SPOTLIGHT ON AUSTRALIA

Aiming for impact

Long recognized as producers of high-quality science, Australian institutions are striving to find better ways to translate research excellence into social, environmental and financial benefit.

"Innovation needs more than one discipline to happen and it tends to happen best at the intersection of disciplines, so collaboration is even more important than ever before."

Dr Larry Marshall, Commonwealth Scientific and Industrial Research Organisation (CSIRO)

WHAT DO Google Maps, the black box flight recorder, and the Flying Electric Generator wind turbine have in common? They were conceived in Australia but born elsewhere because, despite its strengths, Australian science falters when it comes to moving from innovation through to commercialisation.

Australia is often said to punch above its weight when it comes to science; despite being a relatively small country of 23 million people, it keeps pace with larger nations in terms of scientific discovery.

Its reputation for research strength is borne out by scholarly measures of research impact. Australia was once again ranked 12th in the 2015 Nature Index and this year ranks 4th on Scientific American Worldview's global biotechnology performance scorecard. In 2014, the publication rate of Australian scientists placed them at number eleven on the global SCImago Journal & Country Rank.

The country is home to some world-class research infrastructure and institutions. Since 2007 the Australian Synchrotron in Melbourne has been a jewel in the crown; a high-energy electron accelerator with nine beamlines, supporting a range of research across health, industry, manufacturing, agriculture, and communication technology. Opening in the same year, the Australian Nuclear Science and Technology Organisation's Open Pool Australian Lightwater (OPAL) reactor is rated as one of the world's best research reactors.

More recently built, the National Sea Simulator (SeaSim) is an aquarium facility at the Australian Institute of Marine Science in Townsville that can replicate conditions of the open ocean, a reef lagoon or a flooding river to provide new insights for marine research. Opening its doors in 2013, this facility helps to better understand threats to the Great Barrier Reef.

Australia will also soon host the Square Kilometre Array; the massive, next-generation radio telescope array setting a new benchmark for global scientific collaboration.

While facilities are important, brainpower drives innovation. Australia lays claim to an impressive list of world-class researchers; its list of Nobel laureates includes biochemist Elizabeth Blackburn, immunologist Peter Doherty, physician Barry Marshall, pathologist Howard Florey and the father-and-son team of x-ray crystallographers William Henry Bragg and William Lawrence Bragg.

More recent leading lights include quantum computing's Michelle Simmons, astronomer Martin Asplund, physicist Tanya Monro, and coral reef biologist Terry Hughes. In 2014, Australian computational physicist Amanda Barnard became the first woman to win the prestigious Feynman Prize in Nanotechnology.

Confronting a challenge

But while Australia has some impressive players, who have benefitted from fantastic training and facilities, it hasn't performed as well when it comes to translating research into results. While ranked 10th in the world for innovation inputs by the Global Innovation Index, Australia is demoted to 81st for 'innovation efficiency.'

"Where we come a cropper is in the second stage of the innovation cycle," says Dr Alan Finkel, chancellor of Monash University and president of the Australian Academy of Technological Sciences and Engineering. Australia excels in the first stage of innovation — coming up with bright ideas — but according to Finkel, the second step of progressing that idea or invention to market is where many great Australian ideas or discoveries fall into a black hole.

"In general, we don't have the money, nor do we have a directed capacity to go from research outcomes to proven technology," Finkel says.

This is partly due to a lack of government funding to help with early feasibility studies and commercial pilots that drive research outcomes to proven technologies, explains Finkel. Australia also has a far smaller pool of venture capital funding than might be found in the United States, and fewer large companies in a position to harvest innovations at an early stage.

The Cooperative Research Centres programme, now in its 25th year, fosters industry-led

collaborations with research institutions that have delivered a significant return on investment.

But Australian innovation is hamstrung by a lack of engagement with industry woven into the very fabric of the country's research environment, Finkel says.

"We tend to have excellence measured to a large extent by publications and citations," he notes. "If you go out and spend three years starting up a $600 million success story, you think you'd be valued but you're not; you're seen as having a three-year gap in your publication record."

Awareness of Australia's relatively poor performance in translating innovations to market has been growing, and discontent is giving way to action. Universities and government science agencies are now testing new models for working with industry to effectively combine science and market knowledge.

In January 2015 Australia's largest scientific organisation, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), appointed a former Silicon Valley entrepreneur and venture capitalist, Dr Larry Marshall, as its CEO, and he is determined to bridge the gap between research and output.

"Our mission is to try and be Australia's innovation catalyst, to solve Australia's innovation dilemma, which is our very high input into invention, but very low output into innovation," says Marshall.

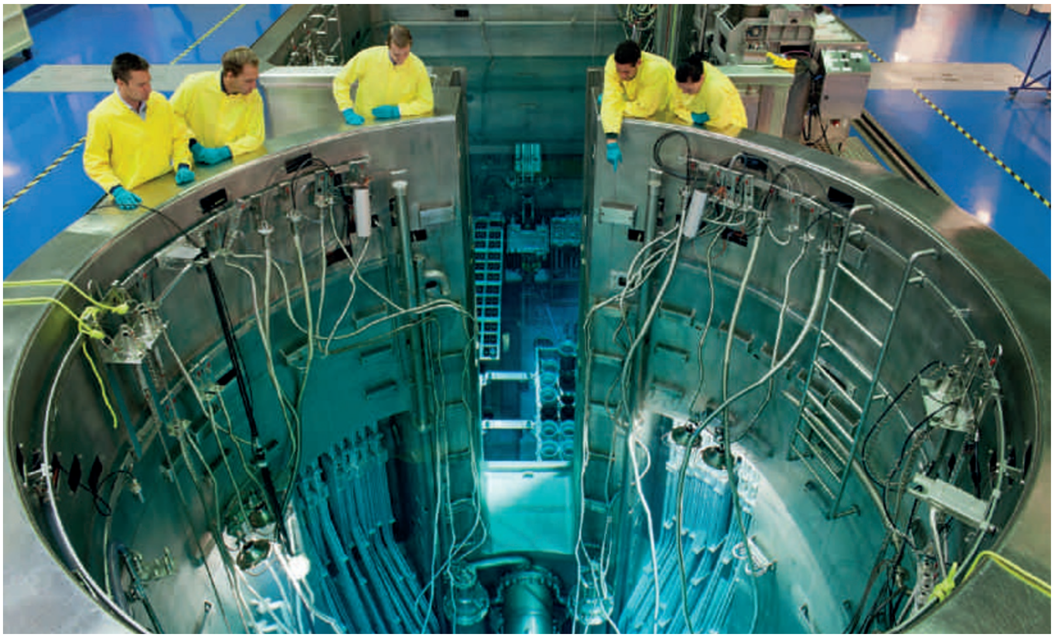
One area Marshall hopes to develop in pursuit of this goal is to widen the realms of collaboration, pointing out that Australia is the lowest collaborating nation in the OECD.

"There are two dimensions; the one that people talk about, which is industry to research and that's way too low, but there's also collaboration between research institutions and that's even lower," says Marshall.

"Innovation needs more than one discipline to happen and it tends to happen best at the intersection of disciplines, so collaboration is even more important than ever before."

An indicator of Marshall's approach is a new internal crowd-sourcing platform through which the CSIRO actively seeks ideas and input to strategy from staff »

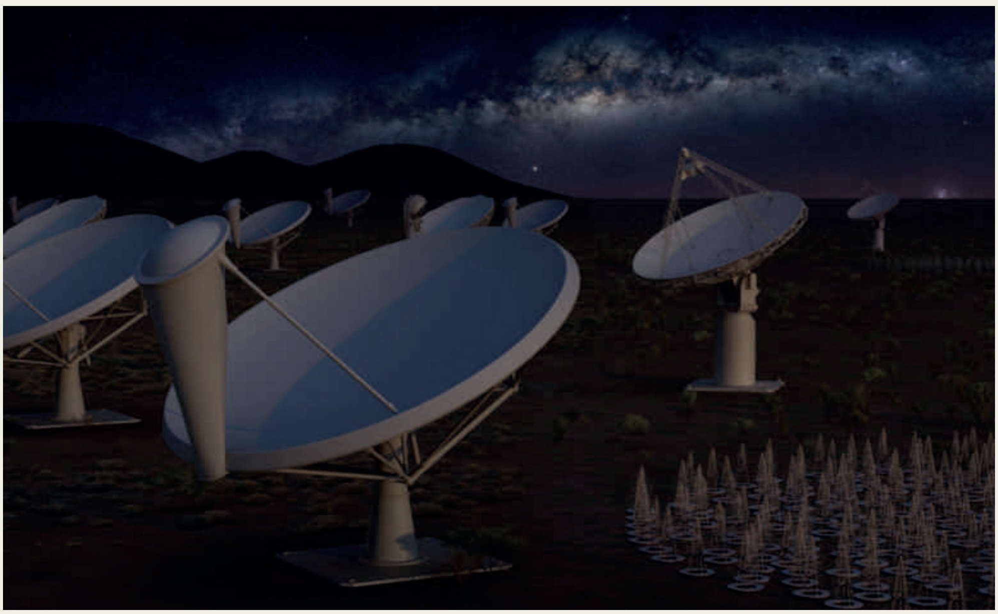
DAVID SMYTH



ANSTO's reactor, just outside Sydney, is regarded among the world's best research reactors.

Exciting times for radioastronomers

SKA ORGANISATION / EYE CANDY ANIMATION



Artist impression of the first phase of the Square Kilometre Array under a relatively unexplored southern sky.

It's one of the most ambitious astronomy projects ever undertaken; a radio telescope comprising 130,000 low — frequency antennas built in the deserts of southwestern Australia and a 200-dish array across southern Africa. The Square Kilometre Array (SKA) is also a pioneering effort in global collaboration, with more than 20 countries involved in its design and construction.

Choosing Australia for the SKA is partly because of the availability of remote locations untainted by nearby radio noise and the lure of the southern hemisphere's relatively unexplored skies. It's also a credit to Australian radioastronomy, says SKA director David Luchetti.

"CSIRO did a lot of work during World War 2 on radar technology and after that a lot of that work flowed into radioastronomy, so we've got a comparatively strong standing," says Luchetti.

The project is now in the pre-construction phase and the finer details of the telescope's design are being worked out.

There are exciting times ahead for radioastronomers. The SKA will make it possible to look even deeper into the Universe and therefore further back in time than ever before, studying the evolution of black holes and galaxies, exploring giant magnetic fields in space, and looking for short-lived, high-energy phenomena such as radio bursts and supernovae.

across the entire organisation and its collaborators. Already, this method is attracting good take-up, with response rates of up to 40 % of staff — including more than 6000 contributions.

Working together

Collaboration is also the driving force behind the Newcastle Institute for Energy and Resources (NIER), an initiative of the University of Newcastle that prioritizes research and development according to need.

Its director, Dr Alan Broadfoot, describes the institute's approach to collaboration as a 'plug and play' model, where industry comes in with a problem, and the institute can tap into the university's research community to deliver a solution. The researchers remain attached to their particular academic school or faculty, but through NIER they get the experience of working directly with industry.

The Institute also bucks the trend of seeking government funds and then going to industry. "We engage with the industry partner and then seek to leverage the strategic support from government," Broadfoot says, pointing out that around 60 % of the Institute's funding comes from industry.

"Having an industry partner combined with government support means we can deliver an outcome that's beneficial to the sector."

Another national organisation focusing on translating innovation into invention is the Australian Nuclear Science and Technology Organisation (ANSTO), which operates Australia's nuclear research reactor and is a partner in the Australian Synchrotron.

ANSTO already works closely with industry, providing reactor — based services for a host of applications from materials to radiocarbon dating. It is also a major global player in the radiopharmaceutical industry, supplying a substantial proportion of molybdenum, and supplying irradiated silicon ingots for use in everything from transistors to hybrid cars.

But ANSTO's group executive of the Nuclear Science & Technology Group, Greg Storr, has the remit to

CSIRO

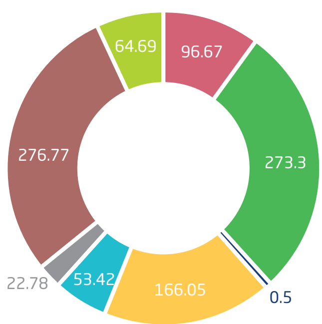
A solar tower in operation at a solar array located at the CSIRO Energy Centre in Newcastle.

AUSTRALIA BY NUMBERS

DATA: NATUREINDEX.COM

Australia state by state (2014 WFC)

The states of Victoria, New South Wales and Queensland dominate output of high quality research articles from Australia.



Victoria
Three-quarters the size of its nearest rival, the state of Victoria manages to narrowly outclass New South Wales on publishing strength, thanks to world-leading institutions such as the University of Melbourne and the Walter and Eliza Hall Institute of Medical Research.

New South Wales
Australia's most populous state is also home to some of Australia's top universities, such as the University of Sydney and University of New South Wales, both of which are in the top five Australian institutions in the Nature Index by WFC.

Queensland
Building on a previous state government slogan of 'The smart state', Queensland is once again championing scientific and medical innovation with initiatives such as 'Advance Queensland'. The state is home to the country's leading institution by WFC in 2014, The University of Queensland.

Australian Capital Territory
The tiny Australian Capital Territory hosts the headquarters and many business units of CSIRO, as well as the Australian National University, which help it to achieve an impressive publication record despite its size.

Western Australia
The Western Australian state government launched a major statement on the region's science future in April this year, with a focus on areas such as mining and energy, agriculture, radio astronomy, biodiversity and health. The state's reputation as a centre for radio astronomy research will be boosted with the building of the Square Kilometre Array.

South Australia
South Australia has a proud scientific history stretching back to the youngest Nobel Laureate in physics, William Lawrence Bragg, who was born and spent his university years in Adelaide.

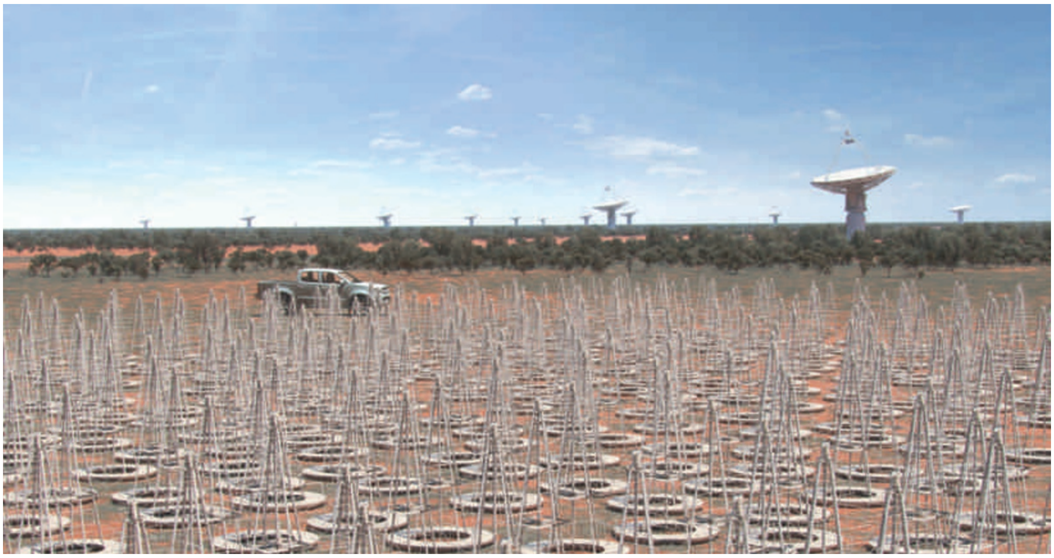
Tasmania
The Apple Isle is famous for its stunning wildness, and has a strong publishing tradition thanks to the University of Tasmania. It is also the leaping off point for Antarctic expeditions being the headquarters for Australia's Antarctic research programme.

Northern Territory
Home to extraordinary natural wilderness, the Northern Territory has few major research organisations or institutes, but is home to Australia's newest public university established in 2003, Charles Darwin University.

The Nature Index is a database of author affiliation information collated from research articles published in an independently selected group of 68 high-quality science journals. It tracks article output by institution and country. Article Count (AC) includes total number of articles. Weighted Fractional Count (WFC) accounts for relative contributions of each author to an article and applies a weighting to correct imbalances in the Index's subject area coverage.

For more information visit **natureindex.com**.

SKA ORGANISATION / EYE CANDY ANIMATION



How the planned SKA wide field low-frequency aperture will appear in the southwestern deserts of Australia.

develop a more consistent, focused strategy for innovation, under which an internal test — bed has been set up for possible new ventures.

"We put it together as though it's a little company and the process works on how can we get our technology to be a product and out to market," Storr says.

"The idea is to modify the culture within the organisation so researchers can see the value of what they're working on and how it can be turned into a product, and people in industry can see we're working towards products that will solve their problems."

Innovation is also being promoted at the political level. Queensland's state government recently launched the four-year, $180 million Advance Queensland initiative specifically to help "create the knowledge-based jobs of the future, drive productivity improvements and build on our natural advantages". The state's chief scientist Dr Geoff Garrett says this initiative builds on a foundation laid through earlier investments, signalling that science and innovation are front and centre of Queensland's strategy.

"Advance Queensland is designed to get to grips with the double challenge of continuing to nurture talent, and to really focus effort on facilitating and improving the all-important 'translation' between the research effort in the university and research institute environment, and the growth of new, small-to-medium businesses in particular," Garrett says.

The state will offer research grants for which fellows will be required to spend half their time working directly with industry, with the goal of creating a new league of more industry — savvy researchers, as well as helping better uptake.

Advance Queensland was launched with a backdrop of three major collaboration announcements between academia and industry in the state: between Queensland's Translational Research Institute and Siemens; Emory University and the University of Queensland; and the Queensland University of Technology and Johnson & Johnson.

The triple bottom line

There is also a national move to formulate a new metric for scientific achievement that would work alongside the existing measurement of publication and citation success. Alan Finkel has been a key player in pushing for what he and colleagues are calling the 'REA' measurement, for Research Engagement Australia, which is a wry twist on the existing ERA — Excellence in Research in Australia — process.

"It's not that the ERA intended to undervalue people who spend time on engagement, but it's an inadvertent consequence if you're mainly focusing on crediting their publications and citations," Finkel says.

But science owes much to serendipity, so picking winners before the horses have left the stables is extremely difficult. Larry Marshall says the challenge is how to focus on the social, environmental and financial "triple bottom line" without sacrificing the kind of blue-sky research from which many Australian success stories have emerged.

"I think it would be a shame if universities were forced to try to measure and direct their science to be industrially focused," Marshall says. "You can't tell a professor what to be interested in and professors are at their best when they pursue their instincts."

At a time of uncertainty for science funding in Australia, with significant cuts to funding bodies such as the Australian Research Council and the National Health and Medical Research Council, it is more important than ever that scientific research proves its worth and diversifies its funding.

Collaboration with industry can attract funding, but, just as valuable, it will ensure that more Australian research will achieve real-world impact; something Geoff Garrett maintains is of fundamental importance.

"Innovation is 'ideas successfully applied', so if the fruits of great research, publishing quality papers and great citation levels don't get into the broader marketplace and create jobs, wealth, improving the quality of life, then we've failed. It's not either research excellence or effective application, it's both." ■

This content was commissioned and edited by Naturejobs editors.

Australia's top 20 institutions (2014 WFC)

Source: natureindex.com

Rank	Institution	WFC 2014
1	The University of Queensland (UQ)	109.43
2	Monash University	105.74
3	University of New South Wales (UNSW)	87.33
4	Australian National University (ANU)	87.07
5	The University of Sydney (USYD)	81.56
6	The University of Melbourne (UniMelb)	79.23
7	The University of Adelaide (Adelaide Uni)	39.23
8	The University of Western Australia (UWA)	37.60
9	The Commonwealth Scientific and Industrial Research Organisation (CSIRO)	34.62
10	Macquarie University	20.31
11	University of Tasmania (UTAS)	19.31
12	Curtin University	18.92
13	RMIT University	17.65
14	James Cook University (JCU)	15.76
15	Griffith University	15.54
16	The University of Wollongong (UOW)	14.71
17	Swinburne University of Technology	13.77
18	The Walter and Eliza Hall Institute of Medical Research (WEHI)	13.73
19	QIMR Berghofer Medical Research Institute	11.06
20	Australian Nuclear Science and Technology Organisation (ANSTO)	9.74

Swinburne University of Technology

Award-winning research to solve big data problem

As data grows in size and complexity, the quest for greater storage capacity intensifies.

An optical data storage breakthrough at Swinburne University of Technology's Centre for Micro-Photonics has delivered the cornerstone of a patented technique that could provide the ultimate solution in the 'big data' era.

This technique lays the groundwork for big data storage with longevity and sustainability.

Factory of the Future:

Swinburne's new Factory of the Future will help industry explore ideas and solutions for advanced manufacturing of high value-add products.

- **3D Visualisation and Design Studio**
- **Rapid Manufacturing Studio**
- **Advanced Inspection and Machining Studio**
- **Biodevice Innovation Studio**
- **Design for Resource Efficiency Studio**
- **Micro-photonics Fabrication Centre**
- **3D Printing Lab**

In 2013, Swinburne researchers Min Gu, Zongsong Gan, Yaoyu Cao, and Xiangping Li announced a leap forward in data storage technology, dramatically increasing the capacity of a DVD from 4.7 gigabytes to 1,000 terabytes. This is the equivalent of storing 50,000 high definition movies.

The technique enables three-dimensional optical beam lithography at nine nanometres.

It uses two laser beams, instead of the conventional single beam, with different colours for recording onto the disc.

One beam, referred to as the 'writing beam' records the information, while the second beam inhibits the writing beam.

This produces a focal spot that is one ten thousandth of a human hair, allowing petabyte storage — the equivalent of 50,000 high definition movies — on a single disc.

As only conventional optical and laser elements are used, the technology is both cost-effective and portable.

The impact of this technology goes beyond storage capacity and has significant implications for energy consumption.

"Optical discs are what we call 'cool technology' they don't require cooling systems, and they also have long lifetimes of around 20-30 years," Gu said.

In 2014, start-up company Optical Archive Inc. (OAI) licensed this technology. The following year the Sony Corporation of America purchased the start-up.

The team at OAI consisted of some of the founders that had built a business dealing with data management systems who were deemed most likely to commercially develop the Swinburne discovery.

As energy consumption and physical space allocations could potentially be dramatically reduced, the technology provides an ideal platform for the next-generation of scaled-back exabyte data centres.

The new technology and the future development plans have laid the groundwork for big data storage with longevity and sustainability.

The wide public appeal of this data storage technology breakthrough was recognized by the 2015 Knowledge Commercialisation Australasia (KCA) Research Commercialisation Awards, through the team's recent win of The People's Choice Award in the best commercial deal category.

SWINBURNE UNIVERSITY OF TECHNOLOGY

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Macquarie University:
Commemorating 50 years

Australia's most distinctive university blazes its own path

"In Macquarie University I see an extraordinary opportunity," says S Bruce Dowton, the university's fifth Vice-Chancellor. "It is old enough to be well established but also young enough to be dynamic and innovative. We have a financial capacity other universities can only dream of, and a deep and abiding warmth and collegiality unlike any other. This gives us the freedom to make bold decisions: to devote significant resources to targeted research areas, to acquire entire research teams, and even to build an academic hospital."

The history of Macquarie University is brief but emblazoned with distinction. "Our story is under-told, even in Australia. Universities in this country tend to be homogeneous, but from its very outset Macquarie was created to be different, and those origins create our opportunities today," explains Dowton.

Macquarie University was founded as a public institution in 1964 with a 'gift' of 126 hectares of freehold land just 16 kilometres northwest of the centre of Sydney. This legacy has secured the university's future. "No other university in Australia in such a cosmopolitan location has this kind of land asset," says Dowton. "It gives us a credit rating better than some state governments, and with that a significant source of research funding as well as opportunities for development as a diversified source of income. But it also gives us this extraordinary academic space that is a short drive from the city centre."

With acres of grass and even a lake, the Macquarie campus offers a serenity rarely found in urban universities. It is a sanctuary that nurtures fast and enduring bonds, and dissolves the arbitrary walls between disciplines. "We have none of the fiefdoms common in older universities," says Dowton. "We are fundamentally a very transdisciplinary research community. Engagement, both internally and with the external community and industry, is part of our culture."

One of the pillars of Macquarie's research strength is its long history of productive collaboration with industry. The campus in Macquarie Park sits alongside Australia's largest business park, and more than 20 private companies lease premises within the Macquarie grounds. "We have a very porous boundary with the business park and collaborations that extend internationally. This not only fosters terrific relationships with industry, but also stimulates research. It is part of who we are; part of the distinctive character of Macquarie."

S Bruce Dowton, Vice-Chancellor of Macquarie University

Macquarie University:

World-leading research with world-changing impact

With 14 National Research Centres backed by generous government funding, and 19 internally funded research centres, Macquarie boasts a remarkable cluster of research excellence for its size and age. Add to that a highly successful university-owned and -operated hospital, an array of world-class clinics and facilities, and several high-profile industrial collaborations with major corporations such as Optus, Honeywell, Luxottica, and pioneering hearing-implant maker Cochlear. The University has also made significant investments in establishing the Australian Hearing Hub, a collaborative research centre for hearing, language and cognition, which also hosts the National Acoustics Laboratories.

"We are a billion-dollar university, which is really remarkable for a university of this size," notes Deputy Vice-Chancellor (Research) Sakkie Pretorius. "Macquarie has never shied away from risk, and our unique ability to invest significantly in research has allowed us to leapfrog many other well-established universities — we are in the top five universities in Australia in terms of internal funding for research."

Macquarie's research coverage is reasonably broad, but deliberately does not aim to be all things to all people. "We have enough breadth to focus on certain areas and do them well," explains Dowton. "We don't want to dilute what we do for the sake of adding a faculty here, a department there. Our excellence in specific areas

Synthetic biology: The new frontier

One of the most important achievements in the history of the life sciences was the sequencing of the human genome. Genomics is now a fundamental and routine part of clinical and biological research and medicine, but the Human Genome Project was responsible for stimulating the development of the technology that now allows us to sequence in hours what once took months or even years. Less than two decades later, the life sciences are on the cusp of yet another revolution — synthetic biology.

"We're very much in the gold-rush era for synthetic biology," says Ian Paulsen, Australian Research Council Laureate Fellow and Deputy Director of Macquarie University's Biomolecular Frontiers Research Centre. "Building on our long-term strengths in genomics and proteomics, Macquarie has the potential to play a global leadership role in synthetic biology.

Synthetic biology is about assembling genetic building blocks to reconstruct an organism from scratch. Ultimately, it is expected to be possible to design and construct sequences of DNA from a library of 'biobricks', resulting in a designed organism with tailored characteristics and functionality. "A lot of technology development still needs to happen before it can become a completely mature science, similar to the situation with genomics 20 years ago," notes Paulsen, "but there is a lot of activity in this area and it is only a matter of time before we will be able to build novel chromosomes and organisms, as well as entire synthetic microbial communities."

In 2014, Macquarie joined the global Yeast 2.0 project, which aims to build the world's first synthetic eukaryotic genome by the end of 2017. Macquarie's Yeast 2.0 team have been tasked with building two of the yeast's sixteen

chromosomes. "We joined the project later than others, but have had significant investment from Macquarie and the State Government and are on track to deliver our contribution by 2016. We have the advantage of having access to the new technologies that have been developed as part of the project, and we are already working on ideas around potential applications, such as for the wine industry. Macquarie is well positioned to become a future leader in the field."

Emotional health: Getting in early

Nearly all of us will experience the most common manifestations of mental disorder — anxiety and depression — at some time in our lives. Often the triggers for these issues are environmental, but we are only just beginning to understand what makes one person resilient to such stresses while another person experiences mental illness. Understanding the causes of emotional health issues and developing preventative programmes and treatments to deal with them are the two research areas being addressed by Macquarie University's Centre for Emotional Health (CEH).

"Our centre is unusual in that we look across the lifespan, from infants to older adults," says Jennifer Hudson, Director of the CEH. "The clinic associated with our research centre was established by Australian Research Council Laureate Fellow, Ronald Rapee, more than 20 years ago, and we are now recognized as one of the leading clinics for emotional health in the world, particularly for children."

The CEH is collaborating with over a dozen child anxiety clinics around the world, giving it access to the largest pool ever of young people with anxiety disorders. "Children's emotional health is so important," explains Hudson. "It is a strong predictor of life satisfaction and happiness as an adult. We know that if you're a child with an emotional health difficulty, you're much more likely to develop a mental disorder later in life. By intervening in childhood, we can work towards raising more emotionally healthy adults, and in doing so reducing the societal burden and cost of mental disorders in the community."

The CEH has developed a range of programmes for treating emotional health issues that are now in use around the world, such as the Cool Kids programme for child and adolescent emotional health disorders. "We specialize in skills-based cognitive behavioural therapies, which we develop at the centre and refine through our clinic. We now have effective treatments that work for most children."

allows us to collaborate with the world's top universities and allows our research to have a real international reach."

Developing minds: Unravelling the mysteries of childhood development

"Surprisingly, very little is known about how children's minds develop," says Stephen Crain, Director of the Australian Research Council (ARC) Centre of Excellence in Cognition and its Disorders (CCD). "The conventional techniques used to measure brain function are not child friendly, and so obtaining measurements that are not affected by a child's reaction to noisy, confining or invasive equipment has been very difficult."

An alternative is magnetoencephalography (MEG), which uses highly sensitive magnetic detectors to locate activity sources in the brain. A noncontact and unimposing device, it is a natural fit with child research.

"We were the first to develop an MEG system for children, and that system is now the core of our brain imaging laboratory, which is the most extensive of its kind in the world," says Crain. "MEG has excellent temporal and spatial resolution, which has allowed us, for example, to investigate the temporal dynamics of language — how it develops and how it is processed in real time. This gives us for the first time a window into conditions such as language acquisition disorders."

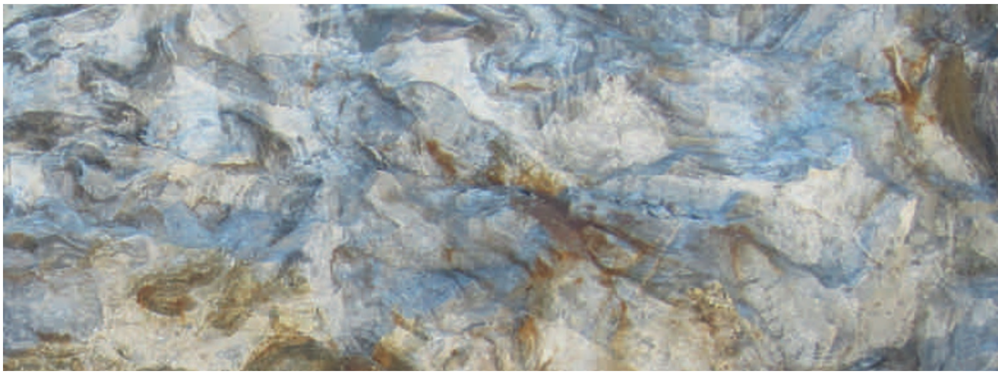
As with all Macquarie endeavours, research at the CCD is acutely focussed on applications. The centre's research on language has led to the development of therapy programmes for adults, and revealed new insights into conditions such as aphasia and specific language impairment. "We're finding out things that we simply didn't know, and some of these findings have a direct impact on treatment plans," explains Crain. "Our future work will be even more focussed on children, including how the brain processes information from cochlear implants."

Macquarie has a long heritage in cognitive science research, which extends to reading. "We have developed strong theoretical models for reading cognition that allow us to better understand reading disorders," says CCD Deputy Director Anne Castles. "Our models are used worldwide and Macquarie is an internationally recognized leader in the field, with the largest concentration of researchers in reading to be found anywhere."

One of the centre's main goals is to promote interdisciplinary and collaborative research to realize lasting impact. The CCD itself was founded through a collaboration between Macquarie University and other key partner universities in Australia, with funding from the ARC. "We have strong links with our reading clinic, the Australian Hearing Hub and Macquarie University Hospital, as well as access to fantastic labs and facilities, which has allowed us to focus on the dynamic interplay between research and practice," says Castles. "The next big frontier is understanding the foundations of how reading develops in early life. We now understand enough about the basic processes of reading to be able to track its development."

Wireless networking: Solving the spectrum crunch

Part of Macquarie University's "under-told" story is its involvement in the invention and development of the now-ubiquitous broadband WiFi technology in the 1990s. It was here, in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), that the first 802.11a WiFi prototype system was constructed — a technology that catalysed a successful commercial spinoff that was ultimately acquired by global networking giant Cisco. Since that time, Macquarie University has been at the global forefront of wireless technology development.



"We still lead the development of the 802.11a global wireless standard," says Stephen Hanly, CSIRO–Macquarie University Chair in Wireless Communications, "but the technology keeps progressing. Today's needs differ completely from those envisaged by the WiFi pioneers in the 1990s. We now need to cater for the proliferation of sensing devices or the 'Internet of Things', as well as new low-latency, mission-critical applications in areas such as medicine, transport and smart electricity grids."

The focus today is on the optimal allocation of wireless resources. Wireless users are each allotted a small slice of the available electromagnetic spectrum, but often there are vastly more potential users than bands available. "We call it the spectrum crunch," says Hanly. "Spectrum, particularly for carriers, is getting more and more precious." And with hundreds of thousands of wirelessly connected devices per square kilometre, the crunch is only going to get worse.

The problem with so many connections is that the systems have become so complex that existing methodologies for capacity planning are becoming unusable. "For example, carriers are now installing small cellular base stations called picocells to help cope with the wireless load, but because of their operational complexity we have not been able to measure or even model whether such cells are efficient or worth the cost," explains Hanly. "We have developed a capacity analysis that quantifies this, making it possible to analyse the cost–benefits of picocells for the first time. This is an example of where I believe future wireless communications research needs to be. We need to take into account not only novel engineering paradigms, but also economic theory in order to make effective network deployments and efficient use of the scarce radio resource of spectrum."

Earth science: From core to crust

The ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS) and its predecessors have a history of doing things differently, and in the process have elevated Macquarie University as a world-leading research partner in Earth sciences and mineral exploration.

"Our board of advisors includes several industry and government representatives," says Stephen Foley, Research Coordinator at the CCFS. "While that may not be unusual, what is different is the quality and depth of discussions between members representing different sectors. Industry is directly involved and contributes to the

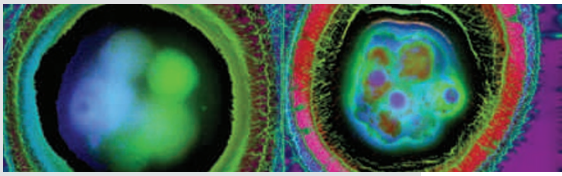
Nanobiophotonics: Windows into the body

Macquarie University is recognized internationally for its research strengths in the fields of physics and biomolecular sciences. Bringing these disciplines together opens up immense possibilities for the application of light-based technologies to better understand cellular and molecular processes in the living body.

On this foundation, Macquarie University is a major node and key collaborator amongst other Australian universities of the Australian Research Council Centre for Nanoscale BioPhotonics (CNBP). The new centre draws together Macquarie's expertise in nanotechnology, photonics, genomics, proteomics, transcriptomics and glycomics to carve out a new field of inquiry — nanoscale biophotonics.

"The centre develops innovative optical fibres to probe deep into tissue, as well as advanced chemical sensors for real-time diagnostics and novel imaging techniques," says Ewa Goldys, Deputy Director of the CNBP. "Our centre's mission is to create new windows into the body. We are taking a new generation of researchers on a fantastic journey of exploration and discovery."

The key challenge facing CNBP researchers is how to directly visualize biological mechanisms in living organisms at the cellular level, noninvasively and in real time. The solutions can be found at the intersection between physics, chemistry, biology and medicine. Centre physicists build luminescent nanoparticle probes, while the biochemists determine how to link the probes with molecules of biological interest in applications such as chronic pain, fertility and cardiovascular health. Through engagement with international research partners and industry, the CNBP aims to translate these research ideas into technologies with commercial impact.



"Our approaches to biomolecular imaging are truly transforming our understanding of health and complex disease," says Nicolle Packer, Chief Investigator at the CNBP and a world-leading expert in glycomics, proteomics and biomolecular chemistry. "Macquarie University has first-rate expertise in this area including the outstanding Australian Proteome Analysis Facility. We are currently conjugating probes to carbohydrate molecules on the surfaces of cells to visualize cellular processes. We have already developed a probe to identify molecular markers of prostate cancer in urine." It is an approach that is expected to be very influential in medicine.

"We are dealing with complex biological environments," continues Goldys, "which require sophisticated technologies and advances in physics and engineering. We look to inspire our bright young researchers to advance our understanding of the very essence of life itself."

Shaping the future of research

"The extent of Macquarie's research achievements to date belies the University's youthfulness, yet accurately reflects the agility and audacity shown over the University's first 50 years," observes Macquarie University Deputy Vice-Chancellor (Research) Sakkie Pretorius. "Inspired by these remarkable research achievements, Macquarie stands ready to play its part in building a future and making the world a better place for all. We will do this by expanding our cross-disciplinary, fundamental and applied research and building on the tremendous depth of fundamental research and disciplinary expertise that underpins much of our history of discovery."

Just over ten years ago Macquarie University took the first steps in a deliberate strategy to take its research activities to the next level. Key to that initiative was the University's bold move to secure a bond market credit rating based on its land assets, which has provided financial freedom to fully back some of Macquarie's most audacious projects, such as the construction of the world-class Australian Hearing Hub and Macquarie University Hospital. The waves of opportunities now lapping at Macquarie's feet are a testament to the success of those initiatives.

"To take us forward, we wanted to come up with a research framework that harnesses the total effort at Macquarie, not just part of it," says Pretorius. "Out of a year-long process of discussions with stakeholders from across the University, we developed five Future-Shaping Research Priorities — Healthy People, Resilient Societies, Prosperous Economies, Secure Planet, Innovative Technologies — as a means of aligning our current and emerging areas of disciplinary research strength with the significant challenges of today and tomorrow," continues Pretorius. "We are committed to maintaining these priorities over the next ten years, but we will retain flexibility in the support of research streams. Stability without stifling freedom. I believe this is a unique structure in this sector."

The ten-year Strategic Research Framework and its Future-Shaping Research Priorities allow the University to channel its funding and resources effectively into strategic areas with a high level of current and potential impact. Macquarie has

always been mindful that even the most fundamental research should impact the society that it serves, and from which it draws a considerable proportion of its funding.

"We believe we need to formulate research questions in a way that captures potential applications," says Pretorius. "Research is our way of systematically unravelling nature's laws and understanding society through theory and experiment, which in turn sparks new ideas, expands the frontiers of knowledge and advances our world. Macquarie has had several significantly impactful achievements over its first 50 years. With this new strategic framework we are hopeful for many more over the next decade."

palette of projects we undertake. We do the fundamental research needed to improve our understanding of how the Earth works, but base the targets of our research on what is most important to the mineral resources industry. The result is that Australia has become a world leader in providing the tools needed for mineral explorers."

The CCFS is an ARC-funded collaboration with other key Australian universities and the Geological Survey of Western Australia, along with several international partners. The centre is very much an extension of the work overseen by the centre's Director, Suzanne O'Reilly, which began with the ARC National Key Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC) that preceded the CCFS. "Sue has really been the driving force behind our achievements, and Macquarie has been prepared to make strong decisions to back her work with support and internal funding," says Foley.

One of the group's most important breakthroughs has been the development of isotopic mapping as an exploration tool. "The maturation of laser-ablation mass spectroscopy has made it possible to map the isotope-based age of rocks on a regional scale," explains Foley. "This adds the dimension of time to geological maps, which helps the exploration industry in that episodes of continent formation correlate well with mineralization." The technique, developed by GEMOC through research led by Elena Belousova, is now a commercial technology called *TerraneChron*®. "Mineral explorers will go where the information is good. Due to several years of work with *TerraneChron*®, Western Australia now has the best isotopic mapping coverage anywhere in the world, and Macquarie has made that possible."

The University of Queensland

Pioneering research for global change

The University of Queensland has made significant contributions to Queensland, Australia and the world through its unrelenting pursuit of academic excellence, innovative research and contemporary social relevance.

The University of Queensland (UQ) is one of Australia's leading teaching and research universities, having educated more than 225,000 alumni who pioneer positive change worldwide. The university ranks in the top 50 in both the *US News* Best Global Universities Rankings and the QS World University Rankings; 56 in the Performance Ranking of Scientific Papers for World Universities; 65 in the *Times Higher Education* World University Rankings; and 77 in the Academic Ranking of World Universities. UQ also ranks first in the *2015 Global Nature Index Institution Rankings for Australia.*

UQ's research community excels, contributing solutions to some of the great challenges of our time. Some of the genuinely life-changing advances our innovators have made include:

- The world-first Gardasil™ cervical cancer vaccine, invented by Professor Ian Frazer AC (pictured top right) and the late Dr. Jian Zhou, which is now approved for use in more than 120 countries, has benefited tens of millions of women worldwide, and is expected to save 250,000 lives annually;
- The Triple P – Positive Parenting Program, which has been translated into over 20 languages, reaching more than 7 million children and their families in 25 countries;
- UQ-founded biopharmaceutical company Spinifex, which is based on a discovery by Professor Maree Smith (pictured top left with Dr. Nemat Khan), and has now been acquired by Novartis International AG in one of Australia's biggest biotech deals to develop innovative treatments for chronic pain relief;
- Signal correction technology licensed to Siemens and GE Healthcare, which is used in two-thirds of the world's magnetic resonance imaging machines and has resulted in more than 8 billion patient scans to date.

UQ's main commercialization company, UniQuest Pty Ltd, plays a vital role in translating UQ researchers' discoveries and advances in the areas of health, engineering, information and communications technology, science and social enterprise into globally accessible business outcomes through industry partnerships to improve the lives of millions around the world. By engaging with industry and investors, UniQuest has developed an impressive portfolio of over 1,500 patents and more than 70 start-up companies. UniQuest has raised Aus$500 million to take innovations to the marketplace, with over Aus$12 billion in gross product sales.

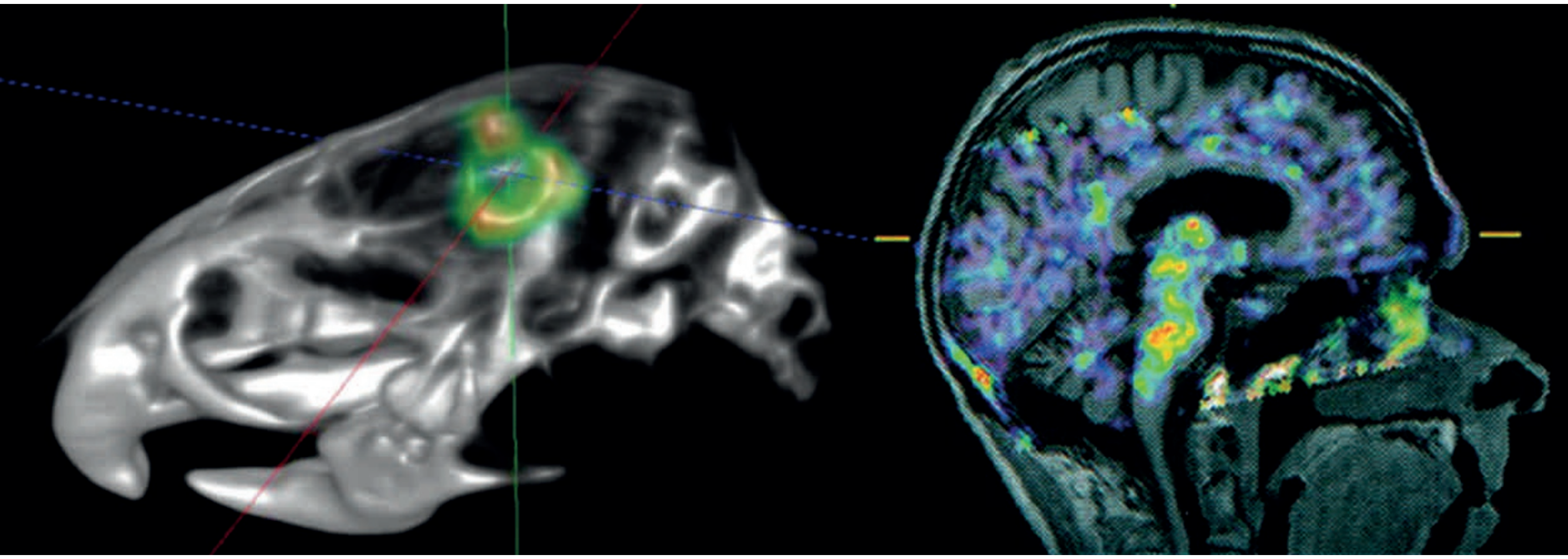
UQ is also proud to partner with global research institutions and industry partners to amplify the positive potential of our research. Our partnerships in 48 countries take many forms, including joint research-and-development centres, licensing deals, scholarships, internships, graduate employment programs and philanthropic foundations.

UQ's success is underpinned by the quality of its people and research excellence, as demonstrated by the Australian Government's Excellence in Research for Australia (ERA) 2012 assessment, which ranked all of UQ's research fields as world standard or above.

By pursuing excellence in discovery, learning and engagement, UQ is committed to transforming our successes into far-reaching benefits for people globally.

Fast facts:

- **Number 1 ARC Future Fellowships income (cumulatively 2009–2014)**
- **Equal 1st ARC Laureate Fellows for two years running (2014–2015)**
- **100% world standard or above research in 2012 ERA assessment**
- **1,543 active Australian and global industry collaborations and partnerships**
- **25% growth in research industry funding since 2012 (Aus$382 million in 2013)**



Australian Nuclear Science and Technology Organisation

Ancient gene ignites potential for drug development

The creation of the first healthy mouse without the evolutionary conserved mitochondrial translocator protein, long thought to be essential for life, is an important scientific breakthrough. Developed at the Australian Nuclear Science and Technology Organisation, it paves the way to new diagnostics and treatments for inflammation, dementia, obesity and cancer.

To aid the systematic study of the translocator protein (TSPO) in membranes, scientists at the Australian Nuclear Science and Technology Organisation (ANSTO) and colleagues at the Brain and Mind Centre at the University of Sydney have been using Australia's landmark and national nuclear science infrastructure, which includes ANSTO's neutron reflectometer instrument (Platypus), to develop diagnostic tools, such as radioligands for positron emission tomography (PET) and single-photon emission computed tomography (SPECT) imaging. This is part of a strategic interdisciplinary research project aimed at understanding the function of this abundant and highly regulated, ancient mitochondrial protein.

The broad diagnostic and therapeutic importance of the TSPO stems from the observation that its cellular expression increases dramatically during inflammation, dementia, obesity and cancer, and also appears to play a role in behavioural conditions, such as anxiety. Moreover, the interaction of small molecule drugs with lipid membranes can modulate the conformation and function of resident membrane proteins such as TSPO (see top image overleaf). Thus, in addition to its role as a diagnostic biomarker of disease progression, TSPO is also attracting attention as an important therapeutic target. As of 2014, there have been well over 30 clinical trials involving diagnostic and therapeutic aspects of the TSPO in disease conditions ranging from inflammation to neurodegeneration and behavioural illnesses.

In their latest study (*Nature Communications* **5**, 5452; 2014), the

ANSTO fast facts:

- **ANSTO is custodian of much of Australia's national research infrastructure:**
  - **OPAL, one of the world's most effective multipurpose research reactors**
  - **A comprehensive suite of thirteen neutron-beam instruments**
  - **The Australian Synchrotron, which has nine experimental beamlines**
  - **The Centre for Accelerator Science, which offers four ion accelerators**
  - **The National Deuteration Facility**
- **ANSTO hosts over 1,800 visiting researchers each year**
- **The new ANSTO Nuclear Medicine (ANM) Project will help position Australia as a global leader in the manufacture of molybdenum-99**

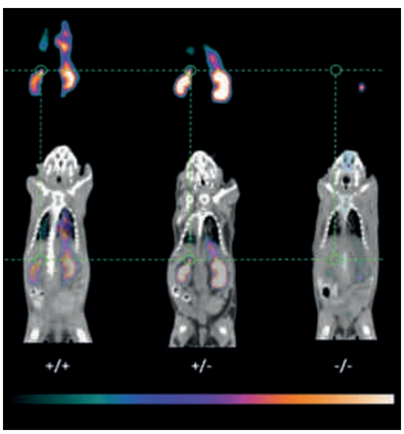
team, led by Richard Banati, reported the existence of healthy global TSPO gene knock-out mice and confirms the presence and absence of the gene by *in vivo*-imaging (see image below). The team's findings came as a surprise since previous observations had suggested that the loss of the TSPO, in line with its pivotal role in steroid synthesis, was embryonal lethal. Consequently, the new findings have generated a lively debate about some of the most basic aspects of physiology, such as the synthesis pathways of steroids, for which the TSPO has long been thought to be one of the rate-limiting steps.

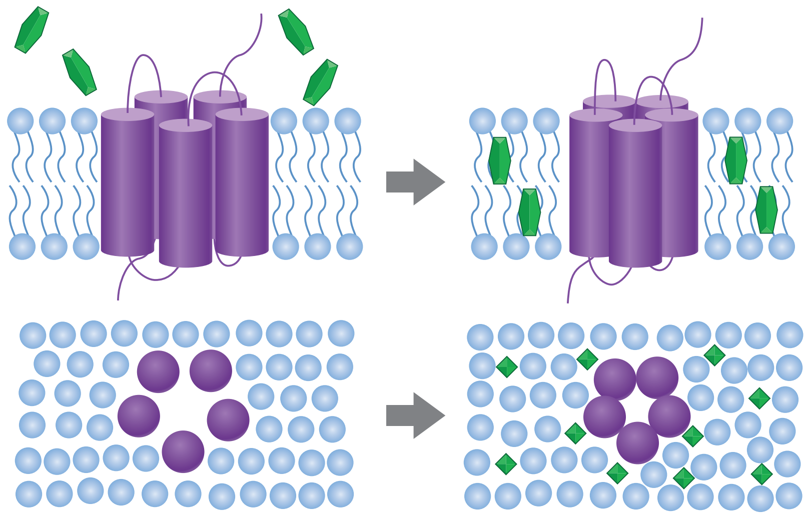
As part of their ongoing investigations, the ANSTO team observed alterations in the energy metabolism in microglia cells, the brain's resident immune cells.

With a nod to the birthplace of the mice and the fact that mitochondrial energy production may be altered, the scientists named their mouse *Guwiyang Wurra*, which means 'fire mouse' in the local indigenous Dharwal language.

"Obviously, understanding the true role of the TSPO is of fundamental scientific interest and a global gene knock-out model is important for systematic loss-of-function and mechanisms of compensation studies," says Banati. "However, while we are trying to develop such a model, we have already demonstrated the immense practical utility of this animal model for TSPO drug development, particularly for assessing drug selectivity in life and off-target effects that may cause toxic or other effects."

The researchers are especially excited about the possibility of creating tailored cancer models. For example, the TSPO knock-outs could be used to study





syngeneic brain tumours that have retained their wild-type TSPO, and observe the tumour response to treatment in virtual isolation from the surrounding tissue under realistic *in vivo* conditions. The team were able to generate high resolution and contrast micro PET and computed topography images (using TSPO ligand PBR111) to show TSPO expressing tumour cells in a TSPO knock-out animal (see image on previous page - left) and in a human brain (see image on previous page - right). "Such biologically background-free imaging in the living animal has never been done before," comments Banati.

ANSTO recognises that effective partnering can accelerate realising the potential of discoveries, turning them into innovative products more quickly and cost effectively than is possible through purely in-house development. ANSTO is therefore actively seeking collaborative partners to use the TSPO knock-out mouse model (C57BL/6-*Tspo*^{tm1GuWu}) to determine the action of new compounds, including the repurposing of existing compounds and the development of novel therapeutic approaches.

Partnership opportunities include:

- TSPO KO mouse: strong intellectual property portfolio to develop collaborations
- Ligand screening: TSPO KO and wild-type mice to evaluate TSPO ligands (ligand does or does not bind to the TSPO)
- Drug development: validate the biological pathways involving the TSPO; identify lead compounds that have therapeutic effects
- Preclinical: lead candidates developed using the TSPO KO mouse are established or are being developed in a preclinical environment
- Clinical trials: trials of drug candidates for potential registration

The work on the knock-out mouse model and the extensive medicinal chemistry research at ANSTO is part of a broader portfolio that ranges from structural biology using synchrotron X-ray, neutron scattering and cancer therapeutics, to environmental health studies using the largest particle accelerator infrastructure in the Southern Hemisphere.

Potential collaborative partners should contact us

Web: www.ansto.gov.au
e-mail: enquiries@ansto.gov.au
richard.banati@ansto.gov.au

Australian Government

ansto

Nuclear-based science benefiting all Australians

The University of Western Australia

Sustaining Australia's rich biodiversity and resources

The University of Western Australia is one of Australia's leading research-intensive universities. Located in a global biodiversity hotspot, it enjoys access to a radiofrequency 'quiet zone' and highly automated mining, energy and resource industries. Its high-quality research benefits from the university's strategic position and significant investments in world-class infrastructure.

The University of Western Australia (UWA) was founded in 1911 with a mission to advance the welfare and prosperity of the people. Close to 24,000 students are enrolled in the nine faculties of UWA, which is currently ranked 87th in the Shanghai Jiao Tong University's Academic Ranking of World Universities.

As one of Australia's leading research-intensive universities, UWA is a member of the internationally recognized Group of Eight Australian universities committed to research excellence. It is the only Australian member of the Matariki Network of Universities and part of the Worldwide Universities Network — both groups designed to support collaborative research and the exchange of research staff and students. In 2012, the Australian Government's national research quality evaluation, Excellence in Research for Australia, classified all UWA research as world standard or above.

Global shifts in the balance of power are creating unprecedented opportunities for Australian universities to engage more widely with their Asian neighbours, while continuing to build on their traditional associations with Europe and North America. UWA has the further advantage of sharing the same time zone with 25 per cent of the world's population, including China, Malaysia and central Russia.

International collaboration will be especially vital for tackling global research challenges, such as adapting to and mitigating the effects of climate change, feeding, caring for and healing an ageing population, preserving local and global culture and heritage, ensuring the sustainable use of minerals and energy, and understanding our place in the Universe.

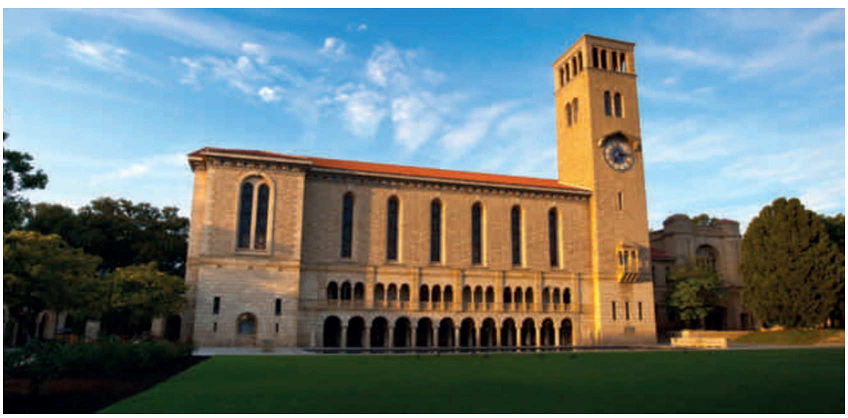
Through deep collaboration, UWA has harnessed its research expertise and engaged with local and international partners to tackle these global challenges. Its partners include researchers, government, industry and the wider community.

Tackling global challenges

UWA has a long and distinguished record of contributing to health and medicine. Among its notable research initiatives are those by Nobel Laureate Barry Marshall to develop novel vaccine delivery systems, Graeme Hankey's research into treating and preventing stroke and Bruce Robinson's studies of mesothelioma — cancer of the membrane lining many of the body's internal organs. UWA was also central to the establishment of the world's largest health data linkage database, which has since been replicated globally.

Protecting the world's precious biodiversity hotspots is another significant global challenge. UWA is located in a global biodiversity hotspot in south west Australia. The region covers an area of 470,000 square kilometres and is home to at least 8,000 plant species and a host of endemic mammals. Western Australia also has the World Heritage-listed Shark Bay and Ningaloo Coast, one of the world's largest fringing reefs, on its doorstep.

Further north, the Pilbara, Kimberley and Western Desert regions offer tangible evidence of human social and symbolic



practices dating back tens of thousands of years with some of Australia's most spectacular rock art galleries. These landscapes offer archaeologists and rock art researchers an extraordinary opportunity to study the rich cultural history visually recorded in rock art. Indigenous knowledge is one of the university's strategic research areas and UWA's Centre for Rock Art Research and Management plays an important role in understanding and conserving the region's indigenous heritage.

The UWA Oceans Institute brings together UWA's multidisciplinary research strengths in areas such as oceanography, ecology, engineering, resource management and governance to support the delivery of ocean solutions. The institute identifies sustainable and innovative ways to manage critical ocean resources for human development, including water, food, energy and bioresources. It also aims to protect the underlying biodiversity and ecosystems that support these resources.

Resourceful innovation

The oceans are only one element of Western Australia's rich natural resources. Researchers at UWA are harnessing the powerful capability of the university's cutting-edge facilities to meet global demands for world-class innovation within the resources sector. They work with industry and government to tackle solutions that address pipeline stability and deep-water engineering, carbon dioxide sequestration, mineral exploration, soil science, harnessing alternative energy sources, environmental impact and many other human resource issues, such as occupational health and safety, sleep science and leadership development.

UWA's Energy and Minerals Institute provides a gateway to UWA's expertise, high-tech infrastructure and collaborations. In 2013, mineral and energy exports contributed up to 91 per cent of the State's export earnings. Key research areas at the institute include natural gas to liquid fuel conversion, extraction of nitrogen and carbon dioxide from natural gas, advanced distillation of petroleum, mining and seismic monitoring and the environmental impact of mining. Dedicated centres for energy, geomechanics, mining engineering and rock mechanics at UWA are also currently undertaking cutting-edge research.

People at UWA:

- **According to the 2014 Thomson Reuters Highly Cited Researchers list, UWA hosts 22 of the world's most highly cited researchers.**
- **Nobel Prize winners Barry Marshall and Robin Warren revolutionized the treatment of gastroduodenal ulcers.**
- **Alistair Forrest has helped create the first map of cell-to-cell communication, while Ryan Lister has mapped how genes are turned on and off.**
- **Malcolm McCulloch studies the impact of global climate change on Australia's coral reefs, while microscopist David Wacey maps the earliest evidence of life on Earth.**

In 2014, UWA opened its Aus$10 million state-of-the-art CO2 Geosequestration Research Laboratory, which is part of the National Geosequestration Laboratory — a multi-site facility backed by Aus$48.4 million in government funding. It focuses on delivering research and development solutions to enable commercial-scale capture and storage of carbon dioxide with the goal of reducing greenhouse gas emissions.

Western Australia is the nation's largest grain-producing region as well as a significant producer of Australia's meat and livestock, dairy, wool, horticulture and honey products. The UWA Institute of Agriculture plays an important role in advancing research, education, training and communication in agriculture and natural resource management for the benefit of the local, national and international community. It integrates the activities of university groups involved in integrated land and water management, animal production systems, plant production systems, rural economy, policy and development, and education, outreach and technology exchange.

World-class infrastructure

UWA supports its high-quality research through substantial investments in world-class infrastructure, including a Aus$40-million Centre for Microscopy, Characterisation and Analysis. The centre is a collaborative research facility that supports innovation in biological, biomedical, geo-environmental and physical sciences, as well as in the energy and minerals sectors. Expert scientists at the centre have conducted atomic-level analysis to understand new-generation steel, contributed to alumina-based research and development projects, identified and validated new mining exploration methods and helped 'crack' methane gas.

The International Centre for Radio Astronomy Research is another internationally collaborative centre established through a joint venture with Curtin University. It achieves research excellence in astronomy and engineering and is making a fundamental contribution to the realization and scientific success of the Square Kilometre Array project — the world's largest ground-based telescope array. As part of the initiative, a radio quiet zone of extremely low radiofrequency interference has been established in the region.

UWA is also connected to the national Infrastructure Investment Programme through its nodes of the Australian Microscopy and Microanalysis Research Facility, the Australian National Fabrication Facility, Bioplatforms Australia, the Integrated Marine Observing System, Metabolomics Australia, the National Imaging Facility and the Population Health Research Network. It is also a major partner in the Pawsey Supercomputing Centre.

Contact

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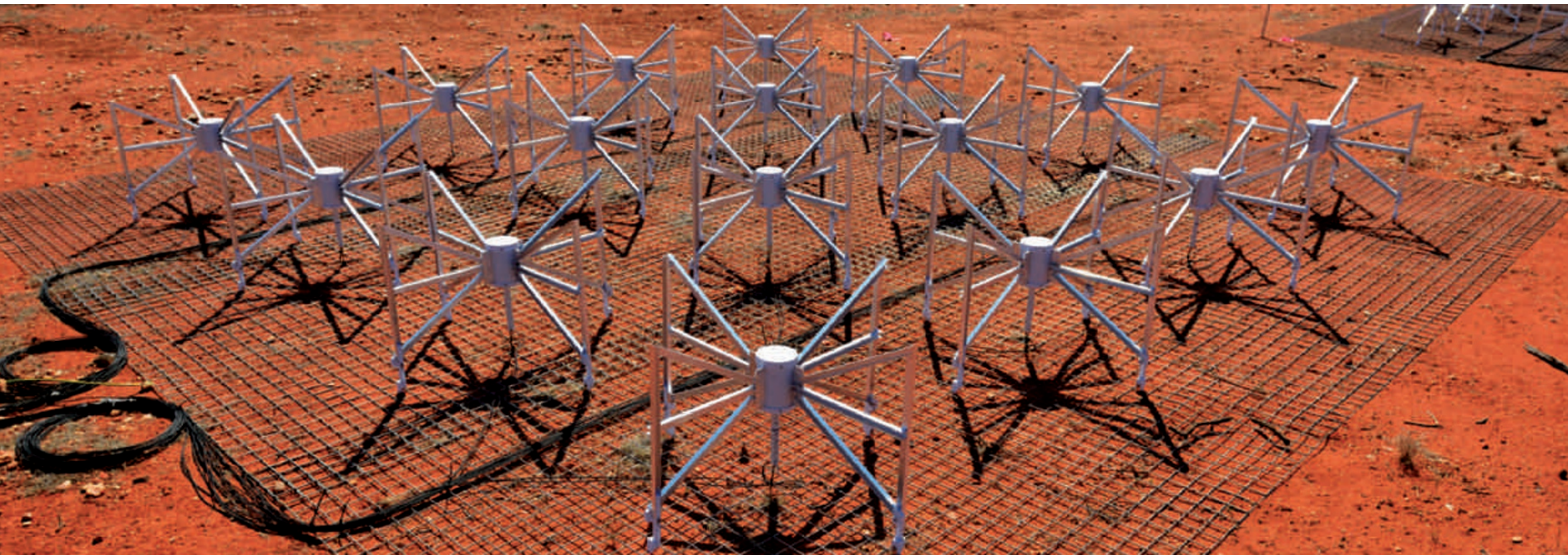
THE UNIVERSITY OF WESTERN AUSTRALIA



Curtin University

A rising star in astronomy

A leading institution in the preconstruction of the world's most powerful radio telescope, Curtin University is helping to change the way we see the cosmos.

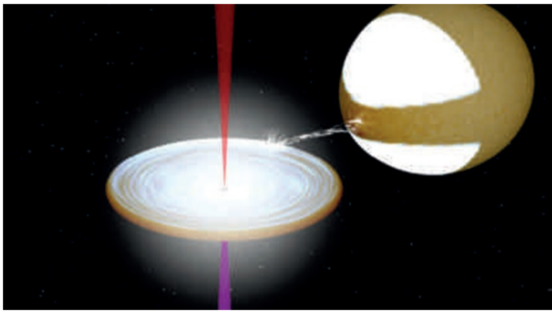
Curtin University in Western Australia is preparing the world for the arrival of the Aus$2.5 billion Square Kilometre Array (SKA) radio telescope, which will be the largest and most powerful ground-based array of antennas ever built. SKA will stretch across Australia and South Africa, with Western Australia hosting 'SKA-low', a massive all-electronic aperture array telescope, at the Murchison Radioastronomy Observatory in the state's remote mid-west. Construction for the international project is due to begin in 2017 and early science expected in 2020.

Since 2007, Curtin has been leading activities on important paths to SKA, and in 2009 co-established the joint venture known as the International Centre for Radio Astronomy Research, which plays a key role in the project.

Working with partners such as the University of Cambridge, the University of Oxford, ASTRON (Netherlands Institute for Radio Astronomy) and the National Institute for Astrophysics (INAF) in Italy, Curtin leads the establishment and characterization of SKA prototypes at the Murchison Radioastronomy Observatory. One system is operational and has produced the first images and measurements taken with SKA-low antennas, while a second, and much bigger system, will be completed over the coming months. Using new radio science techniques developed at Curtin, this prototype will serve as the primary SKA-low verification platform and trailblazer to the SKA Phase 1 construction. Even in its first phase, SKA-low will consist of more than 130,000 stationary and electronically steered wideband antennas.

Explosive cosmic events

As well as SKA engineering activities, Curtin leads a prestigious group of partners, including Massachusetts Institute of Technology and Harvard University, on an SKA-low precursor project known as the Murchison Widefield Array (MWA). The low-frequency radio telescope will play a vital role in developing the SKA's low-frequency science programme.



The MWA is a groundbreaking project in its own right. It consists of 2,000 antennas operating at radio frequencies between 80 and 300 megahertz spread out over three kilometres in the Shire of Murchison in remote Western Australia. The antennas are grouped into 128 square tiles of 16 antennas each (see top image). Applications of the MWA range from the detection of plasma ducts in the Earth's stratosphere to the study of the first stars and galaxies.

The MWA was designed to address four areas of focus: the epoch in the early cosmos of primordial hydrogen reionization, galactic and extragalactic surveys, space weather, and the changes that astronomical objects undergo over time.

Room with a view

Located at the Murchison Radio Observatory in Western Australia, 300 kilometres from the nearest city of Geraldton, the Murchison Widefield Array stretches across three kilometres of Western Australian outback. It is an isolated place; flat, sparse and brimming with red dust. Along with extremely low levels of radio interference, the site is perfectly situated for observing the centre of the Milky Way.

Observations of the epoch of reionization, a period that took place some 13 billion years ago, will offer crucial insight into how the Universe evolved into what it is today. The MWA has been designed to detect the presence of large 'bubbles' of ionized plasma formed during this period.

Astronomers are further using the MWA to find the remnants of old and faint supernova explosions known as supernova remnants. Currently, scientists know of around 300 supernova remnants in the Milky Way. The MWA could bring us closer to the total number believed to be in the realm of 1,200 to 3,000 — allowing for more accurate measurement of our Galaxy's total energy.

The array is also uniquely designed for space weather science. With solar storms capable of causing damage to communication networks of up to US$2 trillion, the MWA can act as a warning system, observing multiple aspects of solar bursts as they travel from the surface of the Sun to the Earth.

The MWA is also exploring explosive events such as gamma-ray bursts and supernovae, stellar and planetary emissions from Jupiter-like planets in other solar systems, and compact objects such as black holes.

In addition to using the MWA to produce valuable astronomy research, Curtin has linked the array with the SKA-low verification systems to enable the precision metrology and array characterization needed for SKA development. In a reverse flow, new techniques learned with the SKA platforms have been fed back to the MWA, improving its scientific capacity.

Hungry black holes

Curtin's reputation for astronomy is growing fast, with three recent papers on black holes appearing in *Nature*. Astronomers James Miller-Jones, Roberto Soria and Peter Curran from the Curtin Institute of Radio Astronomy worked as key members of international teams that challenged our understanding of these mysterious objects.

In 2012, Miller-Jones was part of an international team that studied an ultraluminous X-ray source in our nearest neighbouring galaxy, Andromeda. The study helped to solve a long-running debate over whether these emissions are from ordinary small black holes gorging themselves on gas from an orbiting star (see image on opposite page), or whether they are from more massive black holes eating sedately. The answer: "They are normal, everyday black holes," says Miller-Jones.

The breakthrough was made by connecting changes in the bright X-rays emitted from the source with dramatic variations in the radio emissions. The drop in radio luminosity by half in under 30 minutes indicated that the region producing the radio waves was small. The study was the first to detect such a jet emission from a stellar-mass black hole outside our own Milky Way.

Curtin research has also shed new light on the amount of matter a black hole is capable of consuming. In 2014, Roberto Soria was part of the team investigating an exceptionally bright black hole known as P13 in the galaxy NGC 7793, 12 million light-years from the Earth. Once again, they found that P13's high luminosity is not because it is bigger than the black holes we observe in our Galaxy, but because it is feeding from its companion star at a faster rate than previously thought.

Scientists generally believed that the maximum speed at which a black hole could swallow gas and produce light was tightly determined by its size, a concept known as the Eddington limit. "We have shown that P13 is feeding at a rate ten times faster than its Eddington limit, a regime known as 'supercritical accretion'," says Soria.

The result has prompted astronomers to reconsider theories about how fast a black hole can consume matter.

In 2014, Peter Curran was part of a team that observed a gamma ray burst with an afterglow of circularly polarized light, travelling through space in a helical motion, like a corkscrew. The finding defied the predictions of conventional theory and highlighted the need for new theoretical models capable of producing the complex microphysics of gamma ray bursts.

Over the past two years, Curtin has risen up the Academic Ranking of World Universities by more than 150 places, largely due to international research collaborations like the ones mentioned above. Co-director of the Curtin Institute of Radio Astronomy, Peter Hall, couldn't be happier about the university's progress.

"I mentally allowed a decade for Curtin to mature in its radio astronomy but it has been a privilege to help guide a much more rapid growth, to the extent that radio astronomy is now a significant force in driving the university's research trajectory," says Hall.

WHERE IDE

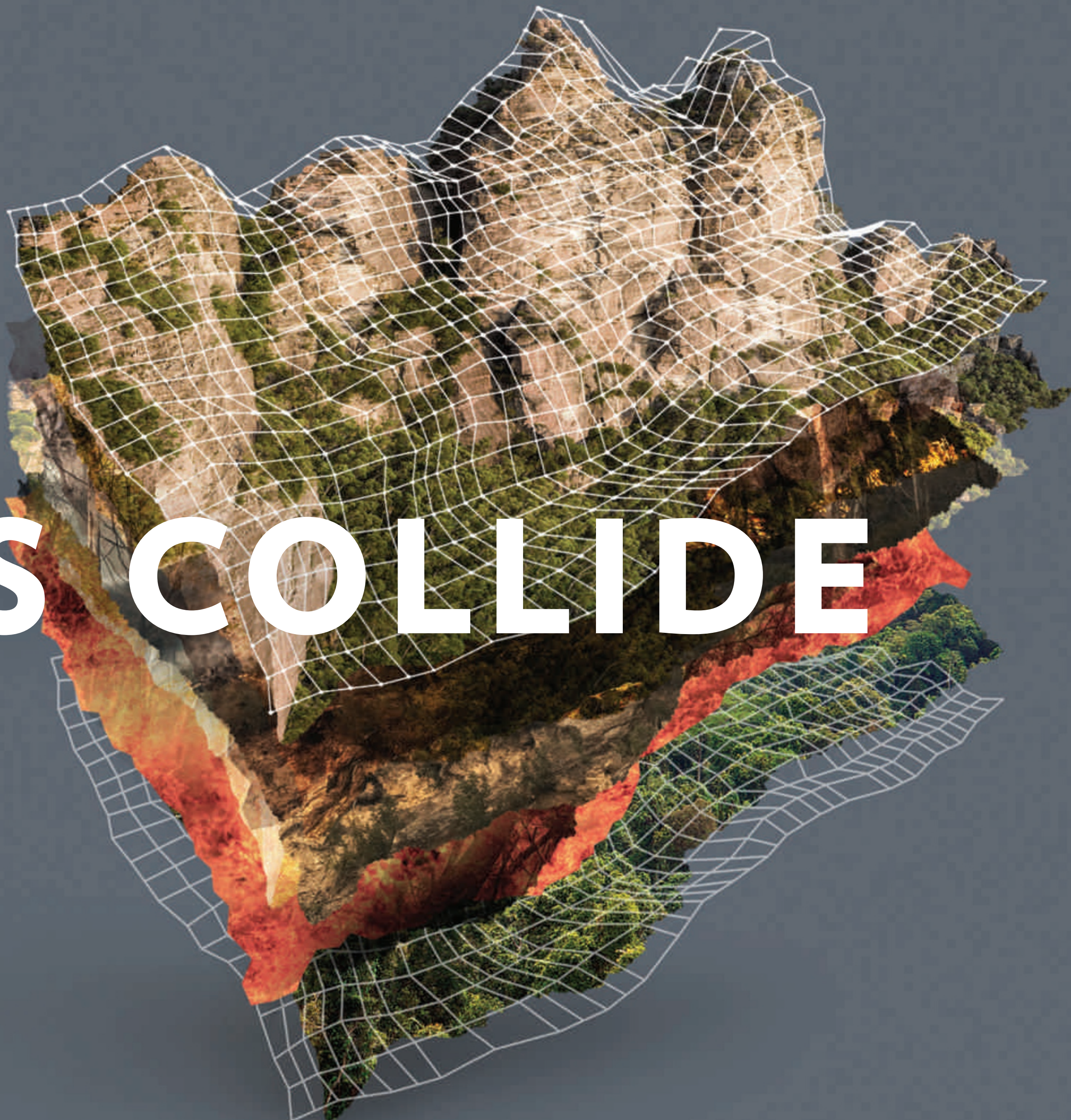
SUPPORTING WORLD-CLASS INNOVATION

The research undertaken by the University of Melbourne has the potential to impact many people, in many ways. Recent projects include Australia's first 3D printed jaw joint, and the software program, PHOENIX RapidFire, which is helping fire analysts to predict the path of bushfires. These studies, along with the countless others that take place at the University, are tackling some of the most important issues that face our world.

Within the Melbourne biosciences precinct we've worked to create a hub for entrepreneurialism across the fields of science, medicine, technology and engineering. As part of this, we're nurturing innovation through seed funding, mentoring, and a strong focus on supporting truly exceptional research and translation.

To read more about the 3D printed jaw joint, or the impacts of PHOENIX RapidFire,

go to PURSUIT.UNIMELB.EDU.AU.



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THE UNIVERSITY OF
MELBOURNE

Queensland University of Technology

Australia's fastest growing research university

Located in one of the world's most liveable cities, Queensland University of Technology is proud to be Australia's fastest growing research university.

Queensland University of Technology (QUT) has an impressive track record in research and is consistently ranked in the top ten for Australian Government research funding, which is awarded on performance. Effective communication between schools and disciplines means a trans-disciplinary focus is integrated into undergraduate and postgraduate programmes for quality learning and research recruitment. Strength across disciplines and comprehensive trans-disciplinary application through major industry partnerships allows QUT to perform research that has a real impact on pressing global issues.

The university aims to develop technologies of automation, personalization and big data to advance understanding, transform professions and disrupt business models. It is well positioned in terms of capability, world-class facilities, student population and financial management to advance teaching, research and research applications.

The Australian Research Council (ARC) rated 88 per cent of QUT research as being world class in its Excellence in Research Australia (ERA) Assessment. According to the *Times Higher Education* World University Rankings for 2015, QUT is ranked 33 out of all the world's universities that are less than 50 years old.

Building a knowledge-based economy

Meeting global research challenges requires new industries and a sustainable and capable workforce. Science, technology, engineering, mathematics (STEM) and urban development are the engines driving modern society and have a wide-reaching impact on society. As Australia moves towards a knowledge-based economy, these fields will be increasingly critical for our future economic, social and environmental prosperity.

QUT shapes future environments through world-leading science and engineering innovation. The 2016 Hobson's Good Universities Guide awards QUT five stars for research intensity, learning and teaching excellence and student satisfaction. It produces outstanding graduates through innovative, world-class teaching; conducting cutting-edge, high-impact research; building productive, sustainable and global partnerships; and supporting a thriving community empowered to achieve academic excellence.

The university's capacity for applying new knowledge to innovation development extends from quality teaching and research through to implementation and commercialization. QUT is renowned for its trans-disciplinary collaboration with industry and government, positioning it well to maximize the exchange of resources and ideas between researchers and partners to address multifaceted research challenges. Flexibility improves the relevance and efficiency of engaging in research and education partnerships that support industry, government and communities to meet current and future economic, social and environmental goals.

Leading this charge, its Science and Engineering Faculty (SEF) draws from 21 disciplines across six high-performing schools to achieve far-reaching outcomes in key research programmes with collaborators around the globe. Experts focus on both fundamental and applied research, with a mission to solve real-world problems for industry and the community.

Crop protection

Biosecurity is a priority in countries facing critical threats to crops from insect pests, weeds, drought, salinity and extreme temperatures. QUT leads multidisciplinary collaborations to address crop protection issues through soil science, robotics and engineering, and spatial science, modelling and decision support. Its facilities throughout south-east and central Queensland increase agricultural research capability and development, as well as pilot production of highly value added biocommodities such as fuel.

Outcomes are expected to help agri-businesses around the world sustain global food production and increase quality and competitiveness through efficiencies, economies of scale and natural disaster responses.

Smart and strategic transport

The Science and Engineering Faculty aims to enhance the efficiency and safety of transport systems, including airport planning, personal mobility and freight, to improve productivity and overall economic growth. Access to multi-owner transport information through the Smart Transport Research Centre (STRC) enables its researchers to investigate improvements to transport networks, infrastructure and users within urban and resource-based environments.

It is searching for better strategies to utilize existing networks and transport system risk management, optimization of signals, roads, network access locations, and planning for infrastructure, as well as the application of advanced technologies and proactive safety systems, such as video and sensor monitoring.

Mobility research also explores how people use transport networks and make decisions relative to residential choices, departure times, and satisfying personal needs through vehicle choice, lease or sharing arrangements.

Integrated energy systems

As the world moves from fossil fuel dependence towards cleaner, safer and more affordable low-carbon energy production, SEF researchers are contributing to the development of distributed energy systems with embedded renewable generation and storage capability.

Teams focus on improved and integrated production, control and delivery technologies. Investigations include the development of renewable energy technologies, integrated energy systems and modelling, smarter use of power grids, innovative control techniques, battery technologies, and increased energy efficiency in homes, buildings and industry. QUT also has Australia's only comprehensive research programme in biofuels that extends from processing to engine use and emissions testing.

At a community level, it taps into the evolution of localized renewable energy adoption as a mechanism for large-scale distributed power systems, for applied research to electricity generation and storage to demonstrate loss reduction and cost-saving opportunities.

STEM in education and research

With the increasing importance of STEM knowledge and skills, QUT is committed to engaging students from school through to university and graduate education. Trans-disciplinary and intersecting applied research groups focus on curriculum innovation, learning design and improving the learning experience through teaching strategies.

Curriculum innovation aims to ignite interest during compulsory schooling years. Learning design personalizes the learning experience by applying analytics, gamification and information science

research methodologies to the educational context. Researchers also diagnose and address misconceptions, improve teaching strategies for active learning and student engagement, and align teaching and assessment through the whole curriculum to improve the student STEM experience in higher education.

Delivering science and engineering research capability into leading institutes

Through QUT, SEF's fundamental and applied research capability in STEM delivers real-world outcomes that transform industry and government practice.

Key research strengths include robotics and computer vision; plant biotechnology; biomedical engineering; materials science and engineering; data science, computational modelling and simulation science and business process management.

QUT consistently secures significant government and industry funding for research. The ARC funds the Centre of Excellence for Robotic Vision (ACRV), headquartered at QUT, and the university's major involvement in the ARC Centre of Excellence for Mathematical and Statistical Frontiers (ACEMS), highlights research leadership in these areas.

Contact

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