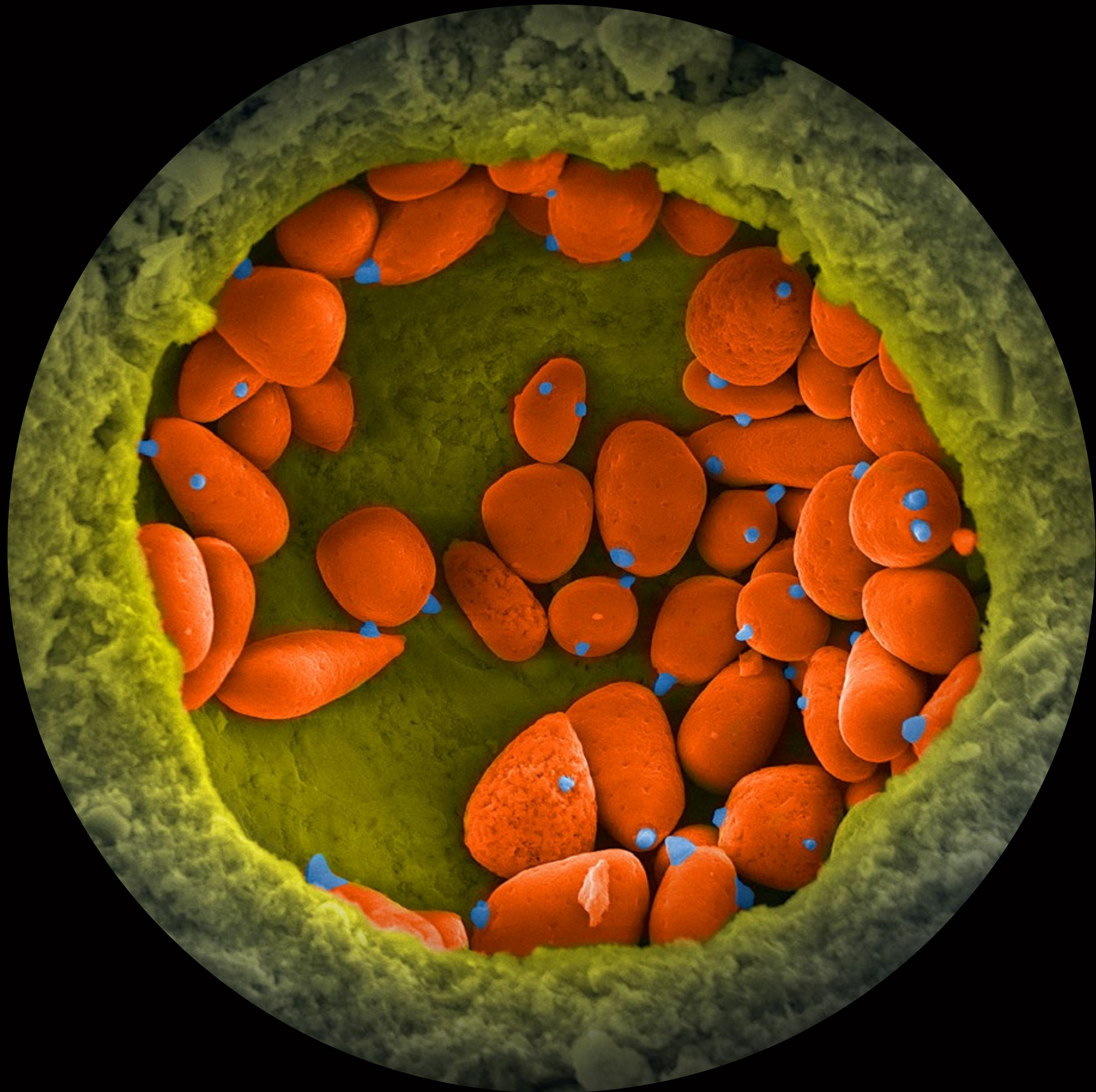
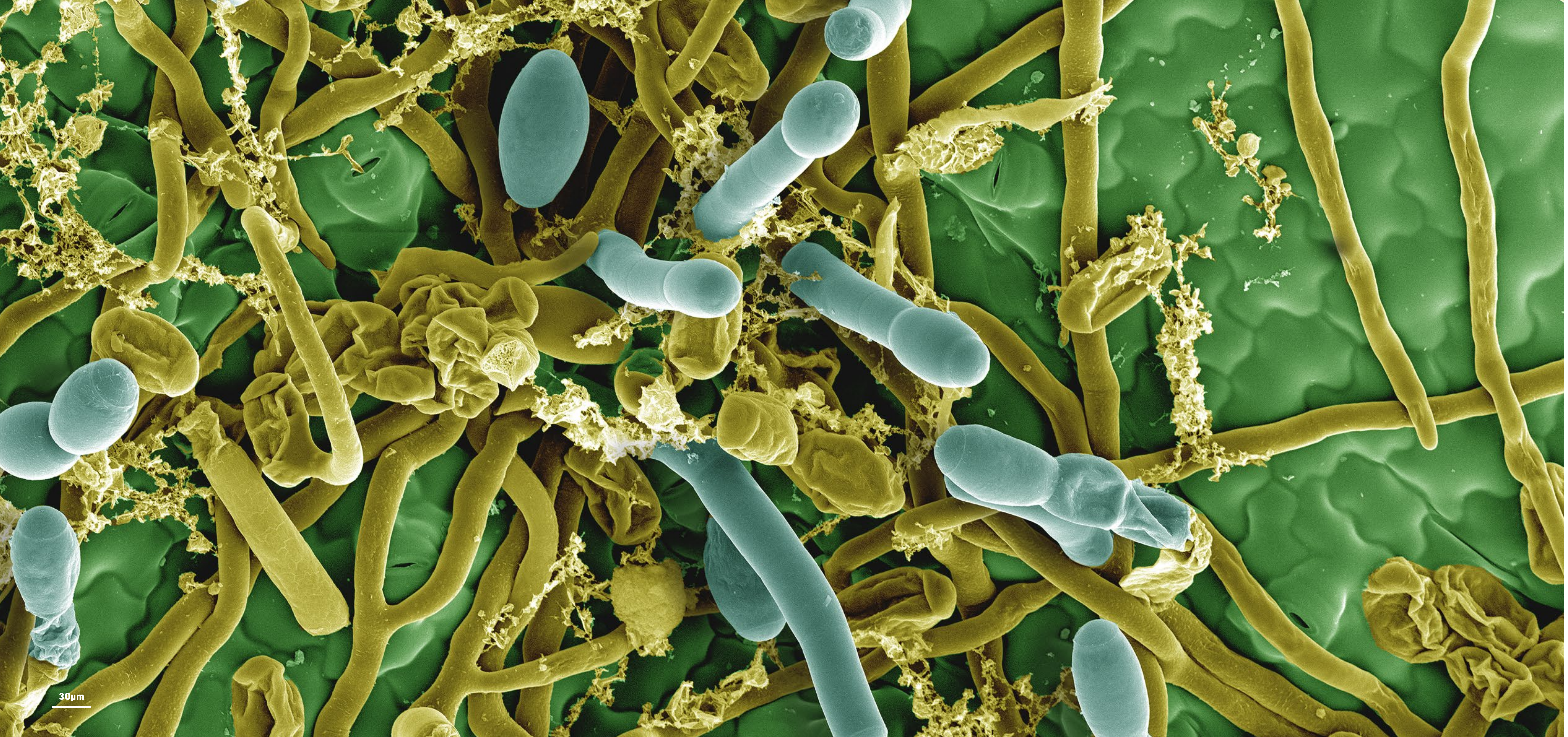
MICROSCOPY AUSTRALIA RESEARCH HIGHLIGHTS 2021





Explore how our collaborative research infrastructure empowers discovery and innovation. This new knowledge is delivering a healthier and more prosperous Australia.

CONTENTS

Cover: SEM Image of fossilised yeast, part of an Australian Museum citizen science project, taken at our Australian National University facility by A/Prof. Michael Frese, University of Canberra and coloured by Mike Cheeseman, studiothreedesign.

Left: A cryo-SEM image of mildew on a zucchini by A/Prof. Peta Clode, colour enhanced by Dr Jeremy Shaw, both from our University of Western Australia facility.

LEADERSHIP REFLECTIONS

MINISTER

Senator the Hon. Alan Tudge
Minister for Education & Youth

This year, Microscopy Australia has contributed to research that fundamentally changed our understanding of how the first continents were formed, created new manufacturing processes to minimise pollution, and used petroleum by-products to clean up contaminants like heavy metals.

And that's just the beginning. I want to congratulate Microscopy Australia for another year of excellence.

Your vision, to provide world-leading microscopes and expertise that keeps Australia at the forefront of global research, is admirable and despite the challenges of COVID-19 you have continued to achieve this.

Over 3000 users have accessed advanced microscopes through Microscopy Australia in the past year, and more than 120,000 people worldwide used the online training tool to upskill in microscopy and microanalysis.

The Morrison Government continues to support this fantastic work by providing Microscopy Australia $4.9 million in funding through NCRIS – the National Collaborative Research Infrastructure Strategy – in 2021. Through NCRIS, Microscopy Australia will receive $53.1 million up to 2023.

Congratulations to Microscopy Australia for another achievement-filled year. I look forward to seeing your continued success in 2022.

CHAIR

Dr Gregory R. Smith
Chair of Board

During 2021, despite the restrictions, Microscopy Australia has worked surprisingly effectively. A number of our facilities have experienced reduced access due to the changing pandemic conditions seen in the various states. However, as will be noted below, despite numerous challenges, 2021 facility metrics are relatively close to those seen in previous less-virus-challenged years.

Although recruiting for some additional microscopy expertise was delayed by the pandemic, acquisition of all remaining skilled new staff should be completed early in 2022.

During the second half of 2021, Microscopy Australia contributed significantly towards the latest round of road-mapping regarding future Australian research infrastructure needs; particularly as related to microscopy and microanalysis across various fields of Australian research and industry endeavour.

The Microscopy Australia Board dedicated time to re-examining its governance framework. The governance structure was re-evaluated and tested, as was the overall balance of Board membership, representation and skills. Updated Board governance documentation is near to completion.

Retirement of the Board's previous independent industrial representative, Dr Jim Patrick AO, was advised last year. Since then, Dr Deborah Rathjen has been welcomed as a new industry representative on Microscopy Australia's Board. Deborah has highly respected and successful experience in Australian biotechnology company leadership. She also has participated on a number of important Australian governmental advisory bodies.

With the impending easing of restrictions across Australia, the Board believes that Microscopy Australia is very well placed to support the foreseen acceleration of research and innovation across the public and private sectors.

CEO

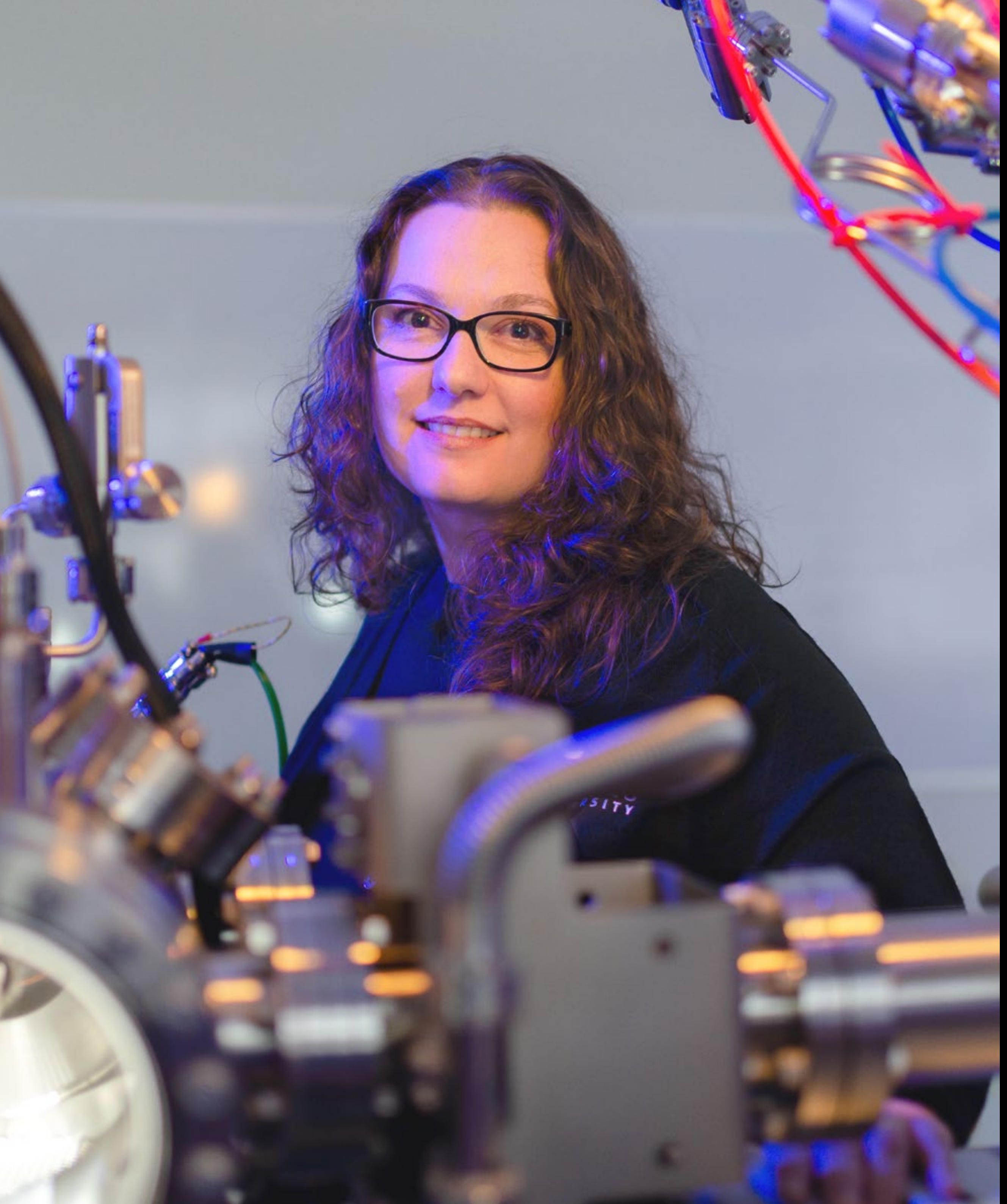
Prof. Julie Cairney
Chief Executive Officer

Throughout 2021, Microscopy Australia facilities and staff have continued to show incredible resilience and persistence as we face the ongoing impacts of the pandemic. Despite these challenges, demand continues for access to our facilities. It has been tremendous to see how those facilities have continued to safely support critical research activities. In some cases, our facilities have remained operational to support researchers even in regions that were affected by stay-at-home orders.

We have been delivering new capabilities and new instruments around the nation as we implement our 2018–2023 5-year plan. Over ten new instruments have arrived at our facilities, and we are in the process of procuring another eight platforms. We have also welcomed more than 15 new staff across the facilities in Microscopy Australia, supporting cutting-edge instruments, technique development and data management/analysis. We have continued to improve and develop MyScope, the world's leading online training for microscopy. New and updated modules were released for light and confocal microscopy, transmission electron microscopy and X-ray diffraction.

We have also been preparing strategic long-term plans to ensure we are ready for the future. The 2030 Microscopy Australia strategic plan includes much-needed investment in important emerging microscopy technologies, with a focus on atomic-scale microscopy, cryo-electron microscopy, correlative microscopy and high-sensitivity microanalytical tools. Microscopy Australia has been actively participating in the development of the 2021 National Research Infrastructure Roadmap. We look forward to delivering critical underpinning microscopy to enable world-leading Australian research.

In this year's research highlights, we have placed an emphasis on the broad range of impact that comes from the excellent research that our facilities support. I hope you enjoy reading about the incredible work that our facilities enable.



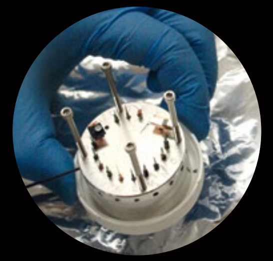
Prof. Sarah Harmer, Director of Flinders Microscopy and Microanalysis, with Australia's first photoemission electron microscope, installed this year.

EQUIPMENT AND EXPERTISE

Microscopy Australia empowers research by providing open access to sophisticated instruments and expertise for researchers around the country. Our dedicated staff ensure that researchers collect high quality data. Our range of specialised techniques is summarised here.

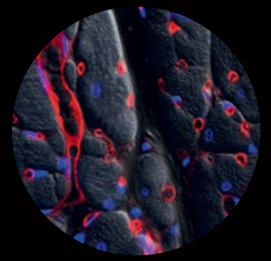
Our online microscopy training tools are also openly accessible with over 120,000 users worldwide in the last year alone.

With the nation's largest range of high-end microscopes and specialists, we also support business across a wide range of industry sectors. Companies of all sizes, from start-ups to multi-nationals, benefit from our services, training and R&D partnerships.



SPECIMEN PREPARATION

- Biological & Materials
- Cell Culturing & Molecular Preparation
- Thermomechanical Processing
- Ion Milling & Machining
- Ion Implantation



LIGHT & LASER TECHNIQUES

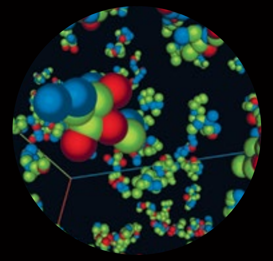
- Fluorescence, Confocal & Multiphoton Microscopy
- Super Resolution Microscopy
- Analytical Spectroscopy
- Flow Cytometry
- Laser Microdissection

SCANNING ELECTRON MICROSCOPY

- Imaging & Analytical Spectroscopy
- In-situ Imaging & Testing
- Cathodoluminescence
- Electron Backscatter Diffraction

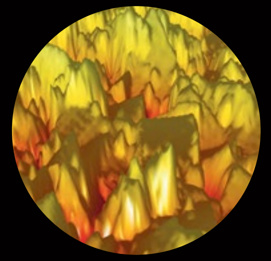
TRANSMISSION ELECTRON MICROSCOPY

- Imaging & Analytical Spectroscopy
- Cryo-techniques & Tomography
- Phase & Z-contrast Imaging
- Electron Diffraction



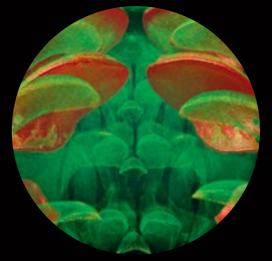
ION & SPECTROSCOPY PLATFORMS

- Secondary Ion Mass Spectroscopy
- Imaging Mass Spectroscopy
- Atom Probe
- LA-ICP-MS



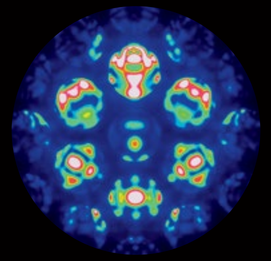
SCANNED PROBE TECHNIQUES

- Atomic Force Microscopy
- Scanning Tunneling Microscopy
- Near-field Scanning Optical Microscopy



X-RAY TECHNOLOGIES

- X-ray Diffraction
- X-ray Fluorescence
- X-ray Microtomography
- Photoemission Electron Microscopy



VISUALISATION & SIMULATION

- Computed Spectroscopy
- Computed Diffraction
- Image Simulation & Analysis
- Data Mining

Data from March 2021 collection. Left: Super-resolution confocal image of a sea sponge embryo inside the parent by Ayla Manwaring, ANU.

269
INSTRUMENTS

137
EXPERTS

3,235
USERS

288
INDUSTRY CLIENTS

260,668
HRS BEAMTIME

129,286
MYSCOPE USERS

1,615
PUBLICATIONS

45% PHYSICAL & MATERIALS
42% BIOLOGICAL & MEDICAL
13% GEOSCIENCE & ENVIRONMENT

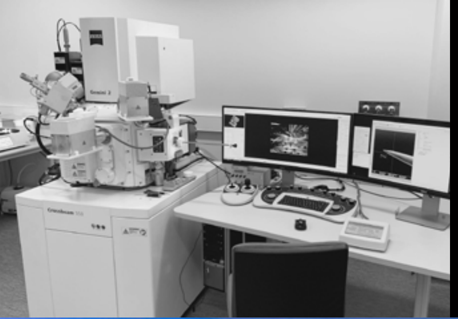
52% MANUFACTURING
11% BIOMEDICAL
37% RESOURCES & ENVIRONMENT

OPEN TO ALL

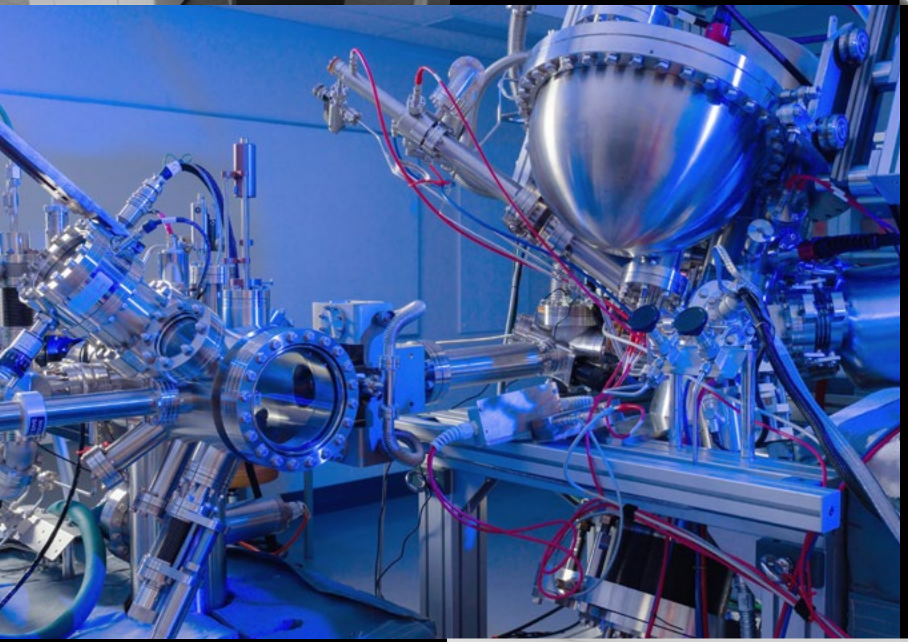
Established in 2007, Microscopy Australia is a consortium of open-access microscopy facilities and linked laboratories based at universities around the country. These facilities are open to all, regardless of institution, or whether you are in academia or industry. Microscopy Australia was formed under the National Collaborative Research Infrastructure Strategy (NCRIS) to support strategic investment into research infrastructure.

This year's standout achievements include:

- New NCRIS-supported experts and instruments arrived at our facilities
- Remote access and training was offered as part of our COVID-safe operating procedures
- 99% of our users said they would recommend our facilities to a colleague, despite the pandemic
- We developed our Research Data Management Framework, and released our Data Management Policy
- New modules for MyScope were released: TEM, Light & Fluorescence, X-ray Diffraction, and Data Management. *www.myscope.training*
- National collaboration was enabled by virtual meetings, including the 2021 Microscopy Australia Annual Workshop, masterclasses, webinars, videos and MicroChats
- Active participation in the 2021 roadmapping process to highlight the future microscopy needs for research and industry
- Continued to enable high quality research with real world impacts – see some of the highlights from p18.



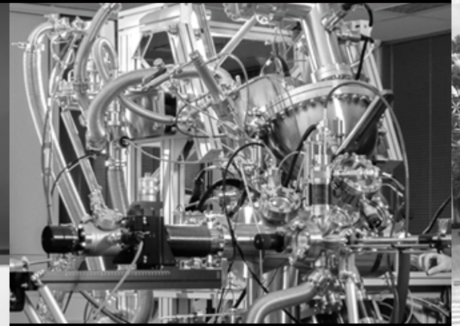
CORRELATIVE



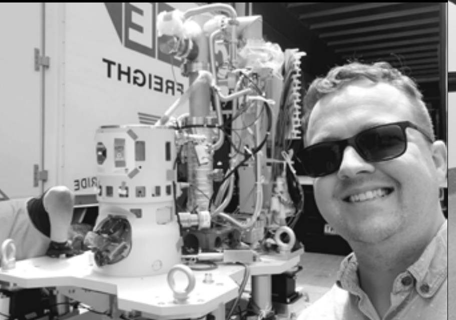
NEW INSTRUMENTS

Microscopy Australia has been investing in instruments to maintain our state-of-the-art facilities. In the last two years, more than ten instruments were delivered around the country. This includes Australia's first photoemission electron microscope, a new aberration-corrected TEM suite, a cryo-CLEM microscopy suite, multiple cryo electron microscopes, an ultra-high resolution SEM suite, a MALDI with a post-ionisation laser, and a new XPS instrument.

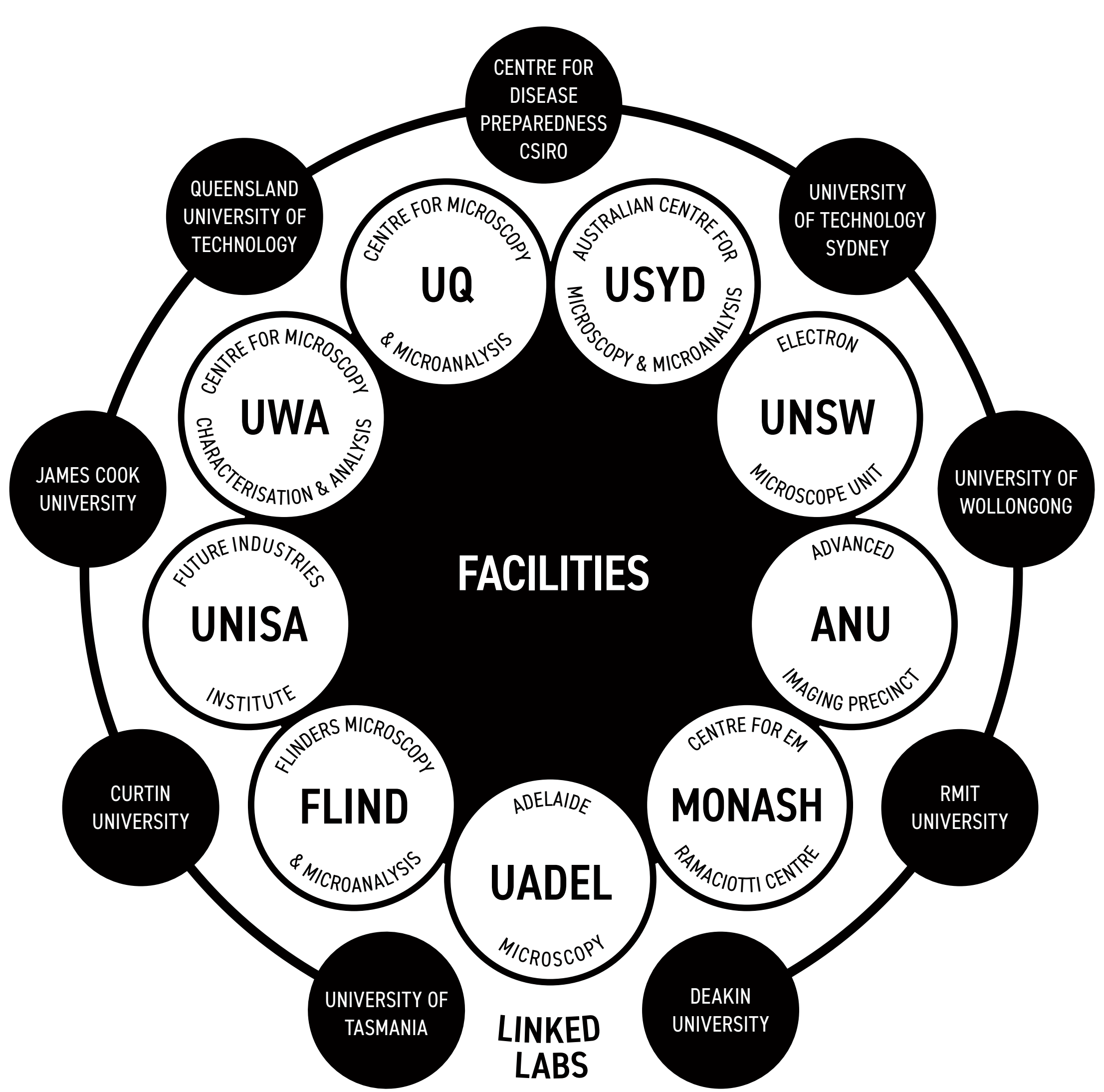
CRYO

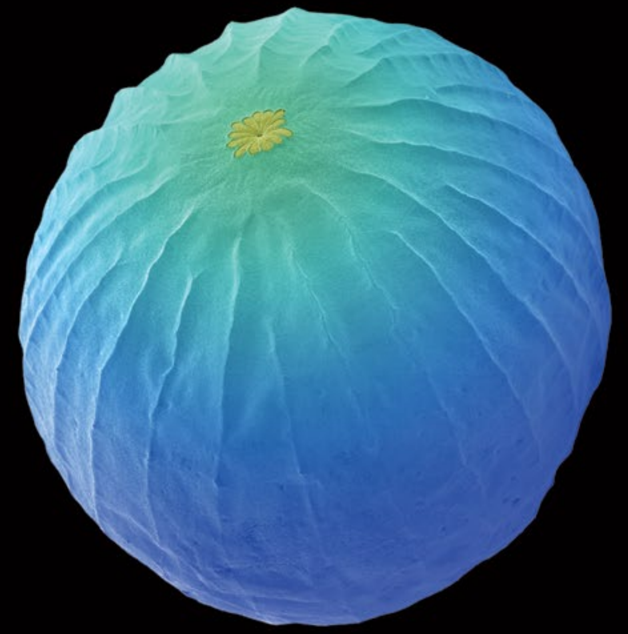


MICROANALYSIS



NETWORK





MYSCOPE
MICROSCOPY TRAINING

Explore our free online advanced microscopy training platform:

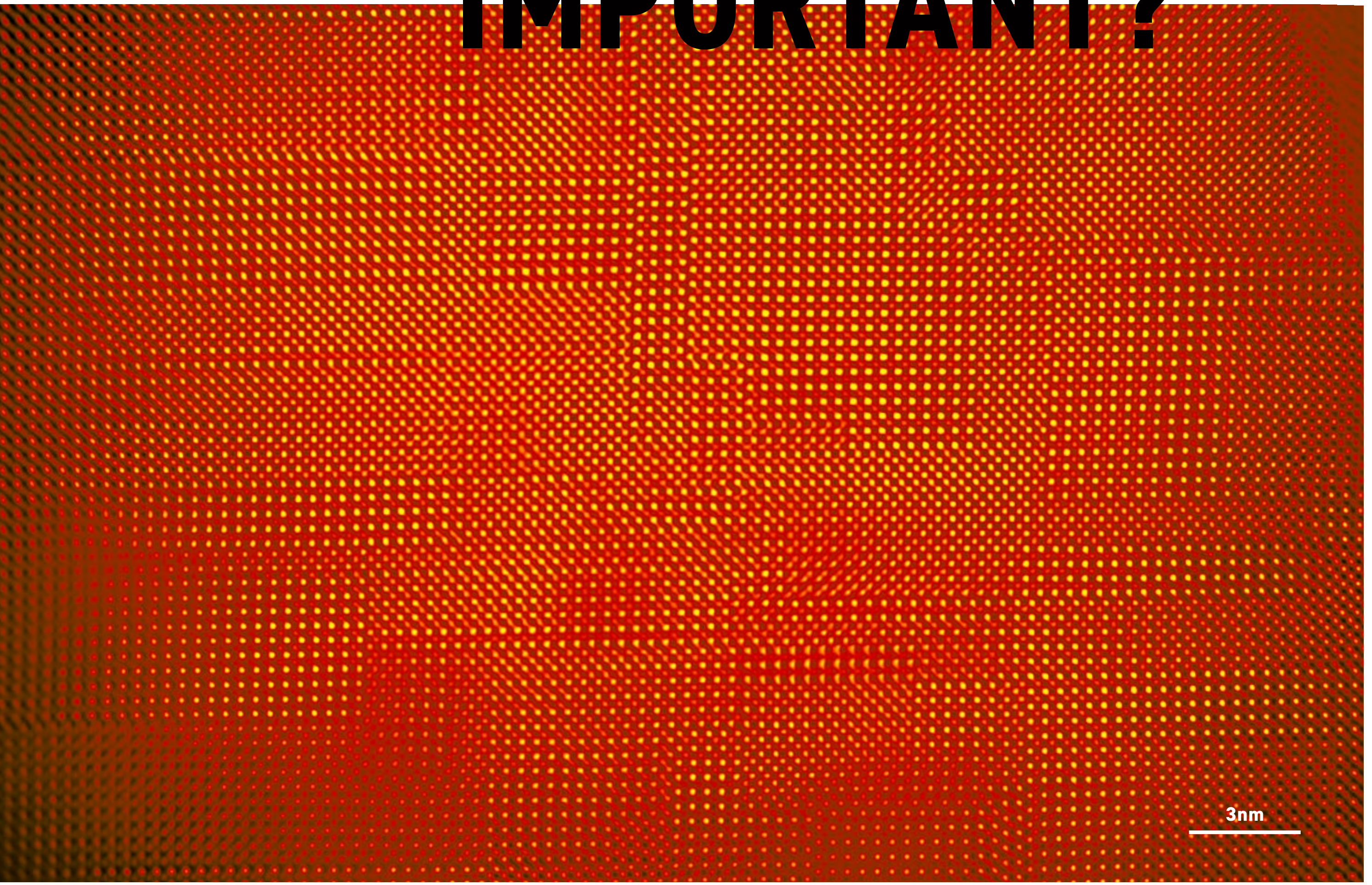
www.myscope.training

Introduce your family to microscopy with our engaging simulator activities:

www.myscope-explore.org

Image: Colour-enhanced scanning electron micrograph of a moth egg.

WHY IS MICROSCOPY SO IMPORTANT?



Scanning transmission electron micrograph of a LaNiO3 perovskite electrocatalyst for renewable energy production prepared by Prof. Thomas Maschmayer's group at the University of Sydney. DOI: 10.1002/chem.202102672

Microscopy is a fundamental scientific technique. It reveals the structure and properties of materials and living systems at unimaginably tiny scales, down as far as individual atoms. It is these microscopic structures that shape the materials and organisms we encounter in our everyday lives. Because of this, microscopy is fundamental to the creation of new knowledge in many fields from science and engineering to art and archaeology: without microscopy, scientific knowledge as we know it would not be possible.

Microscopy is a critical part of Australia's research infrastructure landscape. Researchers from all sectors require access to cutting-edge microscopes and platform experts. This access enables them to address local research priorities, global challenges, and industrial R&D needs.

> **"Without microscopy, there is no modern science – end of story."**
>
> – Dr Alan Finkel, former Chief Scientist of Australia, Opening Address at IMC19.

99%

OF OUR USERS REPORT MICROSCOPY WAS VALUABLE TO THEIR RESEARCH

99%

OF OUR USERS WOULD RECOMMEND OUR FACILITIES TO A COLLEAGUE

58%

OF OUR USERS EXPECT THEIR FUTURE MICROSCOPY USE WILL INCREASE

FUTURE DIRECTIONS

Microscopy Australia enables researchers to respond rapidly to emerging challenges and underpins an incredible range of real world outcomes: fighting disease, responding to disaster, creating new materials for modern manufacturing, improving mineral exploration and extraction, ensuring food security, and enabling sustainable development and clean energy solutions.

The Microscopy Australia 2030 Strategic Plan requires significant ongoing capital and operational funding to continue to provide the instruments and experts for a future-ready national capability.

- **Priority 1:** Support Excellent Research
- **Priority 2:** Enable Innovative Industries
- **Priority 3:** Deliver Accessible Instruments
- **Priority 4:** Empower Facility Staff

MEETING FUTURE NEEDS

Microscopy Australia is built on the principles of open access to cutting-edge instruments and expertise to drive research excellence and innovation. This proven model helps research feed into our sovereign capability in next-generation healthcare and modern manufacturing for social and economic benefit while helping Australia prepare for, and respond to, disasters.

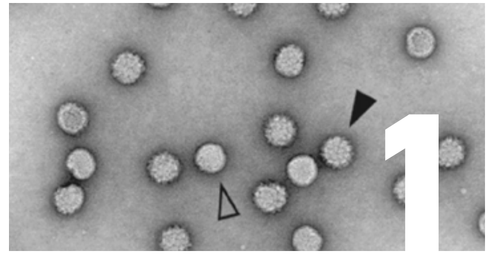
Consultations with researchers and our international team of advisors have emphasised the need for Microscopy Australia to continue building our capability in four key platform areas that will provide optimal support for ongoing and emerging research needs:

- **Atomic-scale microscopy** that includes the ability to watch atomic-scale changes in materials over time.
- **Techniques to correlate different types of data** from multiple microscopy techniques along with automated and machine learning workflows to support this.
- **Cryogenic electron microscopy (Cryo-EM)** to determine detailed shapes of biological molecules and structures in their natural states.
- **High-sensitivity analytical tools** to understand the composition and structures of complex materials.

Just as critical to these platforms are the experienced world-class experts who are essential to operate instruments, provide training, and support cutting-edge research and innovation. They also develop techniques and analytical tools ready to optimise support for the exciting research that will emerge in the future.

UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

MICROSCOPY AUSTRALIA SUPPORTS 14 OF THE 17 SUSTAINABILITY GOALS BY ENABLING RESEARCH INTO...

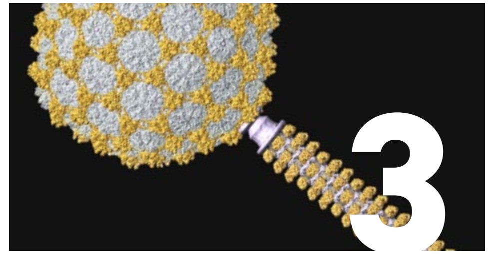


NO POVERTY

cheap and effective solutions for issues facing the poor, including solar-powered water desalination and decontamination; and new temperature-stable vaccines, drugs and devices to tackle antibiotic resistance, emerging and tropical diseases, and natural disasters.

ZERO HUNGER

more productive, drought tolerant and pest resistant crops; better fertilisers and pesticides; improved soils; and new low-energy, on-site technology to produce the world's most important fertiliser, ammonia, reducing the need for bulk storage, and therefore risk of explosion.

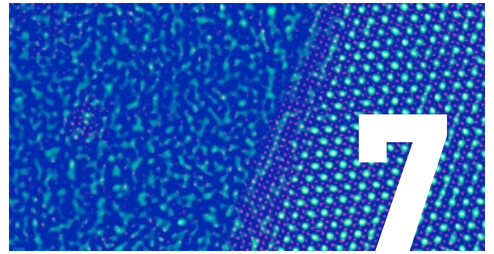


GOOD HEALTH & WELLBEING

a spectrum of vaccines, drugs and medical devices to treat and prevent infectious and non-infectious diseases, including the HD-MAP for temperature stable vaccines, bacteriophages to fight antibiotic resistance, and bee venom to treat aggressive breast cancer.

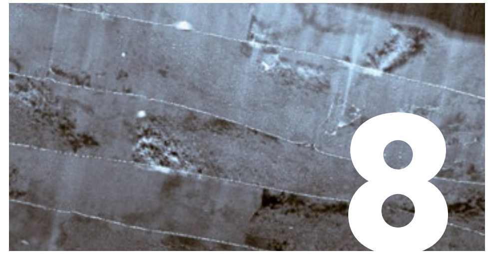
CLEAN WATER & SANITATION

cheap, portable water desalination and decontamination technologies that don't rely on electricity; polymer sponges made from waste that remove contaminants from water; and new non-toxic industrial materials that require less energy.



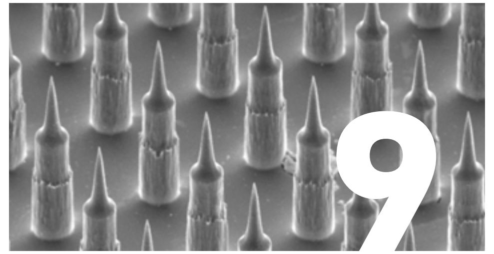
AFFORDABLE & CLEAN ENERGY

new, affordable, less toxic and more efficient solar materials, such as, quantum dots, perovskite and kesterite; new batteries for more reliable power; new alloys for hydrogen transport and storage; and low energy ammonia production method to reduce global energy.



DECENT WORK & ECONOMIC GROWTH

more efficient extraction and use of natural resources; lighter, stronger, more durable materials such as alloys, ceramics, graphene and nanocellulose for advanced manufacturing; and technology to build a circular economy.

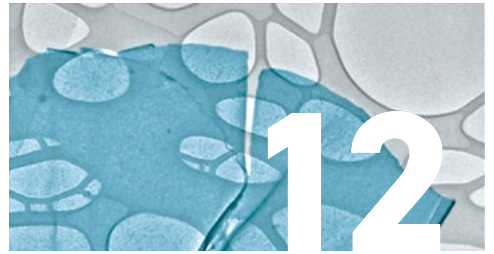


INDUSTRY, INNOVATION & INFRASTRUCTURE

new technologies to create sovereign capability including seven of the World Economic Forum's top ten emerging technologies: microneedles, sun-powered chemistry, electric aviation, digital medicine, low-carbon cement, quantum sensing, and green hydrogen.

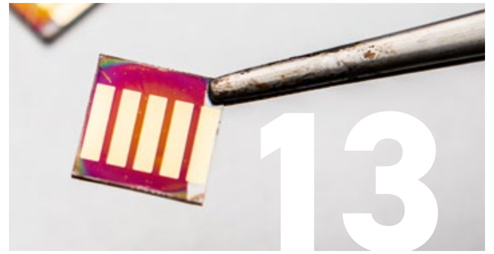
SUSTAINABLE CITIES & COMMUNITIES

lighter, greener, and stronger materials for more efficient buildings and fuel-efficient transport systems; cheap, non-toxic, and low-energy solutions for critical infrastructure such as power, water and sanitation; and ways to turn waste into industrial feedstock.



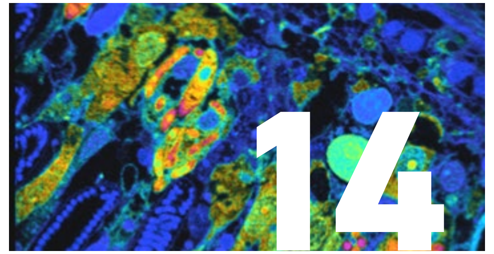
RESPONSIBLE CONSUMPTION & PRODUCTION

technologies that underpin the circular economy; enable more efficient exploration, mining and mineral processing; allow for more efficient use of existing resources by making lighter, stronger materials that use less toxic and reactive components.



CLIMATE ACTION

technologies that prevent and create resilience to climate extremes and their consequences, including green energy and its storage; drought- and salt-resistant crops; medical devices, portable power and water purification for emergency response to disaster.

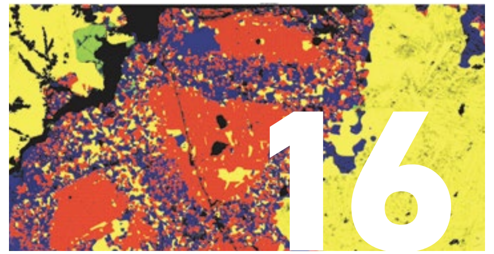


LIFE BELOW WATER

coral bleaching, reef health and seagrass meadows; fish development and growth; the impacts of ocean acidification and microplastics on marine life; and technologies to absorb oil spills.

LIFE ON LAND

restoration of degraded soils and ecosystems, through use of biochar, plant probiotics and removal of contamination; the impact of bushfire on native ecosystems; exploring Australia's biodiversity as a resource for new drugs, materials and crops.



PEACE, JUSTICE & STRONG INSTITUTIONS

Our University of Western Australia facility is the first university in the world to join the United Nations' international nuclear verification program, to help monitor global nuclear safeguards.

PARTNERSHIPS TO ACHIEVE THE GOAL

We are helping to build an active international network of microscopy facilities that includes developing nations, through our membership in Global Bioimaging. Through this initiative we take an active role in developing international standards for best practice in microscopy.

MANUFACTURING & INNOVATION

Our microscopy is helping feed-in research, high-tech spin-outs, national brands and global giants to innovate in manufacturing. This aligns with the six National Manufacturing Priorities:

RESOURCES & MINERAL PROCESSING

Microscopy is informing the design of better alloys for tougher mining machinery and helping to understand mineral structures and origins to plan exploration and improve processing.

FOOD & BEVERAGE

Microscopy is helping develop crops that resist pests, salt and drought, and to find innovative uses for waste biomass to build new business opportunities, and support the development of new food production processes.

MEDICAL PRODUCTS

Microscopy is enabling design, R&D and QA of medical devices including sensors, tissue scaffolds, vaccines, drugs and drug delivery systems. It also helps to understand new biocompatible alloys, coatings and composite materials and to develop antibacterial coatings.

RECYCLING & CLEAN ENERGY

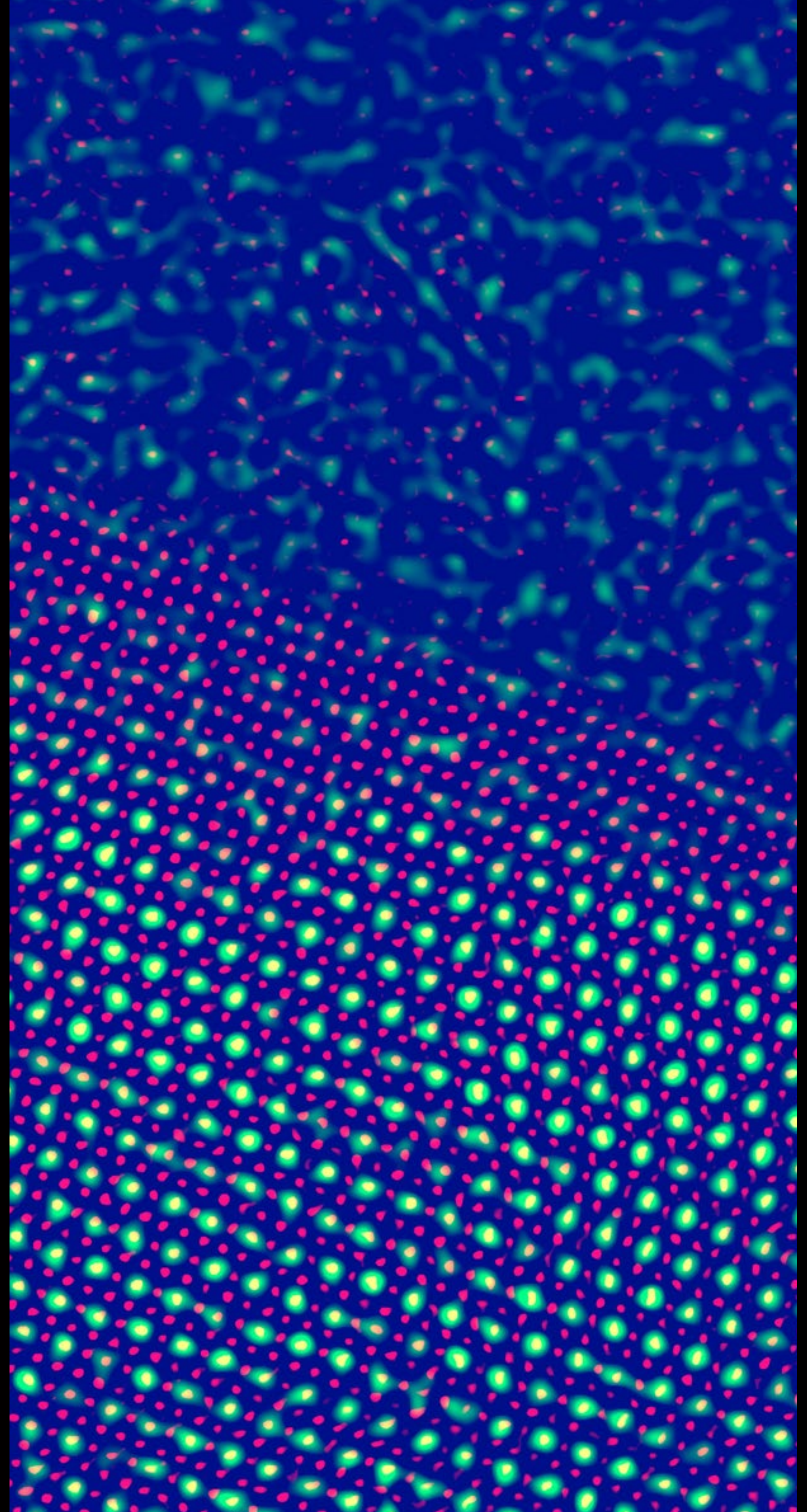
Microscopy is enabling solar and battery technologies, hydrogen production and storage materials. It also allows us to develop processes for turning waste into innovative products.

DEFENCE

Microscopy is enabling the development of next generation sensors for detecting chemical warfare agents, and portable X-ray devices for airport security, IED identification and military hospitals. It is also used to help develop flexible, motion-powered electronics for wearable sensors and communications.

SPACE

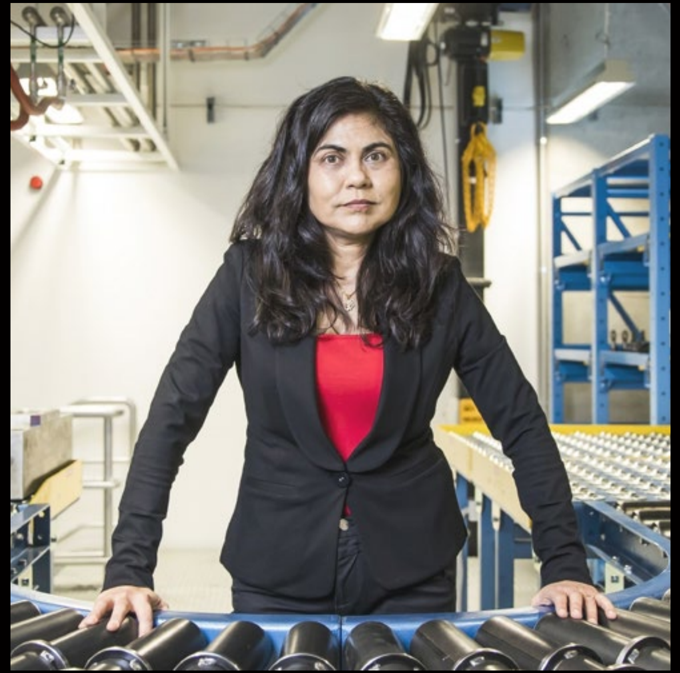
Microscopy is enabling the development of super-strong alloys, ceramics and composites for aerospace applications that can withstand highly demanding environments of space and planetary exploration. It is also used in the development of lighter, more efficient solar power and storage options.



Atomic scale transmission electron microscope image of next generation kesterite solar cells by A/Prof. Xiaojing Hao, UNSW

MEET OUR RECYCLING HEROES

HARVESTING OPPORTUNITY FROM WASTE AND BUILDING THE CIRCULAR ECONOMY



PROF. VEENA SAHAJWALLA

Depending on our microscopy to help her and her team understand the processes they develop, Prof. Veena Sahajwalla, from UNSW Sydney's Centre for Sustainable Materials Research and Technology, sees waste as an opportunity with huge potential.

She has harnessed that potential to develop a wide range of manufacturing processes that add value to waste and minimise pollution: green steel that uses waste tyres and plastic in place of coking coal; toughened steel from scrapped cars; purified aluminium from used coffee pods; textile-reinforced ceramics from waste glass and clothing for use in building interiors; local micro-factories for e-waste and more. She is truly an Australian recycling hero!

A/PROF. JUSTIN CHALKER

A/Prof. Justin Chalker from Flinders University also depends on our microscopy as his team creates versatile polymers from waste cooking oil and sulfur, a by-product from petroleum processing. He chemically combines these resources to make a spongy material that absorbs environmental contaminants such as mercury from artisanal gold mining, other heavy metals, spilled oil and toxic chemicals (like PFAS).

He is now combining his polymers with raw wool to make sustainable, fire-resistant insulation. The patents for these polymers have been sold to Clean Earth Technologies, who continue to partner with A/Prof. Chalker's team. They are bringing the polymers to commercial production to help clean up the planet. Another Australian recycling hero!

TAKE A CLOSER LOOK

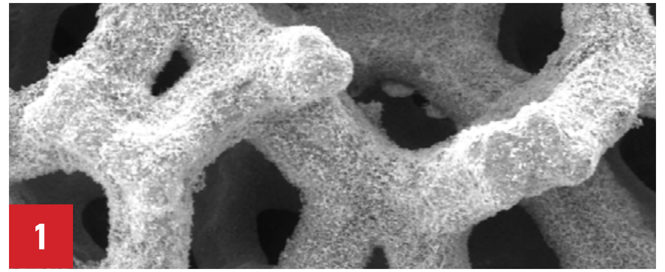
SUPER-RESOLUTION CONFOCAL IMAGE OF DEVELOPING DROSOPHILA EGGS (PINK) SHOWING DNA (YELLOW) AND CYTOPLASM (PURPLE) BY DR OLGA ZAYTSEVA, ANU

RESEARCH OUTCOMES & SOCIAL IMPACT

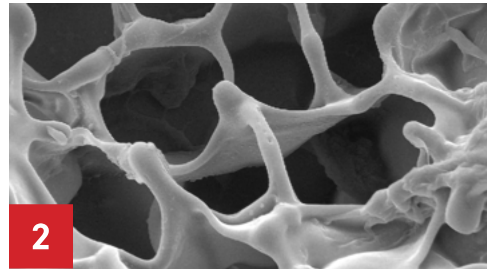
Take a closer look at this year's research highlights – all enabled by Microscopy Australia. With over 3,000 researchers annually, here are just a few of our recent outcomes.

2021

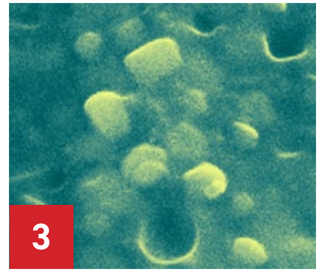
MATERIALS FOR A GREENER, HEALTHIER FUTURE



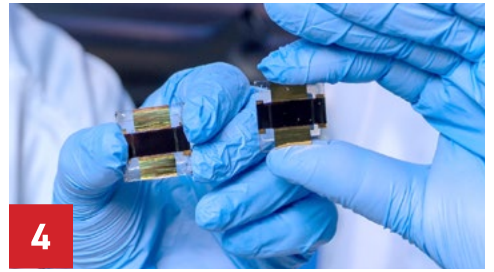
ECO-FRIENDLY AMMONIA PRODUCTION INSPIRED BY LIGHTNING



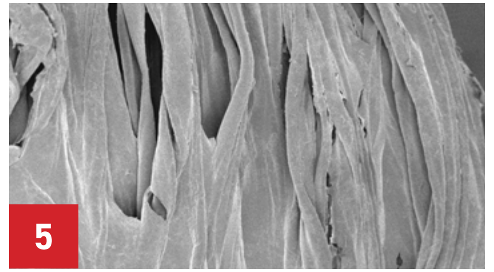
GRAPHENE TO CLEAN CONTAMINATED LAND



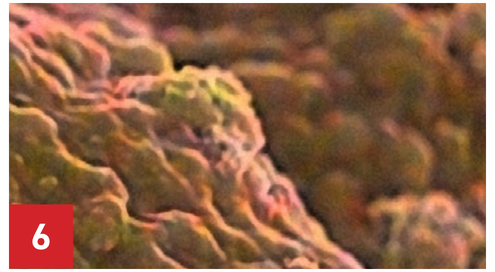
BROKEN SCREENS A THING OF THE PAST



PEROVSKITE SOLAR CELL BREAKS WORLD RECORD

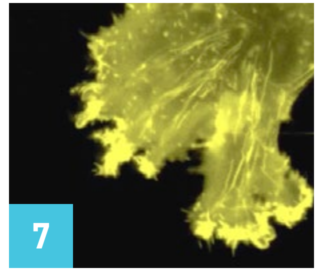


SUN-POWERED CLEAN WATER



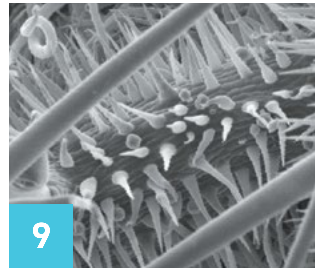
GLUCOSE MAKES BETTER BATTERIES

MOLECULAR APPROACHES TO DISEASE

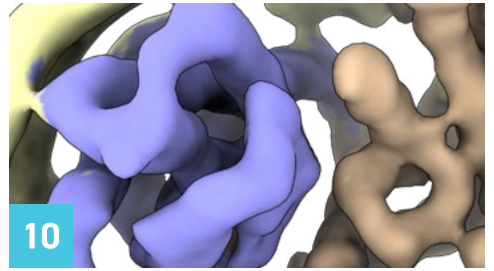


INSULIN-MODERATION SIGNAL FOUND

UNDERSTANDING THE BACTERIAL ENEMY



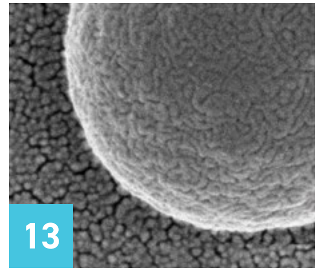
VENOM TO UNCOVER PAIN PATHWAYS



MULTITASKING MOLECULAR MACHINERY

EFFICIENT VACCINE DELIVERY TO THE WORLD

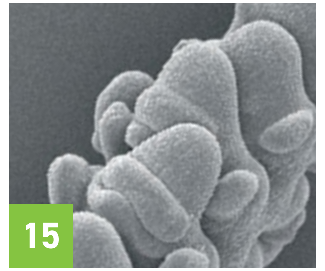
CAPSULE TO DIAGNOSE GUT DISORDERS



BACTERIOPHAGE GIVE NEW LIFE TO ANTIBIOTICS

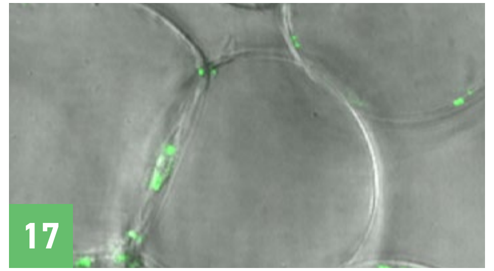
FIXING BROKEN HEARTS

AGRICULTURE FOR A CHANGING CLIMATE

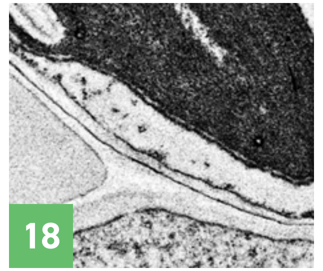


BARLEY TO TAKE THE HEAT

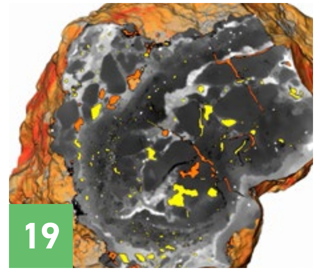
BOOST TO MICROALGAE HEALTH SUPPLEMENTS



BACTERIA HIDDEN IN PLAIN SIGHT



BUILDING FUTURE FOOD SECURITY



GETTING MORE FROM GRAVEL SOILS

OUR PLANET

COST-EFFECTIVE MINERAL EXPLORATION

ORIGINS OF THE CONTINENTS

SUPPORTING SUSTAINABLE DEVELOPMENT GOALS 12 & 13

RESPONSIBLE PRODUCTION & CLIMATE ACTION

1

ECO-FRIENDLY AMMONIA PRODUCTION INSPIRED BY LIGHTNING

CHALLENGE

Ammonia is the second-most-produced chemical globally, and its use in fertiliser feeds half of the world's population. However, current production methods are energy intensive, accounting for 1% of global greenhouse gas emissions and consuming 2% of global energy. To make ammonia production viable in a sustainable economy, a new, less energy-intensive process needs to be developed.

RESEARCH

Now a revolutionary method has been developed to make 'green' ammonia from air, water and renewable electricity, which does not need high temperatures, high pressure or huge infrastructure.

One option for creating 'green ammonia' uses renewable energy and electrolysis. For this to work, nitrogen needs to be dissolved in water, then electrolysis can convert the nitrogen into ammonia. However, nitrogen is not very soluble. Nitrite and nitrates, which contain nitrogen and oxygen are, however, highly soluble. The problem is that they are currently produced *using* ammonia.

The new approach mimics lightning, which produces nitrite and nitrates when it strikes nitrogen in the air. The team at UNSW Sydney, led by Prof. Rose Amal, and Drs Ali Jalili and Emma Lovell, saw the potential of replicating this natural phenomenon using plasma. The University of Sydney team, led by Prof. Patrick Cullen, designed a scalable and energy-efficient plasma reactor that generates nitrite and nitrates by discharging plasma into water bubbles.

Electrolysis then converted these nitrogen-based chemicals into ammonia, using copper nanowires, developed to catalyse the electrolysis. These were imaged using scanning electron microscopy at Microscopy Australia's UNSW Sydney facility.

Prof. Patrick Cullen, said "By inducing the plasma discharges inside water bubbles, we have developed a means of overcoming the challenges of energy efficiency and process scaling, moving the technology closer to industrial adoption."

IMPACT

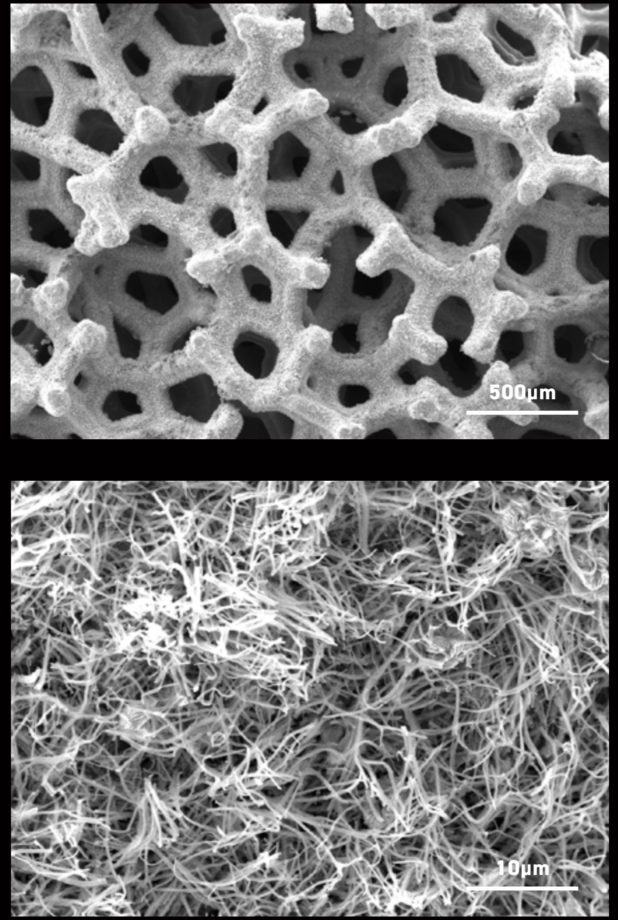
This technology only uses 1% of the energy currently needed. It is scalable and can be implemented anywhere ammonia is needed. This overcomes the need to store and transport large quantities of highly explosive ammonia, preventing potential disasters such as the Beirut explosion in 2020 that left 300,000 homeless and at least 204 dead.

'Green' ammonia could also solve the problem of hydrogen transport and storage. "Hydrogen is very light, so you need a lot of space to store it, otherwise you have to compress or liquify it. But ammonia is a liquid at ambient temperature and actually stores more hydrogen [in a given volume] than liquid hydrogen itself. And so there has been increasing interest in the use of ammonia as a potential energy vector for a carbon-free economy.

"We can use electrons from solar farms to make ammonia and then export our sunshine as ammonia rather than hydrogen. And when it gets to countries like Japan and Germany, they can either split the ammonia and convert it back into hydrogen and nitrogen, or they can use it as a fuel" says Prof. Amal.

The team will next turn its attention to forming a spin-out company to commercialise this breakthrough and take its technology from laboratory-scale into the field.

J. Sun et al., Energy Environ. Sci. 2021
DOI: 10.1039/D0EE03769A



Scanning electron micrographs: Upper image shows copper nanowires growing on underlying copper foam. This was the most efficient structure for converting nitrates and nitrites into ammonia. Lower image is a close up of the nanowires on the foam substrate.

2 GRAPHENE TO CLEAN CONTAMINATED LAND

Per- and poly-fluoroalkyl substances (PFAS) were first created in the 1940s and now contaminate water, food, plants, animals and the human body. Exposure, even at very low concentrations, can lead to adverse health effects including reproductive, developmental, liver, kidney and immunological damage.

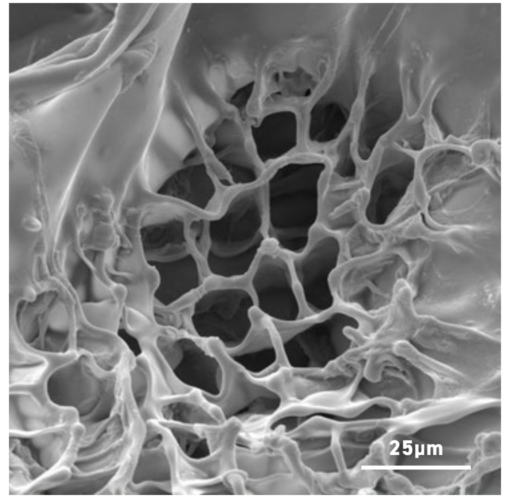
Despite this known risk, PFAS are still used widely in industrial and commercial applications from fire-retardants and fire-fighting foams, wetting agents, lubricants, and corrosion inhibitors, to cosmetics, packaging, and cookware, and there is still significant persistent environmental contamination from their use.

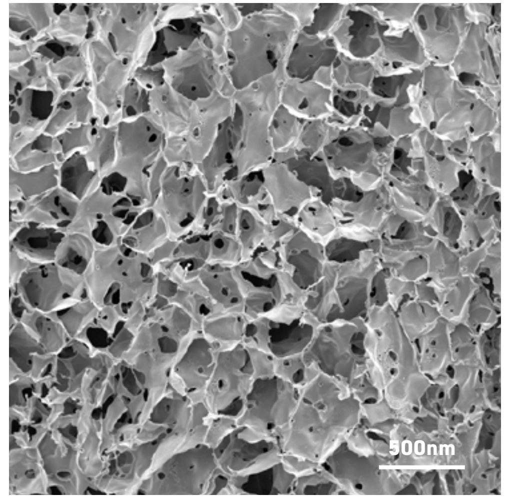
A University of Adelaide research team led by Profs Dusan Losic and Mike McLaughlin have partnered with local graphene technology company Sparc Technologies (ASX: SPN), to develop a new graphene-based adsorbent. The product has outperformed currently available activated carbon adsorbents when tested on PFAS-contaminated soils and water.

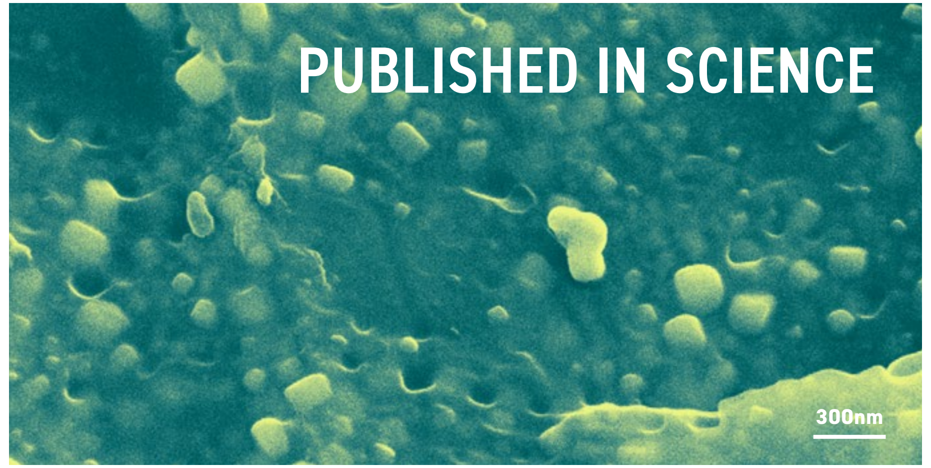
Scanning and transmission electron microscopy at Microscopy Australia's University of Adelaide facility were used extensively to study the surface structures and porosity of these graphene-based adsorbents. The first kilogram batch of this product will be evaluated at a pilot PFAS soil remediation trial with Australian remediation company JBS&G.

The ARC Research Hub for Graphene Enabled Industry Transformation where the team is based continues to work actively with industry partners and leading Australian graphene companies to develop graphene-based solutions and products.

Below: Scanning electron microscope images of functionalised graphene materials for environmental remediation.







3 BROKEN SCREENS A THING OF THE PAST

A solution may be on the horizon for the all too familiar problem of broken phone screens with the development of a new ultra-tough composite glass containing perovskite nanocrystals.

Lead–halide perovskites are semiconductors that can convert light to electricity and vice versa. They are one of the main materials for next generation solar cells and are also being intensively studied for a range of other applications that involve converting electricity to light and one wavelength of light to another. This is exactly what you need for touch screens on electronic devices.

One of the most efficient, and therefore desirable lead–halide perovskites is made from caesium, lead and iodine ($CsPbI_3$). Unfortunately, it doesn't work well at ambient temperatures or if it gets wet. It also leaches dangerous lead, causing a health problem for users and difficulties in recycling.

Researchers led by Dr Jingwei Hou and Prof. Lianzhou Wang at the University of Queensland, along with collaborators at Cambridge and Leeds Universities, have managed to overcome these limitations. They've made a new composite glass that has $CsPbI_3$ nanocrystals embedded in a highly compatible glassy material called a metal–organic framework (MOF). The MOF stabilises the structure of the perovskite nanocrystals, making them able to work at ambient temperatures, and also increases their efficiency by 100–1000 fold. The composite is incredibly tough and resilient making it ideal for developing into unbreakable glass screens for smartphones, computers and TVs. Due to the minute size of the perovskite nanocrystals, it will also deliver crystal clear image quality.

Microscopy Australia's University of Queensland facility was used by the team as they began to understand and test various recipes for their composite.

J. Hou et al., Science 2021
DOI: 10.1126/science.abf4460

Above: Scanning electron micrograph showing perovskite nanocrystals embedded in the MOF matrix.

4 PEROVSKITE SOLAR CELL BREAKS WORLD RECORD

More efficient solar cells are paving the way to cheaper and more sustainable energy. The silicon solar cells that currently dominate the market are plateauing in efficiency and are expensive to manufacture. Perovskite solar cells are a next generation alternative that are more efficient, easier to manufacture, and made of cheaper materials. However, these cells have issues with stability. One of these issues is that defects in the atomic structure of the cell can trap electrons, reducing the solar cell's efficiency over time.

Dr Jun Peng from the Australian National University (ANU), along with a team led by A/Prof. Tom White and Prof. Kylie Catchpole, have been investigating ways to prevent these defects.

By applying a thin, non-conductive layer inside the perovskite solar cells they found they could prevent defects from forming. However, as this coating is not conductive, it also blocked electrons from traveling through the cell. To combat this, the team perforated the coating with titanium dioxide nanorods allowing the electrons to flow through the layer, while still protecting the cell from defects and increasing its efficiency.

At our ANU facility transmission electron microscopy was used for quality control on the non-conductive layer. Fellow NCRIS facility ANFF was also used for fabrication and imaging.

The team achieved 21.6% efficiency in converting sunlight into electricity, a new world record for perovskite solar cells larger than one square centimetre in size. In comparison, typical solar panels being installed on rooftops right now have efficiencies of 17-18%.

This new, more efficient solar cell:

- demonstrated great stability over time
- will be easier and cheaper to manufacture
- will provide more options in the renewable energy market.

"When [solar cells are] very small it's difficult to measure them accurately, and it's not necessarily representative of what would happen if you scaled up. So our result is the highest on a scale that many consider the minimum - one square centimetre… Ultimately, the aim is to combine these perovskites with silicon in a tandem solar cell. Putting the two materials together can give us higher efficiencies than either one alone," says A/Prof. White.

Improvements such as these would start to bring efficiencies to the levels where they can become commercially viable.

J. Peng et al., Science 2021
DOI: 10.1126/science.abb8687

Dr Jun Peng and A/Prof. Tom White from the ANU with their record breaking perovskite solar cells (Lannon Harley/ANU).

Transmission electron microscopy of the non-conductive layer was used for quality control purposes to check that the polymer blend was smooth and homogenous.

SUPPORTING SUSTAINABLE DEVELOPMENT GOAL 6

CLEAN WATER & SANITATION

5

SUN-POWERED CLEAN WATER

CHALLENGE

1.42 billion people live with high water vulnerability, and that figure is expected to grow in coming decades. Current desalination plants that rely on reverse osmosis are expensive to build and maintain, and require huge amounts of electricity to operate. Cheap and sustainable ways of desalinating seawater, that don't rely on electricity and need minimal maintenance, will be key to reducing this vulnerability.

RESEARCH

A team led by A/Prof. Haolan Xu at the University of South Australia has developed a highly efficient 3D solar evaporator to derive freshwater from seawater or contaminated water using sunlight as an energy source.

More efficient than previous solar evaporation techniques that lose 10-20% of their energy into the environment, the team's 3D evaporator loses none. In fact it captures additional energy from the surrounding environment and directs it to the evaporative surfaces.

The key to the technology's heat absorption is the carefully designed 3D evaporator that uses a photothermal aerogel sheet as its evaporative surface. This sheet is made up of cotton towelling fabric sprayed with reduced graphene oxide and held on with sodium alginate and/or agarose. Reduced graphene oxide is very efficient at absorbing light and converting light into heat. Transmission and scanning electron microscopy, along with spectroscopy, at Microscopy Australia's University of South Australia facility were used to confirm the quality of the reduced graphene oxide and the evenness of the coating at the microscale.

IMPACT

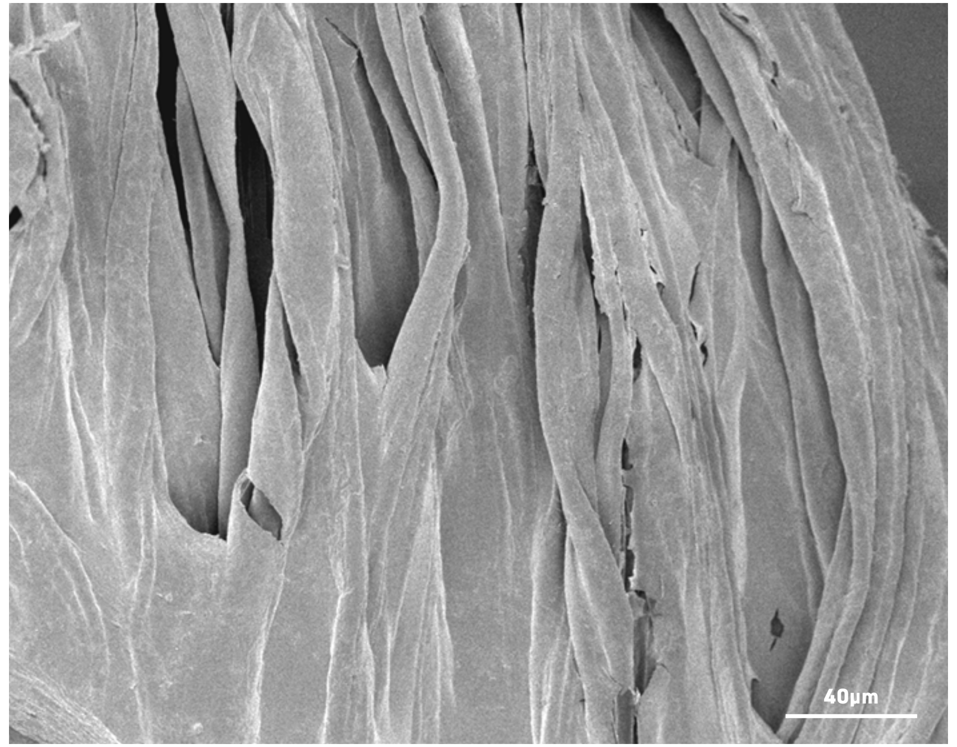
This new super-efficient solar evaporator can deliver enough daily fresh drinking water for a family of four from just one square metre of source water. It is also cheap to construct and apart from the aerogel sheet, can be made almost entirely from materials that can be sourced from a local supermarket or hardware store.

"…Our technique could deliver a very low cost alternative [to reverse osmosis] that would be easy to set up and basically free to run. Also, because it is so simple and requires virtually no maintenance, there is no technical expertise needed to keep it running and upkeep costs are minimal.

"This technology really has the potential to provide a long-term clean water solution to people and communities who can't afford other options, and these are the places such solutions are most needed," says A/Prof. Xu.

T. Gao et al., Solar RRL 2021
DOI: 10.1002/solr.202100053

X. Wu et al., Advanced Science 2021
DOI: 10.1002/advs.202002501



Scanning electron micrograph of cotton towelling coated in reduced graphene oxide.

6

GLUCOSE MAKES BETTER BATTERIES

SUPPORTING SUSTAINABLE DEVELOPMENT GOAL 3

AFFORDABLE CLEAN ENERGY

CHALLENGE

Electric vehicles, mobile phones and other consumer electronics mostly use lithium-ion batteries that were commercialised in the 1990s. They're made using toxic materials such as cobalt, nickel and manganese that are in increasingly short supply around the world.

Lithium–sulfur batteries are an emerging alternative that use cheaper, more abundant materials and are able to store two to five times more energy per kilogram than lithium-ion batteries. However, they degrade rapidly through the recharging process. A solution to this problem needs to be found for lithium–sulfur batteries to be viable.

RESEARCH

A team from Monash University led by Prof. Mainak Majumder have found a way of making lithium–sulfur batteries that are robust enough to be recharged 1000 times.

In a lithium–sulfur battery, energy is stored when lithium ions are absorbed by an electrode made of sulfur particles. The electrode swells up to almost double its size when it is fully charged, then shrinks as it's discharged. This expansion and contraction caused by the cycle of charging and recharging weakens and distorts the electrode. This reduces the battery's performance and limits the number of recharge cycles to around 50 compared to around 1000 for lithium-ion batteries.

When looking for a solution, PhD student Yingyi Huang found a geochemistry paper published in the late 1980s describing how sugar can help soil retain sulfur compounds. Inspired by this, the team tried adding glucose to the sulfur electrodes in the battery and found that they became much more stable. The electrode also became more open, facilitating the interaction between the lithium ions and the sulfur, which in turn, improved performance, increasing the battery's durability to 1,000 cycles; a twenty-fold improvement over the original batteries. The team are now exploring additives to increase durability even further.

Scanning electron microscopy, elemental analysis and focused ion-beam techniques at the Microscopy Australia facility at Monash University allowed the team to understand the structural and functional changes in the different types of electrodes.

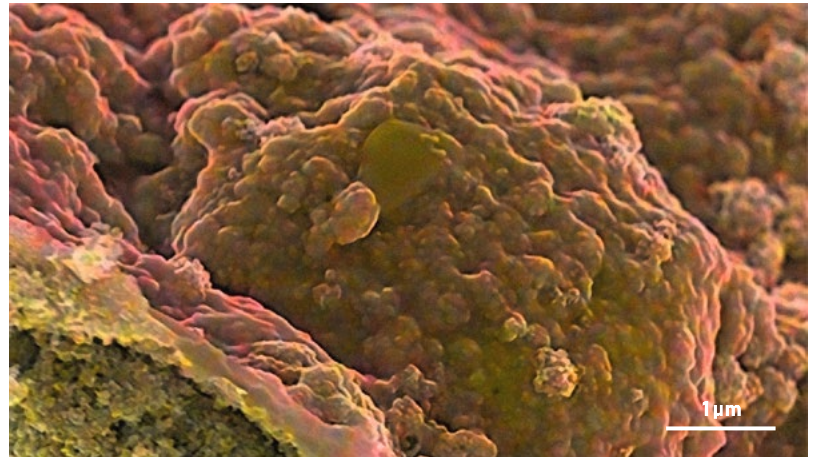
IMPACT

When commercialised, lithium–sulfur batteries will have several benefits over lithium-ion:

- They are cheaper and more environmentally sustainable
- They are smaller – the team aim to develop a prototype battery able to store two to three times more energy than a lithium-ion one of the same size
- They would allow an electric vehicle to drive from Melbourne to Sydney on a single charge, something not currently possible

A/Prof. Glushenkov, from the Australian National University's Battery Storage and Grid Integration Program, who was not involved in the research, said "I do believe there will be a prototype that will be usable in five to 10 years."

Y. Huang et al., Nature Communications 2021
DOI: 10.1038/s41467-021-25612-5



Scanning electron microscope images, overlaid with an elemental map showing the structural differences in electrodes with (bottom) and without (top) glucose. Without glucose the binding material (red) covers the sulfur (yellow), whereas with glucose, the structure is more open and more sulfur is exposed so it can interact with lithium.

7

INSULIN-MODERATION SIGNAL FOUND

Survival depends on effective communication. In cells, molecular signals transmit messages from the cell surface through to where it has its effect. Just as a faulty antenna results in a garbled TV image, if these molecular signals are distorted, messages don't get through and the outcomes can be catastrophic.

Researchers Alison Kearney and Dr Dougall Norris under the supervision of Dr James Burchfield and Prof. David James from the University of Sydney, and colleagues at the Monash Biomedicine Discovery Institute, have used microscopy at our University of Sydney facility. Combining this with cell biology and mathematical modelling, they have identified a new part of a complex cell communication pathway that controls how insulin signals are conveyed.

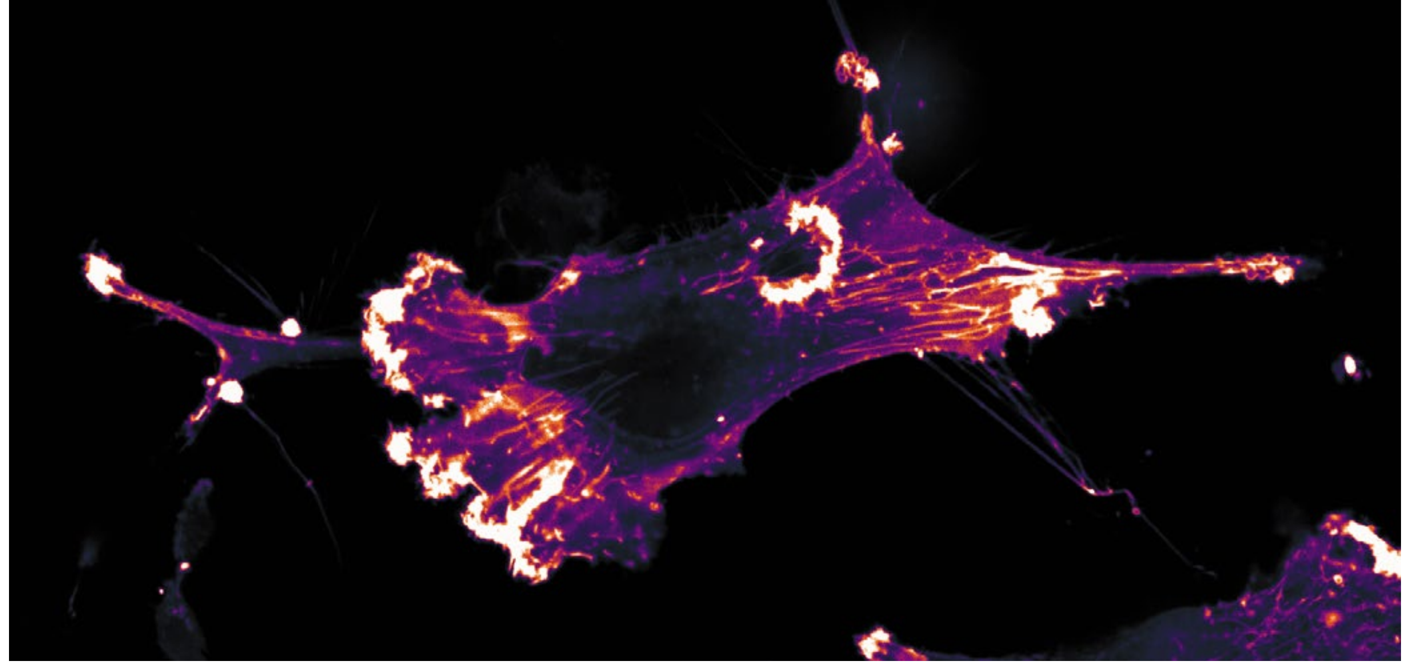
Insulin is a potent signal for growth that increases in the body following a meal, to promote the storage of sugar in muscle and fat cells all over the body. If the insulin signal is inadequate, diabetes can develop. Conversely, if the signal cannot be switched off well enough, cancer can develop. Control of this signalling process is therefore crucial to keep our bodies functioning correctly. Understanding how the signals go wrong can really help researchers understand how disease develops and therefore how to design new treatments.

"We have discovered a new part of a cell communication system that prevents the insulin signal from overactivating, just like a thermostat controlling a heater," Dr Burchfield said.

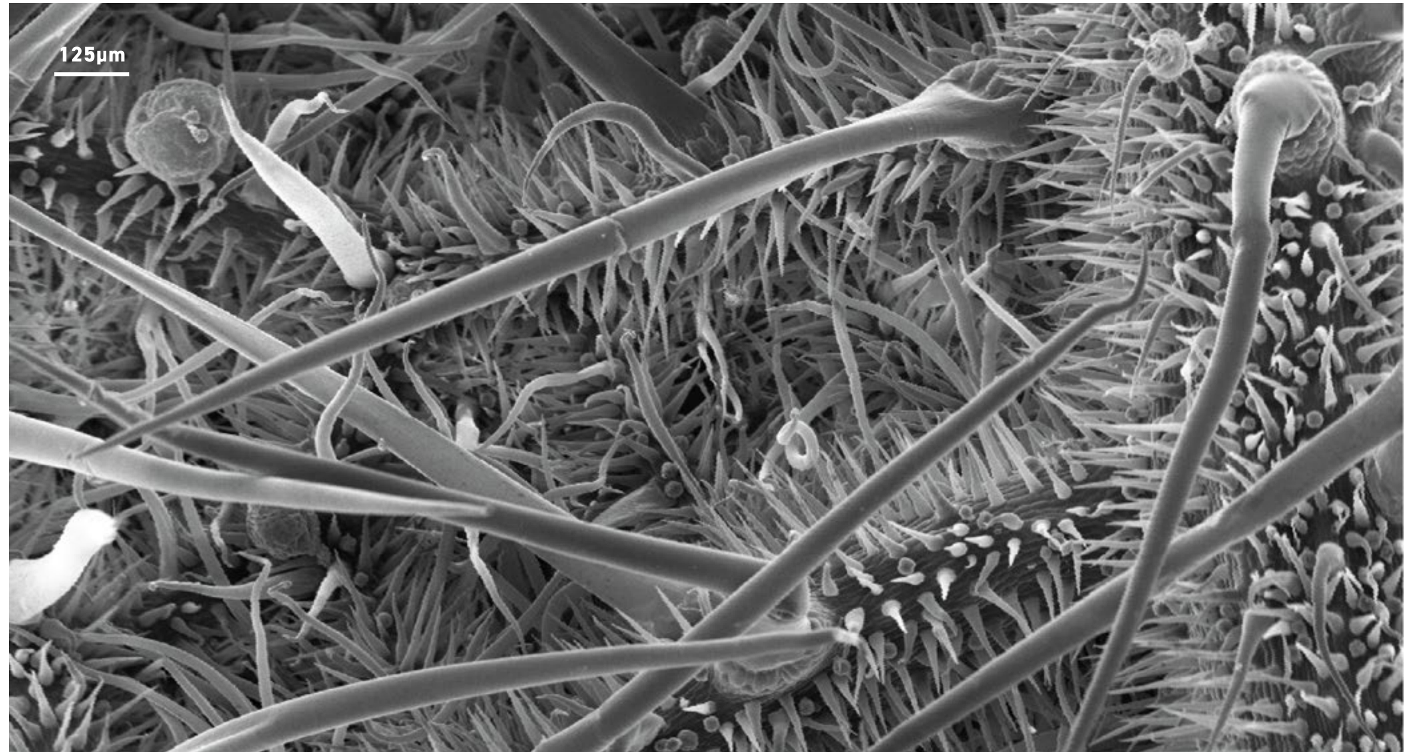
When insulin arrives at the outside of a cell, it sticks onto a special receptor protein that spans the cell membrane, connecting the outside of the cell to the inside. Once insulin has bound to its receptor on the outside, another protein inside the cell sticks onto the inner part of the receptor from where it activates the chain of communication through the cell. The team discovered that as one of the steps along this pathway gets more and more active, it goes back and modifies the protein stuck to the inside part of the receptor. This makes it fall off the receptor, which in turn switches off the insulin signal.

"If cells lost this mechanism, the growth signal would no longer be controlled, and tumours could develop. Some current anti-cancer drugs may actually impair this mechanism and ironically lead to increased tumour growth and drug resistance. Thus, identifying these mechanisms and understanding how they work will aid the development of better cancer therapy," Dr Burchfield added.

A. L. Kearney et al., eLife 2021
DOI: 10.7554/eLife.66942



Confocal image of proteins (white) accumulating at the edges of the cell (purple).



8

UNDERSTANDING THE BACTERIAL ENEMY

Three international research teams – from Australia, headed by Dr Gökhan Tolun from the University of Wollongong, along with international collaborators from the Czech Republic and a German/US/Finnish consortium – have discovered how bacteria keep their genes working efficiently. By understanding the details of how bacterial genes are controlled, we can develop new approaches that interfere with the processes and kill deadly bacteria.

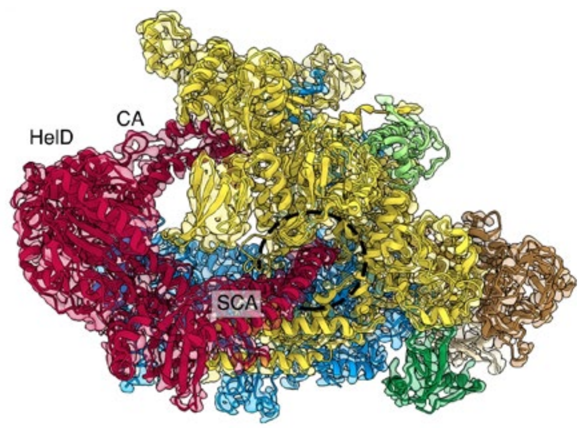
A dedicated protein called RNA polymerase (RNAP) moves along DNA copying its information into a strand of RNA. This RNA then directs the production of the proteins that build and control most of the processes in all living cells. However, sometimes as the RNAP moves along the DNA, it gets stuck and blocks other processes, potentially leading to cell death.

The researchers found that another protein called HelD removes and recycles stuck RNAP from the DNA. Now, by using cryo-transmission electron microscopy at the Microscopy Australia Linked Lab at the University of Wollongong, the researchers have worked out how HelD does it in the bacterium, *Bacillus subtilis*, which is related to dangerous human pathogens *Bacillus anthracis* (anthrax) and *Clostridium difficile*. The Czech collaborators discovered a variant of the same mechanism in mycobacteria, which cause tuberculosis and other devastating diseases.

The cryo-TEM revealed that HelD has powerful 'arms' that reach deep into the RNAP to prise it open and clear away all the residual material that had been blocking it up. HelD, then resets the RNAP structure so it can start working again.

This previously unknown mechanism for RNAP rescue and recycling leads the way to development of new drugs to fight bacteria.

T. P. Newing, et al., Nature Communications 2020
DOI: 10.1038/s41467-020-20157-5



Reconstruction from cryo-TEM data showing the structure of HelD (red) interacting with RNAP.

9

VENOM TO UNCOVER PAIN PATHWAYS

Many natural venoms produce intense pain and Australia certainly has its share of these painful molecular cocktails. Researchers including Dr Samuel Robinson, Dr Thomas Durek and Prof. Irena Vetter at the University of Queensland are investigating how venoms cause pain. This should inform the development of new drugs that might be able to intervene and break the pain chain, not only to treat stings but for pain relief more generally.

Giant Australian stinging trees (*Dendrocnide* species) cause long lasting and extremely painful stings delivered through the stiff hairs on their leaves. These stings are caused by a venom cocktail that includes neurotransmitter molecules and others that cause inflammation. However, those molecules alone could not explain the powerful pain encountered when stung.

While investigating further, the team discovered a new group of miniproteins, they called 'gympietides', after the Indigenous name for the plant. In mice, these miniproteins potently activate pain neurons and delay the switching off of other proteins that would normally moderate pain signals.

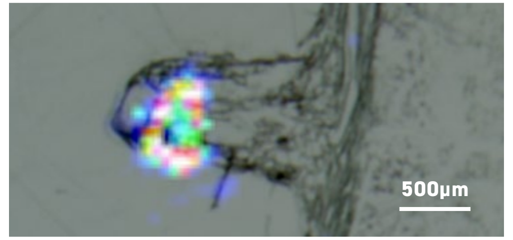
The team used scanning electron microscopy at Microscopy Australia's University of Queensland facility to visualise the hairs, and used the MALDI-TOF instrument to show that the gympietides are located specifically in the stinging hairs of the tree.

Structural studies showed that even though the order of the constituent amino acids in the gympietide miniproteins is completely different to that in other venoms, their 3D structures are the same. The 3D shape causes the gympietides to act in the same way as the other venoms with that same shape, such as those in spiders and cone snails. This similarity is striking when you think about the evolutionary distance between trees and venomous animals.

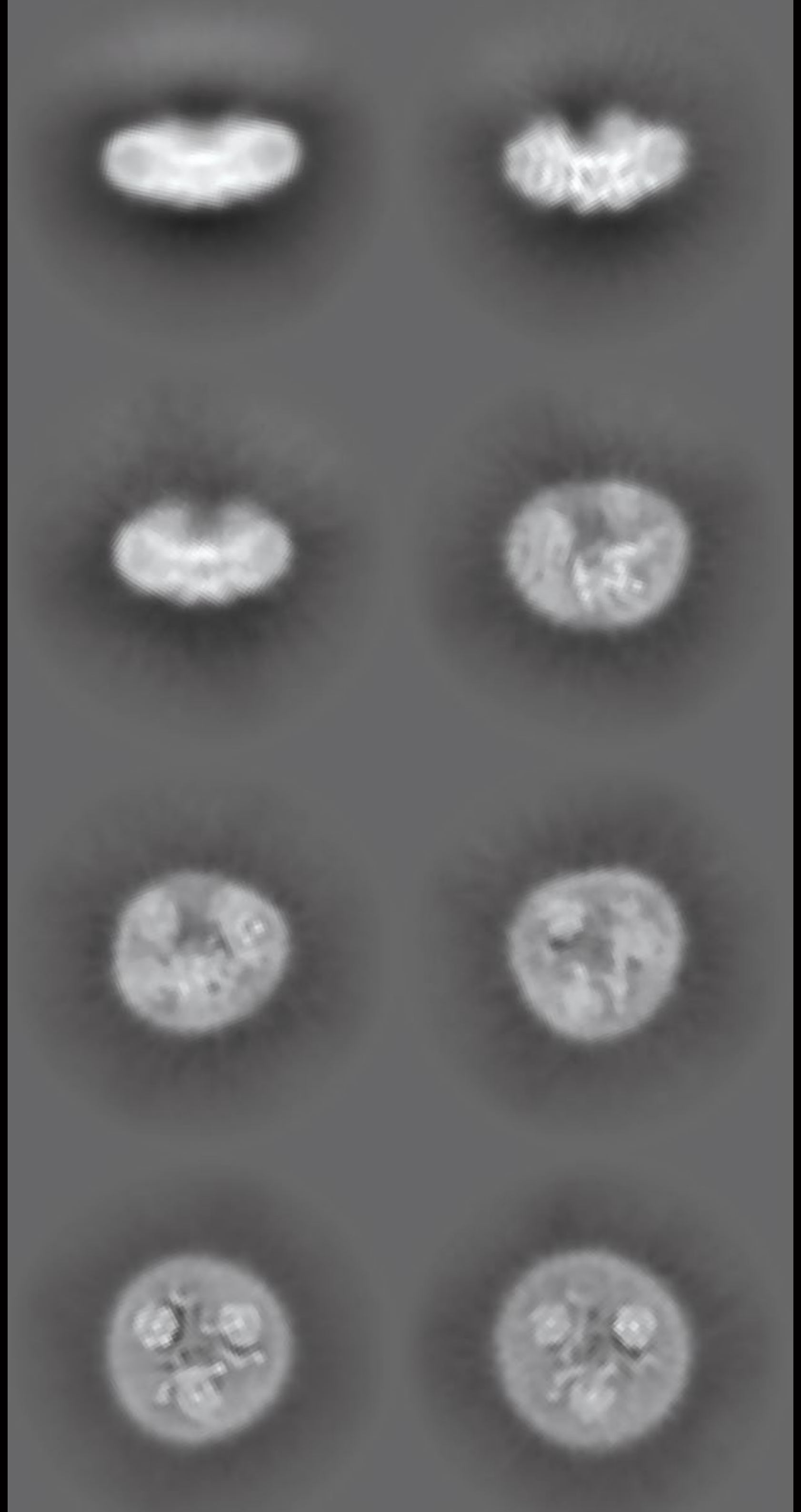
By unravelling how pain pathways react to these venoms, researchers will hopefully be able to create new treatments for pain.

E. K. Gilding et al., Science Advances 2020
DOI: 10.1126/sciadv.abb8828

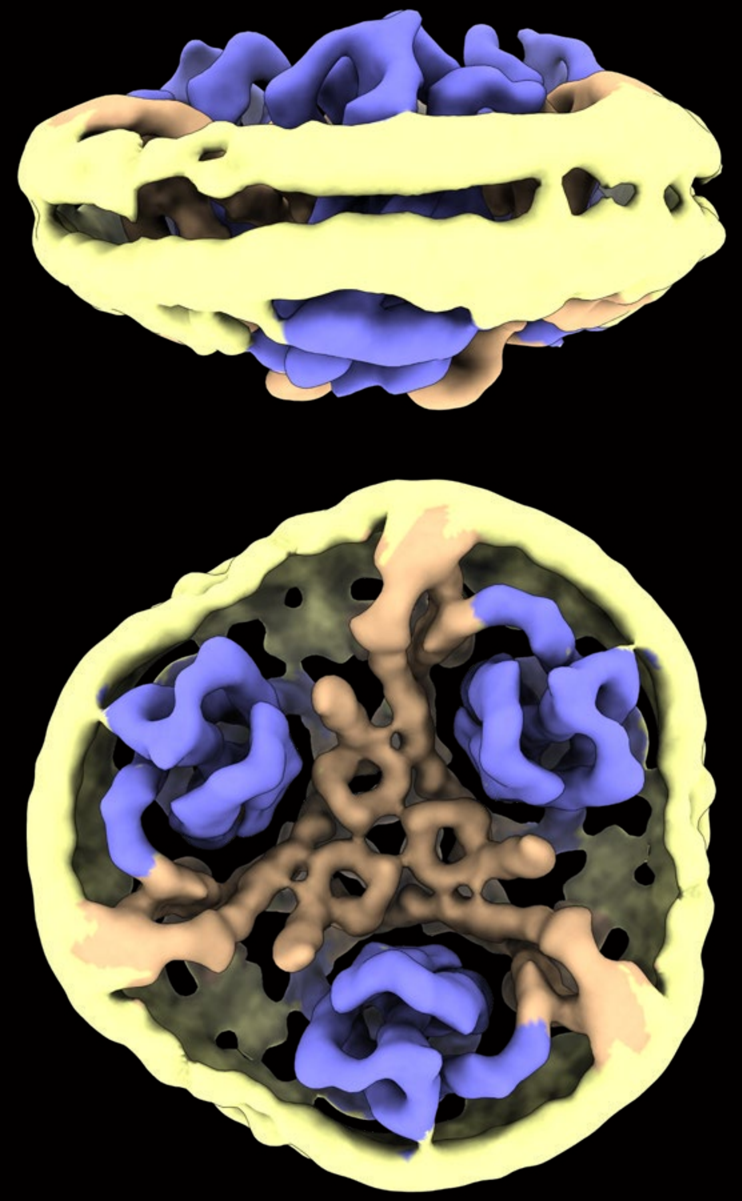
Left: Scanning electron micrograph of stinging tree hairs.



Correlative light and MALDI-TOF image showing the gympietides (coloured pixels) in a stinging hair.



Panel of 2D classification images (left) used to create the 3D reconstruction (right) of the glutamate transporter trimer (blue and brown) in a lipid nanodisc (yellow). This mimics how the transporter sits in the cell membrane. This whole complex is 11nm across.



PUBLISHED IN NATURE

10

MULTI-TASKING MOLECULAR MACHINERY

CHALLENGE

Brain cells communicate through chemical signals that pass from one cell to another. One of the major signalling chemicals is glutamate. Its movement in and out of cells is controlled by a protein called a glutamate transporter that works like a molecular machine, moving glutamate through the cell membrane. But this protein also has a separate important function: to transport chloride ions.

This glutamate transporter is involved in nerve signalling, metabolism, learning and memory. So, understanding the details of how it works is crucial in understanding how the brain works. It also helps to inform the design of precisely targeted drugs to treat and modulate brain disorders from movement problems to Alzheimer's disease.

Although the mechanism for glutamate transport has been known for some time, the way chloride ions are transported remained elusive. Researchers led by Prof. Renae Ryan at the University of Sydney, had been implementing X-ray crystallography to try and understand the location and nature of the chloride channel for many years without success. Instead, in collaboration with colleagues at the Victor Chang Cardiac Research Institute, UNSW Sydney (UNSW), they tried a new approach.

SUPPORTING SUSTAINABLE DEVELOPMENT GOAL 3

GOOD HEALTH & WELLBEING

RESEARCH

The team turned to the Microscopy Australia facilities at UNSW, where they used their co-funded cryogenic electron microscope (cryo-EM) to successfully determine the 3D structure of the protein in a state where chloride ions can pass through. Cryo-EM revealed that the protein took two forms in the same sample, explaining why X-ray crystallography, which requires a single form, was unable to resolve its structure. These two structures could be distinguished in the cryo-EM data using sorting algorithms implemented in single particle analysis. One of the structures observed in this sample contained the chloride channel and computer simulations performed by collaborators in the USA revealed the principles of chloride translocation.

"Using cryo-EM, we have uncovered for the first time just how these transporters can multitask: carrying out the dual functions of moving glutamate across the cell membrane while also allowing water and chloride ions through at the same time," said senior researcher Prof. Renae Ryan.

IMPACT

"Understanding how the molecular machines in our cells work enables us to interpret defects in these machines in disease states and also gives us clues to how we might target these machines with therapeutics," says Prof. Ryan.

Rare diseases such as episodic ataxia, a disease that impacts movement and causes periodic paralysis, is caused by an uncontrolled leak of chloride through the glutamate transporter in brain cells.

Effective treatments for the diverse conditions influenced by the glutamate transporter could have a huge impact on health care costs, quality of life and productivity for the tens of millions of people worldwide living with Alzheimer's disease and the impact of stroke alone.

"Understanding the glutamate transporter structure, which controls the normal flow of chloride, could help design drugs that can 'plug up' the chloride channel in episodic ataxia," says researcher Dr Qianyi Wu.

I. Chen et al., Nature 2021
DOI: 10.1038/s41586-021-03240-9

11 EFFICIENT VACCINE DELIVERY TO THE WORLD

The high-density micro-array patch (HD-MAP), previously known as the Nanopatch, was developed at the University of Queensland by Prof. Mark Kendall's team and is now being commercialised by Vaxxas.

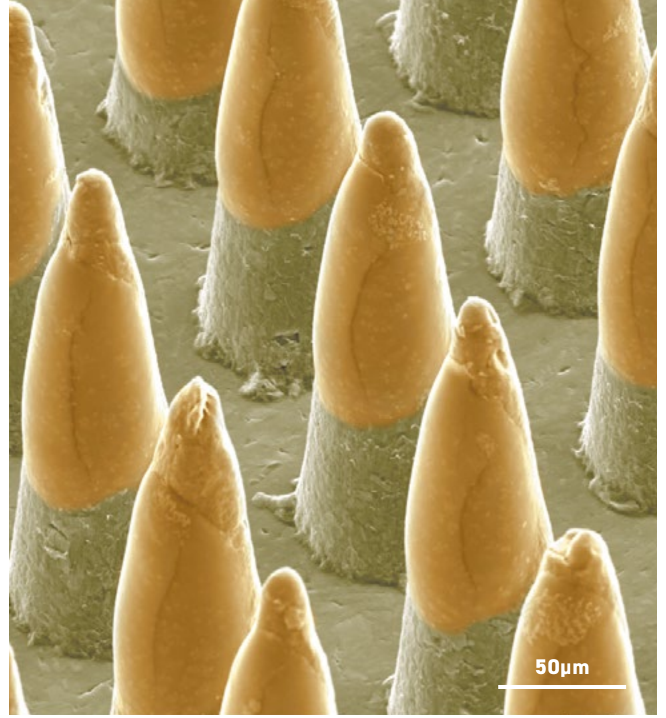
It was highlighted in the World Economic Forum's 2020 report as one of the top ten emerging technologies. Vaccines, dry coated onto 5000 tiny projections are delivered directly to very receptive immune cells in the skin. This generates a much stronger immune response than is elicited by traditional injections into muscle.

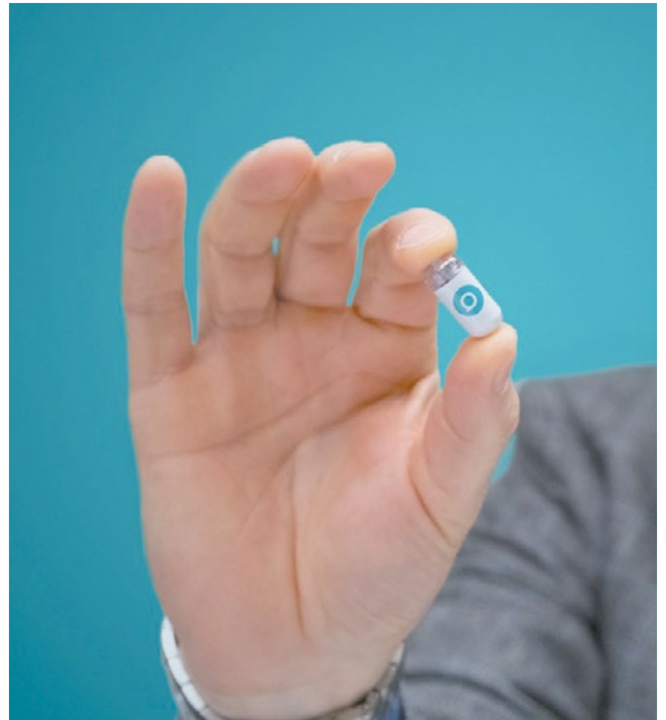
The latest trials have used the HD-MAP to deliver various vaccines including a newly developed dengue vaccine from the University of Queensland and the COVID-19 vaccine HexaPro. Both elicit strong immunity when given using the HD-MAP. Dengue is the most significant mosquito-borne viral disease in the world. With an estimated 390 million cases annually, it results in approximately US$6.9 billion in economic losses. Both the HD-MAP and the dengue vaccine have relied on Microscopy Australia's University of Queensland facility.

After earlier successful trials with polio and influenza vaccines, the two latest successes demonstrate multiple benefits. Compared to existing needle-based COVID-19 vaccinations for instance, delivery with HD-MAP is effective against multiple strains of COVID-19; is stable at room temperature (25°C) for at least 30 days; does not need to be stored or transported at ultra-low temperatures; uses significantly less vaccine per dose; only requires one dose; produces a more protective immune response; is completely pain free and can be self administered.

C. McMillan et al., bioRxiv 2021
DOI: 10.1101/2021.05.30.446357

Top: Colour-enhanced scanning electron micrograph of the HD-MAP (previously Nanopatch™) (green) coated in vaccine (yellow).





12 GAS-SENSING CAPSULE TO DIAGNOSE GUT DISORDERS

One-in-five people worldwide suffer from a gastrointestinal disorder. Now, an ingestible diagnostic capsule, the size of a vitamin pill, can provide better diagnoses, and treat disorders such as irritable bowel syndrome and small intestinal bacterial overgrowth.

Developed by Prof. Kourosh Kalantar-Zadeh and his team while at RMIT University, it is now being commercialised by start-up, Atmo Biosciences Pty Ltd. This capsule could prevent the need for many invasive colonoscopies by measuring gut gases – hydrogen, carbon dioxide and oxygen – in real time, and at known locations, as it passes through the patient's gut.

Nanocomposite membranes in the capsule are used to separate the gases. During development these were analysed using a variety of microscopy techniques at the Microscopy Australia linked lab at RMIT.

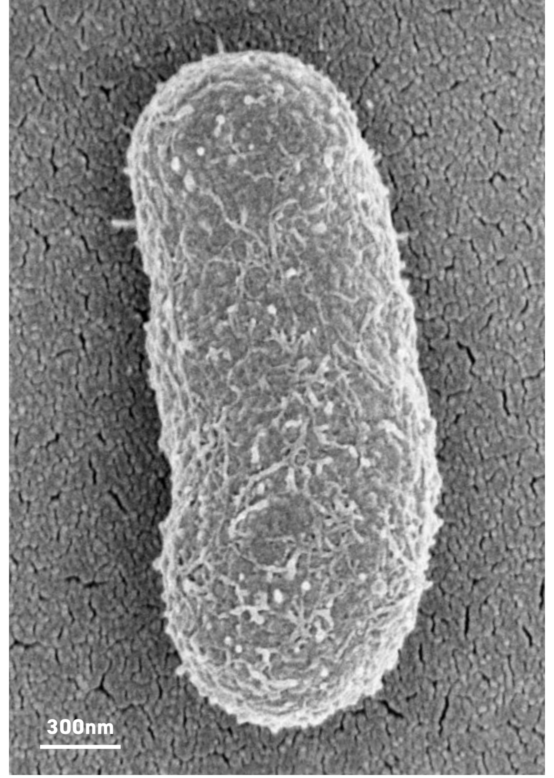
"IBS affects 10% of the population, but there is currently no definitive diagnostic test or biomarker; diagnosis, treatment and management is challenging because it is based almost entirely on symptoms," Atmo Biosciences CEO, Mal Hebblewhite said.

Phase 1 human trials of a prototype capsule established that the capsules were safe and reliable, and far more accurate than breath tests in detecting gaseous biomarkers. More human trials are underway at Monash University and the Alfred Hospital, Melboune.

Through the Government's Modern Manufacturing Strategy, Atmo was recently awarded a $317,500 grant, to scale up manufacturing capacity at their manufacturing facility at Planet Innovation in Melbourne. This will let Atmo produce more capsules for further trials and to meet growing demand from commercial and research customers. They have also recently raised $9.6 million from investors led by Sydney-based investment firm Alium Capital Management and Japanese multinational company Otsuka Pharmaceutical.

Bottom: The Atmo Biosciences gas-sensing capsule.

13 BACTERIOPHAGE GIVE NEW LIFE TO ANTIBIOTICS



With the rise of superbugs, finding new ways to tackle these antibiotic-resistant bacteria is becoming more and more critical. New research by Monash University researchers has found a way to give a second wind to the antibiotics we do have.

Acinetobacter baumannii is a bacteria responsible for up to 20% of infections in intensive care units. It attaches to medical devices such as ventilator tubes, and urinary and intravenous catheters causing devastating infections in the lungs, urinary tract, wounds and the bloodstream. Treatment is difficult because *A. baumannii* can produce enzymes that destroy entire families of antibiotics. Other antibiotics simply never make it past its thick outer layer that protects the bacteria from the body's immune system. In some cases, not even the strongest, and most toxic, antibiotics can kill *A. baumannii.* As a result, the World Health Organisation named it a critical priority for the discovery of new treatments.

Bacteriophages are viruses that infect bacteria. Their name means "bacteria eater". Despite being viruses, they cannot infect humans, and a single bacteriophage normally infects only one type of bacteria. Since their discovery in the 1900s they've been used to combat bacterial infections. However, with the introduction of antibiotics in the 1940s their use fell out of fashion. Phage therapy is seeing a resurgence with the rise of antibiotic-resistant superbugs.

The Monash University team, lead by Dr Jeremy Barr and Fernando Gordillo-Altamirano, isolated bacteriophages in wastewater samples, from all over Australia. They successfully isolated a range of phages capable of killing *A. baumannii*. However, they found that while the phages could wipe out most of the bacteria, within hours the superbug had found a way to become resistant to the phages.

At first this seemed like a setback, however, when examined using electron microscopy at our Monash University facility the researchers found that the phage-resistant *A. baumannii* were missing their outer layer. The bacteriophages attach to *A. baumannii* using a specific receptor that is on the surface of this outer layer. When attacked by the phages, *A. baumannii* escaped by letting go of this layer.

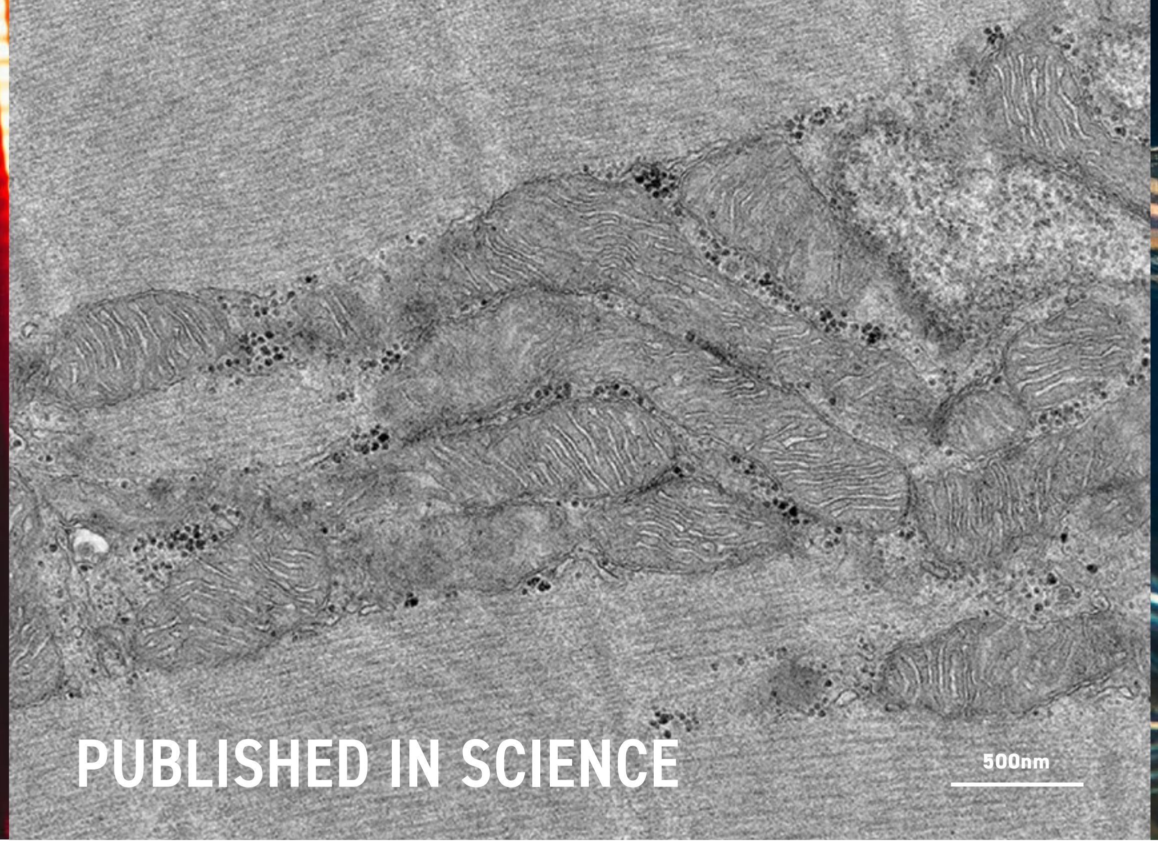
Without this protective layer, *A. baumannii* was shown to be vulnerable to reduced doses of three antibiotics. These reduced doses are less harmful to the patients while still killing the harmful bacteria. This study opens up the possibility of using combined phage and antibiotic treatment more generally to fight other emerging superbugs.

F. G. Altamirano et al., Nature Microbiology 2021
DOI: 10.1038/s41564-020-00830-7

Images: Scanning electron micrographs showing a normal A. baumannii (left) and one missing its outer coat (right).

SUPPORTING SUSTAINABLE DEVELOPMENT GOAL 3

GOOD HEALTH & WELLBEING



PUBLISHED IN SCIENCE

14

FIXING BROKEN HEARTS

CHALLENGE

Heart attack is a leading cause of hospitalisation and death in Australia, claiming on average 21 lives every day. Every year, 57,000 Australians suffer a heart attack. $680 million is spent on health care services related to patients admitted to hospital for heart attacks, with several times this in productivity losses.

Despite advances in treatments, death rates among people aged 65 or older who survive a heart attack are still not good. If you survive a heart attack, fibrous scar tissue forms in place of the damaged heart muscle. This scar tissue can't contract and reduces the heart's ability to pump, potentially leading to congestive heart failure, where everyday activities become extremely difficult.

RESEARCH

Our human hearts don't naturally repair themselves being damaged. Zebrafish on the other hand, efficiently regenerate damaged heart muscle. If we could harness this regenerative capacity, we could have an effective treatment for heart attacks.

Researchers at the Victor Chang Cardiac Research Institute, led by Dr Kazu Kikuchi and colleagues at the Garvan Institute of Medical Research, discovered that a specific protein called Krüppel-like factor 1 (Klf1) become active when the fish heart muscle is damaged. Mature muscle cells can't divide to make more muscle cells. However, Klf1 alters the mature heart muscle cells and helps to return them to an earlier stage of development where they can then divide to make new heart muscle cells. This process switches itself off again when the heart has fully healed.

Humans also have a version of the Klf1 protein. If that could be activated after a heart attack, it may be able to trigger regeneration of human heart muscle. Understanding how Klf1 is controlled in zebrafish and in humans will be vital to see if such treatments could become a reality.

Transmission electron microscopy at the Microscopy Australia facility at UNSW Sydney helped the researchers to make this discovery.

IMPACT

Improved treatment for heart attacks will:

- Improve patient quality of life and long-term health following a heart attack
- Reduce ongoing financial burden on the health service and families
- Reduce productivity losses due to long-term heart disease

M. Ogawa et al., Science 2021
DOI: 10.1126/science.abe2762

Image: Transmission electron micrograph of normal zebrafish muscle.

15 BARLEY TO TAKE THE HEAT

Cereal crops such as wheat and barley are worth over $12 billion to the Australian economy. These crops are highly sensitive to changing environmental conditions with higher temperatures reducing the number of seeds that they produce.

An international collaboration between researchers at the University of Adelaide and Shanghai Jiao Tong University's Joint Lab for Plant Science and Breeding and led by Prof. Dabing Zhang, has now identified a gene in barley that could help crop growers maintain high yields as temperatures rise.

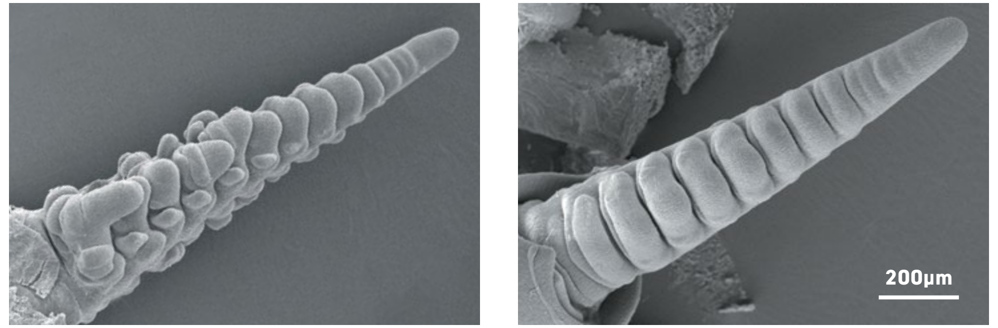
With the help of light and electron microscopy at Microscopy Australia's University of Adelaide facility, the team discovered that a barley protein, known as HvMADS1, limits the number of flowers generated on each spike when plants are grown at high temperatures. As temperatures rise, HvMADS1 binds more tightly to specific regions of DNA, reducing the action of genes that normally encourage cell division and flower formation.

Using a genome editing technique, the researchers generated new plants that lack HvMADS1. These new plants grew branched spike structures, bearing more flowers at high ambient temperatures.

Co-author A/Prof. Matthew Tucker, Deputy Director of the University of Adelaide's Waite Research Institute said: "This study reveals a new role of this protein family in responding to thermal change and directing the composition of flowers on a stem. With temperature rises predicted globally, plant scientists and breeders have an enormous challenge ahead of them to generate crop yields needed to feed growing populations in higher temperatures."

This discovery of how HvMADS1 acts in response to temperature gives scientists insights into how to breed climate-smart plants to sustain productivity.

G. Li et al., Nature Plants 2021
DOI: 10.1038/s41477-021-00957-3



SEM images of a developing normal barley spike grown at high temperatures (right) and one where HvMADS1 has been removed, showing greater branching (left).

16 BOOST TO MICROALGAE HEALTH SUPPLEMENTS

Microalgae are a great source of antioxidants, vitamins, and fatty acids. With a low environmental footprint, they could form part of the answer to providing an ever growing world population with essential nutrients.

Microalgae have a large range of applications in both nutri- and pharmaceuticals, in particular as an omega-3 fatty acid supplement. Omega-3 plays an important role in preventing obesity, diabetes and fatty liver disease and can assist wound healing.

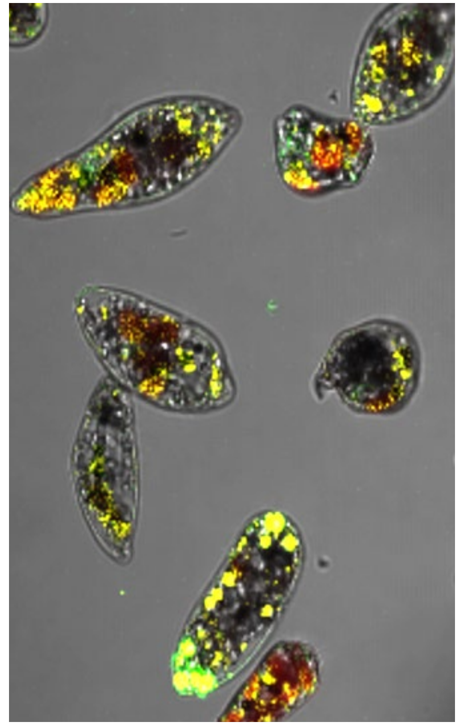
Today most omega-3 supplements are fish- or krill-oil based. Microalgae, from which fish obtain their omega-3, is much cheaper and easier to cultivate, does not have fish-based contaminants such as polychlorinated biphenyls, and is also vegetarian and vegan friendly. However, its widespread uptake as a source of omega-3 has been hampered by a lack of techniques that can easily measure its fatty acid content, making it difficult to monitor and optimise as a product.

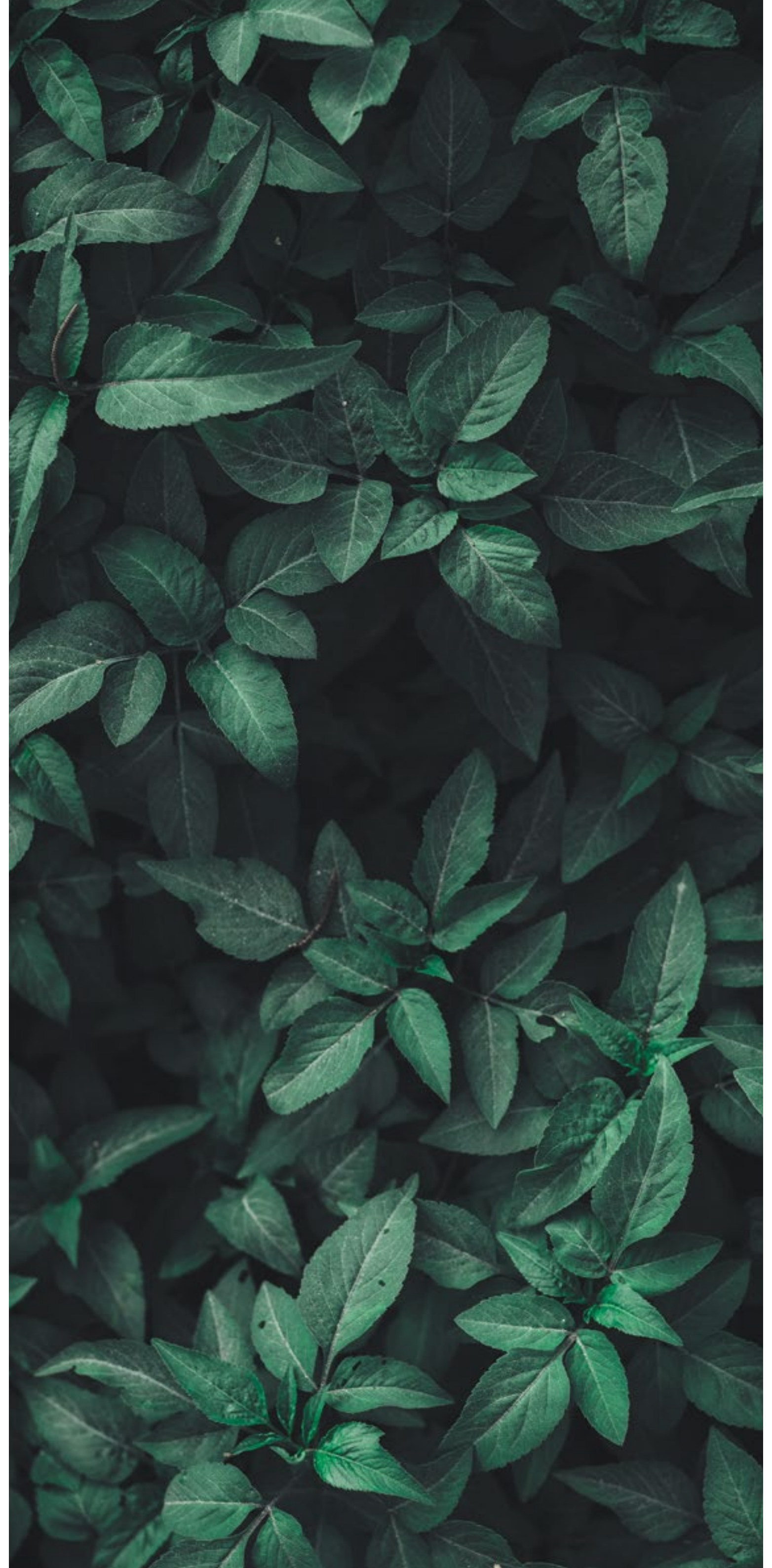
Now, a research team at Flinders University has developed a stable fluorescent bioprobe that specifically binds to fats. When viewed on a confocal microscope, it allows for easy monitoring of fats within the microalgae. At Microscopy Australia's Flinders University facility, the team, led by Mohsinul Reza under the supervision of Profs Jian Qin and Youhong Tang, was able to use the technique to determine the optimal growing conditions to maximise fat production in a species of microalgae called *Euglena gracilis*.

The new monitoring technique is quick, easy, cheaper to make, and more accurate than existing options. It will allow companies to screen different algae types for fatty acid production potential and optimise growing conditions for creating renewable, eco-friendly health supplements.

A. M. Reza et al., Materials Chemistry Frontiers
2021 DOI: 10.1039/D0QM00621A

Image: Brightfield image of microalgae cells highlighting different components including lipids (yellow).





17 BACTERIA HIDDEN IN PLAIN SIGHT

An international research collaboration has shown for the first time that healthy plants carry bacteria inside their cells. This opens a new avenue of research to improve plant health and propagation efforts of food crops such as grains and fruit such as grapes, bananas and papaya.

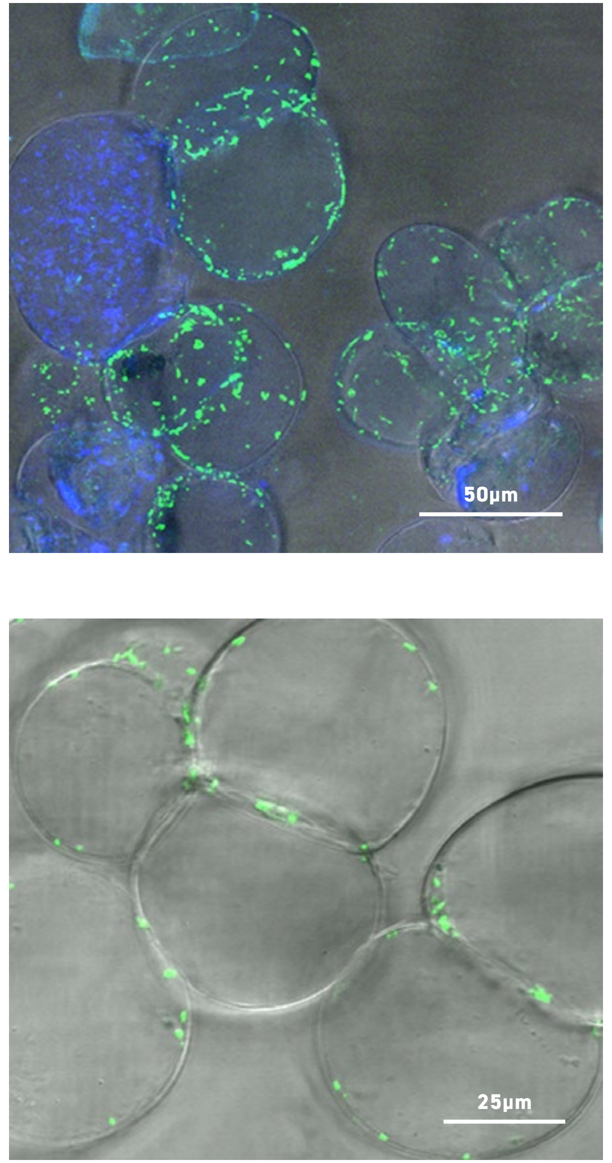
Microbes mainly colonise roots and have long been seen living in between the plant cells. Now, this new study shows that a huge diversity of bacteria are also living happily inside these plant cells and contribute to normal plant cell metabolic functions. Researchers have named them 'Cytobacts'.

The long-term study that led to these findings started ten years ago when Dr Pious Thomas, then from the Indian Institute of Horticultural Research, visited the lab of Prof. Chris Franco at Flinders University. Using a combination of molecular biology, and microscopy techniques at the Microscopy Australia facility at Flinders University, the pair looked at many different plant species. To confirm that the bacteria were not introduced by contamination, they tested plants that had been growing in the lab for years, as well as newly established lab stocks and fresh tissue from plants growing in the field. In all cases they showed the presence of multiple bacteria inside the plant cells. For example, 40-year-old grape vine cells revealed more than 250 types of bacteria, all of which are either extremely difficult or impossible to grow independently of the plant cells.

"Potentially [cytobacts] are involved in some of the integral functions of plants, such as energy metabolism, or as an inducer of defence responses against other microorganisms" Prof. Franco says.

P. Thomas & C. M. M. Franco, Microorganisms 2021
DOI: 10.3390/microorganisms9020269

Right: Confocal images of green fluorescently labelled bacteria inside plant cells.

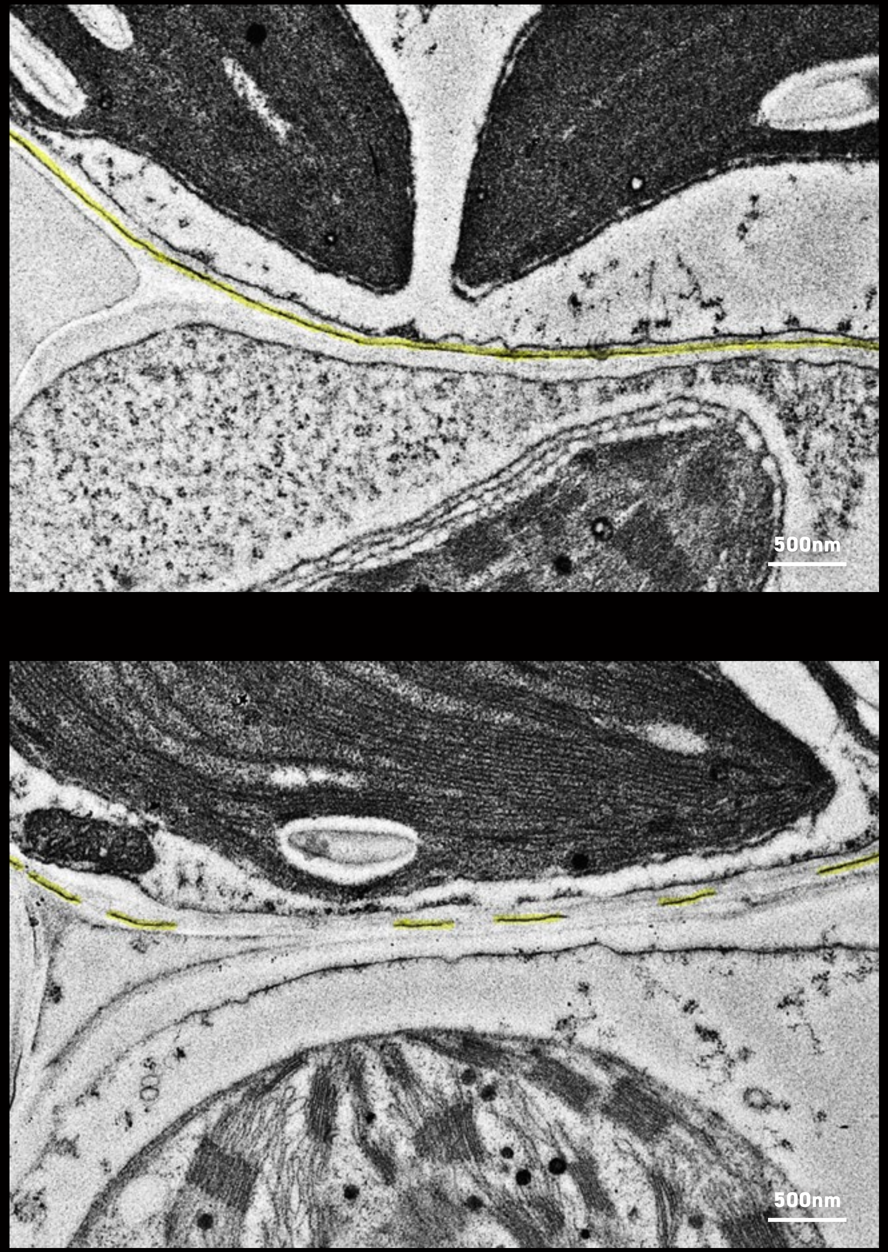


SUPPORTING SUSTAINABLE DEVELOPMENT GOAL 2

ZERO HUNGER

18

BUILDING FUTURE FOOD SECURITY



CHALLENGE

As the world population grows, food security becomes an increasing challenge. Currently, over 3 billion people depend on rice for survival. By 2050, with projected population growth, the same land will need to increase its productivity by 50%. Traditional breeding programs have hit a productivity barrier and other approaches are needed.

Photosynthesis is the process that plants use to capture sunlight and turn it into food. All photosynthesis uses CO_2 and sunlight to produce sugars, but there are actually two types of photosynthesis, used by different types of plants. These are known as C_3 and C_4, with C_4 being more efficient. Highly productive crops such as sugarcane, sorghum, millet and maize are C_4 plants, whereas rice and wheat are C_3 plants. There is a lot of work being done to understand the details of the C_4 process with the aim of engineering more productive crops and ensuring future food security.

RESEARCH

C_4 plants can enclose CO_2 inside a gas-tight compartment in a type of leaf cell called bundle sheath cells. This makes it easier for photosynthesis to fix carbon, increasing its efficiency. Until now, it wasn't clear what makes this compartment gas tight so CO_2 can't escape.

An international research collaboration has found the answer. The team led by Dr Florence Danila and Prof. Susanne von Caemmerer, from the ARC Centre of Excellence for Translational Photosynthesis at the Australian National University, is part of the international C_4 Rice Project, led by Oxford University. They analysed a mutant C_4 millet plant that was found to lack a waxy substance called suberin in its bundle sheath cells, as do C_3 plants. This mutation reduced the plant's growth and its ability to photosynthesise. By using transmission electron microscopy (TEM) in the Microscopy Australia facility at ANU, the researchers showed that the bundle sheath cells lacked a barrier layer seen in normal C_4 plants, telling them that suberin forms the gas-tight seal.

This new understanding will help the researchers develop new strategies to engineer C_3 plants to behave like C_4 plants. In particular, the team aims to convert rice (a C_3 crop) into a more productive C_4 plant.

IMPACT

Introducing C_4 traits into rice is predicted to increase photosynthetic efficiency by 50%, double water use efficiency and increase efficiency of nitrogen use. This type of plant engineering is one of the most plausible approaches to enhancing crop yields and increasing resilience in the face of reduced land area, decreased use of fertilisers and less predictable supplies of water.

F. R. Danila et al., Communications Biology 2021
DOI: 10.1038/s42003-021-01772-4

TEM images of bundle sheath cells in the normal (top) and mutant (bottom) millet. The barrier layer (the black line highlighted in yellow) is solid in the normal cells and incomplete in the mutant cells.

19 GETTING MORE FROM GRAVEL SOILS

Ironstone gravel soils, common in Australia's southern agricultural regions, are often discounted by grain growers as under-performing. Curiously, they can't all be reliably improved by fertilisers: new research has now uncovered why.

In an ongoing research project between Prof. Daniel Murphy from SoilsWest at Murdoch University and the Grains Research and Development Corporation, researchers are using Microscopy Australia's University of Western Australia facility to discover new information on gravel composition, water absorption and nutrient dynamics. Their aim is to unlock the potential and improve the management of this challenging soil type.

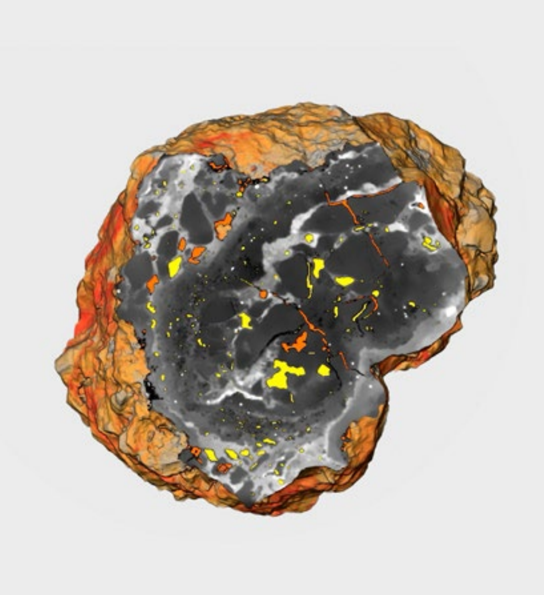
The research team accessed Microscopy Australia's high-sensitivity analytical tools, including the nano-SIMS, and elemental analysis on the scanning electron microscope, to look at the chemical composition of around 400 gravel soil samples from around WA and SA. To complement the elemental studies, X-ray microtomography has allowed the team to see how water and nutrients move into the different gravels by visualising the interconnectedness of pores within individual gravel particles.

Their studies have revealed a lot of variation in gravel soils: they are not all the same. Gravels high in silica tend to be able to hold more water and nutrients whereas iron-dominated gravels tend to hold and release nitrogen well but hold onto phosphorus tightly, not releasing it to the crops. This explains why farmers see no improvement in their yields even when more phosphorus fertiliser is added.

This project is providing highly valuable information to help farmers understand and efficiently manage water and nutrient use on ironstone gravel soils to maximise their crop yields into the future.

Top left: MicroCT image of a gravel particle (4.2cm across) showing pores that are accessible to water in orange and inaccessible in yellow.

Photos: the gravel soils studied by the team.



20

COST-EFFECTIVE MINERAL EXPLORATION

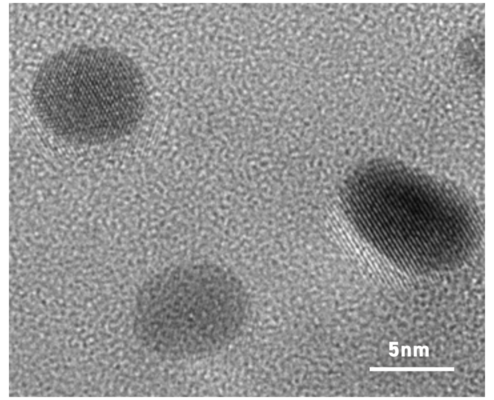
Geologists love the imperfections in minerals as they record the history of how and when those minerals formed and how metals concentrate in rocks to form ore deposits. Researchers at the Centre for Exploration Targeting (CET) at the University of Western Australia (UWA) are building this knowledge, which is very valuable to the mineral exploration companies as it allows them to better predict where undiscovered ore bodies might be found.

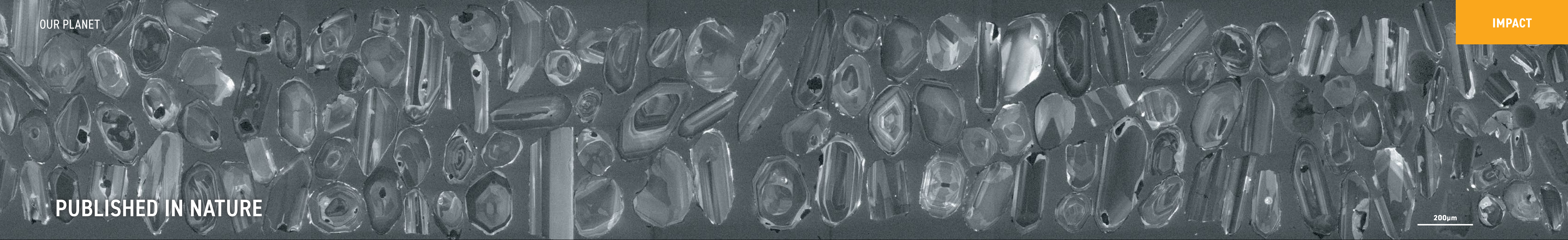
Metals like gold and nickel tend to be carried through the Earth's crust along with sulfur, so understanding how sulfur moves can help trace where metals are likely to occur. The Microscopy Australia facility at UWA, working with CET researchers, have used our SIMS instrument to develop a way to identify unique sulfur fingerprints associated with regions rich in gold and nickel. Mining companies can test samples from their prospective mine sites and compare them to those in the database. This informs further exploration and adds value to Australia's resources sector, and economy generally.

At a smaller size scale transmission electron microscopy (TEM), is revealing the structure of gold at the nanoscale, which is used to identify how sought-after high-grade gold deposits form and therefore where they are likely to be. These are much easier to mine, more environmentally sustainable and cost-effective but are rare and difficult to find. Built on earlier work with Newmont Mining Corporation, an ARC Linkage Project is supporting Northern Star Resources Ltd, Karora Resources Pty Ltd & Fosterville Gold Mine Pty Ltd, as they work with CET researchers. They are using Microscopy Australia to better understand high-grade gold deposits and continue to refine exploration strategies for gold resources in Australia.

Right: Image of high-grade gold in quartz courtesy of Geoscience Australia.

Below: TEM image of gold nanoparticles in an amorphous silica mineral.

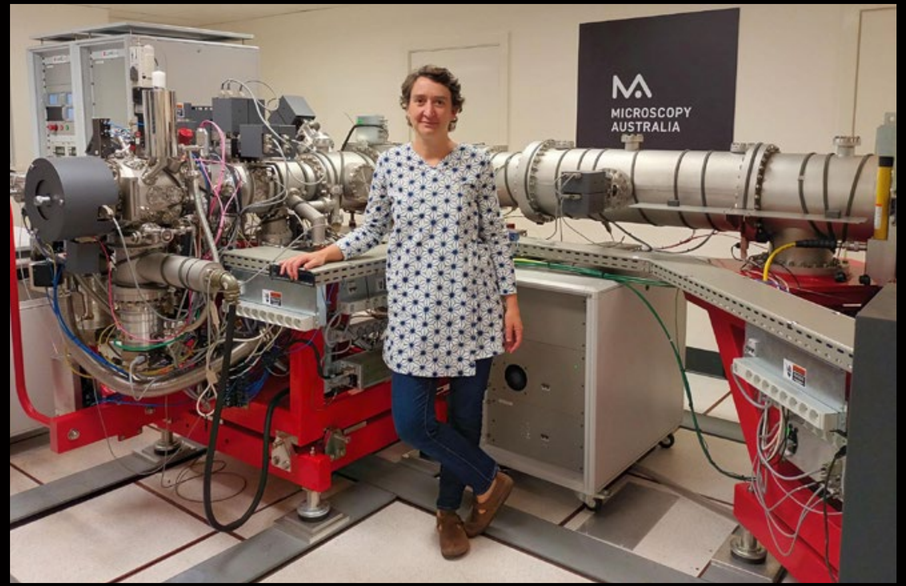




PUBLISHED IN NATURE

21

UNCOVERING THE ORIGINS OF THE CONTINENTS



CHALLENGE

Today, the Earth's surface is made up of continental and oceanic crust. Continental crust makes up the land we live on, and oceanic crust makes up the ocean floors. One of the major differences between oceanic crust and continental crust is that continental crust incorporates water into its minerals as it forms.

Nowadays, when continental and oceanic crust collides, the heavier, denser oceanic crust gets thrust down under the continental crust. As it plunges down into the Earth, the oceanic crust takes ocean water with it. Eventually, the heat and pressure cause this oceanic crust to melt and combine with the water, forming a lighter weight magma that rises and cools to form new continental crust. This process is called subduction. However, when the earth first formed there were no continents and therefore no subduction, so where did the water needed to create the earliest continental crust come from?

RESEARCH

New research by a team from the Geological Survey of Western Australia and Curtin University led by Dr Hugh Smithies has uncovered the source of this water. The team studied tiny crystals, called zircons, collected from some of Earth's earliest continental crust located in the Pilbara, Western Australia. Compositional analysis of these zircons at Microscopy Australia's University of Western Australia facility allowed the team to determine both the source of the water that formed them, and the date at which they formed. It also revealed that early continental crust did not form from surface water as it does today, but instead from primordial water, that already existed deep within the Earth.

IMPACT

This implies that the Earth contained far more primordial water than previously thought and will alter how scientists think about how our planet formed. It also challenges one of the central tenets of physical sciences: uniformitarianism, or the idea that physical processes in the present reflect the physical processes of the past.

R. H. Smithies et al., Nature 2021
DOI: 10.1038/s41586-021-03337-1

Above: Scanning electron micrographs of zircon crystals from early continental crust taken at our linked lab at Curtin University, from Dr Yongjun Lu.

Left: Dr Laure Martin from UWA with the SIMS instrument used in the compositional analysis of the zircons.

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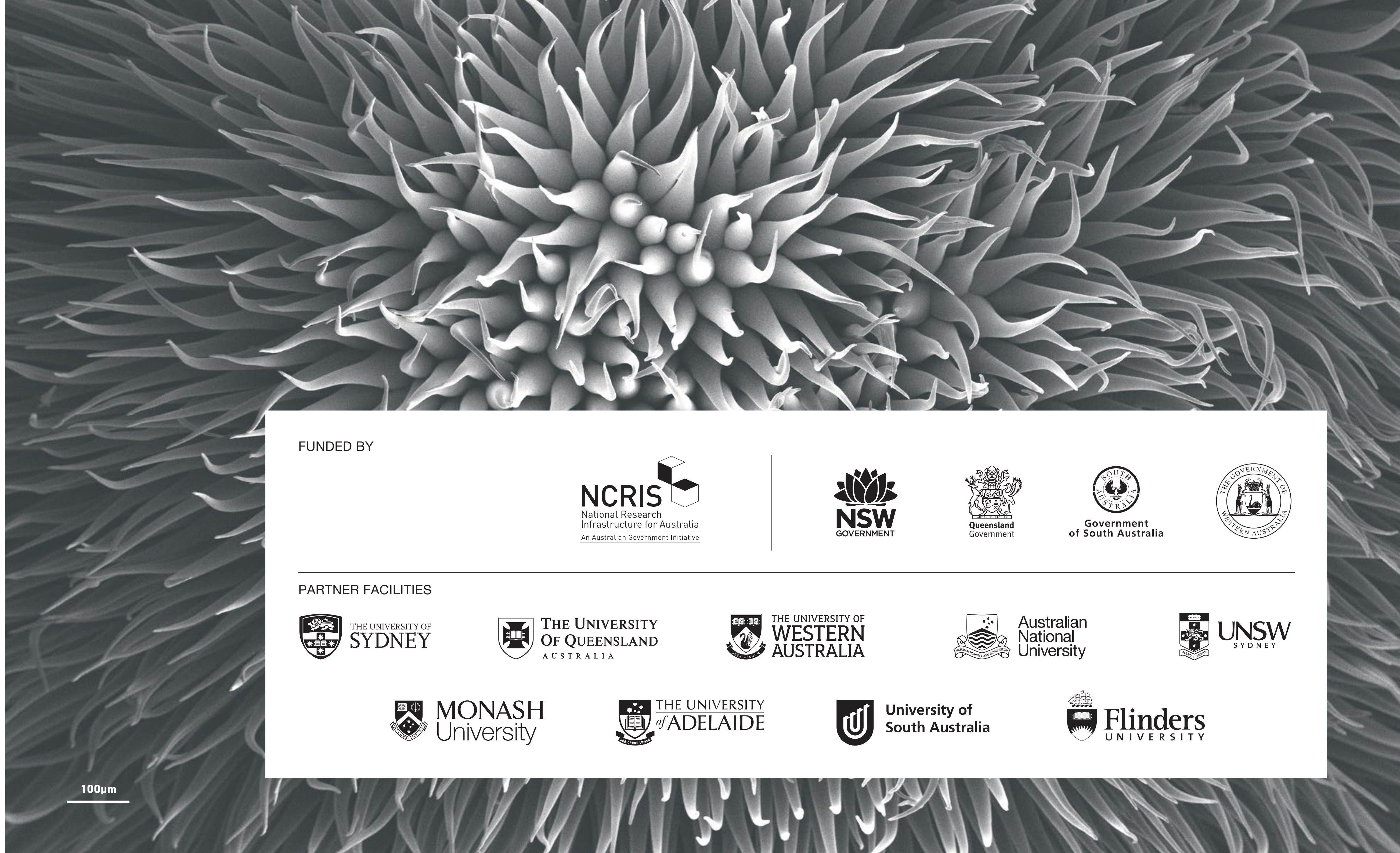
Right: Scanning electron micrograph of a hibiscus stigma by A/Prof. Peta Clode from our University of Western Australia facility



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