3001

TELEPHONE
+61 3 9864 0900

EMAIL
communications@atse.org.au

CEO
Dr Margaret Hartley FTSE

EDITOR
Benjamin Hickey

DESIGN
Elizabeth Geddes

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The Academy acknowledges the Traditional Owners of the land on which we meet and work. We pay our respects to Elders, past, present and emerging.

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REGULARS

By Hugh Bradlow

Technology & data in healthcare

In theory the use of technology, specifically the Internet of Things (IoT), should transform healthcare: it should enable continuous (instead of episodic) monitoring of chronic conditions, prediction of adverse events, and improved diagnosis. In practice however, these benefits are yet to materialise (with some notable exceptions in the imaging space).

Why is that?

Professor Hugh Bradlow
FTSE

Hugh Bradlow is the President of the Australian Academy of Technology and Engineering. You can hear more of his thoughts on Big Data and healthcare in a podcast available on the Academy's website.

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The cost of monitoring devices (eg, single lead ECGs) has come down dramatically while at the same time their accuracy has been enhanced. Our ability to collect and analyse data using new machine learning algorithms has improved out of sight.

However, "the fault, dear Brutus, lies not in our stars" but in our data. Machine learning has two preconditions, namely that you collect all relevant data and that the data is accurate. In terms of collecting relevant data, work by IBM has indicated that endogenous data (the data arising inside the medical system – pathology reports, doctors' notes, imaging, etc) will influence only 10 per cent of the outcomes. Even if we add genomics data to the endogenous data, the impact on outcomes rises only by 30 per cent.

The remaining 60 per cent of outcomes are influenced by exogenous data – the information about our lifestyles which is not collected by the medical system. Examples of such exogenous data are many but include diet, exercise, location and travel, human interactions and other considerations.

Even if we could determine which data we must collect, our ability to assemble that data into a format accessible to physicians and researchers is constrained by many factors. While the country is moving glacially towards a consolidated Electronic Health Record (EHR), as individuals we collect very little of the exogenous data. For example, how many people keep track of their daily food intake?

Furthermore, even for the few that do collect such data, the plethora of systems and formats used to do so do not encourage sharing. Finally, privacy considerations quite rightly create significant (but not insuperable) barriers to data collection and sharing. As an example, consider the discussion about the change in approach to Australia's My Health Record from "opt in" to "opt out". Before "opt out" the EHR was barely used.

Returning to the 10 per cent of outcomes that could be influenced by comprehensive EHRs, assuming the collection of endogenous data is complete, accuracy is still an issue. Clinical Decision Support (CDS) systems, often based on Artificial Intelligence, should be able to assist doctors in avoiding medical errors, determining the optimum treatment for a specific patient's condition, and identifying the critical pathology tests that should be conducted. However, they are dependent on the data supplied to them via the electronic health record system.

Research has shown that this data has a "half-life" of a mere four months due to rapidly changing treatment regimes and is often wildly inaccurate due to poor record-keeping by physicians. As a result, doctors either ignore or override the CDS systems, making them of little value. This is not a technology issue – it is a human behaviour issue making it much harder, but not impossible, to fix. However, until the health system recognises that the EHR is just the beginning and that they need to tackle the quality, as well as completeness of the data that is used to populate the EHR, progress will be slow. The USA is starting to tackle these types of problem with their shift to outcomes-based health payments.

Moving on, assume that we have EHRs that are populated with a complete and accurate set of endogenous, genomic and exogenous data. Goodness knows how long it will take us to get there but what could we achieve? The short answer is a transformation of healthcare.

Consider the use of machine learning to predict adverse health events before they occur. In the hype around machine learning it is usually forgotten that it is just pattern recognition. If you train a neural network with enough patterns, eventually it will recognise variants of those patterns with a high probability. So if you are able to feed data about an individual (their ECG, their food consumption, exercise, travel, etc) continuously into a big data environment it is conceivable that patterns will emerge that enable the pre-conditions for events to be recognised before the actual event (eg, a heart attack) occurs.

My favourite scenario is that you are happily going about your business when an ambulance appears and carts you off to hospital even though you are protesting that you feel fine. Seems pretty invasive doesn't it? – but it beats actually having a heart attack because if not treated within 12 hours the heart damage is irreversible.

There is another consideration in having access to complete and accurate data, namely healthcare provider performance. It is well known that the medical system regards healthcare as a free market and doctors are not constrained from charging anything the market will bear, with the result that charges vary by an order of magnitude depending on the provider. In a normal free market the consumer can also make a judgement on the value of the product being provided but in medicine no such data is available to the patient. Even if data is available (eg, success rate of procedures performed) the providers have plausible ways of rationalising their differences in outcomes – the patient was more difficult, the hospital nursing staff was not up to scratch, key personnel were not available that day, etc.

Now consider what we could do if we had accurate data on all the relevant variables: patient data (medical history, activity history, genome, etc); practitioner data (procedure outcomes, qualifications, professional history, activity history, food history, etc); data about other staff involved in the treatment (nurses, anaesthetists, etc); hospital data (history, staffing levels, etc); environmental data (weather, traffic, etc) and so on.

Conceivably it would be possible to pick a pattern in an individual healthcare provider's performance – effectively define a "figure of merit" for the ability of that doctor – which would then enable patients to determine whether it was worth paying extra for that person. I have no idea what a complete data set would like (I have suggested some of the parameters above) nor whether there is an actual pattern that could be picked out for a given practitioner but I do know that this is an active area of research and we should find out in the next decade.

In summary, technology and data have a huge role to play in healthcare. However, we are just at the very beginning of a long and complex journey which will be more governed by human behaviour issues than technology.

By Kathryn Fagg and Drew Clarke

Shifting gears

Preparing for a transport revolution

The first petrol engine car in Australia hit the streets of Melbourne in the closing years of the 19th century.

In the 120 years since, the internal combustion engine came to dominate mobility in Australia, playing a key role in the industrialisation of the Australian economy. In 2018, there were almost four million such vehicles on Australian roads. As the saying goes, in Australia the car is king.

With the benefits that these vehicles brought, however, came a darker side. Urban congestion is estimated to cost Australia $16.5 billion per year, a figure that is projected to almost double by 2030. Emissions from the transport sector account for about one-fifth of Australia's greenhouse gas emissions and are on the rise.

And although significant advances in safety have been made over the past few decades, more than 1000 Australians still die on our roads each year. So while transport is a key enabler for the Australian economy, significant challenges remain in dealing with sustainability, productivity and health.

Thankfully, new technologies could provide some of the solutions. The rapid advance of digital technologies across all sectors of the global economy has resulted in an extraordinary period of change.

With Australia's geographic isolation and long distances between large urban centres, the transport sector will be one area that is both significantly disrupted and revolutionised by this technological transformation.

New technologies are emerging in the areas of digital and data, communications, sensing and spatial, and energy. In the transport sector, these technologies will see deployment on platforms such as low and zero emissions vehicles, connected autonomous vehicles and high-frequency mass transit, and intelligent transport systems.

Used effectively, these platforms have the potential to transform the Australian transport sector and help achieve some significant progress in reducing emissions, moving people and freight more efficiently, and reducing deaths and serious injuries.

The Academy has undertaken a major 12-month study to look at the Australian transport sector's readiness to adapt, adopt or develop these emerging technologies.

The study is part of a larger project to look at technology readiness across a number of Australian industry sectors, with a view to informing policy decisions that will help prepare our industries and communities for the oncoming wave of technological disruption.

The first phase of the project focused on the urban transport sector, with a horizon out to 2030, on the following bases:

- Transport affects all sectors of the Australian economy and enables or impedes productivity and lifestyle improvements.
- Transport is subject to significant disruption due to emerging technology.
- Transport is heavily influenced by regulatory intervention.

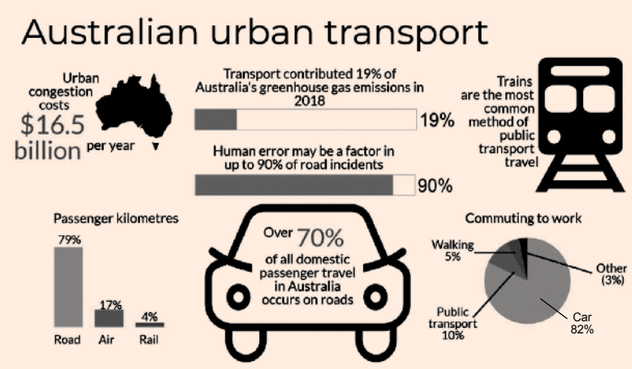
Failure to be prepared will risk in a decline in many aspects of our Australian way of life and society.

Kathryn Fagg
AO FTSE

Kathryn Fagg is Chair of Boral and former Board Member of the Reserve Bank of Australia. She was formerly President of Chief Executive Women and is on the board of Male Champions of Change. She co-chaired the steering committee for the transport report project.

Drew Clarke
AO PSM FTSE

Drew Clarke is Chair of the Australian Energy Market Operator (AEMO), a Director of CSIRO and the nbn, and a former Secretary of the Federal Department of Resources, Energy and Tourism. He was Chief of Staff in the Office of the Prime Minister 2015-2017. He also co-chaired the steering committee for this project.



For example, inadequate planning, population growth and the spread of urban centres could significantly impede the mobility of passengers and freight in both urban and regional areas.

This could increase congestion and vehicle-related emissions; lead to a deterioration in health, safety and security; and negatively impact the cost of living, productivity and the ease of mobility.

In this early phase of the transition, it is critical that Australia identifies what we want for our society, what action government and industry need to take, and how this will translate to a transport sector of the future.

Our report has examined transport technology readiness across five parameters: infrastructure, skills, social, economic and commercial, and policy and regulatory. Our analysis also shows that Australia is performing well on a number of readiness indicators and is well placed to capitalise on the coming technology revolution.

However, with technology developing at a rapid pace and competitor countries investing and acting strategically, Australia needs to ensure we also make smart, strategic decisions to keep pace with the technological frontier.

Australia has more work to do to prepare our infrastructure for low and zero emissions vehicles, high frequency mass transit and intelligent transport systems, and to develop the skills needed for their introduction.

The Academy makes four key recommendations to help industry and government prepare for the new technology platforms. Importantly, we need to implement mechanisms to drive a widespread shift towards low-emission transport options, which should include a national target and associated regulatory mechanism to drive the uptake of low and zero emissions vehicles and their increased use in government and commercial fleets.

The fact that both major parties are seriously looking at the role of low and zero emissions vehicles in our national transport mix is an important development.

Other recommendations focus on flexible and adaptable regulation of new technologies, the need to adapt new technologies to Australian environments, and preparing the workforce for a transition to future transport models.

The recommendations also included a range of questions for the research community, such as "how can we ensure that electric vehicles have a neutral to positive impact on the electricity grid" and "to what extent and in what situations are Australian climatic and topographical conditions so unique as to warrant special technological adaptations?".

The internal combustion engine played a key role in shaping the 20th century. It's important that Australia prepare itself now to take full advantage of the technologies that will shape the 21st.

The Australian Academy of Technology and Engineering is undertaking a major three-year (2018–2020) Australian Research Council Learned Academies Special Projects-funded research project to examine the readiness of different Australian industry sectors to develop, adapt and adopt new and emerging technologies, with a horizon out to 2030.

The transport sector is the first industry sector to be examined by the project. Work is now under way on the health technology sector, with a report set to be published in the first part of 2020.

Shifting Gears – Preparing for a Transport Revolution was published in April 2019.

MORE

IMPACT
The report gained considerable media coverage, including the lead story in *The Advertiser* on 29 April. An opinion piece about the report by Academy President Professor Hugh Bradlow was printed in *The Sydney Morning Herald*. Dr Matt Wenham – our Executive Director, Policy – also discussed it on Sky News.

WATCH
A video accompanying the report was viewed more than 30,000 times on Twitter, and featured in a suite of online News Ltd newspapers on three separate occasions. It can be viewed online: atse.org.au

READ
Read the full report online under Research & policy.

atse.org.au

Submissions from the Academy

In helping develop effective public policy across science, technology and engineering, the Academy draws on the expertise of our Fellows to make submissions to Government and Parliamentary Inquiries and legislative initiatives.

Here are some of our recent submissions.

Response to the COAG Energy Council National Hydrogen Strategy Discussion Paper

If hydrogen is to play a significant long-term role in reducing emissions it should be produced using electrolysis powered by renewable energy resources.

A clear policy and regulatory environment is needed, as well as initial financial incentives from governments.

The Academy recommends continued government support for innovation and the commercialisation of hydrogen-associated technology through grants and support for innovation funds.

Australia needs to adopt a strategic national approach to hydrogen. Without such a framework the hydrogen industry will struggle to become commercially viable, including for export markets.

The Academy recommends that any hydrogen production, use or export in Australia should be accompanied by the introduction of clear, appropriate regulatory frameworks and standards to ensure minimal environmental impact and encourage community acceptance.

Implementation of the National Science and Research Priorities under the National Competitive Grants Program

The Academy acknowledges the importance of setting national priorities for our research and development efforts.

We strongly support efforts to review the Priorities themselves, but recognise that this is the responsibility of the Department of Industry, Innovation and Science and beyond the scope of the ARC's current review.

The Academy looks forward to engaging with the broader review of the Priorities themselves.

Submission to the Review of Tasmania's genetically modified organisms (GMO) Moratorium

Genetic modification and editing technologies hold exceptional promise in their application to the agriculture sector.

Given their rapid development and potential to create extensive economic and environmental benefit, it is important that the Tasmanian agriculture sector is able to access these innovations.

The current GMO moratorium denies the Tasmanian agriculture sector access to existing and emerging technologies that can enhance profitability, increase resilience and provide a safe, reliable and affordable food supply, with increased environmental sustainability.

These emerging technologies simply involve gene editing, not the insertion of whole genes, and are similar to classical mutagenesis.

Other Australian experiences (such as in South Australia) have demonstrated that the maintenance of a GMO-free regulatory environment does not lead to substantial price premiums for GMO-free commodities.

Artificial Intelligence: Australia's Ethics Framework Discussion Paper

The Academy recognises the importance of discussing the ethical issues related to the existing and upcoming AI technologies that have enormous potential to impact every facet of our lives.

The discussion paper developed by CSIRO's Data61: Artificial Intelligence: Australia's Ethics Framework, is an excellent piece of work that explores the issues Australia faces in its path towards progressive development and use of AI.

It needs active participation from stakeholders across government, industry, academia and broader society if we aim to achieve positive outcomes from the rapidly evolving AI technologies.

Australian and New Zealand Standard Research Classification (ANZSRC) Review 2019

The Academy welcomes the opportunity to provide input into the review of the Australian and New Zealand Standard Research Classification (ANZSRC).

The Academy has provided specific responses to a limited number of questions from the discussion paper.

The Academy is aware of a submission from the Australian Council of Engineering Deans that recommends a number of specific changes to Fields of Research (FoR) codes at the four and six digit level and is broadly supportive of these proposals, subject to further consultation with the engineering community.

MORE

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Read our recent submissions online under Research & policy.

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Innovation Metrics Review

At the recommendation of Innovation and Science Australia, the Australian Government is reviewing the innovation metrics it uses to measure and communicate innovation performance and its impacts.

This review is being undertaken by a Taskforce based in the Department of Industry, Innovation and Science, consisting of officers from within the Department and representatives from the Australian Bureau of Statistics, IP Australia, and the Academy.

It is co-chaired by the Chief Scientist Dr Alan Finkel AO FTSE and the Chief Economist Mark Cully. A Steering Committee and an Expert Group of Australian and international experts are assisting the Taskforce.

The Academy was also commissioned to deliver an independent but complementary review. The key benefit of the Academy's inclusion has been the ability to draw on the expertise and networks of its 850+ Fellows, who are leaders in applied science, technology and engineering drawn from industry, academia and government, which provided a different but complementary network of input to that drawn on by the Taskforce.

The Academy has prepared a review of the academic and policy literature on innovation measurement, and has also been advising on:

- a conceptual innovation metric framework
- the data currently available, including gaps
- the metrics for inclusion, including development of new metrics.

The Taskforce consulted with about 100 innovation system organisations and experts, who have identified gaps, issues and opportunities for innovation metrics. It also examined existing metrics and prepared case studies on specific sectors to help test the quality of data sources.

The Academy's literature review will be be published on the Academy's website, and the Taskforce is due to report by the end of 2019. The Taskforce will deliver a report to the government recommending an appropriate data and measurement infrastructure for capturing innovation metrics that is cost-effective and sets out a roadmap for change, and a set of innovation metrics that:

- accurately measure and communicate innovation performance and its impacts
- is useful for government policy and program development
- can measure the impact of government policy initiatives on innovation
- may be compared internationally.

Six technology priorities for federal government

In the run-up to this year's federal election, the Academy identified key technology priorities for an incoming federal government, where immediate action would result in significant benefit to Australia.

The Academy promoted the priorities online and through social media, reaching some 150,000 readers.

The six priorities are:

CLIMATE CHANGE AND SUSTAINABILITY

Energy
Urgently accelerate Australia's transition to low-emission energy generation through:

- ongoing support for the Northern Australia Infrastructure Fund, ARENA, and the Clean Energy Finance Corporation
- investing in national energy storage technologies to improve electricity grid stability and security
- developing economic opportunities through leadership in low emission technologies – examples include adopting a National Hydrogen Strategy through COAG and supplying value-added raw materials for energy storage technologies.

Water
Work with the states and territories to develop a new decadal strategy for national water management, which includes:

- an integrated plan for the water, food, energy and environment sectors
- the use of the Internet of Things to provide real-time, information-based management systems.

Agriculture
Drive change in agricultural practices to reduce greenhouse emissions intensity and increase net carbon sequestration in the land sector including:

- investing in farm-scale climate modelling and seasonal forecasting systems to better guide adaptation responses
- using big data to develop new and modified farming systems to optimise production and resource use across the sector.

HEALTH TECHNOLOGY

- Redesign the healthcare compensation system to enable incentives for healthcare providers to adopt preventative technologies that will improve quality of life and reduce healthcare costs.
- As the proportion of Australia's aged population increases, incentivise uptake of in-home technology and encourage community- and home-based provision of services for the aged.
- Provide incentives for consumers to use the My Health Record system for data collection and sharing, which will enable collection of longitudinal data on healthcare procedure outcomes.

PRIVACY AND DATA SECURITY

- Enact data protection legislation that ensures consumer privacy (like Europe's GDPR) and makes enterprises responsible for the protection of the consumer data they hold (including criminal charges for negligence causing data breaches).
- Enact legislation that ensures that law enforcement agencies have access to the data they are entitled to (with warranted protections) but does not harm Australia's international reputation as a safe location for tech investment.

SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION

- Ensure high-quality, discipline-specific teacher training in STEM subjects.
- Phase out, as soon as feasible, the out-of-field teaching of STEM subjects in years 7 to 10.
- Invest $20 million to enable all schools to have access to the Academy's STELR (Science and Technology Education Leveraging Relevance) schools program, which has been demonstrated to increase the number of students undertaking senior STEM subjects via relevance-based, in-curriculum modules.
- Prepare the workforce of the future for technology disruption by ensuring that school education encompasses both STEM and human disciplines and providing continuing education for those already in the workforce.

TRANSPORT INFRASTRUCTURE

- Adopt standards and policies that support a transition to low-emission vehicles, including support for infrastructure such as charging networks, which should be supplied by low-emission energy sources.
- Prepare regulations and infrastructure to enable Australia to be a leading adopter of safe and convenient transport systems enabled by cooperative intelligent vehicles.

DIVERSITY AND INCLUSION

- Implement a coordinated, national policy to overcome the cultural, institutional and organisational factors that discourage girls and women from studying STEM, and that limit their opportunities to pursue careers in STEM-underpinned organisations.
- Develop a national gender equity framework tailored for small and medium enterprises, which includes a toolkit of proven actions and approaches to advance gender equity without regulatory burden.
- Progressively incentivise gender equity across STEM-underpinned businesses through procurement and grant policies.

Let's be smart about artificial intelligence

Artificial intelligence (AI) is already changing the world around us but to maximise the benefits – and minimise the risks – Australia needs to develop a national framework.

That's the conclusion of a report launched by the Australian Council of Learned Academies (ACOLA), titled *The Effective and Ethical Development of Artificial Intelligence: An Opportunity to Develop Our Wellbeing*.

The report defines AI as "the collection of interrelated technologies, such as natural language processing, speech recognition, computer vision, machine learning and automated reasoning that gives machines the ability to perform tasks and solve problems that would otherwise require human cognition".

Drawn up by a panel of experts including two Fellows of the Australian Academy of Technology and Engineering, the report proposes an independent AI body that could lead five key actions:

- Educational platforms to foster public understanding
- Guidelines for public sector and SME procurement
- Better governance of issues arising from AI
- Designing AI to have positive social impacts
- Investment in the core science of AI

Professor Hugh Bradlow FTSE, Chair of the ACOLA Board and Academy President, said: "By bringing together Australia's leading experts from the sciences, technology and engineering, humanities, arts and social sciences, this ACOLA report comprehensively examines the key issues arising from the development and implementation of AI technologies, and importantly places the wellbeing of society at the centre of any development."

Launching the report, Australia's Chief Scientist and former Academy President Dr Alan Finkel AO FTSE, emphasised that nations had choices.

"This report was commissioned by the National Science and Technology Council to develop an intellectual context for our human society to turn to in deciding what living well in this new era will mean," Dr Finkel said.

"What kind of society do we want to be? That is the crucial question for all Australians, and for governments as our elected representatives." The findings recognise the importance of having a national strategy, a community awareness campaign, safe and accessible digital infrastructure, a responsive regulatory system and a diverse and highly skilled workforce.

New techniques of machine learning are spurring unprecedented developments in AI applications.

Next-generation robotics promise to transform our manufacturing, infrastructure and agriculture sectors; advances in natural language processing are revolutionising the way clinicians interpret the results of diagnostic tests and treat patients; and chatbots and automated assistants are ushering in a new world of communication, analytics and customer service.

Unmanned autonomous vehicles are changing our capacities for defence, security and emergency response; intelligent financial technologies are establishing a more accountable, transparent and risk-aware financial sector; and autonomous vehicles will revolutionise transport.

Professor Toby Walsh, co-chair of the ACOLA expert panel, said: "With careful planning, AI offers great opportunities for Australia, provided we ensure that the use of the technology does not compromise our human values. As a nation, we should look to set the global example for the responsible adoption of AI."

The two Academy Fellows on the expert panel were Distinguished Professor Genevieve Bell FTSE, Director of the 3A Institute at the Australian National University, and a Vice-President and Senior Fellow at Intel, and Professor Iven Mareels FTSE, Lab Director at IBM Research Australia.

ACOLA's report is the fourth in the Horizon Scanning series, each scoping the human implications of fast-evolving technologies in the decade ahead.

The Australian Academy of Technology and Engineering is a member of ACOLA, along with the Australian Academy of the Humanities, the Australian Academy of Science and the Academy of the Social Sciences in Australia.

MORE

READ
Read the full report online.

acola.org

atse.org.au

Celebrating innovation EXCELLENCE

Innovations ranging from speeding up the manufacture of solar cells to the development of synthetic skin, from using science to boost manufacturing jobs to speed breeding wheat, were among the achievements honoured at a gala event in Sydney. On 13 June, researchers and entrepreneurs received the Clunies Ross Awards, the Batterham Medal, the ICM Agrifood Awards and the Ezio Rizzardo Polymer Scholarship, all administered by the Academy. The awards presentation was addressed by Karen Andrews, Minister for Industry, Science and Technology. Full details of the award winners and the event's keynote speech by Distinguished Professor Genevieve Bell FTSE can be found on the Academy website.

Left to right: Professor Lindsay Falvey FTSE; ICM Agrifood awardee Dr Lydia Ong; Batterham Medal awardee Professor Michael Milford; Professor Iven Mareels FTSE; ICM Agrifood awardee Dr Lee Hickey; Clunies Ross Innovation awardees Professor Thorsten Trupke FTSE and Adjunct Associate Professor Robert Bardos; Professor Mark Hoffman FTSE; Mr Richard Wang (representing Professor Tony Weiss AM FTSE); Clunies Ross Entrepreneur of the Year Dr Jane Oppenheim; Ezio Rizzardo Polymer Scholarship awardee Naomi Paxton; Dr Ezio Rizzardo AC FTSE; Mr Johann (Hans) Zank.

The 2019 Clunies Ross Award winners: Professor Thorsten Trupke; Adjunct Associate Professor Robert Bardos; and Dr Jane Oppenheim.

Absent on the night was Clunies Ross Innovation Award winner Professor Anthony Weiss.

Read more about Tony Weiss on page 24.

2019 INNOVATION & EXCELLENCE AWARDS

Clunies Ross Entrepreneur of the Year Award
Dr Jane Oppenheim

Clunies Ross Knowledge Commercialisation Award
Professor Tony Weiss AM FTSE

Clunies Ross Innovation Award
Professor Thorsten Trupke FTSE and Adjunct Associate Professor Robert Bardos

ICM Agrifood
Dr Lee Hickey

Dr Lydia Ong

Batterham Medal
Professor Michael Milford

Ezio Rizzardo Polymer Scholarship
Naomi Paxton

Karen Andrews, Minister for Industry, Science and Technology
Photography by Ewan Maclean

Marine scientist to promote WA ocean research

Tackling the issues affecting the ocean off WA's lengthy coastline is the theme of a year of talks by one of the state's leading researchers.

Professor Jessica Meeuwig, Director of the Centre for Marine Futures at The University of Western Australia, is the Australian Academy of Technology and Engineering's Eminent Speaker for 2019.

The role recognises a Western Australian scientist whose research is having significant economic or environmental impact and who is an outstanding communicator – able to share the excitement and impact of research and development based in WA.

During the year Professor Meeuwig will speak to high school and university students, and the public to promote the importance of science in understanding our environment and how to manage it better.

Public lectures have included one at UWA on 23 July and two days talking to school students in Albany during National Science Week.

Professor Meeuwig said she was excited at the opportunity to promote the science and management of our ocean.

"Western Australia with its enormous coastline is both a great place and an important place to engage in marine research," she said.

"Unfortunately the oceans are largely out of sight and out of mind and I hope that during 2019 I can share with the public some of the important issues that put our oceans at risk now and, in particular, inspire young scientists to help build resilient oceans."

Professor Meeuwig is a highly regarded expert in marine science, marine policy and the translation of science into management outcomes.

As the Foundation Director of the Centre for Marine Futures she has developed a team which focuses on high-impact applied marine research that supports ocean management and links to the commercial and government sectors locally and around the world.

The Chair of the Academy's WA Division, Professor Dongke Zhang, said that in appointing the Eminent Speaker the Academy was recognising both an applied scientist who was making impact and an outstanding communicator. "Professor Meeuwig delivers in both areas," he said.

The Academy began the Eminent Speaker program in 2001 and previous speakers have covered areas as diverse as mineral resources, health, agriculture and meteorology. Professor Meeuwig is the first from the marine sciences area.

Focus on engineering education

The International Council of Academies of Engineering and Technological Sciences (CAETS) held its annual meeting in Stockholm in June.

The Academy was represented by the President, Professor Hugh Bradlow and Dr Matt Wenham, Executive Director, Policy.

The program included bilateral meetings with several sister academies and sessions on communicating with the public, diversity and inclusion, engineering education, achieving the Sustainable Development Goals, and energy.

There was a great deal of discussion about the future of engineering education.

Professor Bradlow said: "One interesting new approach is the US National Academy of Engineering's Grand Challenges Scholars Program, which rethinks the competencies engineers will need in the 21st century.

"In addition to core engineering skills, it includes multidisciplinarity, entrepreneurship, multicultural consciousness and social consciousness.

"So far 122 universities have adopted the Grand Challenge Scholars Program in their degrees, though only one of these is in Australia (ANU)."

Professor Bradlow was elected to the Board of CAETS, of which the Academy was a founding member in 1978.

During the Annual Council Meeting, CAETS elected three new members: New Zealand's Royal Society Te Aparangi, the Nigerian Academy of Engineering and the Academy of Engineering Sciences of Serbia.

CAETS membership now spans 30 countries across six continents.

New award recognises industry collaboration

The *David and Valerie Solomon Award* is a new early-mid career award for a science or technology graduate working in academia/research or industry R&D who demonstrates substantial ability to foster research-industry collaboration and knowledge transfer for the benefit of Australia.

The winner will receive a unique award, a cash prize of $15,000 and 12 months mentoring from a senior entrepreneur/industry Fellow of the Academy, with $5000 travel expenses to enhance this mentoring experience.

The Academy administers the award, which will be presented for the first time at the Academy's Oration and New Fellows Dinner on 29 November 2019 in Melbourne.

The award recognises and incentivises public sector researchers who are engaged with industry and university-engaged industrial researchers who drive collaborative activities to produce real-world impact.

Specifically it will:

- highlight the importance of collaboration between industry and research, and the translation of research for economic, social and environmental benefit
- recognise the achievements of an early-mid career researcher who has worked across the research-industry divide, beyond purely academic research or only experimental development
- bring to the attention of policy-makers the key role applied science, technology and innovation play in the nation's development.

The award honours Professor David Solomon AC FRS FAA FTSE, who is a Foundation Fellow of the Academy and who has been supported in his career by his wife, Valerie (a successful cattle breeder).

The award is made available through a generous donation from David and Valerie Solomon.

MORE

AWARDS
Read more about our awards online under Programs & awards.

atse.org.au

By Kiran Mazumdar-Shaw

Making high-quality healthcare accessible for all

Advances in health technology are bringing hope to millions of patients and their families. People across the globe feel encouraged by the promises these technologies hold to rapidly and disruptively change the way we detect, medicate, alleviate and eradicate diseases.

Artificial intelligence, robotics, the internet of things, machine learning, blockchain and virtual reality are improving the speed, quality and accuracy of health care delivery, leading to better patient experiences.

A better understanding of diseases at the genetic level is allowing the possibilities of personalised medicine to leapfrog into the realm of reality. Genomics is enabling the medical community to predict, diagnose and treat diseases more precisely and personally than ever before.

Increased adoption of electronic medical records, embedded medical devices and the growing use of wearables are also ushering in transformational change.

The convergence of these disruptive technologies is shifting the focus from a system of "sick care", which is reactive and treats patients after they fall ill, to one of "preventative care" that promotes a patient's overall health through prevention, early detection and therapeutic intervention to arrest disease progression.

Today's disruptive health technologies can build a sustainable foundation for affordable, accessible, high-quality health care around the world.

Putting health data to use

For nearly a decade, a huge bank of medical data has been amassed through electronic health records (EHRs) in developed economies.

Apple, the world's largest tech company, is spearheading efforts to make it easier for patients to access their own medical data. Last year the company introduced a feature on the Health app to allow iPhone users to access their medical history directly.

This information spans allergies, immunisation records, laboratory test results, medicines, procedures and vitals directly. At the same time, a growing number of healthcare institutions in the US are supporting health records on smartphones.

However, the potential of EHRs goes far beyond allowing streamlined access to a patient's medical records. Researchers are now trying to extract actionable knowledge from patient-related data in registries, hospital administration databases and payer databases.

In the future, doctors could use algorithms to analyse EHR data from a large patient pool instead of relying on an individual's medical history to decide on a treatment protocol.

Smart use of EHRs can provide a very effective tool for improving healthcare delivery and reducing healthcare disparities. In developing countries like India, cloud-based collection of epidemiological and patient-centric data can enable experts to map the disease burden at the level of the smallest administrative unit.

Comprehensive databases and disease registries will allow better evaluation of the incidence and diversity of diseases, thereby permitting healthcare interventions that are sustainable and more effective.

Data-driven public healthcare interventions

Through its Corporate Social Responsibility (CSR) initiatives, my company Biocon has developed an inclusive, robust and efficient health information system that provides data-driven insight. It facilitates effective preventive and primary healthcare intervention in the rural areas of India for the benefit of communities with poor access to quality healthcare.

The Biocon Foundation, our CSR arm, has developed an integrated eLAJ Smart Clinic platform that captures and securely stores EHRs to ensure that the patient receives a continuing and consistent level of care. The eLAJ model has facilitated on-time treatment, helped reduce out-of-pocket healthcare spending and cut the need for trips to tertiary hospitals for several hundred thousand patients in India.

Mobile phone-based screenings

The Biocon Foundation has implemented a mobile phone-based health (mHealth) platform for early detection, prevention and treatment of oral cancer. The program equips frontline healthcare providers with a mobile phone that has an app to capture data and images of oral abnormalities through population-based and opportunistic screenings.

This Electronic Data Capture (EDC) feature on the mobile phones allows patients in rural areas to connect to specialists for diagnosis of potentially malignant tumours in the mouth. It also creates an opportunity for follow up and referrals. This unique approach is ensuring healthcare reaches remote pockets of India in a cost-effective manner while enabling robust monitoring of high-risk groups.

Increasing access through online stores

As part of its efforts to provide quality healthcare and affordable medicines to the masses, the Indian government is working out a regulatory framework that will allow online pharmacies to operate across the country. Replacing decades-old drug laws with new regulations could also give a much-needed push to e-pharma and related health tech businesses.

In India, nearly 55 million people are pushed into poverty each year because of their inability to afford the cost of treatment. Of these, 38 million fall below the poverty line due to cost of medicines alone.

The Indian government runs the Jan Aushadhi program to supply low-cost, generic medicines to the poor. The impact of this program, which is currently being implemented through physical retail stores, can be amplified manifold through online sales of drugs at affordable rates.

Rising internet penetration and smartphone ownership, along with the ease of ordering medicines through e-commerce platforms, can help drive the growth of the online pharmacies in India. Ernst and Young expects e-pharma players to reach a combined market of $US2.7 billion by 2023, from the current size of $US360 million.

Global e-commerce players are reportedly trying to make inroads into online pharma retailing. There is intense speculation that Amazon, the world's biggest online retailer, is preparing to disrupt the US pharmaceutical industry by bypassing the pharmacy benefit managers that currently negotiate prescription drug costs on behalf of employers and insurers.

If this occurs, the retailer could deal directly with pharmaceutical companies and use its financial muscle to obtain better discounts for drugs it sells on its platform. Amazon's entry is widely expected to improve drug affordability in the US, where the sky-high cost of essential medicines has set off a raging debate on the ethics of pricing in the pharmaceuticals industry.

Health tech start-ups to the fore

In India, technological innovation is ushering in transformational change within healthcare and leading to the emergence of a large number of health tech start-ups.

Some of these health tech companies are using artificial intelligence, machine learning and data analytics to look at faster readouts from medical data, scans, pathology, cell analysis and more. Others like UE Life Sciences, OncoStem Diagnostics, mapmygenome, Strand Life Sciences and Bugworks are leveraging technology to come up with innovative and affordable medical solutions.

UE Lifesciences is addressing the huge unmet medical need of early detection of breast cancer with portable devices like the iBreastExam. This innovative, US FDA-approved handheld device is enabling frontline health workers in India to conduct standardised breast examinations accurately and easily at an average cost of 60 rupees ($1.24) per scan. This is vastly cheaper

Kiran Mazumdar-Shaw
FTSE

Ms Mazumdar-Shaw, a pioneering biotech entrepreneur, is the Chairperson and Managing Director of Biocon, Asia's leading biopharmaceuticals enterprise. She is a well-regarded global influencer and has been named among *TIME* magazine's 100 most influential people in the world.

Kiran is the proud recipient of several national and international honours including India's two highest civilian honours, Padma Shri and Padma Bhushan, and the Othmer Gold Medal from the Chemical Heritage Foundation, USA. She is the first female Foreign Fellow to be elected as a member of the Australian Academy of Technology and Engineering and has been elected a member of the US National Academy of Engineering.

than traditional mammography and other detection techniques involving radiography, which are unaffordable in the Indian context.

OncoStem Diagnostics has developed novel diagnostic tests to predict the risk of cancer recurrence in patients within the first five years of their initial diagnosis, based on the characteristics of their tumour sample.

The knowledge of a patient's risk profile can be critical in tailoring treatment regimens to minimise recurrence. OncoStem uses proteomics-based technology in conjunction with a proprietary machine learning-based algorithm to obtain a CanAssist-breast risk score, which is indicative of the risk of cancer recurrence.

Mapmygenome is a molecular diagnostics and predictive health analytics company offering a full range of tests to identify an individual's genetic predisposition to lifestyle, metabolic, cardiovascular, ocular, skin and hair, orthopaedic, and gender specific conditions. Based on the test results, Mapmygenome counsels people on how to reduce these health risks by modifying their lifestyle.

Strand Life Sciences has developed an innovative yet affordable precision medicine diagnostic technology which uses multi-gene panels to map cancer mutations. This technology enables early detection and aids personalised treatment, leading to much better patient outcomes. The price of these tests is a fraction of what they would cost in Western economies.

Bugworks is a data-driven biotech start-up headquartered in the US that carries out its research and development in Bangalore. It has focused its efforts on leveraging and combining multiple data sets from a vast pool of clinical, genomic, pharmacological and even epidemic data to develop algorithms that can design novel antibiotics to combat wide-ranging infections and even superbugs.

Bugworks has come up with a novel broad-spectrum antibiotic to kill multi-drug resistant Gram-negative bacteria. It has the potential to be used on anything from urinary tract to stomach infections. The drug has proved effective in animal trials and has now reached the clinical trials stage. If successfully commercialised, it will be the first antibiotic for Gram-negative bacteria since 1962.

These start-ups have leveraged transformative new technologies to come up with solutions that can make healthcare available and accessible to millions of patients in India and global markets.

Revolutionising the hunt for new drugs

Today's data science is enabling the pharmaceutical industry to throw off the shackles of the conventional one-drug-one-target-one-disease model of healthcare innovation, which is inefficient, expensive and time-consuming.

In fact, data science is ushering in the next wave of drug innovation, by promising to transform every stage of the new drug discovery and development process.

Bioinformatics, a specialised branch of data science, is helping incorporate knowledge derived from genomics, proteomics and other biological disciplines into drug discovery and design to come up with revolutionary ideas for new molecules.

Advances in data science are leading to accurate predictions of interactions between novel drugs and their targets, helping reduce the cost of drug discovery by several orders of magnitude.

Data analytics is helping predict clinical outcomes, inform clinical trial designs, support evidence of effectiveness, optimise dosing, predict product safety and evaluate potential adverse event mechanisms.

Data analytics is also helping researchers repurpose "old" drugs to treat both common and rare diseases. For example, in 2017 a team from the University of California, San Francisco made an incredible discovery thanks to computational method to systematically probe massive amounts of open-access data to discover new ways to use drugs.

It demonstrated that a US FDA-approved drug called pyrvinium pamoate, which is used to treat pinworms, could shrink hepatocellular carcinoma, a type of liver cancer, in mice. This cancer, which is associated with underlying liver disease and cirrhosis, is the second-largest cause of cancer deaths around the world yet it has no effective treatment.

Advanced data-driven decision-making promises to give pharma innovators the opportunity to drive down the cost of drug development so that they can offer patients new therapies that are affordable and thus accessible.

A new promise

In terms of potential to change the world with technology, we're living in the best and most exciting of times. We are witnessing the birth of technologies that will alter the way we live, work, and relate to one another.

The scale, scope and complexity of the transformation will be unlike anything humankind has experienced before. Next-generation health technologies promise a world where every person on this planet will have access to good quality of health care – and that's a world worth fighting for.

3D vision of cancer research

A 3D bioprinter that can print replicas of tumours has won the prestigious 2019 Good Design Award of the Year. The printer was co-designed by two leading UNSW medical and science academics, one of them an Academy Fellow.

Above: UNSW Professor Maria Kavallaris and Dr Lakmali Atapattu with the 3D bioprinter that has won the prestigious 2019 Good Design Award of the Year.

The prize was awarded to Inventia Life Science, a biomedical company that worked in collaboration with UNSW Sydney's Australian Centre for Nanomedicine co-directors, Professor Justin Gooding FTSE and Professor Maria Kavallaris, to develop printer inks and cell biology components.

The 3D printer gives biomedical researchers and tissue engineers a fast way to create 3D cell structures, proteins and tumour models.

"Cancer research is dominated – and in many ways limited – by two-dimensional in vitro cell culture techniques," said Scientia Professor Gooding from UNSW's School of Chemistry.

"But three-dimensional printing of cell cultures is much more realistic, revealing important features such as the resistance of cells and tumours to treatment.

"This bioprinter allows cancer researchers to rapidly produce 3D cultures and build more complex in vitro cancer models than ever before."

Funding for the printer was secured in 2013 through an ARC linkage grant and the first models were built in 2016. The printer went through a thorough rigorous design and testing period from both the engineering and cell biology perspective.

"The difference between this printer and other 3D bioprinting technology is now we have precise control of the types of cells and the environment they grow in – allowing us to create 3D cell models and print artificial tumours," said Professor Gooding.

"The type of ink developed for the printer means cell biologists for the first time have the capability to precisely deposit multiple cell types in a single 3D cell culture.

"They will also be able to control the proteins that binds cells together. This is critical because it allows cancer researchers to better understand the variables in cancer formation."

Professor Maria Kavallaris, Head of the Tumour Biology and Targeting Program at the Children's Cancer Institute, developed the cell biology behind the printer, analysed the viabilities of cells, how quickly they divide and developed accurate tumour like environments.

"The printer is revolutionary in its ability to control the volatile cancer environment that we are working with and reproduce different types of cancers," she said.

"It gives us enormous opportunities to model real cancer cells. Different tumours survive in different microenvironments – a person doesn't just have a tumour, but many other cells such as immune cells and accessory cells – living around that tumour that influence that environment and response to therapy."

Professor Kavallaris said one of the main applications at this stage would be for the printer to recreate and mimic solid tumours – and it would also have the potential to even recreate blood cell cancers such as leukemia.

"For the first time we've got a machine that can model cancer disease, model therapeutic responses and test new drugs. We can analyse the ways drugs are impacting the survival of the tumour and potentially feed that back to clinicians – even test drugs they may not have thought about giving and reduce exposing patients to undue toxicity.

"This is an amazing starting point for researchers to use our imaginations and develop cell models to study disease," said Professor Kavallaris.

The core technology is also being used to explore the longer-term potential to impact areas like the treatment of burns and wounds through clinical bedside-bioprinting.

The Australian Centre for NanoMedicine combines medicine, science and engineering to deliver therapeutic solutions to research problems in medicine.

"For the first time we've got a machine that can model cancer disease, model therapeutic responses and test new drugs."

By Erica Smyth

Diabetes progress – it's finger-pricking good

From blunt needles to Bluetooth glucose detection, Dr Erica Smyth has experienced the evolution of health technology the hard way.

"You have Type 1 diabetes." I heard this for the first time 45 years ago, and what a shock.

I was five weeks into my first job as a geology graduate at Newman in the Pilbara in 1974, and I hadn't wanted to admit that I was not my usual self. Yes, I had experienced all the classic symptoms – I was tired all the time, I was losing weight at a very rapid pace, I had to wee 20 or more times a day and my eyesight had deteriorated to a point where I couldn't drive.

But my earlier visit to a doctor about my failing eyesight had been short and no real questions were asked. "Just see an ophthalmologist when you're next in Perth." So I just ignored the symptoms. I refused to believe there was anything else wrong with me: it was just the heat and a new job. Not long after that, I was comatose.

By the time the Royal Flying Doctor Service got me to Perth I was in a very bad way. During the next five weeks I was told about all the terrible complications that would probably happen to me if I did not control my blood glucose. The (as it turned out, temporary refractive index-related) failure of my eyesight was the one thing that scared the living daylights out of me. I learned that the real long-term risk was that retinopathy – the bleeding of vessels in the retina – is a major cause of blindness for diabetics.

Ever since, I have been focused on getting my blood glucose under control. This meant I had to learn about this chronic disease and take personal control. It's been an enormous learning curve, and I've been a user of every advancing medical technology. From the 1970s to the 1990s this wasn't easy, as researchers were still debating how the whole hormone system interacts.

Maintaining the balance

First, some background on diabetes. Type 1 (or "juvenile") and type 2 diabetes have different root causes, but the risk of severe complications is the same. It's all about managing blood glucose.

When non-diabetic people digest food, carbohydrates turn into glucose, then enter the blood stream. High glucose in the blood triggers the beta cells in the pancreas to release insulin. Insulin then gives cells access to the glucose so they can convert it to energy.

With the help of other hormones in the pancreas and liver, and the cleaning action of the kidneys, a blood glucose balance is maintained in a range of around 5.5 mmol/l.

My auto-immune system attacked my pancreatic beta cells, so I don't produce any insulin and need to artificially add it. (Type 2 diabetics, on the other hand, have insulin resistance: their cells don't respond effectively to insulin's role in absorbing glucose.)

The big challenge is to balance my food and exercise with the injected insulin. Different types and intensities of exercise combine with the pre-injected insulin to have different short and longer-term effects on my blood glucose.

I need to keep making adjustments to stop my blood glucose getting too high or too low. My cells need a bit of insulin in my system all the time to help the transfer of glucose (even when I sleep), and the impact of exercise can last for hours after the exercise is finished.

The bad old days

In the "olden days" I used fast-acting injections at meal times and slower release insulin at night, but I didn't understand all the chemistry. I had only one way of knowing about my blood glucose level: if it was too high, my kidneys would strip it out.

To see if excess glucose was leaving my body, I had to wee in a test tube and use a small dipstick to compare colours. This wasn't very accurate or convenient, but it was the only method I had. The only way I knew I had low blood glucose was if I started to shake, perspire or get gruff and confused.

My insulin came from pancreases of slaughtered beef and had to be stored in the fridge in a very close temperature range. The glass syringes I used needed to be boiled every week and stored in methylated spirits. The needles themselves were very big and quickly became blunt.

But this "fly by the seat of my pants" world did not last too long, as diabetes was benefiting from excellent international research and major advances in technology. I was willing to try any new advances as soon as they became available.

Leaps and bounds

The first big change was disposable syringes with small needles. This meant the injections – which by then were four times a day – were not nearly as traumatic or painful.

Next came portable blood glucose meters. Initially, these were quite heavy and cumbersome and not easy to use in a crowded place. But they were a step forward from weeing in the test tube. Of course, each new test required pricking one of my fingers. I've had more than 15,000 finger pricks over my lifetime.

The next step was a big one – cloned human insulin (I say thanks to "Dolly the sheep"). This agreed with my biology much better than insulin sourced from beef. It was also more stable from the temperature point of view, making it easier for me to travel.

At about the same time the insulin pen arrived. This is a more discrete method of carrying around an insulin supply and had even smaller needles.

But sometimes I still got it very wrong. Low blood glucose can leave me confused, uncoordinated and often aggressively saying "No" to whatever's going on. This can happen very quickly. At times it scared my work colleagues when I could not string two words together or I had small fits. My handbag store of high-glucose jelly babies often saved me – and still does.

Almost 15 years ago I received an insulin pump, and my life really did start to change for the better. No more four injections a day – only one every three days to change the infusion site. Now I get a little bit of insulin every three minutes, and dial up an extra dose when I eat.

The insulin pump is with me 24/7 (except in the shower) and is a good, though not perfect, solution. My insulin still needs adjustment when I do something outside the normal routine that my pre-programming is designed for.

A smarter way

The latest technology I have taken up – just two years ago – is a method to measure my glucose levels whenever I want by just waving a Bluetooth detector over a patch on my arm. I change the patch every two weeks, and can get an interstitial fluid glucose reading whenever I want. This reading is a bit behind my blood glucose, but it's pretty close.

I have gone from averaging maybe five finger prick tests a day with the old meter to 17 painless tests a day with the new one. Because I can tell whether my blood glucose levels are going up or down, I now have better knowledge of what's going on in my body. I always test my levels before I get into a car to drive.

None of this technology is cheap. Pumps are now about $8000 every four years, and some

"The next step was a big one – cloned human insulin (I say thanks to 'Dolly the sheep')."

Dr Erica Smyth
AC FAICD FTSE

Erica Smyth is a professional Company Director with more than 20 years' experience on minerals, energy, science and education/research boards. She is immediate past Chair, Diabetes Research Foundation WA, Chair of NOPSEMA and a Non-Executive Director of Lions Eye Institute, MinEx CRC, ICRAR and National Energy Resources Australia.

Images: Dr Erica Smyth with staff of the Royal Flying Doctor Service at Jandakot airport, WA. Photographer: Frances Andrijich.

health insurers will not fund them unless there is an "urgent medical need". The consumables for pumps, blood testing meters and insulin are partially subsidised on the National Diabetes Supply Scheme or the Pharmaceutical Benefits Scheme, but my pump and Bluetooth patches are not. The patches are $200 per month, which means they are out of the financial reach of many people.

These costs are covered by the Government for children under 18, but once you are an adult you are pretty much on your own.

Looking ahead

So it might sound like my diabetes is now easy to control, but it can still spring surprises on me and the people around me. The key is for me to be open by explaining my disease and what to do if I "go a bit strange".

Diabetes is like standing on an unstable four-legged stool. The legs of insulin, exercise and food are the normal focus for the balance but the fourth leg – my emotional state – can bring the whole stool tumbling down. Overlying all this is my general health, as infections or even getting the flu can also significantly change the balance.

Looking forward, the next pharma advance I would like to see is a faster acting insulin. After 45 years I don't absorb my insulin as quickly as I used to and there is a significant time delay between delivery and effectiveness. I am testing a new insulin now and have great hope for it.

The next technology advance for me will probably be an automated combined intelligent pump and glucose meter. But first, I need to be sure about the faster acting insulin. The details from the pilot trials of these new automated pumps are still being published, and I am not willing to have one installed – yet. For now, I am sticking with my brain as the main controller.

I have no retinopathy in my eyes, my kidneys still work, I heal well and I can feel the tips of my fingers and toes. So I say thanks to all the wonderful researchers, educators, pharma companies, technologists and engineers that have made my extended life span liveable and enjoyable.

Dr Erica Smyth was Deputy Chair of the Royal Flying Doctor Service 2010-2019 and Non-Executive Director of the RFDS National Board 2016-2018. She has made "invaluable contributions" to the organisation which once saved her life.

By Benjamin Hickey

Body clock linked to healthy ticker

While many innovations improve our health, our tech-heavy lifestyles can have unintended side effects.

Academy Fellow Professor Paul Zimmet AO FTSE has suggested that modern disruption of our "body clocks" may increase rates of heart disease, diabetes and depression.

He calls this "Circadian Syndrome" and is spearheading a joint initiative from Monash University, Tel Aviv University and Imperial College, London to have the term recognised internationally.

"There's a clear clinical situation in about 30 to 40 per cent of adult Australians where a number of important cardiovascular disease risk factors come together," Professor Zimmet said. "And people who have these risk factors are more likely to get co-morbidities such as sleep apnoea, depression, fatty liver disease and cognitive disability."

In a paper published in the Journal of Internal Medicine, Professor Zimmet proposed that disturbed circadian rhythms may provide a connection between these health issues. "We suggest environmental signals associated with the modern western lifestyle can lead to circadian disturbances which result in a cardio-metabolic risk factor cluster."

The circadian rhythm centre ("body clock") is in the brain and controls all metabolic functions in the body. Every major organ and cell in the body has its own peripheral "clock" synchronised by this centre.

Light pollution at night, low light levels during daytime, controlled ambient temperature, overeating, societal and workplace stresses, sedentary behaviour, shift work and jet lag could all disrupt these clocks contribute to the syndrome. Australia's 24/7 economy means more of us are working at night than ever, and the rise of social media is impacting sleep patterns.

"In short, the evidence suggests that we humans are trying to fighting against nature," Professor Zimmet said. "But our circadian rhythms, developed over millions of years, will not allow us to do that so easily. The resulting increased risk of chronic diseases costs our societies billions."

Professor Zimmet, who is Honorary President of the International Diabetes Federation, first noticed the clinical effects of circadian rhythms while working in London in the early 1970s, testing glucose tolerance in patients. He and colleagues found that if a glucose tolerance test was performed in the morning, as is the common and recommended practice, it may be normal. However, if performed in the afternoon, it may be diabetic.

He said that while the idea of a Circadian Syndrome was likely to be controversial and challenging for his medical colleagues, it was important to encourage clinicians and researchers to look at the whole picture of cardiometabolic risk.

"I don't think that my explanation explains all the cases but it must play a very significant role," he said. "It's quite clear that shift workers who have deranged time clocks are much more likely to get diabetes and high blood pressure."

HEALTH TECHNOLOGY

Interview by David Glanz

Skin in the game

Professor Tony Weiss
AM FTSE

Tony Weiss is a Professor of Biochemistry and Molecular Biotechnology at the University of Sydney and the winner of the 2019 Clunies Ross Knowledge Commercialisation Award. He was elected a Fellow of the Academy in 2014.

Imagine you've been hit by a car. You're bleeding, you've got a punctured lung … and the paramedics get out a spray can to fix you. Spray-on surgical glue: it sounds more like something out of the Terminator movies than real life.

But that's just what Academy Fellow Professor Tony Weiss has been working on. His incredible work earned him the 2019 Clunies Ross Knowledge Commercialisation Award, adding to a long list of honours. We spoke to Tony about his work.

Where did the idea of surgical glue come from, and how does it work?

It's one of these classic stories: a long process for an "overnight success".

Remarkably, we realised we could replicate components found in the human body. We could literally make copies of the natural building blocks in a range of different tissues and use them to rapidly repair wounds.

Tropoelastin is a protein found in human skin. It's like a tiny Lego piece – just over a billionth of a metre in size – which assembles with other pieces to build up tissue.

In collaboration with international colleagues (then at Harvard University, now at the University of California, Los Angeles) we modified tropoelastin and put it into a solution. Imagine a clear liquid full of all those little Lego pieces in a spray-on container or a syringe without the needle tip.

All we need to do is squirt the liquid onto a wound site and shine light on it. In less than 60 seconds, the building blocks magically assemble and the whole region is sealed over with an elastic seal that promotes healing.

Just with normal light?

We started using UV light. But extraordinarily, now even visible light will do the job.

And this glue – I think you also refer to it in different places as synthetic skin or an elastic protein – does it bend the way that human skin bends?

Exactly, because it's made of the same building blocks as the elastic tissue in human skin. It works most effectively deep inside the body where there are wet wounds. You use a super glue to seal up skin, but that doesn't really work for wet wounds.

We tailored this for dramatic wounds that need to be treated rapidly, like a damaged blood vessel or a punctured lung. It provides a very tight seal and looks just like the natural material found in those tissues.

If I had a punctured lung and stitches were put in, I could breathe but it would be painful. With your invention, would I both be able to breathe and have some pain relief?

I can't comment on the pain part because it depends upon where and how the actual lesions occurred. The idea is really to do two things: close the wound quicker and help it heal faster.

We've published about the first goal in a fine journal, Science Translational Medicine, again in collaboration with international colleagues. We can now generate a seal on the lung that works better than suturing. Stitches aren't as effective as squirting on our material and shining a light.

But our second aim is just as important. We've demonstrated that these and related materials can accelerate the healing of wounds over time.

Does this have an application for burns?

It does. In more minor burns, there is damage to the upper layers of skin. As burns increase in severity, they go deeper and deeper within tissue.

Now, there are two steps involved in treating more substantial burns. First, to save the patient's life, you surgically cut away the substantially damaged region so something else can hopefully grow in its place. Then, months or even years later, you do follow-up surgeries that provide incremental benefits.

We're seeking to treat burns at both of those stages. We want to save people's lives by shortening how long it takes for the initial type of wound damage to heal.

But giving people high-quality skin repair is also important. Wouldn't it be great to trim dozens of operations down to ideally just two procedures? We've done just that – not with the glue, but with a different material.

What was the light globe moment that made you have this insight?

I was doing foundational research into those little Lego blocks that assemble elastic tissue. What, I wondered, if we taught bacteria to make precise replicas of the protein, like a copy machine?

The proteins would be identical to those in a newborn baby's skin and could be uses to assemble fibres, sheets and tubes of tissue. It would also be ethical because you wouldn't

need to go to animals or humans. If we had this building material, we could create a whole range of extraordinary things. I just sat up one day and realised that all this was a possibility and that no one around the world knew how to do it.

Around the same time this little light bulb appeared above my head, I was very fortunate to be approached by a remarkable PhD student, Stephen Martin, who had just finished at Oxford University and wanted to join my lab.

He and I stood by a white board in Sydney and I scribbled what I wanted to do: find ways to construct these fibres, sheets and tubes to repair a whole range of tissues. It was a light bulb moment followed by a white board moment.

Steve said yeah, he'd love to do it. He'd already been funded anyhow, so maybe I sort of had him entrapped. But to his credit he agreed, and we then set about constructing this rather grand project. And it succeeded.

It was the equivalent of a biochemist climbing Mt Everest. We got to the top and planted our flag (an Aussie flag, but there's a Union Jack somewhere in that as well.) Since, then the lab has produced hundreds of internationally recognised publications in this area.

I should also mention the patents, which have driven the commercialisation. I now have 95 awarded patents in 18 patent families, which I think is fairly unheard of within Australia.

It's been a tremendous journey from that eureka moment, where thankfully I didn't quite do the Archimedes thing and leap up the way he did. But I certainly enjoyed my discovery just as much, and now see it coming full circle and improving people's quality of life.

That's tremendous. What's the sort of time scale we're looking at between now and this being actually available for medical practitioners?

We're taking this Aussie technology from the lab, through the commercial process, to ambulances and hospital shelves. I'm pleased to say we're making dramatic progress and will hopefully help a lot of people.

We expect the earliest products, which are moving through now, to be available in about a year. They're designed to treat small wounds and small lesions on skin. After that, there is a slightly slower process involving the larger and larger wounds, because the trials take longer.

But even with the large wounds, we're moving quickly. We have a path that we hope will ensure that the materials are available to help people in three to five years.

The company you founded, Elastagen, has been bought by Allergan, one of the 20 largest biopharmaceutical companies in the world. How have you found marrying pure science with its commercialisation? Are there compromises you've had to make or has it been smooth sailing?

It's never smooth sailing to do anything, particularly when there are always naysayers. You just need to keep focused on what you believe is worthwhile.

I strongly believe university researchers like me have a social contract of sorts. We receive funding from the Australian taxpayers so it's important to give back to the community. It's great to receive grants to pursue our research and our dreams, but using these discoveries to help save, and improve the quality of, people's lives is deeply satisfying.

It turns out that in our society, one of the best ways to do that is to establish a company to carry the technology forward. That's why I founded Elastagen in 2008 – to provide real help to a lot people.

We sold it in 2018, so it was a 10-year journey motivated by the belief that this how to help the broad community. Of course, many great hands were involved in the story, not just me as the founder.

I find it easy to reconcile the two approaches. For example, I'm delighted to be a recognised academic and I'm thrilled about the Clunies Ross Award.

I love pursuing research for knowledge' sake and I love using research to improve the quality of life of those around us. Interacting with the commercial world to get a better outcome for all concerned is a wonderful scenario – as long as I can keep my day job as a professor at a fine university.

The fundamental research came out of your lab in Sydney and Allergans' involvement means that people worldwide will be able to benefit from your research, once it's approved for human use. Where will the commercial benefit flow to?

The sale of Elastagen to Allergan has provided an incredible boost for a technology that's gone from a twinkle in the eye to something involving many hundreds of millions of dollars. It's one of the most financially successful trade sales in the healthcare space in Australian history. The nice thing is that these dollars have flowed back into this country, primarily through superannuation funds that backed the venture capital that made Elastagen a success. We'll also see all these lovely products that can help save lives.

I want to say thank you to the Academy for the generous process of giving me this wonderful award, which I'm absolutely thrilled about. ▶

Image on previous page: Tony Weiss in the lab. Image courtesy of the University of Sydney.

"I strongly believe university researchers like me have a social contract of sorts. We receive funding from the Australian taxpayers so it's important to give back to the community."

MORE

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This interview is an abridged version of a podcast, one of a growing library that can be found online. All podcasts feature interviews with Fellows about their work, ranging from the Australian Space Agency to urban design and the need for more women in STEM.

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By Greg Tegart and Anne Livingstone

Improving the lives of Australians with dementia

Australia's population is ageing. As in many other countries, a combination of improved health care, shifting birth rates and declining death rates are increasing the number and proportion of older people in our society.

In 2017, 3.8 million Australians were aged 65 and over – 15 per cent of the total population. By 2057, that number is projected to grow to 8.8 million, or 22 per cent of the population. The ageing of our society presents a number of challenges, including mounting pressure on national budgets and health and social services.

But there are also growing opportunities for ageing people to live a high quality of life independent from institutionalised care like nursing homes and hospitals. Digital technologies and data processing provide new tools for people to effectively manage their long-term care. Innovations in assistive technologies for security, safety, diagnosis, treatment and mobility are helping develop this concept of "ageing in place".

A growing challenge

However, there is a significant cohort of older people who need special consideration: people with dementia. The number of dementia cases worldwide has increased at a disproportionate rate and the World Health Organization has stated that "dementia represents one of the greatest societal challenges for the 21st century".

In 2019 there are an estimated 450,000 Australians living with dementia. This number is projected to increase to about 600,000 by 2028 and 1.1 million by 2058. More starkly, dementia is the second leading cause of total death, the leading cause of women's death and the primary cause of disability for people aged 65 and over. More than half the people in residential aged care facilities have some form of dementia.

Dementia is a special case for assistive technologies because it isn't a specific disease. Rather, it's a syndrome that refers to groups of characteristic symptoms related to impairment of brain functions. While various types of dementia have been identified – Alzheimer's disease is the most common, at about 70 per cent of cases – the symptoms and patterns of deterioration are highly individualised.

Since there is currently no cure, the primary care goal is to maintain or even increase the quality of life for people with dementia. Carers need to identify changes and alter patterns of care accordingly. Technologies can make this easier by assisting in prevention, engagement, compensation, care support, enhancement and satisfaction.

Boosting quality of life

However, we are only just beginning to interpret how older adults perceive and interact with assistive technologies. This is particularly true for people with dementia, who may experience agitation in reaction to particular types of care.

Some of the assistive technologies currently applied in home environments are:

- communication technologies such as real-time alarms, telecare, telemedicine and social support networking
- robotics for cleaning, assistance with eating and companionship
- home automation such as motion detection, safety monitoring and environment control.

Additionally, micro- and personal devices increasingly allow care to continue outside of the home. They include:

- smart phones with suitable apps
- wearable and flexible medical diagnostic instruments
- tracking sensors for navigation and location.

Wandering can provide people affected by dementia with important physical activity and allow them to express emotions they may find difficult to communicate. But it's important to ensure that safety issues are covered. Forms of dementia, especially Alzheimer's, are associated with a severe decline in navigational skills. Technology can help address these needs.

Participation in green and gardening activities can also improve wellbeing and health for people with dementia. Virtual reality is being used to redesign homes, gardens and surrounding environments based on psychological and neuroscientific research.

There are now well-established principles for renovating and constructing new houses that support people with dementia to live in calm, coherent, orientating and gently stimulating environments.

Tech that cares

It's especially important to minimise the amount of interaction required for everyday living because declines in procedural memory reduce people's capabilities and place more demands on carers and family. Robots can be beneficial in this regard – not to replace or compete with humans but to provide assistance and augment available care.

Together with Denmark, Germany and the United States, Australia has been an early adopter of robotic technologies such as telepresence robots, service robots and companion robots.

Carers and family can drive telepresence robots remotely to gain visual access for monitoring and to help with caring tasks like medication control. People with early stage dementia can use simpler service robots to assist with cleaning and routine activities.

There is evidence of a strong connection between companionship and caregiving. Older adults involved in testing robotic technologies can become emotionally attached to the robots performing tasks beyond their own capabilities.

This is particularly evident with companion robots that take the form of animals, such as PARO – a baby harp seal robot developed in Japan. PARO has sensors that change behaviour depending on the environment, so it is active in the day and "asleep" at night.

We need to develop all of these technologies further, particularly through co-design and co-evaluation with patients, formal and informal carers, and clinicians. But in many cases, isolated technologies will have limited impact. We can multiply their benefits by combining them.

There is a need for a common system concept to seamlessly integrate devices and service functions through secure networks. This must be linked to a better understanding of the outcomes of care interactions, based on the processing of accumulated end-user data. The lack of a standardised language and evaluation criteria to define and describe the technologies and their outcomes is another major challenge.

Empowering the vulnerable

Two important issues arise from developing and using assistive technologies in the treatment of dementia.

The first is alarm fatigue. This commonly occurs across the different uses of technologies that warn of changes in behaviour. Carers can be so bombarded by alarm signals from various sensors that they become desensitised. This results in missed alarms and delayed response times. A solution is to use data processing to intelligently filter signals and guide the carer's response.

Professor Greg Tegart
AM FTSE FIE Aust

Greg Tegart is a retired materials technologist who has had a long career in academia, industry and government. He is currently working on the application of assistive technologies for the aged and disabled. Professor Tegart was elected a Fellow in 1976 and is Deputy Chair of the Academy's Health Technology Forum. He was ACT Senior Australian of the Year in 2016.

Anne Livingstone

Anne Livingstone is Projects and Research Director at Global Community Resourcing and has a particular interest in the application of digital technologies in community-based care and consumer-directed support. She is currently the Australian representative at ISO/TC 314 Working Group 02 Dementia – Inclusive Communities.

Image from previous page: Elfriede Knigge (86) pets the stuffed robot seal 'Ole' at a nursing home for people with dementia in Bremen, Germany. The robot is used in ergotherapy with patients suffering from dementia. It responds to touch and turns its head towards a voice talking to it.

Image above: Patients in a Japanese nursing home for dementia patients interacting with a robot seal.

MORE

HONOUR
Read more about Greg Tegart on page 59.

The second issue is the ethical and legal aspects of developing and using assistive technologies. Dementia challenges traditional principles that guide research, particularly the need to obtain participants' consent. Such consent depends on individuals having decisional capacity.

In the past, the rights of people with dementia have been overridden. Restrictive practices such as physical restraints and medication have been used to exclude older people from making decisions.

A solution is to use the United Nations Convention for the Rights of Persons with Disabilities to develop a robust, rights-focused regulatory framework for the use of assistive technologies in dementia care.

Drawing all these threads together is the concept of dementia-friendly communities. Many of the difficulties faced by people with dementia relate to stigma and lack of awareness about dementia in society. In a dementia-friendly community:

- people are aware of and understand dementia
- people with dementia continue to be active participants in their own lives
- health staff are educated about dementia and treat such people with respect and empathy
- businesses provide accessible services to people with dementia and opportunities for their employment
- the physical environment enables people with dementia to move about safely.

The concept has been implemented in Europe, where many countries have now designated dementia-friendly communities. These build on the Age-Friendly Cities movement promoted by the World Health Organization.

As an example, in 2015 the British Standards Institute published a document titled "The code of practice for recognition of dementia-friendly communities in England". A critical point is that people with dementia and their carers are an integral part of the process.

In Australia, the Federal Government has funded a program administered by Dementia Australia to develop dementia-friendly communities. There are about 160 such communities across all states in Australia. The concept is easier to implement in smaller cities and towns. Three excellent examples are Beechworth, Kiama and Waverton.

Standards for living

It has become clear that we need a national commitment to innovation to drive changes in our approach to ageing and the delivery of aged care, particularly for people with dementia. The work of the British Standards Institute shows that standards could provide a way of setting out the principles for delivering the new products, services and solutions needed to make such changes.

In December 2017 the International Organisation of Standardization (ISO) established a new technical committee (ISO/TC 314 Ageing societies) to address these issues. An Australian national working group (MB-009-11 Ageing workforce) was established to enable our participation. The ISO Technical Committee agreed on three priority areas:

- inclusive ageing workforce
- dementia-inclusive communities
- carer-inclusive and accommodating organisations.

Three international ISO meetings have been held in the UK, China and Germany. They've aimed to gain consensus on the parameters for new standards in each of the priority areas. This work involves 19 countries as participating members and 17 countries as observers.

Specifically, the Dementia-Inclusive Community Committee has explored best-practice case studies from around the world and identified the common themes. It's working to develop the framework for an international standard to be released in 2020.

Australia is moving to set up its own national technical committee. At a Leadership Roundtable in Sydney in December 2018 it was emphasised that Australia particularly needs to:

- support activity on younger onset dementia
- involve culturally and ethnically diverse people and groups
- ensure that activities are driven "by the community for the community".

When it comes to improving their quality of life, the future for people with dementia in Australia looks bright.

By Academy Fellows

Why I mentor

Four Academy Fellows and health tech sector champions explain why they mentor for the Academy's industry mentoring program IMNIS.

"These are important people – why would they mentor me?" That's the question PhD students joining the Industry Mentoring Network in STEM (IMNIS) program ask time and time again.

Tony Radford, **Leonie Walsh**, **Sue MacLeman**, and **Paul Wood** are Academy Fellows and leading lights in health tech. Along with more than 300 other industry leaders in a range of sectors across Australia, they're passionate IMNIS mentors.

So why do they do it? We sat down with Tony, Leonie, Sue and Paul and asked them what they get from giving back.

Why do you mentor?
What have you got out of it?

Tony I have puzzled over this: giving free consultation and advice is not much of a business model! Yet there's an inherent satisfaction in helping people at the start of their careers. I can recognise the uncertainties I faced at that time of life and act as a sounding board and guide. When a mentee thanks you for changing their life, a few hours of thought and understanding seems a very small price.

Leonie Each mentoring experience has been different for me. But each time I've felt the satisfaction of helping someone unravel a personal challenge, diversify their skill base, discover an opportunity or take a step closer to reaching their full potential. It's a way to share knowledge you've gained through lived experience that can't be picked up in the lecture hall.

Sue Throughout my career, I've been lucky to have strong mentors who were willing to share their time and expertise. You get to a point where you want to give back. And while the process is useful for mentees, it's equally useful for the mentors. With each mentee I learn something new and get to view the world through the lens of someone else's experience.

Paul The standout for me is seeing mentees get into industry and start to reach their potential. IMNIS defines "industry" pretty widely – it includes government, NGOs, and basically anything that isn't academia. One of my mentees is in the US with Genotech and another is in Canberra with the Department of Innovation. PhD students are easy to help, they're newcomers when it comes to understanding industry. I know mentoring really works and that I can make a difference.

What insights has mentoring given you into the future workforce – their values, needs and drives?

Paul Australia produces about 10,000 PhDs a year, with approximately 6000 in STEM fields. The scary thing is that less than 10 per cent of people doing PhDs end up in long-term academic roles, so nine out of 10 need to seriously think about what they're going to do.

Sue The workforce is changing and I'm not sure we're changing our curriculums fast enough to adapt. As we separate intelligence from consciousness with the rise of new technologies, we're going to need to hone our critical thinking and enterprise skills. We're also going to see a rise in micro-credentialing and continuous learning.

Tony I don't think much has changed in the attitudes of those looking at a career in STEM. There's the same hope for a successful career, happy life and chance to make a difference. But social media adds a conscious desire to be perceived well, which is a pressure people don't need. It's hard enough to work out your life by yourself without the world looking over your shoulder.

Leonie My mentees have come from a mix of demographics and faced different sets of challenges. Young scientists are starting to get the message about the value of industry careers, but often don't know how to transition from

IMNIS
INDUSTRY MENTORING NETWORK IN **STEM**

IMNIS

The Industry Mentoring Network in STEM (IMNIS) is an award-winning industry-led initiative of the Australian Academy of Technology and Engineering. IMNIS connects motivated PhD students (mentees) in science, technology, engineering and mathematics (STEM) with outstanding high level industry leaders (mentors) in a one year industry mentoring program.

IMNIS provides Australia's future STEM leaders the opportunity to engage with industry, extend their professional network, strengthen their implicit skills and get advice from an influential industry mentor. Student mentees learn what it takes to succeed in any part of the STEM ecosystem, gain a better understanding of how industry works and learn about career opportunities in other professional sectors.

imnis.org.au

academia. Mature-age mentees might be making a career change to work more flexibly or make a societal impact, so need different approaches. There are rich, diverse opportunities out there, but mentees are often not sure where to start.

Paul We know PhD students are bright. But that doesn't necessarily make them successful outside the cloistered environment of academia. That's why they need these other skillsets: adaptability, networking, leadership and both oral and written communication. Sometimes it's simply a matter of teaching them business 101.

IMNIS aims to break down barriers, extend professional networks, advance skills, expand career scope and develop future STEM leaders. What does that look like?

Leonie This is many of these future STEM leaders' first experience being mentored. Even those who have other big milestones going on in their life get a valuable taste of this type of support. For those who can fully embrace the breadth of the program, the outcomes can be incredibly rich and career-changing.

Sue I am immensely proud of the work IMNIS does. It's a wonderful opportunity to meet one-on-one with a dedicated, experienced professional who can provide insights, introductions and guidance. I was delighted that MTPConnect could fund the IMNIS program to go national as part of our support for the medtech and pharma sector.

Tony Ideally we will see a diminishing barrier between industry and academia. People talk of research as if it is the exclusive province of academia, and this needs to change. Success for IMNIS would be when scientists and engineers within industry and those in academic institutes understand each other's strengths and interact as equals.

Paul Australia has the lowest rate of industry-academia connections in the OECD. Industry professionals who do approach universities find that it's like dealing with an octopus. You knock on one door, but is it the right door? The program creates an easy way for people in industry to get engaged. I do a lot of email introductions – it's about creating connections.

What's the next big challenge facing Australia's health tech sector?

Leonie How do we leverage disruptive technologies to deliver better health outcomes to a growing and ageing population while managing cost, quality and equity of care? We need to build new skillsets, change the way we educate, and increase investment in health research, translation and delivery.

Sue We face a lot of challenges: the chronic burden of disease, the rise of digital, consumers being more in control of their healthcare, precision healthcare, changing integrated care models, global biosecurity and the needs of developing markets. These megatrends are often disruptive. They change existing business models and presents challenges and opportunities.

Tony I think the biggest challenge is still the absence of diversity and scale in the commercial sector. Australian health tech companies often reach a certain size then are internationally acquired – only a few become mature standalone organisations. I have no simple answer, but in countries where entrepreneurial STEM graduates make their way in industry, tech sectors thrive.

Paul One opportunity in Australia is medtech. A lot of big multinationals are pulling back and creating space for start-ups. But while we do the fundamental research really well, we often don't do the translational piece. Tech on its own isn't going to make you successful. Innovators need to constantly ask themselves who their customers are and what the benefits will be.

Mentees speak about how the program boosts their confidence and organisational skills. How have you seen mentees change over the course of the program?

Sue I'm always surprised and delighted by the calibre of the mentees I work with and meet. They're often ready to take the next step in their career, but don't know how good they are until you sit down and have that conversation. By introducing them to people, working with them on their CV and helping them hone their "pitch", you can empower them to reach out and grab those opportunities.

Paul A lot of students get into the doldrums in their second and third years, wondering what they're going to do. As a mentor you can lift the scales off their eyes. The gloom lifts off them and the smiles and confidence come back. I was chatting to an overseas student, who said the fact that someone cared was enough to boost her confidence. You hear that time and time again.

Tony People might be surprised that PhD candidates lack confidence, but in a prestigious environment where excellence is the norm it's easy to feel unsure if you measure up. Mentoring shows them that industry values their knowledge and skills, and that it's not that hard to adapt. It's many mentees' first exposure to a professional world outside the university or research institute.

Leonie I've seen mentees change their approach to networking at events. Rather than turning up at a conference and hoping for chance meetings with relevant people, they understand the need to prepare. That means reviewing the conference schedule and researching resources like LinkedIn to target companies and individuals with specific questions. This has a significant carry-over effect for their confidence in other areas.

What would you say to a Fellow who is considering becoming a mentor?

Paul You can quickly make significant impact and it takes very little of your time. A lot of mentors are serial mentors – once they get going, any qualms just fade away. They're busy people, but they know they can find an hour a month. The concept is really about two people having a conversation.

Tony It's an everything-to-gain, nothing-to-lose, situation. Although not every mentee will be perfect for you in every way, there will be plenty of times when their enthusiasm, energy and ambition will be a wonderful bit of sunshine in your day.

Leonie It's a great way to give back. The best things you can give someone early in their career are the confidence to believe in themselves and the ability to make sound decisions. And you'll get the benefits of being part of a well-managed program: new networks, knowledge and connections.

Sue Grab the opportunity. If you are thinking about it, reach out to those that have already participated and ask about the value they got from the program. Go along to the info sessions and speak to some potential mentees. You will not regret the experience.

Paul Do you want to help grow the next generation of leaders? Here's your opportunity.

Interviews by Benjamin Hickey.

MORE

INDUSTRY MENTORING
Are you a Fellow or STEM industry leader interested in mentoring? Or do you know a PhD student who could benefit from IMNIS?
Email: admin@imnis.org.au.
Or find out more online.

imnis.org.au

Dr Anthony Radford
AO FTSE

A senior biotech executive with substantial experience in pharmaceuticals and diagnostics, Tony Radford is a founding Director of IMNIS. He has served in leadership roles in various health tech companies, including 12 years as the CEO of Cellestis, which he co-founded. Dr Radford is a Clunies Ross recipient.

Dr Leonie Walsh
FTSE

Leonie Walsh is an expert and adviser in technological innovation and commercialisation. Victoria's inaugural Lead Scientist from 2013-2016, she is the Director and Founder of Productive Management Solutions. Dr Walsh is the Inaugural Women in STEMM Australia Ambassador and a passionate volunteer.

Sue MacLeman
FTSE

Sue MacLeman is a pharmaceutical, biotechnology and medical technology executive who has held senior roles in corporate, medical, commercial and business development. She is the Chair and Non-Executive Director of MTP Connect, a not-for-profit that aims to accelerate the growth of the health sector in Australia.

Professor Paul Wood
AO FTSE

IMNIS co-founder and Director Paul Wood is a leader in the health tech and agriculture industries, and Director of P&R Wood Partners. A Clunies Ross winner, he is internationally recognised for his research in veterinary immunology, tuberculosis and vaccine development; and his numerous patents.

By Alan Trounson

Precision medicine

Changing the DNA of health care

Human disease is generally a consequence of complex interaction between our genes and the environment. Traditionally, medical research focuses on creating therapies to treat specific diseases.

This can be very effective. Individual therapies can have universal benefits across the whole population: look at immunisation against specific pathogens, or how new antiviral medication has helped control the spread of HIV/AIDS.

However, many diseases defy simple drug solutions and strategies for population therapeutics. In our increasingly sophisticated and impatient society, there's more demand than ever on biomedical research to develop therapies across a broad range of clinical conditions.

Bespoke medicine

Genetic and environmental factors mean diseases can have very different trajectories over different people's lives. Considering these factors can reduce the chance of catastrophic events that cause accelerated disability or premature death.

Some people may respond well to a certain therapy while others might react adversely, or not at all. Bioinformatic data analysis helps clinicians work out a person's likely response to medication and how urgent it is to intervene.

Personalised or precision medicine uses genomic and biological data to find the best therapeutic option. This is rather different to symptom-only clinical diagnosis that doesn't take that broader information into account.

First, a consulting clinician needs to submit a patient's e-health record to an informatics centre for detailed analysis. The centre then uses worldwide health and genomics data to identify the diagnostic cluster group a patient belongs to. This is used to compute a diagnosis and the probable best treatment options, which the clinician receives as summary data.

When combined with the patient's molecular diagnostic information from pathology tests and specific patient examination, this data enables the clinician to determine personalised therapies that maximise likely benefit while reducing the chance of adverse events and failure.

Letting the gene out of the bottle

So how can we make all this happen? The genomic and patient history data banks are already being built.

But we need detailed bioinformatics analyses to turn large amounts of complex data into useful information for busy clinicians. The outcomes of diagnosis and treatment then need to be verified and fed back into these data banks.

There's a role for the private sector to enter this space and help provide the needed specialist bioinformatics advice. Since the goal is to improve patients' lives and reduce primary health care costs, government can also play a part.

Insurance policies and their coverage of therapy will need to be revised to ensure equal access to these new precision medicines. The overall economic benefits to the community will drive these transformations in the health industry.

From ER to AI

We'll need to incorporate Artificial Intelligence (AI) into precision medical practice, because the growing mass of data for genomics, biologics, demographics and environmental variants will be beyond individual humans' capacity for useful analysis. Machine learning will increase predictive power and improve accuracy, speed and workflow.

AI has already improved diagnostics through mammograms, colonoscopies, X-rays, brain CT scans, heart MRIs and more. New developments will further enhance the capacity and effectiveness of personalised medicine.

Deep neural networks of AI can accurately and rapidly detect complex patterns associated with genotypes, gene signalling, environmental cues, patient data and disease phenotypes. This will reduce the clinical errors, near-misses and lack of accuracy that often exist in present medical practice.

Gene therapy has helped us make critical advances in the treatment of inheritable genetic diseases, such as sickle cell anaemia. These often-rare disease are caused by inherited genetic errors – generally very specific single-gene DNA mutations.

They can be treated by editing the genes of blood or tissue stem cells, either inside or outside the patient's body, to introduce a corrected version of the abnormal gene to reverse symptoms of the disease.

Gut feelings

The microbiome is rapidly being incorporated into medical diagnostics and therapeutics as we increase our understanding of its association with disease. In the past, this aspect of patient variance hasn't been considered critically for many conditions.

For example, anti-tumour immunity responses have been very clearly associated with microbiota changes in mice. Specific microbial strains can significantly boost immune responses to tumour cells and restricted tumour growth.

Similarly, the composition of patient's gut microbiome can influence the success of cancer immunotherapy. Studies are underway that combine immune checkpoint therapy (ani-PD1 therapy) with oral doses of certain bacteria or fecal matter from other patients who responded well to this treatment. There is interest in adding this information into the data sets for personalised therapy.

Stem-cell STEM

As genomics adopts new advances for identifying and confirming the role of gene signalling pathways in diseases, new drugs will be discovered and personalised medicine will evolve.

For example, large patient-donated samples of stem cells derived from adult tissue (induced pluripotent stem cells, or iPSCs) are being analysed to find out how various diseases respond to different drugs. Experts are connecting this data with gene-edited and genomic screens to develop and repurpose drugs and identify clusters of patients likely to benefit from them.

Similarly, researchers are designing personalised cell therapies for regenerative medicine by using iPSCs from individual patients or rare donors. These studies are entering clinical trials for numerous conditions including blindness, spinal cord injury, diabetes, heart disease, Parkinson's disease and cancer.

It's now possible to generate stem cells from adult tissue that are the equivalent to primitive embryonic stem cells. These iPSCs make it possible to gene-edit very specific genomic designs, dramatically increasing the effectiveness of cancer-destroying white blood cells.

Clone rangers

The success of immune therapies has impacted the present approach to cancer therapeutics. Three particularly exciting developments are monoclonal antibodies, checkpoint inhibitors and chimeric antigen receptor technologies (CAR-T).

Monoclonal antibodies are a fascinating breakthrough. Antibodies are protective proteins in the immune system that attack "foreign" substances like viruses and bacteria. To do this, they recognise and latch onto proteins called antigens.

Thanks to genomics, we can now identify antigen markers specific to an individual cancer. This lets us design specific therapeutic antibodies to bind to and kill tumour cells. These are called "monoclonal antibodies" because they come from identical, cloned immune cells.

The precision sequencing of tumour DNA in patients' blood is a very rapidly expanding area of diagnostics. It's revealing important variations within cancers traditionally considered to be of a single cancer type. This allows us to design specifically targeted therapies that transform patients' lives.

Targeting cancer

Personalised cancer vaccines are also rapidly evolving. These make use of dendritic cells: tree-shaped cells that present antigens to the immune system and instruct it to make antibodies and disease-fighting white blood cells.

Scientists make cancer vaccines by taking the patient's own dendritic cells and activating them with synthesised molecules (peptides) that are based on the specific gene mutations in the patient's tumour.

No two people's tumours are identical: their likely malignancy and spread vary considerably. Additionally, the rapid growth of tumours means that multiple gene mutations in tumour-starting genes (oncogenes) can develop.

Inheritance, mutation, and environmental influence can cause abnormalities in oncogenes and their regulation, which in turn causes cancer. Since each situation is unique, personalising therapy makes a lot of sense.

Checkpoint inhibitor therapy is another exciting area of research. Tumours sometimes use the immune system's own regulators to protect themselves from it. Molecules called checkpoint inhibitors block these regulators and activate the patient's immune system to hunt down and destroy cancers. This is particularly effective against melanomas.

In the blood

The most effective therapy for B cell blood cancers is CAR-T therapy. This involves genetically engineering tumour-recognising proteins called chimeric antigen receptors (CAR) into a patient's own white blood cells. These CAR-T cells are multiplied in the lab then infused back into the patient.

When the CAR-T cells recognise and bind to the cancer cells in the patient, they signal the immune system to kill the tumour. CAR-Ts are incredibly effective at targeting a patient's own specific tumour type, and are being studied for a wide range of cancers.

Presently, CAR-T therapy involves recovering and genetically manipulating the patient's own white blood cells. However, cancer patients' immune systems have often been impaired by long and debilitating chemo- or radiotherapy. This can make it hard to get enough cells for successful treatment.

"Off-the-shelf" CAR-T therapy is emerging as a useful alternative. By removing the major transplant barrier genes in donor cells, or choosing rare donors who are compatible with a high proportion of the population, doctors can use healthy cells that haven't been subjected to chemo. This is also cheaper, because you don't have to manufacture a unique product for every individual patient.

Accessing wellbeing

Unfortunately, precision medicines often cost many hundreds of thousands of dollars for any treatment. While there may be tolerance for expensively funding a few patients with rare diseases, the cost of mass precision medicine will be onerous for present health budgets.

The present health system won't be able to provide public funding and insurance for these treatments unless major changes are implemented. We need to remember that keeping people healthy also has economic benefits. Helping patients meet the increased costs of these personalised therapies is an investment that will drive down the long-term costs of disease care.

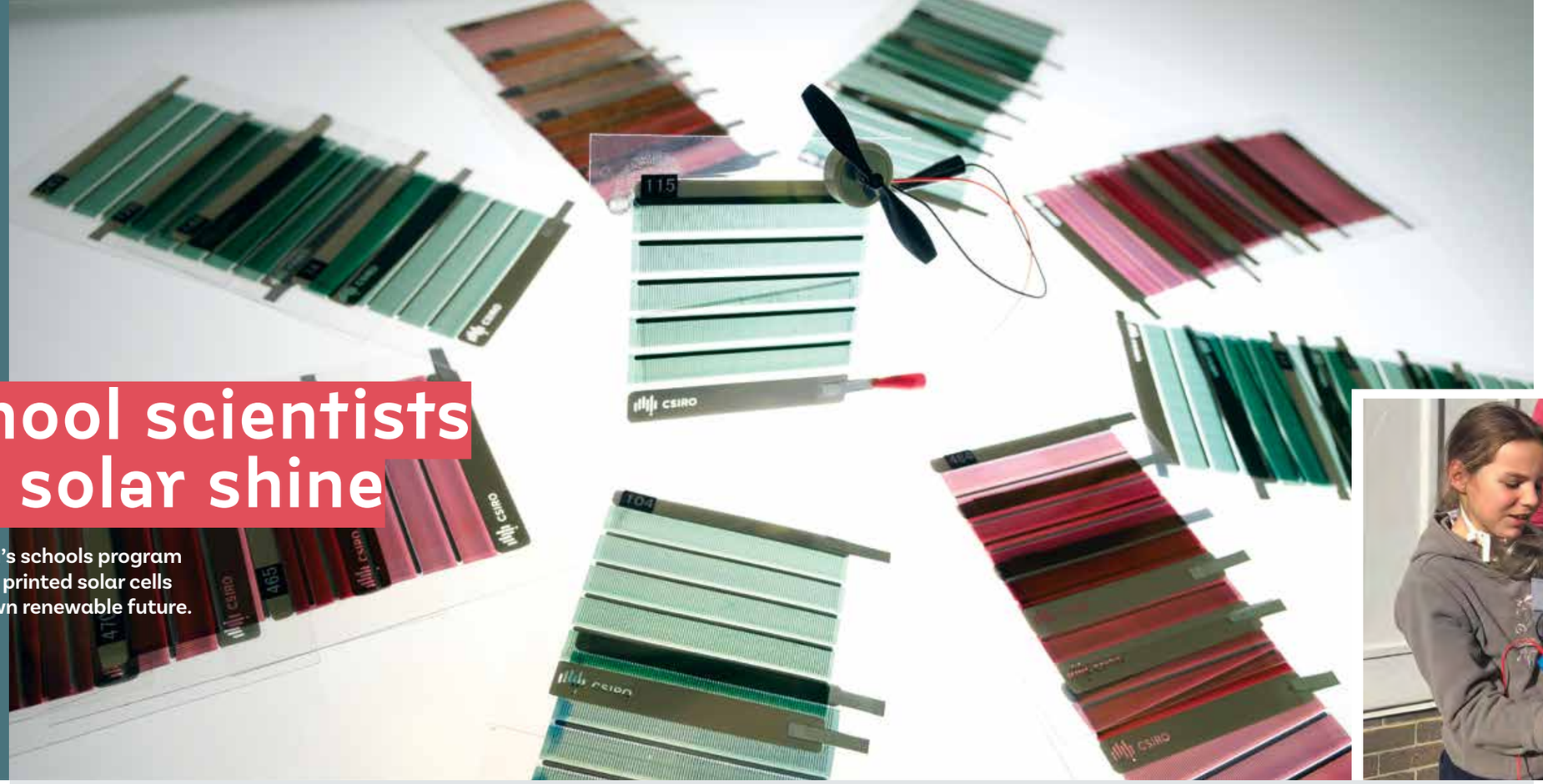
The other great challenge is in training clinicians to use major data resources. That means collecting and interpreting individual patient information to make better diagnoses and therapeutic recommendations.

Our community's health will increasingly be a partnership between patients, consulting clinicians and therapeutic providers. These relationships will be different to what we're used to. Patients' decisions and data inputs will have a bigger role than ever before.

All these changes are already happening. Medical practice, public health, government, health insurance and the community need to come together to be ready for them. It's up to us to create an economically rational, emotionally comfortable and socially just health care system for all.

Emeritus Professor Alan Trounson
FTSE

Alan Trounson is a world-renowned embryologist with an expertise in stem cell research. Elected a Fellow in 2014, he is an Emeritus Professor at Monash University and Distinguished Scientist at the Hudson Institute of Medical Research. Professor Trounson is also the CEO of Cartherics, an immune stem cell cancer therapy company.



By Peter Pentland

The school scientists making solar shine

Students in the Academy's schools program are testing revolutionary printed solar cells and helping build their own renewable future.

Peter Pentland

Peter Pentland is Executive Manager of the Academy's Schools Program, STELR.

STELR

stelr.org.au

It sounds like science fiction: printed solar cells you can stick on your blinds or your backpack. But the CSIRO is developing the materials and processes to print flexible solar panels at very low cost – and STELR students are helping them do it.

Solar energy is a huge source of clean, sustainable power. Even a fraction of the sun's energy could power the world.

As the climate crisis escalates, we need a range of low-cost solar technologies to meet the growing energy needs of the developed and developing worlds.

Made with printable "solar inks", the flexible solar cells are lightweight, thin, and semitransparent. Designed for situations where conventional panels won't suit, they can be integrated into tents, windows, bags, blinds, packaging, roofing, boat sails and a multitude of other products.

But while lab results are promising, research is still being done on how robust the panels are when they're used in the real world. Who better to test that than kids?

Here comes the sun

STELR (Science and Technology Education Leveraging Relevance) is collaborating with CSIRO and Stanford University in a world-first study on the durability of the printed flexible solar panels in non-laboratory environments.

The project, titled "A case study of degradation of flexible photovoltaic modules", is funded by the Australian Centre for Advanced Photovoltaics (ACAP) and the CSIRO.

The study brings the science and education communities together to advance this exciting renewable energy technology. It also aims to build public awareness of next-generation solar tech – especially among the next generation.

At the end of the project, the researchers will be able to:

a) understand the cohesion behaviour of the panels' device layer
b) identify the best performing electroactive inks
c) verify the integrity of the electrical connection
d) compare the performance of encapsulation material in end-user environment settings.

From the lab to the classroom

STELR sees this as a great opportunity for our students to be an essential part of an international scientific study into a cutting-edge renewable energy technology with massive implications for the future.

The project is an example of how STEM should be taught. It's an authentic, interdisciplinary project about complex real-world problems.

The investigations are hands-on and inquiry-based. The students are able to work independently and collaboratively in teams. They're stimulated to ask questions about the technology then devise and carry out their own investigations to find solutions.

The investigations require the students to apply mathematics, engineering and technology principles, and to gather and analyse data.

More than 10,000 students will have access to the practical and engaging program.

Kitted out

The study has produced 500 organic photovoltaic (OPV) modules. These have gone to more than 100 national and international schools or education centres involved in the STELR program.

This includes nine centres of excellence or outreach centres that provide programs for school visits.

Each school received:

- four flexible solar panels (10cm x 10cm)
- one load box to measure the energy output of the panels
- curriculum materials which suggested activities that use the solar panels
- a safety sheet for the OPV modules.

The kits are used to collect data from the panels. This allows students to draw characteristic curves for the different types of flexible panel provided.

They can also compare the effectiveness of the flexible panels with silicon-based solar cells.

The panels can be used in standalone activities or in conjunction with four other STELR modules:

- renewable energy
- sustainable housing
- electricity and energy
- solar cars.

At the end of 2019, the schools will return the panels and researchers will assess their condition to see if and how they've degraded. In exchange, the schools will receive four new panels and can keep the data-gathering equipment.

The data collected about the panels will include:

- the number of times (days, sessions) used
- the amount of time used
- temperature
- voltage
- time indoors and outdoors
- light conditions (direct sunlight, shade, indoors, etc)
- storage conditions.

This program will improve the design of flexible solar products, boosting Australian industry and helping build a carbon-free world.

It proves to young people that they can make a very real difference – and inspire more future scientists and engineers along the way.

Students from Thalgarrah Environment Education Centre in NSW with the flexible solar cells.

MORE

WATCH
Find out more about flexible solar work, including a video about the technology, at: csiro.au/en/Research/MF/Areas/Innovation/Flex-Electronics/Printed-Solar-Cells

By Elizabeth Broderick

Attracting, retaining and supporting

How to help women thrive in STEM

Elizabeth Broderick
AO FTSE

As Australia's longest serving Sex Discrimination Commissioner (2007-2015), Elizabeth Broderick worked tirelessly to break down structural and social barriers faced by women and men, and to promote gender equality. She established and convenes the "Male Champions of Change" strategy and led the review into the treatment of women in the Australian Defence Force.

In 2016, Ms Broderick was appointed an Officer of the Order of Australia and was named NSW Australian of the Year. In 2017 she was appointed by the United Nations in Geneva as a UN Special Rapporteur and Independent Expert on the Issue of Discrimination against Women. In 2018, she became an Honorary Fellow of the Academy.

Technology and science have always been in my DNA. My father, a physician with expertise in nuclear medicine, was the first person in Australia to open a diagnostic nuclear medicine practice outside a hospital environment. Both my sisters pursued careers in STEM. In my own career, technology has been central to my work in law, human rights and gender equality.

Technological disruption is accelerating rapidly, with advances in science and technology opening up exciting possibilities for the future. These technological changes will impact so many aspects of our lives and the benefits for human society are likely to be immense.

But despite increasing workforce demand for people with STEM skills, there are significant challenges in attracting, retaining and supporting women in STEM careers. Given that science, technology, engineering and maths skills are essential to drive innovation and prosperity for Australia, it's vital that we increase women's participation in these fields, particularly in leadership roles.

The evidence is clear: we are losing women and girls at every stage of the STEM talent pipeline. Progress is unacceptably slow. The famous "draw a scientist" study asked primary school-aged children what they thought a scientist looks like. Over 40 years ago, 99 per cent of children drew a man.

In 2009, two out of three children still drew a man. Today women remain poorly represented in many STEM fields, comprising as little as 13 per cent of undergraduates in IT and engineering.

There has been much written about how to change this picture. But it was a recent tweet by Professor Lucy Rogers that caught my attention. Instead of asking "How do we get more girls into STEM?" she asked, "What can YOU do to make the workplace a place where women want to work, where they are treated equally, respected?" This simple but powerful reframe reminds us that everyone of us has a role to play in increasing the participation of women.

To understand the issues more clearly, the Male Champions of Change STEM recently surveyed nearly 3000 women and men in STEM across a diverse range of Australian organisations to provide insights on their motivations, career experiences and priorities for action.

The survey results clearly show that beyond growing the pipeline through concerted interventions in the education system, we need to be more intentional in creating an inclusive and respectful culture in STEM where people's perspectives and contributions are equally valued, regardless of their gender.

The data shows that women and men are equally motivated by the exciting and rewarding work STEM careers offer. But looking at gender differences, women are more motivated by the problem-solving nature of the sector and men are more motivated by earning potential and career opportunities.

> **"What can you do to make the workplace a place where women want to work, where they are treated equally and respected?"**
>
> Professor Lucy Rogers

MORE

READ
Read more about the Women in STEM Decadal Plan on page 44.

Using a fresh approach to reframe STEM for its broader purpose in solving the world's most complex social, economic and environmental problems – rather than STEM for the sake of STEM – is critical for increasing women's and girls' attraction to education and careers in the sector.

Beyond attracting women and girls to STEM, we need to sharpen our focus on how we retain women in the workforce and support them to thrive. Concerningly, over half of the women surveyed, 54 per cent, have considered leaving their STEM role. This is significantly more than the 45 per cent of men. Highly-qualified employees seeking to leave STEM roles is a significant drain on Australia's innovation talent pool.

When we look at reasons people want to leave, women are more likely than men to cite a lack of diversity in senior leadership and behaviour that excludes people based on their gender. The most common reasons for men wanting to leave STEM roles include lack of opportunities for promotion, no pathway to leadership, more opportunity to progress in another profession and higher earning potential in a non-STEM area.

The most alarming finding of the survey relates to everyday sexism. Every interaction in meetings and less formal settings, together with leadership, creates the culture people experience at work. The data showed that women personally experience everyday sexism in all its manifestations at least twice as much as men.

The biggest difference between men and women experiencing everyday sexism in the STEM workforce occurs in the devaluing of women's views and voices. Two thirds of women in STEM experienced their views or voices being devalued in the workplace. Conversely, only one third of men observed this behaviour.

This data suggests women's daily experiences of having their voices devalued are often invisible and normalised. Not only does this create a culture of exclusion for women, it means the organisation misses out on their expertise and ideas.

Further, there is a link between experiencing everyday sexism and women's attrition. Women who experience everyday sexism in the workplace are significantly more likely to want to leave their STEM career.

This finding suggests that even if more women are encouraged into the talent pipeline, there is a risk they will continue to leave at a greater rate than men unless there is a focus on creating a respectful and inclusive environment for all.

When it comes to expectations of future actions, three stand out for women: career development and leadership programs; visible sponsorship of women in STEM from senior leaders; and creating respectful and inclusive cultures. The survey found that actions such as flexible work and support for carers are also important.

Less visible is the direct support and sponsorship for women's careers in STEM, and efforts to create an inclusive culture. This is where we need to sharpen our focus to accelerate progress.

There is much bold experimentation taking place in to shift the culture, including by members of the Male Champions of Change STEM.

Australia's Nuclear Science and Technology Organisation, ANSTO, has a practice of regularly reviewing the process of their last 10 hires and last 10 leavers, with a focus on gender equality and inclusion. This simple process enables the organisation to track how gender bias might be creeping into their recruitment process, but also importantly looks at the gender profile of people who are leaving the organisation.

Accounting software company MYOB is reframing their recruitment to focus on "culture add" rather than "culture fit" to challenge affinity bias in their recruitment.

IT consulting firm Accenture has removed the categories of primary and secondary carers for their parental leave, classifying all parents as primary carers with access to 19 weeks of leave. Such a policy sends a strong message that caring for children is an equal responsibility.

And CSIRO has established inclusive meeting guidelines in all meeting rooms to provide practical support for meeting leaders on ensuring everyone's voices are heard and respected.

Many of these actions are aligned with the Women in STEM Decadal Plan, a comprehensive strategy prepared by the Australian Academy of Technology and Engineering and the Australian Academy of Science to support action from multiple stakeholders.

Our experience from decades of learning shows that gender inequality is not a problem that will correct itself without intentional action from leaders. As Fellows of the Australian Academy of Technology and Engineering, we all have an important role to play.

There are questions we need to ask ourselves. How might we use our collective power and influence to set bold targets to accelerate progress on women's representation in STEM leadership roles? How can we create senior roles that enable flexibility for both women and men?

What if we asked all men in our teams to model flexible work and make their caring responsibilities visible? What if we set and modelled new standards for meetings where everyone has an equal share of voice? These may be small steps but they will drive major shifts.

Above all, can we let existing gender inequalities in STEM be replicated or, worse still, amplified for future generations?

We need to act urgently. Indeed, our nation's future depends on it.

Interview by Benjamin Hickey

The accidental engineer

Maria Skyllas-Kazacos talks about her journey from "too hard" science to inventing the vanadium redox battery.

How did you become interested in science and engineering?

While I was at school I never really saw myself as an engineer and had no specific interest in science. I was more interested in art and English, and was actually afraid of maths and science because I believed they were too hard for me. I even tried to avoid doing the higher level maths and science units.

Thankfully, my maths teacher convinced me that I was quite capable. I took her advice, did advanced mathematics, and realised I was actually quite good at it. I ended up loving maths, although I didn't realise the important connection between maths and engineering at the time.

During year 12 I attended an applied science careers week at the University of NSW. There, I was introduced to a range of courses including chemical engineering, chemical technology, mining engineering, metallurgy and textile technology.

At the end of high school I initially applied to study law, but a solicitor friend of my father's talked me out of it. I quickly changed my preferences and ended up enrolling in chemical engineering at UNSW. Halfway through first year, however, I thought I'd made the wrong choice. I couldn't imagine myself in heavy boots and a hard hat working in a "dirty" chemical plant. I changed my course to industrial chemistry, not realising that about 80 per cent of the classes were from the chemical engineering program anyway!

I must admit that I couldn't relate to these subjects as an undergraduate. I was one of only a handful of female students in a cohort of over 100 in most of my courses. But I wanted to finish what I started. I studied hard, afraid that I would otherwise fail. To my surprise, I ended up with distinctions and high distinctions in all of my subjects, and graduated with first-class honours and the University Medal.

What challenges did you face as a young woman in a male-dominated field?

I was extremely fortunate to have had so much support during my studies. Most of the male lecturers were very encouraging and some became great mentors during my early career.

I was somewhat naïve when it came to planning my career path. But even that seemed to work in my favour: my male colleagues felt they had to help me navigate the complicated academic promotion system.

Every time I attended scientific conferences I was one of a couple of women in the room, so I attracted a lot of attention. Perhaps that's one reason why the vanadium battery work got media attention. That, in turn, brought us early commercial interest and support from around the world.

How did you create the vanadium redox battery?

The creation of the vanadium redox battery has been a team effort involving dozens of students and research fellows over 35 years. The seed was planted while I was a postdoctoral fellow at Bell Telephone Laboratories in Murray Hill, New Jersey, in 1978-79, where my work on liquid junction solar cells and lead-acid batteries introduced me to problems in conventional battery technologies.

On returning to Australia, I was awarded a Queen Elizabeth II Postdoctoral Fellowship to continue my research in liquid junction solar cells at the School of Physics at UNSW. In 1982 I was appointed lecturer in the School of Chemical Engineering and Industrial Chemistry.

As a new academic, I was looking for new research areas to get into. My interest in flow batteries all began with a masters student, Robert Brand, who was working on NASA's iron-chromium flow cell with Professor Martin Green, a world leader in silicon solar cells. In 1983, Bob asked me to co-supervise him for his masters thesis.

> "I realised that science and engineering are just as creative as art or drama. I feel that having multiple perspectives helps you to think on a different plane and opens the mind to possibilities beyond the written text book. In fact, it helps you to see the beauty of science!"

The concept of the flow battery – originally proposed by NASA in the 1970s – intrigued me. It seemed to overcome many of the problems of conventional batteries.

Flow batteries store energy in electrolyte solutions (liquid chemical mixtures) rather than in solid materials. This allows great flexibility in designing battery systems to suit a particular application.

It also means that the cost of stored energy drops dramatically with increased storage capacity, since you just add more electrolyte and bigger tanks, rather than more batteries.

That's why flow batteries, and the vanadium flow battery in particular, offer the lowest cost energy storage option for applications requiring four or more hours of storage capacity, like solar and wind energy storage.

Most types of flow batteries use different elements in the two half-cells. Bob's cell, for instance, would use iron and chromium. After only a single experiment in the lab, however, it became obvious that cross-contamination was an inherent problem for all flow batteries of this type.

The only way to overcome this was using the same element in both half-cells. Vanadium, a rare, silvery-grey metal, was suggested as a good starting point.

Although others had considered vanadium for flow batteries, one important form of the element – the V(V) species – had very low solubility. This limited vanadium's practical viability, so it had always been dismissed.

Undeterred, I decided to set this research topic as an honours project in 1984. But before I gave it to an undergraduate student, I began preliminary electrochemical experiments on vanadium electrolytes. My experiments on a purple salt called vanadium chloride, dissolved in sulfuric acid, showed promise.

During 1984, the honours student, Elaine Sum, screened a number of different solution options. She confirmed that sulfuric acid gave the best results. But the low solubility of V(V) compounds still seemed a limitation.

In 1985, three fellow researchers (Martin Green, Bob Robbins and Tony Fane) and I got a grant from the National Energy Research Development and Demonstration Council. We set out on our attempt to produce concentrated V(V) solutions by oxidising a bright blue powder called vanadyl sulfate, a much more soluble form of vanadium. Together with Dr Miron Rychcik, we produced and tested a successful vanadium electrolyte.

Emeritus Professor Maria Skyllas-Kazacos
AM FTSE

Maria Skyllas-Kazacos is Emeritus Professor of Chemical Engineering at UNSW Sydney. She holds the 1997 Whiffen Medal and 1998 CHEMECA Medal from the Institution of Chemical Engineers Australia, the 2000 R.K. Murphy Medal Royal Australian Chemical Institute, and numerous other honours. She and was elected a Fellow of the Academy in 2014.

The battery was viable! Because of our results, the first patent for the All-Vanadium Redox Flow Battery was filed in 1986. This was the start of a 33-year program at UNSW that continues today.

During the early years, we found that vanadyl sulfate, which costs more than $400/kg, wasn't economical. Our priority was to develop a process for making the electrolyte with the much cheaper vanadium pentoxide – which was $5/kg, and looks a little like turmeric.

Our work expanded to cover all aspects of the vanadium battery, including:

- graphite felt electrode activation
- novel conducting plastic bipolar electrodes
- new modified membranes
- electrolyte production methods
- precipitation inhibitors
- sensors
- shunt current and thermal modelling and simulation
- designs for battery stacks.
- control systems.

All this led through to prototype testing, manufacturing trials and, ultimately, industrial licensing. Today, the vanadium redox battery is a rapidly growing technology and valuable piece of the renewable energy puzzle. And because it's water-based, it's safer than flammable lithium batteries and other alternatives.

You're a world-renowned engineer, yet you also studied drama and art. How did this shape your career?

When I was young, I used to think that science and creative arts were totally different. As an undergraduate, I found engineering and science subjects very dry. I was thrilled to have the opportunity to take several general studies courses, including drama, art history and sociology.

In parallel, I always had a passion for history and read widely. These interests kept me motivated to complete my degree, with the intention of changing my career on graduation so that I might follow my passion.

Once I became involved in research, however, I realised that science and engineering are just as creative as art or drama. I feel that having multiple perspectives helps you to think on a different plane and opens the mind to possibilities beyond the written text book. In fact, it helps you to see the beauty of science!

What advice would you give to women pursuing a career in STEM?

During the 1990s and 2000s, much of my time at UNSW was spent visiting high schools, promoting careers in engineering, especially for girls.

Over the years, we have seen a huge increase in the numbers of women undertaking chemical engineering, and to a lesser extent, other engineering courses. Women have been outperforming male students in most HSC subjects for many years now, so I don't believe they're as uncertain about their competence in science and maths.

But they are still influenced by social perceptions about engineering and the status of engineers compared to doctors and lawyers. They also lack the confidence needed to promote themselves in the workplace.

My advice to young women has always been to recognise the invaluable contributions that engineers are making to improving our environment and to ensuring a future for the planet.

I tell them to keep all their options open at school, and that means including STEM courses. Sadly, the scaling of HSC subjects in recent years has led to many bright students (both girls and boys) choosing easier options to maximise their ATAR. This has seen fewer students taking STEM subjects and progressing into science and engineering courses at university.

For those women (and men) embarking on engineering, or any other career for that matter, my advice is to remember that there's more to life than work. More and more we see young people working 12-15 hours a day. Keep things in perspective and make time for all the other important things in life.

I feel blessed that in my engineering career, work and meaning haven't been mutually exclusive. Doing something that might help humanity and the planet is so rewarding that it's possible to forget that it's "work".

Doreen Thomas inducted into Victorian Honour Roll of Women

A leading Academy Fellow has been honoured for achievements spanning multiple decades, fields of study and sectors.

Emeritus Professor Doreen Thomas FTSE, a Board Director and chair of the Academy's Education Forum, was inducted into the Victorian Honour Roll of Women on 8 March – International Women's Day.

The Honour Roll acknowledges and celebrates the achievements of women in Victoria. Inductees come from all walks of life and have demonstrated inspirational leadership and excellence.

The Victorian Minister for Women, Gabrielle Williams, said of this year's 21 inductees: "Too often we fail to recognise the achievements and contributions of women. But, we know there is no gender equality without women's leadership. So, we must continue to raise the profile of extraordinary Victorian women."

Professor Thomas was awarded in the trailblazer category, with a citation that noted: "Doreen's long and distinguished career has been inspirational for other women in mathematics and science.

"She has made significant contributions to knowledge with real-world impact, promoted the next generation of women in STEM disciplines, and taught mathematics to generations of engineering students."

Her career at the University of Melbourne has lasted more than 40 years. In 2006, she was appointed the university's first female professor in engineering.

She was the first woman at the university to become head of each of the departments she led (Electrical and Electronic Engineering, and Mechanical Engineering), and the first woman in Victoria to become head of two different university departments.

In 2017, she became the inaugural Head of School of Electrical, Mechanical and Infrastructure Engineering.

Professor Thomas applied her mathematical research to software for underground mine tunnel design, reducing development time and haulage costs while optimising usage.

This software has been licensed to some of the world's largest mining companies and she subsequently directed a start-up company to commercialise it.

Professor Thomas is also a powerful advocate for women in engineering and mathematics.

At the University of Melbourne, she helped create nine research fellowships to launch and accelerate the careers of female engineering academics.

Image above: Doreen Thomas. Photographer: Peter Casamento. Image above right: Lusia Guthrie, Chair, BioMelbourne Network; Martin Pakula, Victorian Minister for Jobs, Innovation and Trade, Department of Jobs, Precincts and Regions; Dr Anna Lavelle, Chair, ANDHealth; Her Excellency the Honourable Linda Dessau AC, Governor of Victoria. Image courtesy of BioMelbourne network.

Health sector champion receives Women in Leadership Award

An Academy Fellow has been honoured for years of outstanding leadership in the health industry by the BioMelbourne Network.

Dr Anna Lavelle FTSE, who was elected a Fellow in 2014, has received the BioMelbourne Network 2019 Women in Leadership Award – Impact for Industry.

The award recognises exceptional women who have made vital contributions to biotechnology, medical technology and the pharmaceuticals sector.

"We had a record number of applications this year, and the judges were overwhelmed by the quality and the achievements of women leaders in our industry," said Lusia Guthrie, Chair of BioMelbourne Network.

"This," she added, "is not only a reflection of the growing role and successes of women in Melbourne's medtech sector but also that these achievements are valued and recognised by their colleagues."

Dr Lavelle has spent the better part of 25 years working within and campaigning for the growth and expansion of the life sciences and medical technologies sector. In her various CEO, director and board leadership positions she has been has been a generous mentor, sponsor and advocate for women in STEM.

"Australia is a key player in biotechnology," Dr Lavelle said. "I have been proud to contribute to the global power and vibrancy of this sector in a passionate and determined way for over 20 years."

As CEO at AusBiotech, the national industry organisation for life sciences, Dr Lavelle championed policy changes to support the growth of innovative companies. She is a standard bearer for the local biotechnology industry and has forged global pathways for Australia's innovators to contribute to health of patients worldwide.

Linda Dessau AC, Governor of Victoria, presented the award at a ceremony at Government House.

Women in STEM Decadal Plan

Pathways to Equity in STEM Symposium

The first implementation step of the Women in STEM Decadal Plan – the Pathways to Equity in STEM Symposium – was held in Melbourne earlier this year.

Image above: Members of the Women in STEM Decadal Plan Expert Working Group, project team and Unibank representatives celebrating the Pathways to Equity in STEM event. Left to right: Dr Margaret Hartley FTSE, CEO of the Academy; Mike Lanzing; Rea Kalimtzis, UniBank; Dr Mark Toner AM FTSE; Suzy Urbaniak; Dr Rosalind Dubs FTSE; Professor Jane Latimer; Dr Adi Paterson FTSE; Professor Madhu Bhaskaran; Professor Suzanne O'Reilly; Professor Lisa Harvey-Smith; Anna-Maria Arabia.

Leaders from across the STEM ecosystem came together to turn the plan's recommendations into actions.

Chief Executive of the Australian Academy of Science, Anna-Maria Arabia, opened the symposium. "We must be absolutely resolute in bridging the gender equity gap in STEM," she said.

KEYNOTE ADDRESS
Professor Lisa Harvey-Smith

Women in STEM Ambassador, Professor Lisa Harvey-Smith said her national role was to boost STEM participation in Australia by working with organisations and bodies including:

- schools, universities and research
- SMEs, industry and government
- Science in Australia Gender Equality (SAGE)
- Male Champions of Change
- Science and Technology Australia
- the Australian Academy of Science
- the Australian Academy of Technology and Engineering.

"We need a deep focus on actions to address inequity. These must be bold actions, not more of the same and we must evaluate the way we do things," Professor Harvey-Smith said.

"We need to create workplaces that are respectful, free from discrimination and harassment, free of bias and flexible as well," she said.

"I believe in our collective commitment and ingenuity to address gender equity in STEM in Australia."

Why gender equity is important

Chair of the Equity and Diversity Reference Group, Australian Academy of Science, Professor Sue O'Reilly said we should promote STEM education from early childhood.

"This needs to be a multilayered effort at all stages of learning and include children and people from all backgrounds," Professor O'Reilly said.

Vice-President of Diversity, Australian Academy of Technology and Engineering, Dr Bruce Godfrey FTSE , said STEM workplaces should reflect our population.

"Why would we not want to include the best and most diverse ideas and people in STEM to achieve the best outcomes?" he said.

"Everyone who has a desire to pursue a STEM career should be able to do so."

SESSION 1
Learning from each other

Attendees gave snapshots of initiatives contributing to gender equity in their organisations.

Swinburne University's Professor Virginia Kilborn spoke about the Wattle Women in Leadership program, which operates across multiple universities.

"We are trying to give women the skills and networks for those who are being promoted into leadership roles," she said.

BHP's Head of Diversity and Inclusion Fiona Vines said good leadership and executive accountability is the key to real culture change for gender equity in STEM.

"Addressing unconscious bias is very important and BHP is working towards a much more inclusive culture," Ms Vines said. "Eeryone needs to feel welcome."

SESSION 2
Measuring impact
Do we really know what works?

As the Women in STEM Decadal Plan spans 10 years, we need to have systems in place to measure its initiatives' impacts into the future.

Dr Adi Paterson FTSE, CEO of Australia's Nuclear Science and Technology Organisation, chaired this session.

Elyse Lane, Senior Research and Education Advisor at the Workplace Gender Equality Agency, said: "Difficulty with collecting data on STEM careers means that we know that there are so many careers that rely on STEM that aren't even 'classified' as STEM."

Under-representation of women in STEM is holding back national prosperity

Australia has not yet made the systemic changes required to achieve diversity in science, technology, engineering and mathematics (STEM), with the current under-representation and under-utilisation of women in the STEM workforce posing a threat to Australia's prosperity.

The findings are contained in the Women in STEM Decadal Plan, launched in April at Parliament House in Canberra by the Minister for Industry, Science and Technology, Karen Andrews. The plan was developed by the Australian Academy of Technology and Engineering in partnership with the Australian Academy of Science.

It outlines six opportunities to strengthen gender equity in STEM in Australia over the next 10 years, including establishing a national evaluation framework to guide decision-making and drive investment and effort into STEM measures that work.

Dr Bruce Godfrey FTSE, the Academy's Vice-President Diversity, said the plan provided the first opportunity to tackle the issue of gender equity at a national scale and highlighted the importance of government, academia, industry, the education sector and the community working together to drive change.

"If this plan and the opportunities contained within it are realised, the STEM graduates of 2030 – nine- and 10-year-olds making their way through primary school in 2019, as well as those entering the workforce from other life journeys – will join workplaces that are respectful, free of harassment and discrimination, value diversity, and structured to support a variety of STEM careers that include women in leadership positions," Dr Godfrey said.

Australian Academy of Science Fellow and Expert Working Group member, Professor Sue O'Reilly, said there was an urgent case for cohesive, systemic and sustained change.

The decadal plan highlights the economic case for gender equity, citing the 2017 World Economic Forum's "Gender gap report", which estimates that closing the gender gap in economic participation by 25 per cent by 2025 could add as much as US$5.3 trillion to global gross domestic product in the same timeframe.

"It's not just an equality perspective that's important here, it's a business imperative," said Australia's first ambassador for Women in STEM, Professor Lisa Harvey-Smith. "Australia needs to be the clever country again."

Academy welcomes investment in STEM gender equity revolution.

The Academy has welcomed the Federal Government's commitment to invest $3.4 million in STEM gender equity, announced by Karen Andrews, Minister for Industry, Science and Technology.

Academy Vice-President Diversity, Dr Bruce Godfrey FTSE , said an important component was the $1.8 million to extend Science in Australia Gender Equity (SAGE), a joint initiative of the Australian Academy of Technology and Engineering and the Australian Academy of Science.The funding support will enable SAGE to expand its work in supporting the higher education and research sector to bring about a step change for gender equity in STEM.

"The announcement of building national digital awareness is also welcome as the rate of adoption of automation based on big data, the internet of things, and artificial intelligence, across all Australian industry sectors, is escalating,"
Dr Godfrey said.

"Automation in its broadest application across industry will see the demand for STEM-skilled employees continue to rise rapidly. "This problem cannot be fixed without addressing the significant under-representation of women in our STEM-skilled workforce, particularly at senior operational and leadership levels.

"The announcement is a welcome acknowledgement that we need to build a gender-balanced workforce underpinned by an inclusive workplace culture that values diversity."

Dr Godfrey said the Academy regarded the announcement as an important step in a process involving government, industry, and higher education and research sectors.

"We all have a role to play in achieving this," he said. "Failure to do so will see Australia significantly disadvantaged in the new technology revolution."

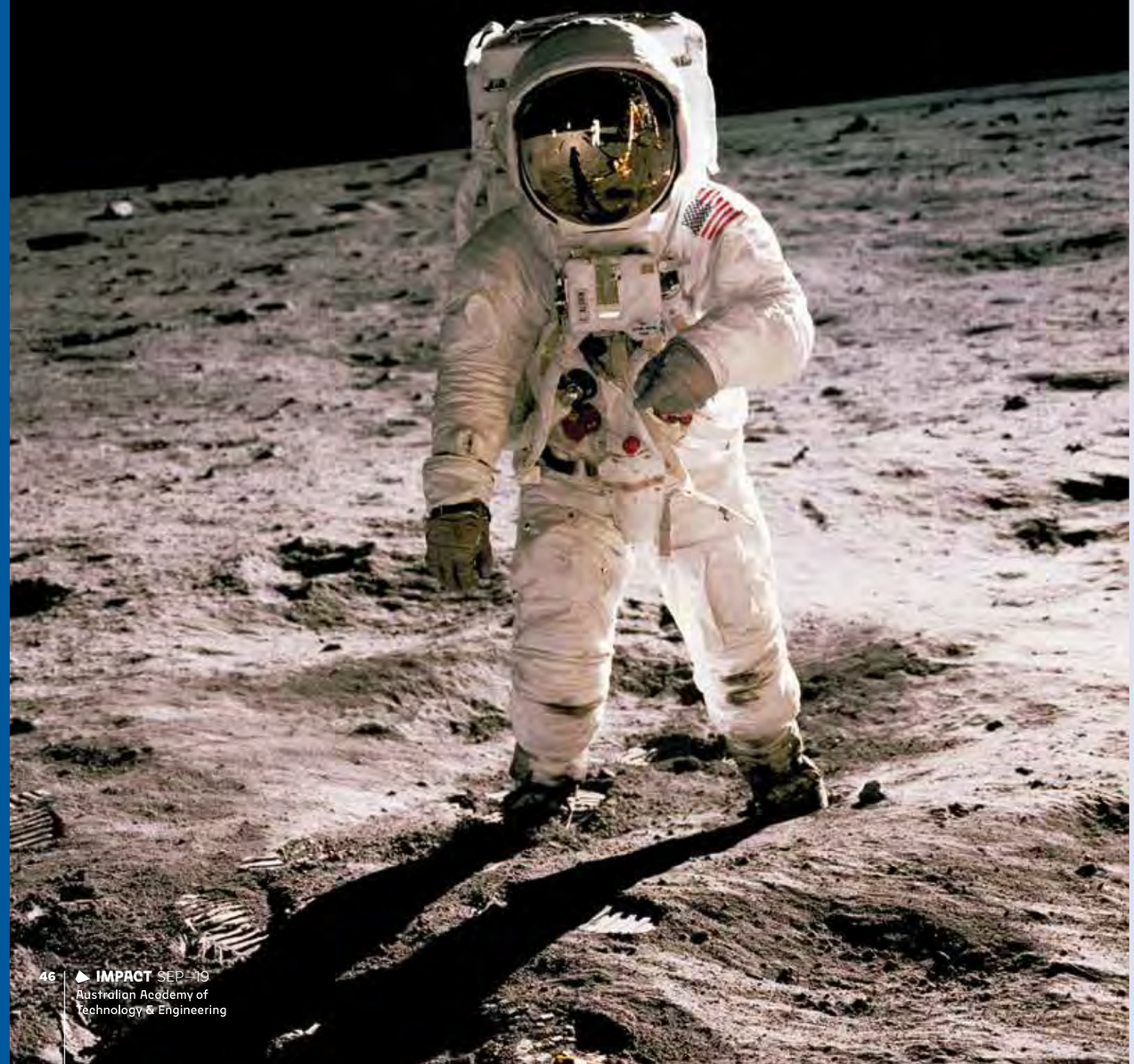
MORE

READ
Read the Women in STEM Decadal Plan online

atse.org.au

By Brian O'Brien

Apollo 11 carried my scientific experiment to the moon, but so what?



In 1957 I tried to get my grandma to marvel at the travelling star-like Sputnik 1. All she said that night in our Strathfield backyard was: "It's not right. It's not right."

Over a generation later, in 1992, in Perth, after a wondrous dinner cooked by my wife, I lovingly carried my oldest grandchild on my shoulders towards her mum's car and in the dark sky above was a wondrous full moon.

I said: "You know Steffie, Grandpa has five experiments way up there on Old Man Moon." Steffie warmed my ears and said: "That's nice Grandpa" before sliding off to play with my wife's cat.

I invented one of two powered experiments successfully deployed on the moon by Buzz Aldrin on Apollo 11. In total, I had two different kinds of experiments on the moon, four measured dust and one measured radiation. Now the world has been celebrating the 50th anniversary of Apollo 11. World media clamours as if it is news. And I admit I'm loving it.

I've spent 53 out of my 85 years on a quest to discover and then publish measurement-based information about the fine, sticky dust which is the No. 1 environmental problem on the moon. Future expeditions will be better prepared as a result.

A US symposium consensus in March accepted that anybody planning an expedition to the moon without a dust detector is dumb. I've had success. But so what? Now, in 2019, what value is Apollo 11 to anybody else, to life today and tomorrow?

The obvious spin-offs include the US winning the space race with the Soviet Union. The world is still enjoying the result of avoiding global nuclear war for the past 50 years, despite a close call in the Cuban crisis in October 1962. After all, if the USA could launch a payload of more than a dozen tonnes and hit where it aimed on the moon, any belligerent nation had to think twice.

Apollo 11 brought immediate joy and global unity as 600 million people watched in awe and wonder. The world, for those special moments, became one. In the midst of racial unrest, burnings of buildings, the Vietnam War and youth rioting, President Kennedy's Camelot dreams became reality before our eyes. And that is an enduring happy memory, easily shared with billions. Even today, if I say "Apollo", people smile.

The world was readied for Apollo 11 by the 24 December 1968 Christmas reading of Genesis from the Bible by the crew of Apollo 8 and the earthrise photo by Apollo 8 astronaut Bill Anders. Both reached deep into hearts and minds.

Never before had we each and all quite absorbed the special nature of Spaceship Earth, the uniqueness of that blue and white globe in the eternal blackness of space. So, in Apollo's time, nation after nation and state after state passed environmental laws to protect the environment.

Sadly, the regulations and controls of many Australian environmental laws have gone far beyond sensible or necessary requirements. If Apollo 11 was governed by versions of the precautionary principle now enshrined in Australian law, it could never have happened.

A new space race is now afoot, this time between the USA and China. But Chang'e-4 and Yutu-2 are working on the far side of the moon, the side we on Earth never see. The first Yutu is stuck motionless in the dust since January 2014, on the near side we always see.

Schoolchildren who watched Apollo 11 are now grown, with bright memories of the time, with tales to tell their children now. They remember where they were when Neil Armstrong made that "one small step".

When I talk to schoolchildren today, anywhere, the very mention of an astronaut, particularly a first-name mention of an Apollo astronaut I know or knew personally (I enjoyed showing and discussing life-sized models of my experiments with Aldrin in 2012 in Washington), ignites a forest of hands eager to ask questions. Apollo is intergenerational, a much-needed bond amid the noisiness and rush-rush indifferences of modern times.

Dream with me, please. Let each of us take only five private minutes sans those abominable mobile phones – with a quiet family member or friend, or simply alone – to gaze in open-air wonder at the moon, full glory or crescent, night or day, in urban or rural areas. Concentrate your mind up there, focus on Buzz and Neil and their extraordinarily isolated bravery walking and stirring up inescapable fine moon dust.

That magic aura of Apollo 11 will refresh your mind and heart, if only you let it. New perspectives can follow. Discuss with your family if you can see a Man on the Moon. Frankly, I prefer the rabbit. Yutu means Jade Rabbit.

And most of all, if you watched Apollo 11 happen when you were young, share your thoughts with children. Just think, in only two generations' time, when you are gone, they will need to know and tell loving stories of your personal thoughts and photos to share celebrations of the 100th anniversary of the greatest human adventure of your lifetime.

Professor Brian O'Brien
FTSE

Brian O'Brien is Adjunct Professor of Physics at University of Western Australia, and was a professor of space science at Rice University, Houston, 1963-1968, and a NASA principal investigator. He was the first Australian awarded the NASA Medal for Exceptional Scientific Achievement for his radiation experiment. Professor O'Brien was elected a Fellow of the Academy in 1993.

By Megan Clark

A year on and we're in orbit

Very few things inspire quite like space, and this has been exemplified during the first year of the Australian Space Agency.

The Australian community is really engaged, our team has opened doors internationally, updated space legislation, and is working with partners on future space missions and projects. You can feel the momentum across the country.

The Agency is on the right trajectory to transform and grow a globally respected space industry, and to reach and inspire all Australians.

We have listened to what the sector has told us through consultations across all states and territories and we have sought to reflect the view of the nation in the Australian Civil Space Strategy 2019-2028.

Threaded through the Strategy are our values – Australia as a responsible global citizen; being safe and secure in space and on Earth; achieving shared ambition through partnership; doing what we say we will do; embracing entrepreneurship and inclusion; and being curious to learn more.

Australia may be considered new to the field, but we are already showing the world our ideas. We have proven we can be on the frontline of technological innovation.

For example, Geoscience Australia is working to deliver 10cm positioning across our sea, land and airspace by correcting the global positioning system satellites signals and 3cm precise positioning in our cities with additional corrections from the mobile phone networks.

3cm accuracy will not only help our emergency services but can transform automated transport in our cities. Farmers, marine vessels and regional services managers will all benefit from bringing our national GPS up to 10cm accuracy.

Australia's position in the southern hemisphere means we have a different view into the solar system. Australia will be a key receiving station for all planned solar system missions for the European Space Agency at their New Norcia facility in WA and for NASA at its Deep Space Communication Centre at Tidbinbilla in the ACT. Both these ground stations are run by CSIRO.

Australia has a lot to offer in the area of automation and robotics. What Australia has learnt – through operating the largest automated railway on earth, and automated drills and trucks in the Pilbara, using control rooms over 1500 km away – is really valuable as we look to return to the Moon and Mars.

NASA's planned command and service module that will orbit the Moon, called Gateway, along with the International Space Station, will have increased levels of automation.

It is not a surprise that NASA is already working with Australian industry partners like Woodside on such automation. NASA is also in discussions with Equatorial Launch Australia to launch small sounding rockets from its commercial space port site in the Northern Territory in 2020. This is a small step, but it's NASA's first use of a non-government spaceport.

Technology is rapidly developing, especially in the space field. The technology being developed in the space sector affects everyone's lives and is changing our society.

Today we locate ourselves using GPS satellites – tomorrow we will automate transport in our cities using precise positioning.

Today we use communication satellites for wi-fi on planes and ships – tomorrow we will industrialise the low earth orbit and use lasers for high bandwidth data links in space and back to earth.

Today our farmers plant their wheat seeds between the rows of stubble of last year's crop using satellite-aided precise positioning and monitor the health of their crops from space – tomorrow they increase yields using several images a day from space and sensor data connected to constellations of small satellites in low earth orbit.

We will 3D print rocket components and use new propulsion systems to develop smaller, cheaper rockets. Spaceports in Australia could support commercial space operations, from space tourism to space station resupply missions.

Australian companies and researchers are working on all of these examples.

Australia is already showing the world our ideas. We are demonstrating that we can be on the frontline of technological innovation.

Dr Megan Clark
AC FTSE

Megan Clarke is Head of the Australian Space Agency. She was CEO of CSIRO 2009-2014 and is a Non-executive Director of Rio Tinto. Dr Clarke has a background in mine geology, and was elected a Fellow of the Academy in 2006.

MORE

EXPLORE
Learn more about the Australian Civil Space Strategy at: industry.gov.au/data-and-publications/australian-civil-space-strategy-2019-2028

HEAR
Hear Dr Clark talk about the Australian Space Agency in one of our podcasts online.

atse.org.au

By Benjamin Hickey

Helping the Sunshine State shine

How Mike Ahern helped move Queensland's tech sector into the 21st century.

When the then Premier of Queensland congratulated Mike Ahern on becoming the state's first technology minister, he answered: "What's technology?"

"You'll work it out," was the Premier's reply. In the almost four decades since, Michael Ahern FTSE has worked tirelessly to make the Sunshine State a brighter place for science and innovation.

"Someone got the idea that we needed a technology minister," Mr Ahern said, "and they appointed me. I was Primary Industries Minister and I have a degree in agricultural science." In fact, he was then the only member of the Queensland Cabinet with a tertiary education.

"It was an interesting challenge because there was no department, no offices and no departmental people designated to technology. But I got on with it, and I enjoyed it, and it's worked."

Mr Ahern travelled around the world to get a handle on what might be possible in a state with a small population. Then, he set about transforming Queensland into a "technology-based community better equipped to handle the challenges of the future" – a mission he continued as Premier from 1987-1989, and in the private sector to this day.

"It's not a short-term project to look at the character of an economy, conclude there's too much dependence on old-style industry like mining, and try to move it to a knowledge and technology base," Mr Ahern said.

At first, not everyone was on board with the fledgling department's ambitions. "We were pilloried to begin with," Mr Ahern said. "We bought a paddock down at Eight Mile Plains on the freeway to the Gold Coast and named it our 'tech park'.

"The Courier Mail ran a series of cartoons saying how ridiculous that was, because the only things on our tech park were two cows. Today there are 400 companies there, including the biggest employer in Brisbane."

One of Mr Ahern's proudest achievements is his championing of health technology. As Premier, he introduced a tobacco tax in Queensland and used the proceeds to fund a new building, the Bancroft Centre, for the QIMR Berghofer Medical Research Institute.

The Institute, located at the Brisbane Royal and Women's Hospital, has more than 1000 researchers. There is a similar-sized research centre at the Princess Alexandra Hospital.

"We've got two of the biggest medical research centres in the world in Brisbane now," Mr Ahern said. "You can't build a hospital in this state unless you've got a research component in what you do."

Until recently, Mr Ahern also chaired the Consultative Committee of the Queensland Centre for Advanced Technology (QCAT), a joint venture between CSIRO and the Queensland Government. He fondly remembers its inception – yet another paddock-related success.

"The CSIRO came to me and said 'We're cluttered where we are at St Lucia, we need to move out into more spacious surroundings'. So we bought a paddock out at Pullenvale, and today QCAT is still there, with close to 400 researchers.

"Outside of China," he says proudly, "it's the biggest mining research centre in the world. Twenty per cent of the people employed in Brisbane are in the mining services sector. It's not just about getting commodities onto trucks and off again, it's about adding value to the industries we have."

Those industries are diverse and Mr Ahern is as excited as ever about the many tech initiatives he's seen, and helped make, flourish.

"The Centre for Defence Technologies has come to Queensland and transformed the state in many ways," he said. "The Centre for Virtual Mining in Brisbane is a remarkable place to visit. And the universities have really blossomed. They're now a very important part of the state's economy."

Mr Ahern is also the founder of the Queensland Community Foundation, a $200 million philanthropic trust. One third of the endeavours it supports are medical research-related.

"Of course, I haven't operated alone. I always had a lot of people that were working with me."

Mr Ahern was elected a Fellow in 1997 and considers his involvement in the Academy "a real pleasure and an honour."

He says that the Academy "has had a very strong presence here in Queensland. It provides leadership in our state, and has played pivotal role through its STEM programs. People have sat up and taken a lot of notice of the Academy.

"There's a vast difference in the character of the state of Queensland from 1968, when I entered the parliament, to today. There's an enthusiasm for innovation that runs up and down the economy, and it's ensuring the future."

Michael Ahern
AO FTSE

Mike Ahern was Premier and Treasurer of Queensland 1987-1989 and a member of Queensland's parliament 1968-1990. He has been on numerous boards across a range of sectors, including the Board of Governors of the Clunies Ross Foundation.

By Marlene Kanga

Creating World Engineering Day

Did you know that, until recently, "engineering day" differed all over the world? Engineers in Bangladesh were honoured on 7 May, Mexican engineers were feted on 1 July, and here in Australia we got a week in August.

Dr Marlene Kanga
AM FTSE

A trailblazing engineer with a successful career in the oil, gas and chemical industries, Marlene Kanga is President of the World Federation of Engineering Organisations. She was named the 2018 Professional Engineer of the Year by Engineers Australia, of which she was previously the National President. Dr Kanga has been listed among the Top 100 Women of Influence in Australia and the Top 100 Engineers in Australia.

Image: The UNESCO Executive Board meeting in Paris in April 2019.

But there's never been a global day to celebrate engineers and engineering – until now. Starting from 2020, 4 March every year will be World Engineering Day for Sustainable Development.

The first stage of this historic decision was made on 17 April, when the UNESCO Executive Board recommended the UNESCO General Conference proclaim the Day when it meets in November.

As President of the World Federation of Engineering Organisations (WFEO), I led the proposal for the Day. I had never done anything like this before and didn't know at the outset whether our dream would be achieved. It's been a remarkable journey with many twists and turns.

Engineers are often not very good at articulating the value of what we do for society. That's a problem, because engineering is critical to achieving the UN Sustainable Development Goals. We have a big role in ensuring that everyone has access to clean water, sanitation, reliable energy and other basic human needs.

There's also a great deal to be done in developed countries. As we all face the impacts of climate change, environmental crises, our growing cities and the challenges posed by new technologies like artificial intelligence, we're going to need more engineers.

So how do we engage with young people – especially girls – and say: "If you want to make change for a better world – become an engineer"?

A globally celebrated day is a wonderful opportunity to talk about these issues and raise community consciousness about our work. The WFEO decided to pursue UNESCO recognition for engineers in 2018, as part of our 50th anniversary celebrations. The Day we chose was 4 March – the day our federation was founded.

Making the Day a reality was like moving a mountain. It was a process of learning fast and engaging with many nations and cultures in a short time. Things really came together in the last three months of the process.

After extraordinary work from all involved, we received some 80 letters of support from peak international and national institutions, academies and national commissions to UNESCO. These organisations represent about 23 million engineers around the world.

I am very pleased to say that our supporters included the Office of the Chief Scientist, the Australian Academy for Technology and Engineering, the Chinese Academy of Engineering and the Royal Academy of Engineering, UK.

One by one, UNESCO member states backed our resolution. I'm especially grateful to Namibia and China, who agreed to lead the proposal. Eventually, we got support from every continent. We now have the backing of more than 40 nations, including:

Namibia, China, Tanzania, Mozambique, Gambia, Equatorial Guinea, Zimbabwe, Palestine, Egypt, Tunisia, Uruguay, Senegal, Liberia, Nigeria, Turkey, Madagascar, Dominican Republic, Guatemala, Mali, Iraq, Gabon, Cote d'Ivoire, Ethiopia, Serbia, Saudi Arabia, Pakistan, Russia, Poland, Kenya, Iran, Nicaragua, Oman, Bangladesh, France, Comoros Islands, Liberia, Jordan, Philippines, UK and others.

In April, the motion passed: 4 March will be World Engineering Day for Sustainable Development every year from now on! An international day with co-ordinated celebrations across the world will, we anticipate, help inspire thousands of young people to become engineers.

This is an opportunity to speak to government, industry and community about the importance of engineering for sustainable development. It's a platform on which to build the strategies, capacity and best practices we need to meet global problems with engineering solutions.

We intend to use social media and traditional media to promote the Day. We're also asking institutions to register their own events through a dedicated web site to build the momentum for celebrations. We expect this to grow become more important each year and as each nation makes the Day their own.

This is a huge achievement for the profession and for the WFEO. I am proud and grateful to have been able to lead and facilitate the initiative. So remember to put 4 March 2020 in your calendar – and, in advance, happy World Engineering Day!

By Mark Hoffman

Safety by design

In less than 12 months, four Sydney unit blocks have been evacuated due to major building defects or safety issues. Professor Mark Hoffman talks about went wrong with the Opal Tower – and what needs to change.

Professor Mark Hoffman
FTSE

Mark Hoffman is the Dean of Engineering at UNSW Sydney. His expertise is in the area of structural integrity of materials, specifically the design of materials for high reliability in complex environments through a combination of computational modelling and investigation using an extensive mechanical property research laboratory at UNSW. His research covers fracture mechanics, fatigue, and wear and tribology from the macro- to nano-scale.

It is now eight months since I was first called upon to investigate the structural damage to the Opal Tower at Sydney Olympic Park.

While obviously an extremely unfortunate and stressful experience for the residents, I believe that if the recommendations emerging from the investigation are put into practice, the event will one day be seen as a watershed moment for construction and design practices – and their regulation – across Australia.

Before looking at what we learned from the Opal Tower incident, let me first recount how it unfolded and how I became involved.

It was 27 December 2018 when I got a call from the then NSW Minister of Planning, Anthony Roberts. Three days earlier, on Christmas Eve, residents of the Opal Tower had made initial reports of "a loud bang" and concrete cracking on the 10th floor.

More than 300 residents were subsequently evacuated, before being allowed to return shortly afterwards. Now it was looking like they needed to evacuate again as further similar damage had been found in another location.

It was, therefore, a highly stressful situation that was unfolding under the glare of the media spotlight – not least for the hundreds of residents whose Christmases had just been ruined.

Minister Roberts told me that he was getting advice from the Opal Tower builders, the engineers, his own department and the apartment owners about what had happened, who was responsible and what needed to be done.

While all had strong opinions, none of them had a view across the whole issue. What he really needed, he told me, was independent expert advice, and he needed it very quickly.

So by the end of that afternoon I was walking into the Opal Tower just as hundreds of people were again on their way out. It was quite slow going because the lifts were packed with people trying to move. It was obvious how distressing this experience was for many of them – understandably so.

With me was University of Newcastle Emeritus Professor John Carter FTSE, who is a geotechnical engineer. There were a lot of the rumours flying around at the time about an issue with the foundations, which is his area of expertise.

Within a few hours, however, it was clear to both John and me that the problem wasn't necessarily with the foundations at all (subsequent investigation confirmed they were fine). Rather, there was a significant issue with reinforced concrete fracturing.

That's when we called in Professor Stephen Foster, Head of UNSW's School of Civil and Environmental Engineering. Steve wrote the Concrete Structures Standard for Australia AS3600, so was a welcome addition to the team.

Over the coming days, we gathered information that we put into an interim report released on 4 January and then a final report on 22 February.

There were four main observations:

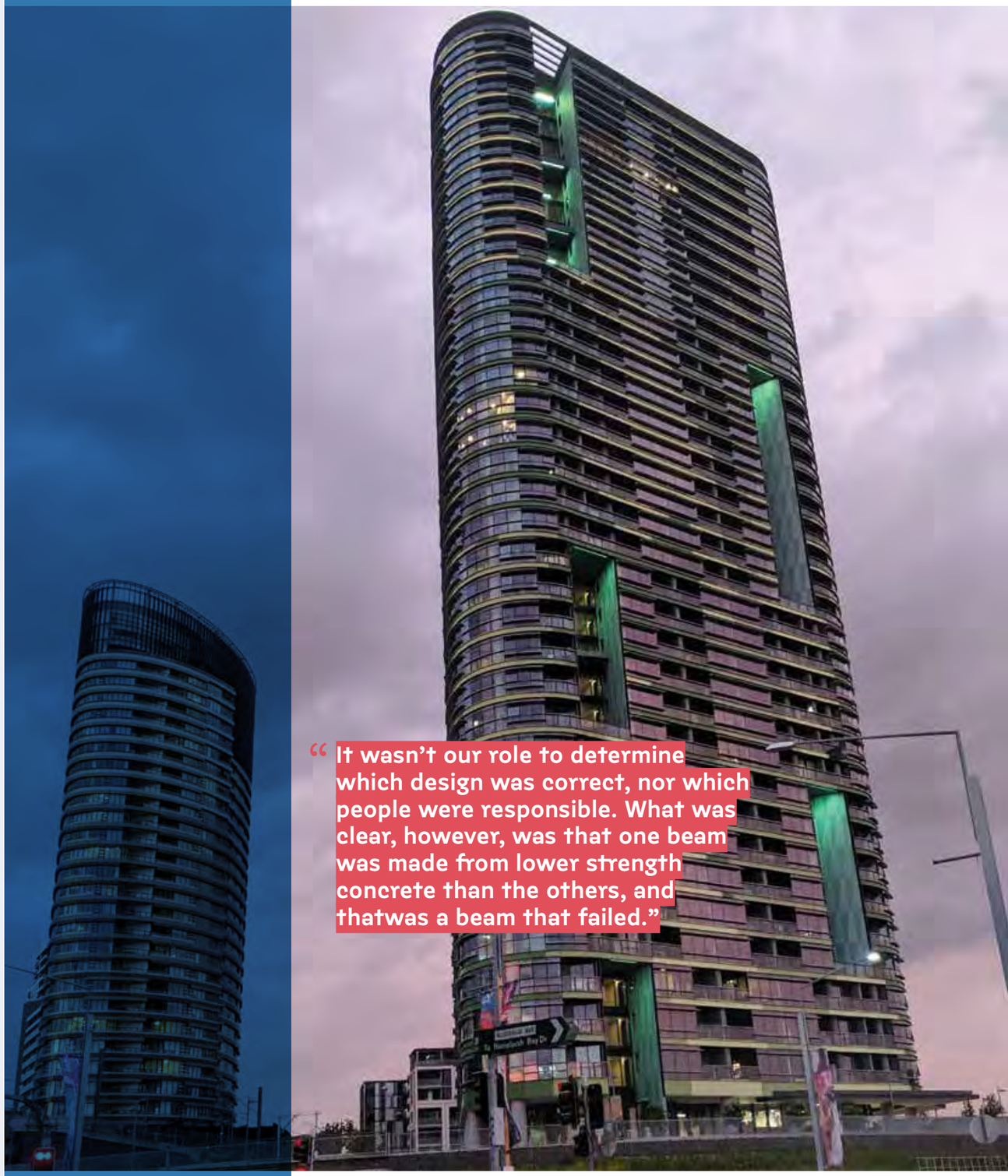
1. Some hob beam/panel assemblies at a number of locations in the building were found to be susceptible to failure by shear compression and bursting. It appeared as-constructed, they were under-designed according to the National Construction Code (NCC) and the Australian Standard for Concrete Structures (AS36001).
2. The decision – taken after the initial design – to grout only partially the joints between the hob beams and panels significantly raised the levels of stress in the hob beams on levels 4, 10, 16 and 26.
3. Construction and material deficiencies likely precipitated the observed major damage to hob beams on Level 10-C and Level 4-A.
4. The observed damage in the concrete panel at Level 10 and in the Level 10 floor slab was likely a consequence of the adjacent hob beam failures and not the original cause of the damage observed at Level 10.

So what led to these failures? Essentially, there were changes made to the initial design during the construction process that raised the loads on some beams. We subsequently identified a problem with processes around design approvals and monitoring during construction that allowed some non-standard practices to slip through.

For example, in one case the initial approved design was changed, specifically to reduce the amount of grout between a pre-cast concrete panel and the hob beam. As a result, the load on the hob beams was increased.

This meant the design was effectively below standard. Generally this would still have been okay, as this standard is conservative. But when incorrectly placed electrical conduit and reinforcing steel reduced the hob beam's strength, this compounded the grouting issue, causing the failure of a concrete beam.

In another case, a beam was found to have failed where a lower-grade concrete was used than in other beams. Different strengths of concrete are



> "It wasn't our role to determine which design was correct, nor which people were responsible. What was clear, however, was that one beam was made from lower strength concrete than the others, and thatwas a beam that failed."

often used on large construction projects like the Opal Tower. For example, columns are built to a strength of 80 megapascals, while the floor is set at 40 megapascals concrete.

On a large-scale construction such as this, trucks are turning up all the time to pump and pour the concrete. It was during this process when a beam was poured with a lower strength concrete than the others.

So in our investigations, we had to ask the question: why wasn't this dealt with at the time? The problem was not that the lower strength concrete beam went through unnoticed.

The real problem was that various versions of the design drawings indicated different strengths of concrete for the same beam. In other words, when consulting one version of the designs, the beam appeared to be following design.

It wasn't our role to determine which design was correct, nor which people were responsible. What was clear, however, was that one beam was made from lower strength concrete than the others, and that was a beam that failed.

Our first recommendation was to fix the structural damage in the building to correct the very localised but significant errors. Very quickly, risks were reduced by inserting grout and bracing around the damaged sections. The highly reputable, independent engineering teams who designed the structural rectifications have ensured it will be far stronger than originally planned.

In our final report, we made other recommendations about how to avoid these incidents in the future.

Australia's National Construction Code is based on the principle that our buildings should be structurally safe. And they are. But the full breadth of consumer expectations regarding building quality is not really addressed in that code.

This is left to the state governments and they have not been as effective in this regard. For example, in NSW to date, much is vested in a sign-off from a building certifier that presumes everything in the build is okay.

Now in the case of Opal Tower, the certifier had done that, and had done nothing wrong that we could see. But the problem is that the certifier's job is not to check that everything's okay. He or she only checks that all the appropriate approvals have been signed off along the way, relying on a trove of documentation.

The certifier signs off on the final layer of a tiered structure of information, and somewhere in that tree somebody may have signed off on something that wasn't right, or proceeded without an approval process. But there's no real double-checking and nor is it transparent to stakeholders.

We had a ministerial directive and it still took us quite a lot of time to get some of the required documentation. It wasn't that people were being obstructionist – the documents just couldn't be accessed easily.

We recommended that all of this documentation should be on a curated website. When you have transparency and names on a document, people have a far different approach to owning the work than when they know the documentation will be filed away in a drawer somewhere.

Another important recommendation we made was a call for the registration of engineers. Most states including NSW don't register engineers, so responsibility to manage construction projects and sign off on the designs is unclear.

Registration of engineers would ensure agreed standards, accountability and reviews of training and performance. This has been talked about for a long time, and I'm hopeful the NSW Government is seriously considering it. This is also an important step for the next two recommendations.

First, all designs should be independently peer reviewed by registered engineers. In many cases, designs are reviewed internally within an organisation. No doubt, there are highly qualified people to undertake these internal reviews, but the dynamics and accountability are much more robust if the review is independent.

Second, it also emerged from our report that there is no robust process for changing an original design. When you're building, things happen. Designs need to be changed or, for example, the wrong concrete truck turns up and pours the concrete for that failed beam. With hundreds turning up in the course of the building, it's no surprise there's a mistake.

But there should have been a formal sign-off process by qualified and registered engineers. Such a practice would have also clarified the design ambiguities we identified.

If it's mandated that designs and any changes to critical elements are signed off by qualified and registered engineers, your system becomes much more robust. Such a system would not be that much more expensive if one focuses on critical components.

Interestingly, there was some commentary in the media that the Opal Tower incident was the tip of the iceberg for a lot of other similar problems in the industry, and that the residents of the Opal Tower were lucky it occurred on Christmas Eve because of the added media coverage it received.

However, in reality, there are very rarely major structural issues with the design and construction of buildings in Australia like we saw here. However, it's true that structures are often not built as they should have been, with deficiencies in cladding, waterproofing problems in bathrooms, or sub-standard electrical work.

So yes, quality is a real issue. But the safety issues addressed by the National Construction Code is more robust. And there's quite a difference if something goes wrong. We're talking about the difference between wasting money from sub-standard quality – which is of course incredibly frustrating – and structural problems that likely endanger people's lives.

From a quality point of view, there are definitely problems in the industry, but from an overall building structure safety point of view, we're in reasonable shape.

It will be interesting to see how the NSW Government reacts to our recommendations. Up until now, there have been a number of reports and anecdotal discussions about the sort of problems that we witnessed here, but no one has ever really wanted to grasp the nettle and do something about it.

With the Opal Tower incident bringing these issues into very sharp focus, perhaps the construction industry will be the better for it.

"Australia's National Construction Code is based on the principle that our buildings should be structurally safe. And they are. But the full breadth of consumer expectations regarding building quality is not really addressed in that code."

Fellows and staff honoured on Queen's Birthday

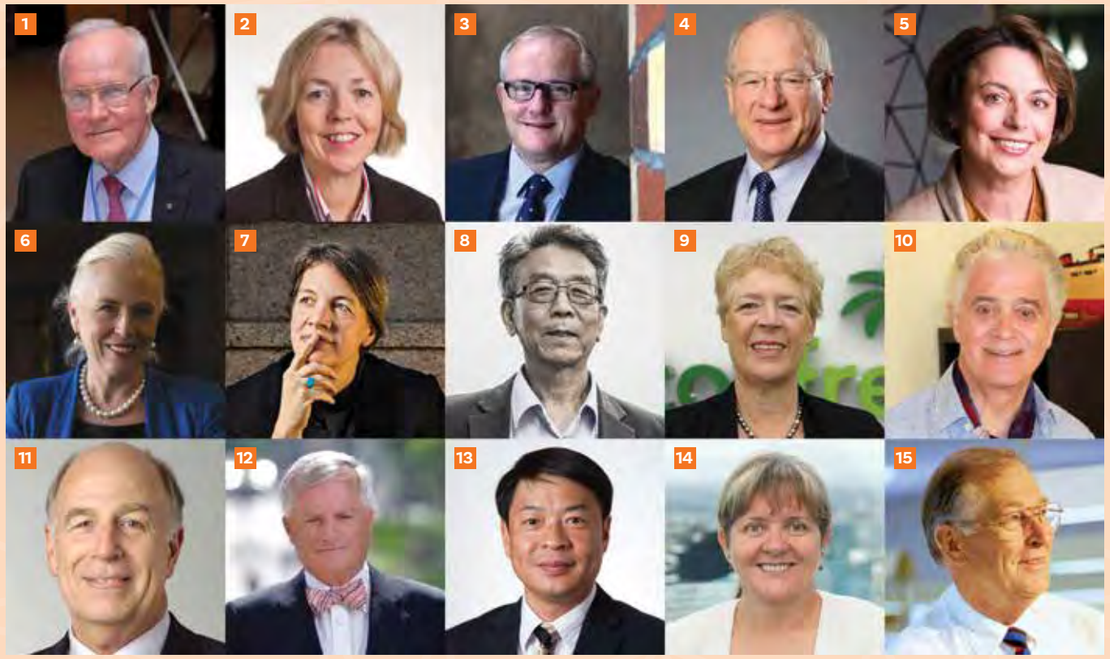
Fourteen Fellows and one Academy staff member have been named in the Queen's Birthday honours list.

Academy President Professor Hugh Bradlow FTSE said: "On behalf of the entire Fellowship, I'd like to congratulate the 14 Fellows and one staff member who have been honoured.

"The awards reflect a deep commitment to applying science and technology to solving the complex problems facing Australia.

"They are also a tribute to many years of dedication to public service, whether in our universities and research organisations or in industry.

"The Academy is proud of all of you."



COMPANION OF THE ORDER OF AUSTRALIA (AC)

1 **Professor David Burke**
AC FTSE FAA (NSW)
University of Sydney
For eminent service to neurophysiology, to innovative treatments for spinal cord and brain trauma injuries, and to professional medical organisations.

2 **Emeritus Professor Maree Smith**
AC FTSE (QLD)
University of Queensland
For eminent service to science through pioneering research and innovation in the treatment of neuropathic pain, to gender equity, and as a role model. She is a 2016 Clunies Ross winner.

OFFICER OF THE ORDER OF AUSTRALIA (AO)

3 **Professor Calum Drummond**
AO FTSE (Vic)
RMIT University
For distinguished service to chemistry and materials science research, to commercialisation initiatives, and as a mentor.

4 **Mr Dale Elphinstone**
AO FTSE (Tas)
Elphinstone Group
For distinguished service to business, particularly to the resources and manufacturing sectors, and to the community of Tasmania.

5 **Ms Kathryn Fagg**
AO FTSE (Vic)
Boral
For distinguished service to business and finance, to the central banking, logistics and manufacturing sectors, and to women.

6 **Ms Susan Murphy**
AO FTSE (WA)
West Australian Treasury Corporation
For distinguished service to the natural resources sector in Western Australia, and
to engineering.

7 **Professor Michelle Simmons**
AO FTSE FAA (NSW)
University of New South Wales
For distinguished service to science education as a leader in quantum and atomic electronics, and as a role model.

MEMBER OF THE ORDER OF AUSTRALIA (AM)

8 **Distinguished Professor Shi Xue Dou**
AM FTSE (NSW)
University of Wollongong
For significant service to science education in the field of superconducting and electronic materials.

9 **Ms Katherine Hirschfeld**
AM FTSE (QLD)
Powerlink
For significant service to engineering, to women, and to business.

10 **Dr Ian MacLeod**
AM FTSE (WA)
Heritage Conservation Solutions
For significant service to the museum and galleries sector.

11 **Dr Mark Toner**
AM FTSE (Vic)
Gender Matters
For significant service to engineering and the technological sciences.

12 **Dr Peter Tyree**
AM FTSE (NSW)
Tyree Foundation
For significant service to engineering and to education.

13 **Professor Yi-Min Xie**
AM FTSE (Vic)
RMIT University
For significant service to higher education, and to civil engineering.

14 **Dr Marguerite Evans-Galea**
AM (Vic)
IMNIS, Academy of Technology and Engineering
For significant service to women in STEMM as an advocate and role model. Dr Evans-Galea is the Executive Director of IMNIS and an Academy staff member.

MEDAL OF THE ORDER OF AUSTRALIA (OAM)

15 **Mr Ernest Frederick Dawes**
OBE OAM (Vic)
Eprep
For service to the community.

Tim Reeves awarded Farrer Memorial Medal

Professor Tim Reeves FTSE was awarded the 2019 Farrer Memorial Medal, acknowledging his contribution to sustainable agriculture through work in agricultural research, development and extension.

Dr John Radcliffe AM FTSE said the Farrer Memorial Research Scholarship provided encouragement and inspiration to those engaged in agricultural science.

"I congratulate Professor Reeves, whose 50-year career has contributed to positive advances in agriculture in Australia and overseas," Dr Radcliffe said.

"As a pioneer of no-till and conservation agriculture research at the Rutherglen Research Institute his impact can be seen in the modern farming practices we use today.

Professor Reeves has served as director of many boards and is currently a director of the Crawford Fund for a Food Secure World. A national and international consultant in agricultural research, his focus remains focused on global food security and the sustainable intensification of agriculture and farming systems.

Professor Reeves was elected a Fellow of the Australian Academy of Technology and Engineering in 2001. He serves on the ICM Agrifood Award Selection Committee and the Academy's International Strategy Group.

The Farrer Memorial Medal is awarded annually to commemorate William James Farrer, Australia's leading wheat breeder, in recognition of distinguished service in agricultural science and contribution to Australia's cropping industries.

More information about the Farrer Memorial Medal is available on the NSW DPI website.

Image above: Professor Tim Reeves FTSE with the Farrer Memorial Medal.

Fellow honoured for 60 years of science leadership

Academy Fellow Professor Greg Tegart AM FTSE has been awarded the Professor Robert Boucher Distinguished Alumni Award by the University of Sheffield in the UK.

University representatives presented the award to Professor Tegart at a reception in Melbourne. It recognises his distinguished career as one of Australia's most eminent scientists and engineers.

Professor Tegart, who celebrated his 90th birthday in March, has made invaluable contributions to research, government and industry.

His ongoing work has spanned six decades, several continents and the breadth of science: from metallurgy to engineering to health technology.

Melbourne-born Professor Tegart completed his PhD in Metallurgy in the University of Sheffield in 1959. He was elected a Fellow in 1976, shortly after the Academy's inception. He served as Secretary of the Federal Department of Science and Technology from 1981-1984.

In 1992 he was awarded a Member of the Order of Australia for services to science and technology.

Professor Tegart has championed technology collaboration across the globe, including in Thailand, Mongolia and Europe. He also edited the IPCC's 1992 supplementary climate change report.

Today, he is an Adjunct Professor at Victoria University, an active contributor to the Academy and Deputy Chair of the Academy's Health Forum.

His current focus is on assistive technologies for the aged and disabled that will enrich the lives of ordinary people.

Professor Tegart joked that his passion for assistive technology came "with a degree of self-interest", but he has no plans to retire just yet.

MORE

READ
Read more about Professor Tegart's latest work on page 28.

Image: Mike Hounslow, Greg Tegart and Miles Stevenson. Image: Courtesy of University of Sheffield.

Movers & Shakers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6A


6B


6C


7A


7B


7C


7D


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1. Veena Sahajwalla
The Federal Government announced that Professor Veena Sahajwalla will lead the new ARC Research Hub for Microrecycling of Battery and Consumer Wastes. She has also been appointed Executive Director of the newly announced Circular Economy Innovation Network (CEIN).

2. Ian Chubb
Former Australian Chief Scientist Professor Ian Chubb AO has been appointed Chair Elect of national peak pain organisation Painaustralia.

3. Emily Hilder
Professor Emily Hilder has been named as a new member of the South Australian Premier's Science and Innovation Council.

4. Tanya Monro
Australia's Chief Defence Scientist Professor Tanya Monro has won the 2019 South Australian Award for Excellence in Women's Leadership.

5. Richard Williams
The Royal Academy of Engineering in the UK has awarded Professor Richard Williams OBE one of its highest accolades, the President's Medal.

6ABC. Peter Klinken, Chris Pigram and Margaret Sheil
Professor Peter Klinken AC, Dr Christopher Pigram AM and Professor Margaret Sheil AO have been appointed to the Australian Space Agency Advisory Group.

7ABCD. Mark Cassidy, Lyn Beazley, Peter Corke and Alexander Zelinsky
Professor Mark Cassidy, Professor Lyn Beazley AO, Distinguished Professor Peter Corke and Professor Alexander Zelinsky AO have been elected Fellows of the Australian Academy of Science.

8. Bruce Godfrey
Dr Bruce Godfrey gave a seminar to the Parliament of Victoria on the future of energy storage.

9. David Hurley
Honorary Fellow HE David Hurley AC DSC has been sworn in as Governor-General of Australia.

10. Leanna Read
Uniseed, the early stage commercialisation fund run by universities and the CSIRO, has appointed Dr Leanna Read to its board.

11. Erica Smyth
Dr Erica Smyth AC has been awarded the Western Australia Business Award 2019 for her ground-breaking work over 45 years in the sector.

12. Kiran Mazumdar-Shaw
Kiran Mazumdar-Shaw has been elected to the Board of Trustees of the Massachusetts Institute of Technology.

13. Peter Yates
Dr Peter Yates AM delivered the prestigious Ralph Slatyer address on science and society at the opening of the Collaborate Innovate 2019 conference.

14. Margaret Hartley
Academy CEO Dr Margaret Hartley spoke on the closing panel of the Collaborate Innovate 2019 conference. The theme of the panel was "maximising research impact".

15. Bogdan Dlugogorski
Professor Bogdan Dlugogorski has been appointed Deputy Vice-Chancellor and Vice-President, Research and Innovation at Charles Darwin University.


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16. Chennupati Jagadish
Professor Chennupati Jagadish has been elected a Foreign Fellow of the European Academy of Sciences. He also led this year's delegation of young Australian physicists to the Lindau Nobel Laureate Meetings in Germany.

17. Peter Høj
Professor Peter Høj has been awarded the Honorary Degree of Doctor of the University of Adelaide. He has also received the Council for Advancement and Support of Education (CASE) award for Asia-Pacific Leadership.

18. Min Gu
Distinguished Professor Min Gu has been appointed Executive Chancellor of the University Council at University of Shanghai for Science and Technology (USST). USST also named him Distinguished Professor for Future Optics in the School of Optical-Electrical and Computer Engineering.

19. Eric Wolanski
The EU Council Presidency invited Professor Eric Wolanski to give a talk in Bucharest in May.

20. Bronwyn Fox
Professor Bronwyn Fox has secured $1 million through the Global Innovation Linkages Program for a project focused on manufacturing high-volume lightweight composites.

21. David Abramson
Professor David Abramson has been elected as this year's President of the Computing Research and Education Association of Australasia (CORE).

22. Tony Weiss
Professor Tony Weiss AM has been elected the next President of the Tissue Engineering and Regenerative Medicine International Society.

23. Deo Prasad
Professor Deo Prasad AO has received the Australian Institute of Architects' National Leadership in Sustainability Awards 2019.

24ABCD. Marlene Kanga, Judy Raper, Bronwyn Evans and Elizabeth Taylor
Dr Marlene Kanga AM, Professor Judy Raper AM, Dr Bronwyn Evans and Professor Elizabeth Taylor were recognised among "10 of Australia's influential women in engineering" by Create magazine on International Women's Day.

25. Sarah Ryan
Dr Sarah Ryan has been appointed to the Director Advisory Panel of ASIC for a four-year term.

26. Di Davidson
The South Australian Government has appointed Di Davidson AM as the Presiding Member of the South Australian Murray-Darling Basin Natural Resources Management Board.

27. Vaughan Beck
Dr Vaughan Beck AM has been appointed to the NT Environment Protection Authority.

28. Karen Reynolds
Academy Director Professor Karen Reynolds has been awarded the Flinders University Convocation Medal.

29. Fiona Stapleton
Professor Fiona Stapleton has received the H Barry Collin medal for outstanding research from Optometry Australia.

30. Anne Simmons
Professor Anne Simmons has become inaugural Provost at the University of New South Wales.

31. Katherine Woodthorpe
Dr Katherine Woodthorpe AO has been appointed Chair of the Bushfire and Natural Hazards CRC.

32. Graeme Jameson
Professor Graeme Jameson AO is a winner of the Coalition for Eco-Efficient Comminution's 2019 Technical Medal.

Sir Arvi Parbo
AC Kt FTSE

The Academy mourns the loss of a towering figure in Australian mining, engineering and business with the death on 1 May of Sir Arvi Parbo AC Kt FTSE.

Sir Arvi was appointed managing director of Western Mining Corporation in 1971 and chairman in 1974. He stepped down as MD in 1986, but stayed on as executive chairman until 1990 and chairman thereafter. From 1989 to 1992, he chaired BHP.

He received a knighthood for services to industry in 1978 and was the inaugural President of the Business Council of Australia from 1983 to 1984.

Sir Arvi was elected to the Academy in 1977 and served a three-year term as our fourth President (1995-1997).

Academy President, Professor Hugh Bradlow FTSE, paid tribute to Sir Arvi's contribution both to the Academy and to Australian industry.

"Sir Arvi is an inspirational example of how talent and hard work can pay off. Born in Estonia, he settled in Australia in 1949, graduating with a Bachelor of Engineering with first class honours from the University of Adelaide just six years later.

"His career was stellar. He is credited for discovering and establishing Olympic Dam, one of the world's most significant deposits of copper, gold, silver and uranium and still being worked by BHP today.

"We benefited from those attributes here at the Academy. Sir Arvi served on our Council from 1988 to 1997 and as a Vice-President from 1989 to 1992, before becoming President. He will be sorely missed."

The Academy expresses its condolences to Sir Arvi's wife, Lady Saima Parbo, their three children, Ellen, Peter and Martin, and six grandchildren.

Image: *Sir Arvi Parbo*, 1993 by William Dargie. Collection: National Portrait Gallery, Canberra. Gift of Alcoa World Alumina Australia, 2005. Image courtesy of National Portrait Gallery, Canberra.

Tim Andrew Fischer
AC FTSE

I would like to touch on Tim Fischer's contributions in three areas where I have been involved – the Crawford Fund, the Crop Trust (previously the Global Crop Diversity Trust) and the Country Education Foundation.

Tim was appointed Crawford Chairman in 1999 for a five-year term, was Patron for several years, and was appointed an Honorary Academy Fellow in 2000. He was persuaded by the then Crawford Fund CEO, Dr Bob Clements AO FTSE, to convince the Australian Government to support the fledgling Global Crop Diversity Trust, with its aim to conserve plant genetic resources.

Tim's appointment as Ambassador to the Holy See in 2008 brought him close to FAO (the UN Food and Agriculture Organisation) and the headquarters of the Trust, and my own Bioversity International.

Tim was Vice-Chair of the Crop Trust from 2013 – 2017 and subsequently Chair in 2018. He visited the Svalbard Global Seed Vault in February 2014 to help the Australian contingent deposit Australia's second tranche of seeds – 15 boxes containing 10,069 samples, including one from his Boree Creek farm.

Finally Tim was Patron of the Country Education Foundation (CEF), based in NSW. This organisation is community-based and helps rural youth to improve their education and career prospects.

I last saw Tim at the May meeting of the Academy's Victorian Division meeting, where I was talking about the future of agriculture and Svalbard. He had called to say that the doctors wouldn't let him out of hospital. Five minutes into the talk he snuck into the back of the room.

A very fine, passionate and generous person whose passing will be a terrible blow to all Australians and especially to his family. I for one will miss him terribly – no more phone calls about the rain, or crops, or an obscure railway branch line near Murtoa, or Mark Twain visiting Horsham!

This tribute was written by Tony Gregson AM FTSE. A longer version can be found at atse.org.au.

Tim Fischer carrying Australian seeds into the Svalbard Global Seed Vault, within the Arctic Circle.

Andrew Elmhirst Potts
FTSE

A deep legacy in the world of drilling

Professor Andrew Elmhirst Potts was an engineer, entrepreneur and luminary who made global breakthroughs in offshore drilling.

Born in 1959, Professor Potts graduated from Monash University with a Bachelor of Engineering in 1983 and a Master's in Offshore-Structural Engineering Science in 1989. He completed his PhD in Offshore Engineering at the University of Reading in 1993.

In 1991 Professor Potts founded the Australian Marine Offshore Group, which went on to trade as AMOG Consulting. AMOG does engineering work in the oil, gas, mining, transport, renewable energy and defence sectors. Under his leadership, the company grew from humble beginnings to become a global consultancy that operates across five continents.

Professor Potts was motivated by a dedication to engineering, a passion for innovation, a devotion to sharing his knowledge and drive to excel. Elected a Fellow in 2017, he championed engineering excellence through partnerships with companies, governments and academia.

Renowned for his commitment to research and development, Professor Potts won numerous awards, spearheaded leading joint industry projects, developed patented technology and presented technical papers at conferences around the globe.

One of his passions was the science of biomimicry: the use of features from nature for mechanical engineering outcomes. He researched the fluting on cactuses that withstand high winds and applied these insights to design more resilient drills.

His work in the offshore oil and gas sector including projects relating to fixed and floating offshore structures, submarine pipelines and highly flexible systems such as moorings and flexible risers. He was an expert in advanced numerical and finite element analyses and physical model testing, and designed criteria, facilities, structures, operations and installations.

A skilled project manager and technical engineer, Professor Potts often provided specialist advice in legal cases, business plans, project management, specification development, tender evaluation, contract negotiation and assessment of contracts..

This work often extended into the field of failure investigation, forensic engineering and the provision of expert witness services. Professor Potts was also an authority in the area of steel wire ropes and fibre rope systems used in marine applications.

Professor Potts died on 6 March 2019 aged 59. He is survived by his wife Sue and six children.

With thanks to AMOG Consulting.

Eric Raymond "Lou" Vance
AO FTSE

Physicist's life full of discovery

Professor Eric Raymond Vance known as Lou to almost all of his friends and colleagues, was born in Ararat in Victoria in 1942.

From his school years at nearby Stawell, Professor Vance showed remarkable capacity for scholastic achievement, sharp insight and unusual inventiveness. He had an early passion for cricket and football and continued to play tennis, golf and bridge throughout his life.

After graduating with a PhD in Physics from Monash University in 1968, Professor Vance held several research positions in Australia, Canada, the UK and the USA.

He finally settled with his wife, Jan, and their two children, Julia and Michael, in a position with ANSTO. There he researched Synroc, an artificial mineral for safely locking away various radioactive elements.

Professor Vance's research embraced many different areas of the physics of materials, and included studies of magnetism in metallic alloys, neutron irradiation effects in diamonds and other minerals, properties of glass ceramics and geopolymers.

Drawing on his knowledge of waste-form technology from his research in Canada, and enthusiastically applying this to the Synroc program, Lou progressed within ANSTO, being promoted to Senior Research Scientist in 1987 and to Chief Research Scientist in 2001.

He was elected a Fellow of the Academy in 2003. In 2007, Lou was awarded the Leverhulme Fellowship to work at Cambridge University in Earth Sciences, and later made a Fellow of Clare Hall. He was also a Fellow of the Australian Institute of Physics, the American Ceramic Society and the Australian Ceramic Society.

Lou was also an Academician of the World Academy of Ceramics, a long-time member of the Materials Research Society and a member of the Australian Nuclear Association.

He was author or co-author to almost 400 articles in international journals or conference proceedings. He held editorial and/or advisory board roles for a number of esteemed academic journals.

In 2018, Lou was awarded the prestigious ANSTO CEO Award, jointly with the late Dr Mark Reinhard, for his sustained research contribution. It is a measure of his scientific leadership and achievements within the Synroc program that a commercial scale Synroc processing plant is currently under construction on the ANSTO site.

He leaves behind a legacy in terms of his science but also his attitude and approach to life. Lou died on 7 March 2019. He is survived by his wife Jan, children Julia and Michael, and four grandchildren.

With thanks to Dr Brian Edwards, Dr Trevor Finlayson, Dr Daniel Gregg and Graeme K

Peter John North
AM FTSE

Captain of industry made his mark

Peter John North was a leader in the engineering and automotive sectors who had a profound insight into the transformative character of emerging technology.

He attained a Bachelor of Mechanical Engineering with Honours at the University of Sydney in 1958 and a Master in Business Administration with Distinction at Harvard University in 1960.

Mr North was Chairman of several listed companies in the wine, heavy engineering and bulk transport industries. He served in senior roles in many organisations, including McKinsey & Co, Ford Australia, British Leyland, Streeton Consulting, Cochlear, Leighton, Mildara Blass, Heggies Bulkhaul, Bishops Austrans and the University of Sydney.

Peter North was a driving force behind the Warren Centre for Advanced Engineering, a strategic thinktank within the University of Sydney. The Warren Centre brings industry, government and academia together to create thought leadership in engineering, technology, and innovation.

A member of the Founding Committee in 1979, he went on to serve as Board Director 1982-2007, Chairman 1996-2007, and was named an Honorary Life Governor.

In 1992 Mr North co-founded the Australian Centre for Innovation, which developed strategies and policies for science, technology and innovation in the public and private sectors. He continued as a Director of the Centre until it wound up in January 2019.

Mr North was elected a Fellow in 2003 and was an active member of the NSW Division. He served on the Council, then the Board, and was a member of the Health Technology and Innovation forums.

He was deeply committed to sustainability. He was a member of the Club of Rome, a proud advocate for action on climate change and, with his wife Ronwyn, a passionate protector of Australia's powerful owls.

He strived to better prepare Australians for a changing future.

Mr North died on 19 March 2019, aged 85.

Bernard Bowen
AM FTSE

How a bare-foot kid from Marradong came to have a minor planet named after him

Bernard Bowen was born on 6 October 1930 in Perth at the start of the Great Depression. His father was a fitter at the Midland Railway Workshops of the Western Australian Government Railways but lost this job in 1932.

The family moved to Marradong where Bernard's mother and father ran the shop, telephone exchange and petrol depot.

Bernard went to Marradong primary school, along with 14 or so other children, until he was seven. He then did correspondence school for two years and rode his bike the 14km to Boddington for another year until his mother decided that correspondence was the best option.

His elder sister, Gwenyth, studied for her Leaving Certificate by correspondence and won a scholarship to Perth Modern School (PMS), the first correspondence student so to do. The family decided that when she went to Perth to attend PMS, Bernard would become a boarder at Wesley College.

The barefoot country lad took a while to settle in at Wesley but eventually excelled both academically and on the sporting fields. He began a science degree at The University of Western Australia in 1949.

In 1951, Bernard graduated from UWA with a double major in mathematics and statistical mathematics, and started work as the Statistical Officer in the Department of Fisheries and Fauna in November. The Head of the Department, Alec Fraser, soon recognised that this was no ordinary statistical officer.

Fraser started giving Bernard books about fisheries, arranged for him to do a zoology major at UWA and then, in 1957, appointed him the research officer in charge of the newly created research division of the department. His main task was to learn all about rock lobsters.

Bernard's research, over a decade or so, established what happens to the rock lobster: it hatches from the egg, is transported by winds and currents well off the continental shelf for about 12 months, changes to its reef dwelling form and then returns to its shallow water grounds looking like a mature rock lobster. This work enabled the department to be able to predict the lobster's population to within about 10 per cent. This was world-class research!

About this time, in 1968, at the age of 37, Bernard was appointed Director of the Department of Fisheries and Fauna. He was therefore able to convert his research findings into a fisheries management plan.

Later, in 2000, the Western Australian rock lobster fishery was the first in the world to be certified as a sustainable and well-managed fishery by the International Marine Stewardship Council. Very few scientists see their research through from the very beginning to a completed result.

When he was appointed as a research officer in 1957, one of Bernard's tasks was to establish sound linkages with CSIRO and UWA. You might think that this sounds an easy task, but it isn't. We in universities and research organisations generally think that we can do it all by ourselves – certainly without the help of a small Western Australia government laboratory!

But Bernard, through persuasion and charm, managed to assemble all the resources needed to solve his rock lobster-related and other problems. Many of us had phone calls from Bernard where he explained that he was involved in a highly significant activity that could only succeed with participation by someone with our intellect and wisdom!

The Bernard Bowen model of collaborative research has been replicated all around the country. It was reinvented by the WA Government in the early 2000s as WAMSI, the Western Australian Marine Science Institute. Bernard's contributions were recognised nationally in 1978 when he became the sixth Western Australian to be elected as a Fellow of the Academy.

Bernard retired as Executive Director of the Department of Fisheries on 15 November 1991, 40 years after he joined as a Statistical Officer. But, of course, he didn't really retire. The Commonwealth immediately appointed him to a three-year term as Director of the newly formed Australian Fisheries Management Authority. He was appointed Chair of the CSIRO Fisheries Division Advisory Committee, Chair of one of the National State of the Environment Report reference groups and became involved with many other projects.

His next major work began in 1994 when he was appointed Deputy Chair of the WA Environmental Protection Agency. He became the full-time Chair in 1997 and remained in that position until 2003.

Bernard was the ideal person to head the EPA. He completely understood that industry's "social licence to operate" included sound environmental management. He enjoyed talking about this to industry, bureaucrats, politicians and the public.

When he retired from this position, the staff produced a glossary to interpret Bernard's sayings. For example, "I see" means "I've understood you, but it's a load of rubbish so I'll ignore it".

In 2002 he was awarded an Honorary Doctor of Science by Murdoch University for his contributions to fisheries research, marine resource management and environmental protection.

In 2008 Bernard was asked to work out how WA could develop a capability in radioastronomy. At that time, Australia was a contender for the location of a new megascience project called the Square Kilometre Array. This would be the largest ground-based astronomical facility in the world and it needed the radio quiet conditions in the midwest of Western Australia to achieve its goal of mapping the early history of the universe.

Bernard's great skills in partnership building were called into action to form the International Centre for Radio Astronomy Research (ICRAR) as a joint venture of UWA and Curtin University. Bernard served as the chair of the ICRAR Board from 2009 to 2016 and guided it through the SKA site decision and its growth into a world-leading research centre in astronomy.

UWA awarded him an Honorary Doctorate of Letters in 2016. In 2017, to recognise Bernard's contribution to the development of Australian astronomy and the SKA project, ICRAR in partnership with the International Astronomical Union, gave Minor Planet (6196) 1991 UO4 the new name "Bernardbowen".

Bernard died on 19 March 2019, aged 88. He is survived by his wife Esmé, four daughters and 11 grandchildren.

By Peter Quinn and Tom Spurling

Keeva Vozoff
AO FTSE

A pioneer in electrical geophysics

Professor Keeva Vozoff FTSE was a pioneer in electrical geophysics, an outstanding educator and mentor to students and colleagues in Australia and overseas.

Keeva was well known internationally for his outstanding achievements in geophysical instrumentation, mathematical modelling and earth sciences.

His international awards include Honorary Membership in the Society of Exploration Geophysicists in 1985 (the first in the southern hemisphere) for "scientific contributions to electrical methods in petroleum and minerals exploration, service to professional organisations worldwide, and particularly his leadership in research and postgraduate teaching of geophysics in Australia."

He received the prestigious Reginald Fessenden Award from the SEG in 2009, at the age of 81, for technical contributions in 3D electromagnetic modelling and mathematical inversion.

Born in Minnesota, he obtained his first degree, in physics, in 1949. Then followed an MSc from Pennsylvania State in 1951 and a PhD at MIT in 1956.

From 1951 to 1993, Keeva applied his talents to private geophysical companies including Geophysical Service. Academically, he was a visiting Professor at the University of Alberta, the University of California (Berkeley) and at the University of Cologne.

Keeva moved to Australia in 1972 to take up the inaugural appointment of Professor of Geophysics at Macquarie University. He immediately set to work to build his network of Australian collaborators and introduced the magnetotelluric method for deep crustal exploration, which was quickly embraced by the Bureau of Mineral Resources, the federal geoscience agency.

In 1981 he established the Centre for Geophysical Exploration Research, an institute unique in Australia at that time. The Centre conducted groundbreaking research in geophysics and hosted visiting post-graduates from many countries. Keeva retained the chair at Macquarie until 1991 and continued to be active in research until last year. He was elected a Fellow of the Academy in 1982.

Before coming to Australia, Keeva was a household name in the geophysical world. By 1958 he was known as the "father of 3D EM modelling", and in 1969, the "father of 2D magnetotelluric (MT) inversion". These milestone achievements were continued at Macquarie when, in 1975 he became the "father" of "Joint Inversion of DC resistivity and MT" and in 1978, "3D MT modelling".

Keeva's international involvement included serving on ad-hoc committees of Soviet-Australia and Indo-Australia scientific and technical cooperation from 1974 to 1975. He was also an honorary fellow of the Association of Exploration Geophysicists of India and an Alexander von Humboldt fellow in Germany in 1992-1993.

Although not an Australian by birth, Keeva has always been one of the locals, endearing him to his colleagues and associates. He has been happily married since 1957 to charming and ever-supportive Elizabeth and they have four children and six grandchildren.

Many of us have worked closely and spent a lot time with Keeva. Our professional and personal lives have been enriched greatly by his intellect and wisdom, his open sharing of knowledge and his impish sense of fun and friendship.

Professor Vozoff died in Sydney on July 18 2019, age 91.

This tribute was written by Dr Brian Spies FTSE, Secretary of the Academy's NSW Division.

Leonard "Len" Kelman Stevens
AM FTSE

Engineer helped create iconic Australian structures.

Emeritus Professor Leonard "Len" Kelman Stevens made major contributions to Australian engineering over his six-decade career.

After serving as a flying officer in the Pacific during World War II, Professor Stevens arrived at the Melbourne School of Engineering during a boom in student numbers. He was given the opportunity to study engineering thanks to a government reconstruction training scheme for those who had served in the war.

He completed his Bachelor of Civil Engineering at the University of Melbourne in 1950 and Master of Engineering in 1954. After securing a scholarship, he completed his PhD in 1955 at Cambridge University.

Because of the support he received at the beginning of his career, Professor Stevens championed the creation of scholarship opportunities throughout his academic life. These initiatives included the Melbourne School of Engineering Foundation, which was established in 1982 under his three-term leadership as Dean. He went on to become Head of the Department of Civil Engineering at the school.

Professor Stevens was involved in some of Australia's most important building projects, such as the Arts Centre in Melbourne and the Australian Academy of Science's Shine Dome. He was the engineer assessor for the New Parliament House design competition and was a design consultant for the building's construction.

Professor Stevens' advice was highly sought after by industry. He played key roles in the inquiry into the Westgate Bridge collapse and its subsequent redesign as well as the aftermath of Cyclone Tracy.

Elected a Fellow of the Academy in 1984, he contributed to the climate change, digital futures, energy and infrastructure forums, and served on the membership selection panel.

Professor Stevens was awarded a Member of the Order of Australia in 2005 for outstanding contribution to the field of engineering, and to education. Although he formally retired in 1990 he continued to consult, research and collaborate with the University of Melbourne until December 2017 – a remarkable feat for a man by then in his 90s.

Few people have influenced engineering in Australia as Professor Stevens did. As an educator, he taught generations of engineering students, occasionally from the same family. Many past students note how his wise counsel made a significant impact on their course and career decisions.

Professor Stevens died on 17 August 2018, aged 93. He is survived by his wife Fay and three children.

With thanks to the University of Melbourne.

Ian Stewart Ferguson
AM FTSE

Timber expert modernised forest sector

The local and international forestry industry lost an outstanding leader in forest science with the death of Emeritus Professor Ian Ferguson, who died on 10 July, aged 84.

Professor Ferguson was born in December 1935 in Melbourne. He completed a Bachelor of Science majoring in Forestry at the University of Melbourne before completing his masters and doctorate at Yale University.

After stints as a lecturer at the University of Melbourne and at the Australian National University he was appointed in 1981 as Foundation Professor of Forest Science at the University of Melbourne.

There he also held many senior appointments including Head of the School of Forestry, Dean of the Faculty of Agriculture and Forestry, Pro Vice-Chancellor and President of the Academic Board.

Professor Ferguson was elected a Fellow of the Academy in 1992, participating in the Agriculture Forum from 2014 until his death.

He retired in 2003 and was appointed Professor Emeritus.

During his working life, he also worked with the Forests Department of Western Australia and in a number of senior positions with the Australian National University.

Professor Ferguson was a highly respected international expert in forest economics, policy and management and served on numerous boards and chaired a major government enquiry into the timber industry that was instrumental in modernising the Victorian forest sector.

His achievements included 1953-57, a Commonwealth Forestry Scholarship; 1962, a Fulbright Travel Grant; 1962-63, Yale University Scholarship; 1963-65, Yale University Fellowship; 1989, MR Jacobs Oration; 1989, Fellow, Institute of Foresters of Australia; 1989, Fellow, Royal Australian Institute of Parks and Recreation (now Parks and Leisure, Australia); NW Jolly Medal: Institute of Foresters of Australia; 2003, Centenary Medal, Commonwealth of Australia; 2005, Erskine Visiting Fellow, University of Canterbury, New Zealand; and 2006, Fellow, Institute of Wood Science (UK).

He was on the governing boards of many organisations including CRC Forestry, Tiaki Plantations, Taswood Growers, Hancock, Forests and Wood Products, Timber Training, Lignotek, Timber Promotions Council, Institute of Foresters and the School of Forestry, Creswick.

He is survived by his wife Sandra, two daughters and five grandchildren.

With thanks to timberbiz.com.au.

Scott William Sloan
AO FTSE

Geotechnical engineer made the world safer

Laureate Professor Scott William Sloan was a pioneering geotechnical engineer who was recognised around the world for his work in soil stability analysis.

He was born in Mildura, Victoria, in 1954 and graduated from Monash University with a Bachelor of Engineering and Master of Engineering. He went on to study at the University of Cambridge where, in 1981, he was awarded a PhD for numerical analysis of incompressible and plastic solids using finite elements.

Passionate about cross-disciplinary research, Laureate Professor Sloan worked in the broad area of geotechnical engineering, with a special emphasis on computational methods.

For more than three decades he worked at the University of Newcastle, where he was laureate Professor of Civil Engineering. He was Director of an ARC Centre of Excellence for Geotechnical Science and Engineering, and an ARC Laureate Fellow.

Laureate Professor Sloan was elected a Fellow of the Academy in 2000. He was also a Fellow of the Royal Society and the Australian Academy of Science. In 2005 Engineers Australia named him one of the 100 Most Influential Engineers. He delivered the prestigious Rankine Lecture in 2011 and, in 2015, the NSW Government named him Scientist of the Year.

In 2018, Laureate Professor Sloan was made an Officer of the Order of Australia (AO) for distinguished service to education, particularly in the field of geotechnical engineering, as an academic and researcher to professional associations, and as a mentor of young engineers.

In March his pioneering research into fighting contamination was awarded $4.7 million in federal funding. Laureate Professor Sloan and his colleague Dr Brett Turner investigated the use of hemp seed proteins to treat water and soil contaminated by per- and poly- fluoroalkyl substances, or PFAS.

PFAS are human-made chemicals that have been widely used in food wrappers, textile stains, insecticides, electronics and fire-fighting foams. Waste PFAS build up in food chains, threaten biota, cause cancer and almost never degrade.

Conventional treatments for PFAS contamination are expensive and often ineffective. Laureate Professor Sloan's remarkable research contributions will improve the lives of thousands of people in Australia and around the world.

Professor Brett Ninness, the University of Newcastle Pro Vice-Chancellor for the Faculty of Engineering and Built Environment, described Laureate Professor Sloan as an "iconic leader" who led the University of Newcastle onto the world stage.

"His personal research accomplishments were a vital part of that journey," Professor Ninness said. "But, strong as they were, they were eclipsed by his vision and leadership to nurture and empower future generations of leading researchers and teachers."

Scott Sloan died on 23 April 2019 and is survived by his wife Denise and children. His vision, talents and generosity will be sorely missed.

With acknowledgement to the University of Newcastle.

Courtney "Ned" John Denton Williams
FTSE

Pyro-metallurgist transformed smelting

Courtney John Denton (Ned) Williams was born in Cardiff in 1923 and became one of the foremost pyro-metallurgists in the world. He was a globally recognised authority on suspension smelting of non-ferrous metals, particularly nickel and copper.

In 1947 he graduated from Sydney Technical College with an Associateship qualification.

Mr Williams worked as a Smelter Superintendent at Electrolytic Refining & Smelting from 1965 to 1971 and Resident Manager at the Western Mining Corporation, Kalgoorlie Nickel Smelter from 1971 to 1980. He later became Deputy General Manager of the Nickel Division at Western Mining Corporation.

Mr Williams was responsible for developing major technical innovations on the Outokumpu Process, a method of smelting ores that contain sulfur. This culminated in the construction and highly successful operation of what was then the largest pure nickel flash smelter in the world. The major conceptual changes Mr Williams developed became standard design for this type of furnace.

Highly regarded with his pyro-metallurgical peers worldwide, Mr Williams provided advice to the Chinese Government. He also served as Chair of the Nickel Producers Environmental Research Association (NiPERA), a worldwide organisation of nickel producers dedicated to researching nickel's effects on health and the environment.

Mr Williams was elected a Fellow in 1984 and was a member of the West Australian Division.

He was awarded a Centenary Medal in 2001, and in 2003 became a Member of the Order of Australia "for service to the Australian mining and metallurgical industries, particularly as a leader in the development of suspension smelting of non-ferrous metals".

Mr Williams died on 7 March 2019, aged 95. The loving husband of the late Margaret was survived by his sons Bruce and Ian, four grandchildren and two great-grandchildren.

Michael "Mike" Rickard

FTSE

A champion of animal welfare

Professor Michael "Mike" Rickard FTSE was a vetinary immunoparasitologist whose outstanding scientific and leadership achievements had a profound impact on animal welfare.

Born in 1941, he graduated from the School of Veterinary Science at the University of Queensland in 1963. He completed his PhD on in 1967 and was awarded the higher degree of Doctor of Veterinary Science by Thesis from the University of Melbourne in 1979.

Professor Rickard lectured in veterinary parasitology at Massey University from 1967 to 1969, when he became Reader in Veterinary Parasitology at the University of Melbourne – a role he held for 20 years.

From 1989 till 2001 he was Chief of the Division of Animal Health at the CSIRO. After retiring from the CSIRO he continued working for animal welfare in the research and teaching sector, and was Chair of the Board of the Animal Welfare Science Centre.

Professor Rickard worked with the Department of Agriculture, Food and Fisheries and had a powerful impact on the development of animal health policies in Australia.

He won international acclaim for developing and commercialising a highly effective vaccine to protect sheep against parasite infection. This is widely recognised as a milestone in the veterinary parasitology, and led to a generation of similar vaccines.

Professor Rickard received many honours, including the Australian Veterinary Association's Gilruth Prize and the Bancroft-Mackerras Medal from the Australian Society for Parasitology. He published more than 110 research papers and more than 20 reviews and book chapters.

Elected a Fellow in 1992, Professor Rickard was one of the first recipients of a Clunies Ross Award. He went on to become a long-time member of the Award's Selection Committee, and was an invaluable member of the Health Forum.

Professor Rickard died on 25 June, aged 77. He is survived by his wife Trish, three children and four grandchildren. He is sorely missed.

With thanks to the Australian Veterinary Association.

Edgar Roger Banks

FTSE

Telecommunications visionary became Telecom leader

Dr Edgar Roger Banks FTSE was the eldest of four born to Raymond and Hilda Banks. He attended Camberwell South Primary School then Brighton Grammar, excelling as a Prefect, School Captain and Dux.

The talented student played sport and became a Scout and Signals Cadet. His lifelong love of music began with violin lessons, and he played in a recreational capacity into later life, transitioning to the cello in his early 50s.

Roger won a scholarship to the University of Melbourne, which gave him a cadetship with the Post Office, allowing him to work on the job and study. After two years he transferred to full-time study and graduated in 1953 with a Bachelor of Electrical Engineering with first-class honours.

Roger was involved in various line work in Western Victoria, Geelong to the Adelaide border and special tension work on wires in Bendigo. He wrote a paper on this subject and received a call to fix faults between Perth and Adelaide with the promise of, and eventual promotion from a Gr 1 engineer to a Gr 3 engineer.

In 1955, he won another scholarship for young engineers and sailed on the Orion to England to learn about the latest switching technologies. He convinced his boss at the time to allow him to visit five companies so he could collect a diverse range of information for future developments in Australia. He visited GEC, British Ericsson, STC, British Siemens and Austel, spending three months with each.

In a heartfelt tribute from children Melissa and Jeremy, they recalled that in 1972 a long black car came to the house and took them to the Steam Ship Canberra bound for England. Roger was an executive for Plessey Telecommunications in Liverpool and had a picturesque existence in Heswall, a beautiful village with cobblestone roads and horses in paddocks.

Roger met Molly May Carmichael from West Derby, Lancashire, and they married in 1956, arriving back in Melbourne just after the 1956 Olympic Games had finished.

Roger's experience in England helped him assist the Post Office in choosing the L M Ericsson Cross Bar Switching System. He wrote an extensive paper on the subject published in the Telecommunications Journal of Australia in 1961.

He was also involved with the International Telegraph and Telephone Consultative Committee (CCITT) and appointed chairman of the working party for National Automatic Networks, sending him around the world for regular meetings.

Roger continued to chair the working party meetings for CCITT until his resignation in July 1968. The assemblies were held in various locations including Montreal, Geneva, New York, Stockholm, Munich and also at home in Melbourne.

In New York in 1964, Roger presented his plenary report along with a handbook called the Manual of National Automatic Networks.

According to Roger, the split of the Australian postal service and the newly formed Telecom meant Australia needed him. At Telecom, Roger was Head of Marketing and by 1980, the Director of Corporate Strategy. Very much a visionary before the internet, he talked about digital switching systems, and the future being in data storage, data transfer, computers and communications.

He was elected a Fellow of the Academy in 1983. He retired in 1988 but remained active as:

- a member of the Athenaeum Club
- a member of the Rumour Tank
- a member of the Brighton Grammar School Top-Enders
- an RACV councillor from 1992-2001
- President of the RACV Club from 1990-1993
- a Board member of VicRoads from 1992-2005
- a Board member for Monash University Accident Research Centre – 2005
- an Honorary Chairman of the Board for Melbourne University Engineering Foundation from 1997-2007.

He was awarded an Honorary Doctorate by the University of Melbourne.

Roger's son, Jeremy Banks, lovingly recalled his father as his "greatest hero" and "a gentleman who used a fountain pen, wore a suit and carried a briefcase.

"In his career and on various boards there are numerous examples of tough decisions he made that others would avoid due to self-interest, lack of vision or not wanting to be unpopular. His motivation was always the greater good for all in the situation, and his logic was flawless."

Daughter Melissa Banks recalled: "Roger was excellent at public speaking as well as speaking in general; he used to say he could talk under wet cement.

"It is hard for me to sum up in words all the various qualities that made up our Dad's character. Roger was a loving, caring, supportive, funny, persistent, hard-working, dedicated, positive, calm, reliable and selfless person, the list could go on and on."

Dr Edgar Roger Banks FTSE died on 26 January 2018, aged 87.

With thanks to Melissa Banks and Jeremy Banks.

Gavin Samuel McDonald

OBE FTSE

Mining engineer made lasting impact

Gavin Samuel McDonald OBE FTSE was a leader and innovator who made significant contributions to Queensland industry and infrastructure. He was born in 1927 in the small Queensland town of Camooweal, just 12km east of the Northern Territory border.

In 1950 Mr McDonald graduated in Civil Engineering from the University of Queensland and begun work as an engineer with the Queensland Co-ordinator General's Department. He worked with the Government in constructing Somerset Dam, the Tully Falls (Kareeya) Hydro-electric Project and Brisbane's Victoria Bridge. In the early 1960s, Mr McDonald was a resident engineer with Ford, Bacon and Davis and worked on reconstruction of the Mount Isa to Townsville railway line. In 1965 he was an engineer/manager to the Gladstone Harbour Board.

Mr McDonald joined the Utah Development Company (UDC) in 1969, and participated in the early development of the port at Hay Point. He was appointed to various roles in the company, including:

- Manager of the Queensland Coal Operations in 1976
- Vice-President in 1978
- Senior Vice-President in 1981
- Executive Vice-President in 1982
- President and General Manager in 1985.

He also represented UDC in a number of industry associations. He served as:

- President of the Queensland Chamber of Mines
- Chairman of the University Minerals Industry Advisory Committee
- Deputy Chairman of the Queensland Coal Association
- Council Member of the Australian Industry Research Association
- Member of the Solar Energy Research Council, University of Queensland.

In 1988 Mr McDonald was elected a Fellow of the Academy and became an Officer of the Order of the British Empire for his work in the mining industry. He was a recipient of a Centenary Medal in 2001.

Mr McDonald died on 2 July 2019, aged 92. He was married to the late Laxie, and is survived by his daughters Ann and Morag, six grandchildren and seven great-grandchildren.

Robert Melville Hobbs

FTSE

Synchrotron scientist leaves historic legacy

Dr Robert Hobbs was an engineer who made historic contributions to a range of fields, from metallurgy to 3D printing.

Born on 13 May 1941, he attained a Bachelor of Engineering (Metallurgy) with Honours at Melbourne University in 1963, and his Masters in 1965. Five years later he completed his PhD at the University of Manchester.

In 1964 he joined BHP he worked in various roles with the research and technical organisations of the company. His career with BHP lasted 37 years, spanning Newcastle, Melbourne and Port Kembla. He would ultimately became BHP's General Manager, Research.

Dr Hobbs was a visiting Professor at McMaster University in Ontario, 1978–1979. During this time he developed and ran an industry course on Advanced Manufacturing for the American Society for Metals.

During 1983 and 1984 he was a Consultant to General Motors Technical Center (Advanced Manufacturing Group), Warren, Michigan on the Saturn Car Project.

Throughout his career he worked with various government advisory bodies.

Dr Hobbs was elected to the Academy in 1996. He won a Clunies Ross award in 1997 and later participated in the award selection process, as well as the Energy and Innovation forums.

One of his many remarkable achievements was his preparation of the Science Case for establishment of the Australian Synchrotron. He assisted with management of the facility during its commissioning and formative stage.

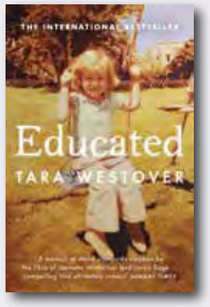
Dr Hobbs also chaired an advisory committee for operation of the Monash University Centre for Electron Microscopy. This centre housed four transmission electron microscopes, three scanning electron microscopes, a dual-beam focused ion beam (FIB) microscope and two three-dimensional atom probes.

Dr Hobbs led a consortium of five companies, two state governments, the Defence Acquisition Organisation, CSIRO Manufacturing Technology and three universities to establish the Cooperative Research Centre for MicroTechnology, which he chaired.

He was chief executive of Amaero Engineering, a spin-off company of Monash University's Centre of Additive Manufacturing (MCAM). In this role he led the creation of the world's first 3D printed jet engine.

Professor Hobbs died on his 78th birthday. He was married to Barbara.

What we're reading



Educated

Tara Westover

In *Educated*, author Tara Westover tells the harrowing tale of her childhood growing up in a Mormon fundamentalist family in Idaho, United States.

Tara's father, Gene, led his family toward the end of the world, which he believed would occur at the stroke of the new millennium. Convinced the government was tracking him and the world was full of sinners, he did not believe in sending his children to school or engaging with society.

Westover's account of her childhood is grim in many ways. Her family was extremely poor; Gene made his seven children work in his junkyard and the children were often injured by their father's manic efforts to bring in more money. They did not believe in modern medicine and serious brain and other injuries went untreated. The whole family lived under the shadow of her father's delusions.

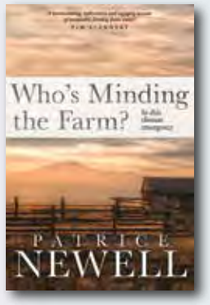
Tara's childhood was filled with fear and violence, but she gradually managed to pull herself out. Despite having no formal education, she taught herself everything she needed to pass an admissions test and gain entry to college.

Westover struggled at college at first – with no schooling, the gaps in her knowledge were enormous – but she persevered and even went on to attain a PhD from Cambridge University. This is an extremely impressive feat, and a reminder of the power of determination.

While *Educated* is not a STEM book, it shows the importance of education for self-discovery: knowledge changed the trajectory of Tara's life. This is an extraordinary true story and the kind of book that stays with you for a long time. Like me, you might find yourself on Google Earth weeks after you've finished reading it, searching for Tara's family home and her father's junkyard.

I would highly recommend adding *Educated* to the top of that "to-read" pile you have on your bedside table.

Dr Emily Finch is Senior Research and Policy Officer at the Australian Council of Learned Academies. She has a PhD in geology and a love of literature.



Who's Minding the Farm? In this climate emergency

Patrice Newell

"Agriculture is a $61 billion industry in Australia but one of the biggest culprits of environmental damage. As the effects of climate change become increasingly obvious, who's watching what happens on our farms?"

Patrice Newell is an Australian farmer. After being given a bulb of purple garlic as a gift (which she mistakenly ate instead of planted) she expanded her 4000-hectare olive, honey and beef farm in the Hunter Valley, NSW, to also include a successful organic garlic business.

Having managed her farm for more than 30 years, Newell has a deep understanding of how the changing environment impacts on her crops, and importantly, how her crops impact on the land.

This account of farming life and the importance of the human connection to the land questions the long-term sustainability of current farming practices. It asks how population growth, the increasing demand for crop and livestock products, and climate change will impact on the farms of the future.

This is a call to action for all Australians to rethink our consumption habits, and to take shared responsibility for the health and sustainability of Australia's agricultural sector.

This book is an important reminder that the implementation of sustainable agricultural practices on any scale can address issues of water scarcity, soil fertility, land stewardship and food security. The responsibility for minding the farm falls on us all.

Dr Fern Beavis is a policy analyst at the Academy. She coordinates the Academy's Mineral Resources, Agriculture and Digital Futures Forums, and is working on the Academy's Industry Technology Readiness Project. She holds a PhD in geochemistry, and her favourite specimen in her ever-growing rock collection is the cranial plate of a placoderm.

The Women of the Moon: Tales of Science, Love, Sorrow and Courage

Daniel R. Altschuler and Fernando J. Ballesteros

Of the 1586 lunar craters that have been named to honour scientists and philosophers, only 28 honour women. The Women of the Moon asks who these women were, and what has happened to make women "deserve" such a singular lack of recognition.

Surely the answer to the latter is obvious, considering that women have been unacknowledged over the centuries and the International Astronomical Union – the authority for the naming of celestial bodies and their surfaces – has been dominated by men since it began in 1919.

The 28 women range from classical figures like Greek astronomer and mathematician Hypatia to intellectual giants like Gerty Cori, a Jewish Austro-Hungarian-American biochemist who was the first American woman to win a Nobel Prize in science and the woman first to win in Physiology or Medicine.

A few of the women were sponsors of science and some were active science communicators. Others stubbornly refused to submit to the prejudices and norms of their time: Caroline Herschel, who was brought up as a servant, became a tour-de-force of astronomical discovery.

More recently, Soviet cosmonaut and heroine Valentina Tereshkova was the first woman in space in 1963.

On the cover jacket, the authors say the book provides two opportunities. The first is to meditate about the gap between men and women who have lunar craters named after them. The second is to talk about these women's lives; women who are mostly unknown today.

The second opportunity is the better one, as the 28 women are all extraordinary and totally worth rediscovering. The book presents a vibrant, distinct and diverse picture of women and what they have achieved throughout the ages.

In her foreword, popular scientific writer Dava Sobel says that in all the romance languages the Moon is feminine. Let's hope that with the publication of this noteworthy book the naming of Moon craters becomes more feminine, too.

Deborah Sippitts is an experienced journalist and writer, and communications, marketing and media professional, who recently worked as Communications Manager for SAGE. Over her career she has often written about technology and science-related topics including energy, engineering, transport, technology, IT and space.

New Dark Age

James Bridle

What happens when information creates heat rather than light? Technologist James Bridle contends that as our world grows in technological complexity, our ability to understand it diminishes – with serious ramifications.

Laser-sharp and well-researched, this illuminating work explores why humanity's greatest technical achievements seem to be fuelling our darkest threats; from climate change to mass surveillance to the "post-truth" erosion of democracy.

One of the culprits, Bridle argues, is the widespread belief that every problem can be solved with computation alone. But hoarding and crunching data without "real systemic literacy" can paradoxically lead to opacity, not clarity.

Worse, because computational thinking doesn't consider structures of power, it can reinforce them by giving vested interests the gloss of objectivity. For instance, there's growing awareness that machine-learning algorithms can reproduce racial and other biases.

But for Bridle, that's just the tip of a poisonous iceberg melting into our economy, culture and psyches. Innovations that once held emancipatory promise are deepening global inequality and driving the earth's natural systems towards collapse.

Social media is flooded with disinformation – from conspiracy theories to "deep fakes" – that buoys extremism and short-circuits the democratic process. YouTube incubates bizarre and traumatising algorithm-generated content, directly targeted at kids. And Silicon Valley is creating artificial minds we can't comprehend, let alone control.

Even academia isn't immune to information overload. The "publish or perish" mantra has fuelled the rise of statistical manipulation like p-hacking (or "data dredging") which threatens the rigour of science itself.

But while Bridle questions the trajectory of our progress, he's no Luddite. To argue against technology, he writes, "would be to argue against ourselves." Rather, he's calling for a deeper, more critical, more human engagement with the technocratic systems we take for granted.

While grand treatises usually end up back on the shelf with a bookmark forever wedged at page seven, New Dark Age is a surprisingly rollicking read. Bridle writes beautifully, and illustrates his ideas with fascinating facts from the history of tech. It's worth a look for the trivia alone.

Whether you take a dim view of digital doomsaying or think these ideas sound enlightening, New Dark Age is an urgent appraisal of the dawn – or the dusk – of an era.

Benjamin Hickey is the editor of *IMPACT* and the Academy's Communications Officer. He is a writer of essays and fiction.

Fostering an industrious approach to research

The traditional university view about developing new technology for industry was to come up with a clever idea, slap patents on it, protect the intellectual property with an iron grip and wait for the prospective licensing partners to come knocking at the door.

At UNSW Sydney we realised some time ago that that sort of approach didn't really work. We believe that intellectual property is best in the hands of those who will be able to exploit it. In other words, we're very keen to make sure that the industry partners have the ability to take the IP wherever it needs to go for their business.

Of course, we expect an appropriate return on what we've created or contributed. But for the true benefit of all – the university, the researchers, the industry partners, government, and society in general – flexibility is the key as is getting partners in early on the commercialisation of research.

Engineering is the largest faculty at UNSW with more than 16,000 students and 650 academics. It is also the largest faculty of its type in Australia and ranks very highly in the international university rankings. It enjoys an enviable position in Australia as a leading supporter of industry and technology development, particularly in future-focused areas such as renewable energy, telecommunications and biomedical devices.

Because of our scale, we offer a very comprehensive range of programs, with specialists in just about every area. I have not once yet spoken to an industry partner where we didn't have an expert that was relevant for the problem at hand.

When we work with industry partners, we have three main goals with a view to commercialising our research.

The first is that we want to make a global impact. We are big and bold enough to have a worldwide impact through partnering with companies that range from huge multinationals to fledgling start-ups.

An obvious example where we can demonstrate how we have made significant global impact is silicon photovoltaics. Many of the CEOs and CTOs of the big silicon photovoltaic manufacturers are graduates from here.

And it is no overstatement to say that the technological genesis of that entire global industry began at UNSW. It is through long-term strategic partnerships with commercialisation partners that these impacts are realised.

The second goal is around fostering an entrepreneurial spirit among our academics and students. There is already a practice in the United States, Israel etc in top institutions where academics will be spinning out multiple start-up companies throughout their academic career.

They might take a CTO-type role or might even take time away with the company but then come back to academia. In Australia this is unusual but I believe we need to make this normal, and we're well on the path to that.

A recent example of this is the start-up BT Imaging. This company sprang from two of our academics in the School of Photovoltaics and Renewable Energy who developed a brand-new technology that allow manufacturers to see defects in silicon solar cells.

As a result, manufacturers can very quickly, cheaply and easily characterise the defects in this cell which has had the effect of revolutionising the way cells are produced and has driven down the price. And they spun that technology out of UNSW. We were very proud to see this team win a 2019 Clunies Ross Award from the Academy of Technology and Engineering.

The third goal with respect to commercialisation of our research is making it easier for SMEs to start their own partnerships with UNSW Engineering, and we do that through our program, TechConnect.

Sometimes universities can be hard to engage with because people don't know who to talk to or how to find the front door. TechConnect, funded through the NSW Government's Boosting Business Innovation Program, helps by establishing some co-working space between the SMEs and UNSW.

And through TechVouchers, prospective partners can be connected with an expert in a relevant field of research and embark on a joint research project. Techvouchers match up to $15,000 of the SME's money to help seed the project. This program has been wildly successful in its three years of operation, with more than 40 Techvouchers issued and some 500 or so SMEs engaged. ▶

Professor Ian Gibson

Ian Gibson is Associate Dean (Industry and Innovation) of the Faculty of Engineering, UNSW Sydney.

unsw.edu.au

Why entrepreneurs must ‘eat their own dog food’

If you really want to show students how to become entrepreneurs, you need to practise what you preach. Or in the words of UNSW Sydney’s Professor François Ladouceur, who teaches a course in entrepreneurship, you need to show students that “you eat your own dog food”.

Having ridden the tech boom and crash of the late ’90s and early 2000s with an expertise in photonics, Professor Ladouceur knows the ins and outs of taking the latest university-led research to launch a start-up.

He even has a couple of his own on the boil. The first is a company named Zedelef that he set up in 2012 and has raised $500,000 from investors to date.

“Zedelef is to do with optical telemetry,” says Professor Ladouceur, who has taught in the School of Electrical Engineering and Telecommunications since 2005.

“In the context of a mine, a power plant or a petrochemical refinery you have to monitor everything like the flow of gas, the level of CO2, the temperature, etc. And these environments are hostile and dangerous. It requires equipment that will not spark and cause an explosion. So we do that with sophisticated technology that uses light signals.”

Professor Ladouceur’s second start-up takes optical telemetry into the human body. It is as ambitious as it is exciting and envisions a day in 20 years’ time when humans will be equipped with brain-machine interfaces. Already he has some stiff competition in the pursuit of this “holy grail” technology.

“Elon Musk has invested $120 million to do this through his company called Neuralink,” says Professor Ladouceur.

“They’re looking at thin pliable meshes of electrodes interfacing with the neurones. We’re looking at just using light. I believe that our technology is the one that could win, and that’s what I’m pitching to investors.”

Professor Ladouceur says even though the brain-machine interface is a couple of decades away, investors could expect a return on investment in the next two to three years as the group develops scientific instruments that analyse how biological tissues work.

Professor François Ladouceur has two start-ups under way.
unsw.edu.au

Reimagining cities for the urban billions

Macquarie explores how cities of the future can prepare for urban population growth and remain sustainable, desirable places for people to live and work.

Urbanisation is one of the key social and economic trends of the 21st century. Currently, 54 per cent of the world’s population lives in cities; by 2050 this will reach 66 per cent. We need to prepare for this future and create cities that are multi-faceted, sustainable and desirable places for people to live.

For cities to prosper, governments, developers, planners and the private sector must return their focus to the central feature of any thriving city: its people.

A return to human-centred city creation is vital in an era when globally mobile, technologically equipped and skilled populations are more readily able to relocate and choose where they invest their time.

Cities that offer convenience, affordability and flexibility, while enhancing the wellbeing and enjoyment of residents, will be best placed to succeed as global populations exercise unprecedented choice about where they live.

Rising incomes and education levels, international travel and a technologically connected world have made people more mobile, which means cities must be more competitive to attract highly skilled people.

A return to human-centred spaces

Urbanisation has been an engine for economic growth and poverty reduction, as well as entrepreneurship and innovation. By 2025 it is forecast that urban consumers will contribute an additional $US20 trillion to global spending .

But the rapid pace of urbanisation has also fuelled challenges such as housing shortages and affordability issues, urban sprawl, environmental degradation, air pollution and congestion in cities with inadequate infrastructure. Development in some cities has been focused on building places for work rather than creating places for engagement and interaction that can be easily accessed by all.

Historically, cities were the focal point of the public realm and acted as a meeting place where people could conduct a number of activities such as work, leisure and cultural engagement. Design and infrastructure that was multi-purpose and driven by a village green or town square approach led to the creation of some of the world’s most celebrated spaces, such as Paris’ Place des Vosges or New York’s Times Square. While the paved squares of Europe’s great historic cities appear physically simple, they offer a complexity of use for activities ranging from summer festivals, to watching a Champions League football match, to hosting a political rally.

There is an opportunity to return to some of these historic principles that originally allowed cities to develop as places of many places, which were inclusive, dynamic and allowed a process of interchange. As urban populations grow, improving life for city dwellers is a task that economies must start addressing now by putting people at the heart of all development.

Visit macquarie.com/built to read the full article.

WE'RE PASSIONATE ABOUT INCREASING THE UPTAKE OF STEM EDUCATION

As the world's largest provider of commercial explosives and innovative blasting systems, we provide expert services to the mining, quarrying, construction, and oil and gas markets.

The STEM disciplines – Science, Technology, Engineering and Mathematics – are critical to the future of a company like Orica, which is why we are committed to increasing the uptake of STEM in schools. With the aim of getting students interested in careers in science and technology, we're proud to be the principal sponsor of the Academy's STELR project, helping more than 700 schools across Australia engage students in STEM through hands-on, inquiry-based and in-curriculum learning.

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