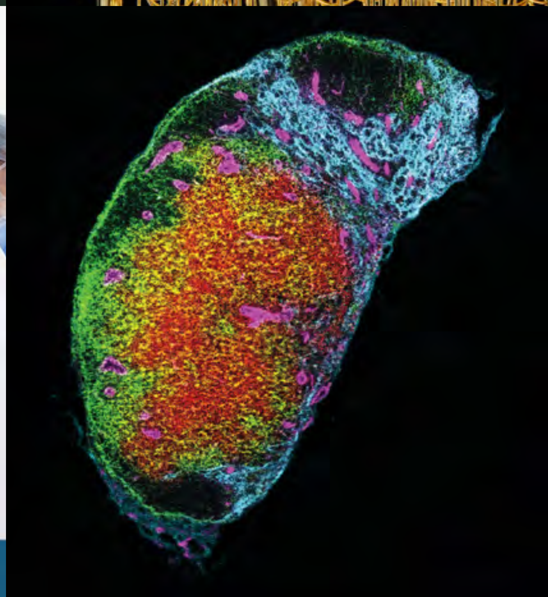
Core Research Facilities
Research Highlights







The University of Sydney's Camperdown campus sits on the lands of the Gadigal people with campuses, teaching and research facilities on the lands of the Gamaraygal, Dharug, Wangal, Darkinyung, Burramadagal, Dharawal, Gandangara, Gamilaraay, Barkindji, Bundjalung, Wiradjuri, Ngunawal, Gurend Gureng and Gagadju peoples. We recognise and pay respect to the Elders and communities of these lands, past present and emerging, who for thousands of years have shared and exchanged knowledges across innumerable generations, for the benefit of all.

Cover: People, processes, equipment and research from across the University of Sydney's Core Research Facilities. Clockwise from top left: Sydney Informatics Hub, Research and Prototype Foundry, Sydney Manufacturing Hub, Sydney Analytical, Sydney Microscopy and Microanalysis, Sydney Mass Spectrometry, Sydney Cytometry, Sydney Imaging.

Sydney Cytometry image courtesy Benita Tse, 'Lipids in Ultraviolet Radiation-Induced Immunomodulation', PhD thesis, 2020.

Core Research Facilities

Research Highlights

Contents

About us

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Find out about the University's Core Research Facilities. Discover what we do, who we partner with and the vision guiding our evolution and growth.

Mission and vision

World-class capabilities enabling world-class research

The University of Sydney operates eight world-class Core Research Facilities as a vital pillar of its commitment to supporting research excellence. These facilities are strategically located across 21 sites and offer access to over 500 cutting-edge instruments, supported by more than 100 highly skilled platform scientists and technicians.

The Core Research Facilities have charted a strong growth trajectory since inception as a University-wide program in 2014, and further growth is in the pipeline. New facility nodes are being planned for the Sydney Biomedical Accelerator, a $500 million strategic partnership between the University and Sydney Local Health District, set to open later this decade. Meanwhile, additional nodes, capabilities and partnerships are continually being developed via our global partners, national programs - notably the National Collaborative Research Infrastructure Strategy - and various New South Wales-based initiatives. These all work to position us at the forefront of research infrastructure.

Under the University's strategic plan, Sydney in 2032, our approach to research infrastructure is entering an ambitious new phase. A broader, more integrated concept – Sydney Research Infrastructure – prevails, incorporating our Core Research Facilities with our Research Service Units such as Laboratory Animal Services and our rapidly evolving digital research infrastructure. This document is focussed on our Core Research Facilities.

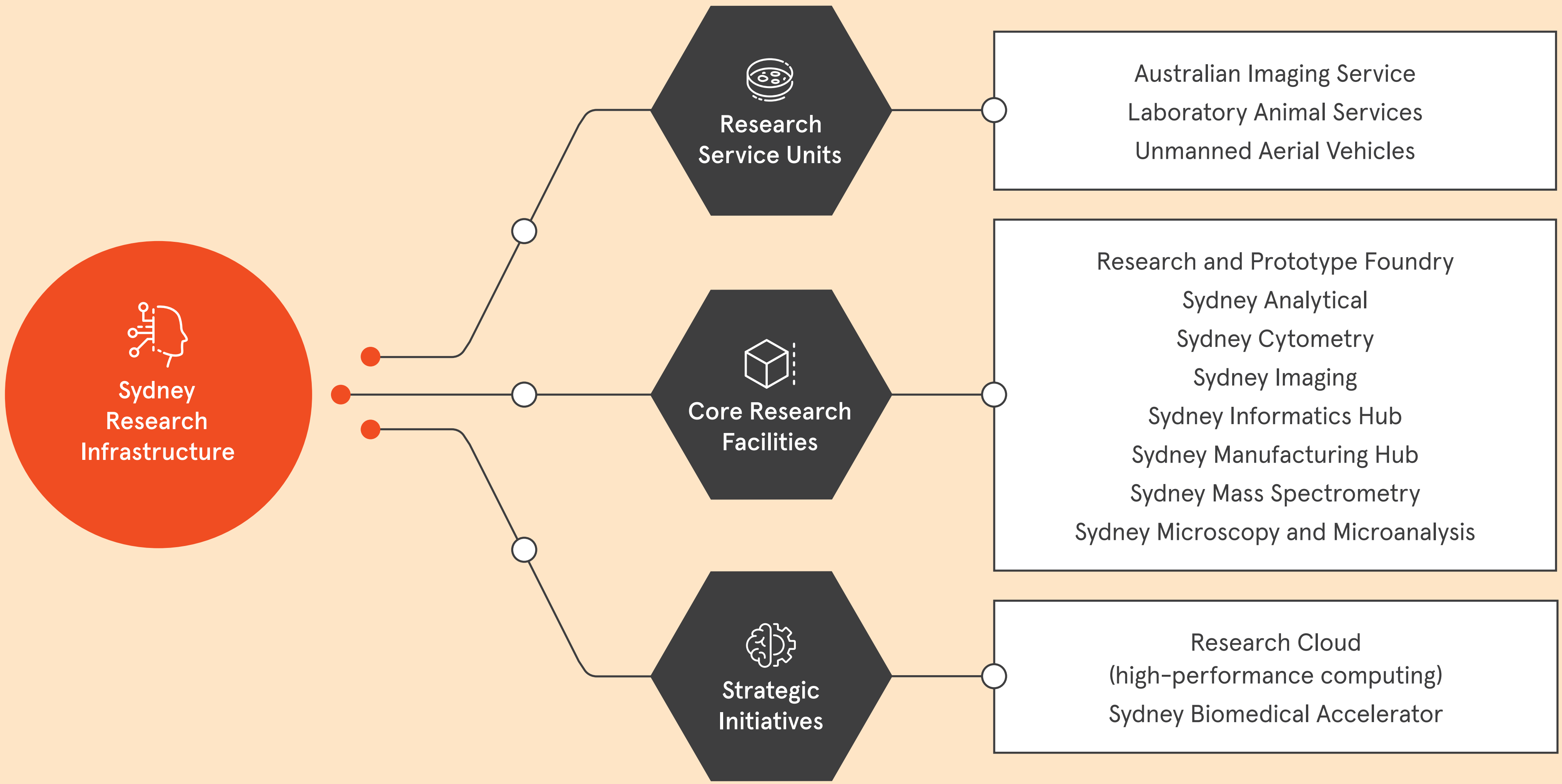
These evolving world class capabilities are nurturing a research ecosystem that empowers our researchers, addresses society's great challenges, and produces transformative, world-class research. I hope that you will see capabilities that are relevant to your research interests here, and that you will contact us to learn more about working with us.

Professor Simon Ringer
Pro-Vice-Chancellor (Research Infrastructure)

“Our Core Research Facilities continue to deliver world-class research capacity for multidisciplinary problem-solving and innovation for the University of Sydney and our collaborators. They also steward outstanding partnerships with national and global research organisations, and integrate with national research infrastructure and technology networks.

Addressing the great challenges of our time requires a steadfast commitment to the research infrastructure that underpins our ability to model, make and measure the details of the world around us.”

Professor Emma Johnston AO FAA FTSE FRSN
Deputy Vice-Chancellor (Research)

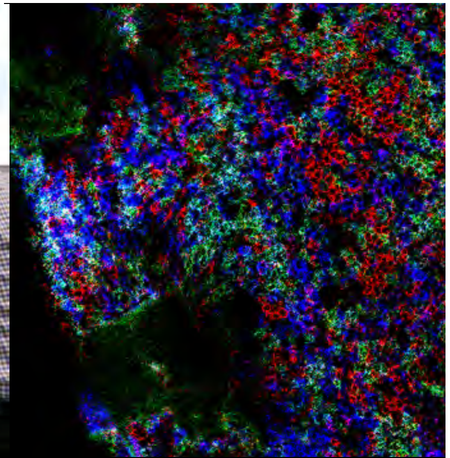

Sydney Research Infrastructure
Research Service Units
Core Research Facilities
Strategic Initiatives
Australian Imaging Service
Laboratory Animal Services
Unmanned Aerial Vehicles
Research and Prototype Foundry
Sydney Analytical
Sydney Cytometry
Sydney Imaging
Sydney Informatics Hub
Sydney Manufacturing Hub
Sydney Mass Spectrometry
Sydney Microscopy and Microanalysis
Research Cloud
(high-performance computing)
Sydney Biomedical Accelerator

Who we are and what we do

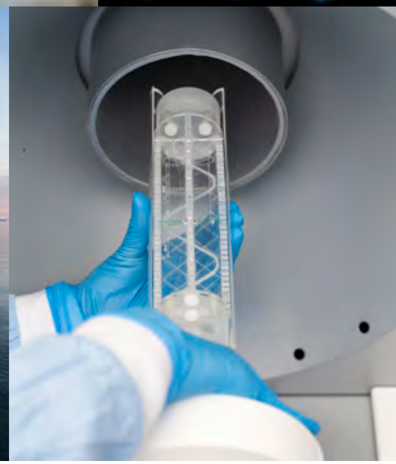
The University of Sydney's Core Research Facilities provide access to world-class equipment and expertise for researchers and industry as they tackle some of the greatest challenges of today.

Our Core Research Facilities are home to an ever-evolving suite of frontier capabilities, including first-in-country technologies, and are backed by frontier academic and technical know-how.

These facilities have been central to advancing knowledge across a diverse range of fields including medicine and health, advanced manufacturing, quantum computing, biomedical engineering, life and earth sciences, digital humanities and cultural heritage, and many more.






Core Research Facilities
Modelling, Making, Measuring

Together, the Core Research Facilities' specialisations cover three foundational areas of research and development *modelling*, *making* and *measuring*.

Modelling

Sydney Informatics Hub
Research data analysis and training

Making

Research and Prototype Foundry
Fabrication at micro and nano scale

Sydney Manufacturing Hub
Additive manufacturing and materials processing

Measuring

Sydney Analytical
Chemical, biological and materials analysis

Sydney Cytometry
Quantitative cell sorting and analysis

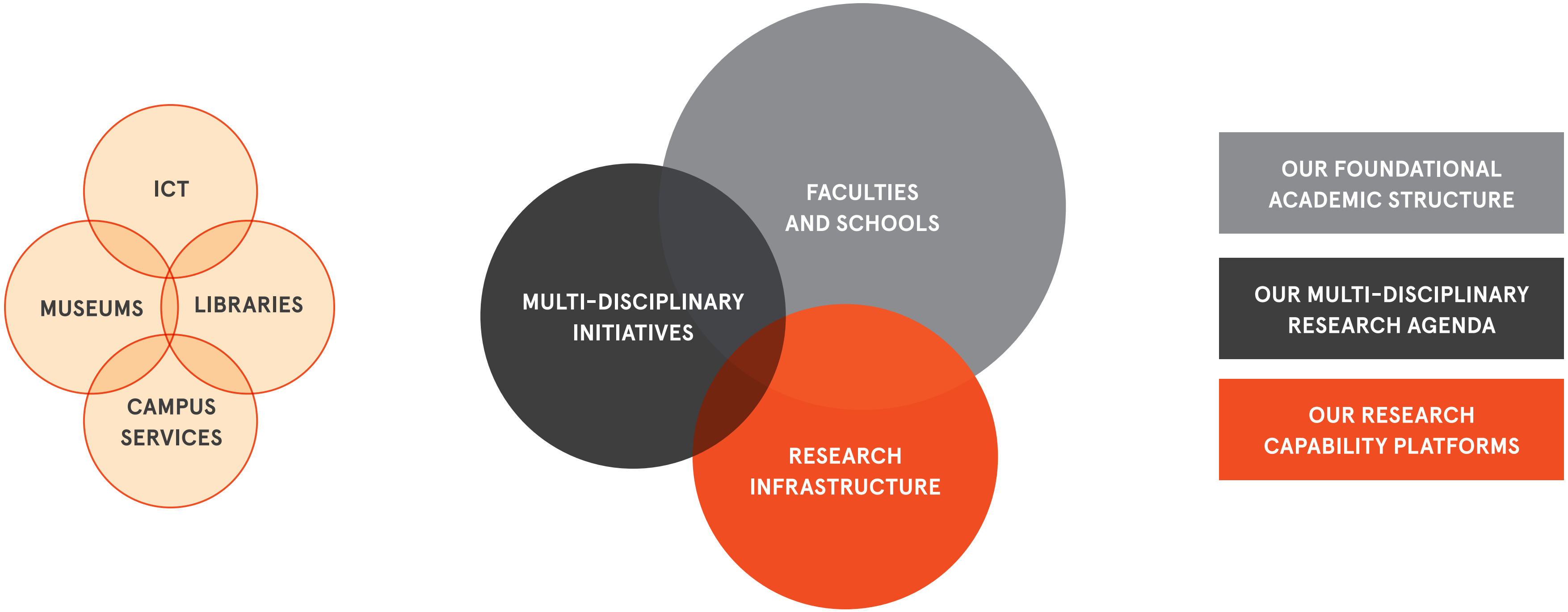
Sydney Imaging
Biomedical imaging

Sydney Mass Spectrometry
Proteomics, metabolomics and lipidomics analysis

Sydney Microscopy and Microanalysis
Micro, nano and atomic-scale exploration

University model for supporting research

The Core Research Facilities are a crucial part of the University's research support structure. They are independent from faculties, schools and research initiatives, and are openly accessible to researchers from across the University and external collaborators.



Our journey so far

Start

2014
Core Research Facilities program established, comprising an integration of **Sydney Microscopy and Microanalysis, Sydney Mass Spectrometry, Sydney Cytometry** and the Vibrational Spectroscopy Core Facility.

2016
The University launches its 2016-2020 Strategy with a focus on growing its Core Research Facility portfolio to support research excellence

April 2016
Launch of the **Research and Prototype Foundry**

October 2016
Launch of **Sydney Informatics Hub**

August 2017
Installation of the Hyperion Imaging mass cytometer, an Australian first – in **Sydney Cytometry**

October 2017
Installation of the Artis Pheno C-arm in **Sydney Imaging** – a first for robotic X-ray imaging facilities dedicated to research

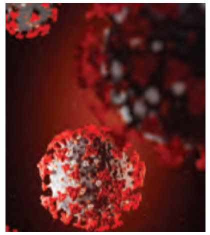
April 2018
Launch of **Sydney Imaging**

August 2018
Launch of **Sydney Analytical** – incorporating Vibrational Spectroscopy, X-ray, and Drug Discovery capabilities

June 2019
Sydney Mass Spectrometry launches a node at the Kolling Institute, Royal North Shore Hospital

January 2020
Sydney Analytical adds Magnetic Resonance capability

June 2020
University and GE-Additive sign a strategic research partnership seeing GE-Additive provide four state-of-the-art 3D metal printers for **Sydney Manufacturing Hub**



July 2020
Bioinformaticians from **Sydney Informatics Hub** co-author a paper in *Nature Medicine* sequencing the SARS-Cov-2 genome when it first appears in Australia

September 2020
The Australian Imaging Service commences, supported by **Sydney Imaging**

March 2021
Sydney Imaging, the National Imaging Facility and the Northern Sydney Local Health District agree to partner and fund the first open-access research Total Body PET system in Australia.

September 2021
Research and Prototype Foundry launches Advanced Fibre-Bragg Grating Facility

December 2021
Official launch of **Sydney Manufacturing Hub**

January 2022
New Engineering and Technology Precinct (J03) launched, including new sites for **Sydney Analytical** and **Sydney Microscopy and Microanalysis**

2022
Announcement of the University's 2032 strategy. The vision includes continued support of world-class research with world-class research infrastructure

June 2022
Semiconductor Sector Service Bureau (S3B) established through a NSW government grant, with **Research and Prototype Foundry's** capabilities playing a key role

August 2022
Announcement of Sydney Biomedical Accelerator, a $500 million partnership with University of Sydney, NSW Health and Sydney Local Health District set to house new Core Research Facility nodes

September 2022
University of Sydney and Northern Sydney Local Health District sign a Total Body PET collaboration agreement

December 2022
Appointment of inaugural Pro-Vice-Chancellor (Research Infrastructure)

February 2023
Announcement of Future Qubit Foundry, which **Research and Prototype Foundry** will support with new fabrication capabilities

Q1 2023
Laboratory Animal Services and Unmanned Aerial Vehicle Unit move into the Sydney Research Infrastructure portfolio. Announcement of myResearch Sydney strategic initiative

June 2023
Siemens Biograph Vision Quadra commissioned at Royal North Shore Hospital for the Australian National Total Body PET Facility

Q4 2023
Launch of the Australian National Total Body PET Facility, with research use to be managed by **Sydney Imaging**

Quick stats

Our current footprint

8
facilities

21
sites

520
instruments

120
onsite experts

To date we have supported

1.2 million
hours of equipment use

4,300
projects

4,700+
facility users

125
industry clients (227 individual industry users)

Our users come from

28%
Faculty of Science

27%
Faculty of Medicine and Health

16%
Faculty of Engineering

12%
Multi-disciplinary initiatives (MDIs), research centres and networks

11%
Publicly funded research organisations

7%
Industry

Our users represent

82%
of total University grants awarded

65%
of the University Research Block Grant income

Our partners

Our facilities are underpinned by partnerships with leading local and global research organisations, and are proudly integrated with the Australian government's national research infrastructure framework.

Common good, locally and globally

—

Our Core Research Facilities support the drive toward a better, more sustainable society. See how the research we enable links to local and global frameworks of advancement of knowledge for the common good.

Critical Technologies in the National Interest

Our Core Research Facilities support a broad cross-section of research that is spearheading advances in areas of national strategic importance, including the Australian government's list of seven Critical Technologies in the National Interest.

Legend: Core Research Facilities

- Research and Prototype Foundry
- Sydney Analytical
- Sydney Cytometry
- Sydney Imaging
- Sydney Informatics Hub
- Sydney Manufacturing Hub
- Sydney Mass Spectrometry
- Sydney Microscopy and Microanalysis

Advanced manufacturing and materials technologies

- Development of nano-patterned film for drag reduction in transport
- Development of new titanium alloys for 3D printing
- Additively manufactured wood-based composites for architectural applications
- Investigating properties of new materials for nanowires in computer chips
- Using plasma to create customisable bio-instructive surfaces

AI technologies

- AI for prediction of soil and crop productivity in space and time
- Application of neural networks package for proteomics data analysis
- Predictive Machine Learning for concussion recovery time
- Scalable genetic sequencing pipelines for high-thoughput bioinformatics on national compute infrastructure

Advanced information and communication technologies

- Analytical design and model optimisation to investigate risk factors for poor diet using wearable camera technology
- National platform for aggregating biomedical imaging data
- Optic fibre support structure additively manufactured on high-resolution resin and ceramic 3D printers
- Validation of wearable technology for mental health monitoring

Quantum technologies

- Additive manufacturing of a quantum magnetometer prototype interface
- Quantum computing training program
- Scalable assembly of qubit components for quantum computing
- Supporting major quantum activities: Microsoft collaboration, Future Qubit Foundry and Sydney Quantum Academy

Autonomous systems, robotics, positioning, timing and sensing

- Autonomous vehicle acceptability experiments
- Custom designed high-throughput proteomics sample preparation
- Development of a device for sensing hazardous gases
- Economic evaluation of robotic dairy system, contributing to world's first robotic milking decision-making tool
- Interface design for non-humanoid robots in urban contexts
- Robotic soil pH detection
- Wearable augmented reality for autonomous vehicle-pedestrian interaction

Biotechnologies

- Additive manufacturing of protective casing for a device to help stroke patients blink
- Advanced approaches to bioengineered diabetes therapy
- Bionic eye research, development and testing
- Developing chemical tools to improve cardiovascular therapeutics
- Development of biocompatible implantables for bone reconstruction
- Development of a microfluidic device to detect cardiovascular disease
- Development of nano-insulin formulations as a new delivery method
- Discovery work for breast cancer therapy
- Identification of genetic signatures and biomarkers in COVID-19 patients
- Investigation of fluid management for temporary Left Ventricular Assist Devices
- Lab-grown food
- Next-generation anti-inflammatory therapeutics
- SARS-CoV-2 vaccine development
- Wearable technology to monitor blood pressure using novel soft fibres

Clean energy generation and storage technologies

- Additive manufacturing of components for solar panel models to measure local pressures
- Additive manufacturing of electrochemical flow cells
- Additive manufacturing of gyroid mesh cartridges for direct capture of carbon dioxide
- Characterising composite materials for battery anodes
- Development of cheaper, non-toxic alternatives for upscaling use of thin-film solar cells
- Development of new materials to increase efficiency of solar cells
- Functional materials for building a better all-solid-state battery

United Nations Sustainable Development Goals

Our facilities enable research that addresses internationally recognised goals for creating a better world. Look for the UN Sustainable Development Goal symbols in our featured research highlights to see how the projects we enable align with these global priorities.

Enabling research excellence

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Our Core Research Facilities support hundreds of projects annually through three foundational areas of research and development *modelling, making* and *measuring.*

See how our frontier capabilities enable research excellence, tackling the greatest challenges and contributing to the common good.

Sydney Informatics Hub

Research data analysis and training

Sydney Informatics Hub enables excellence in computational and data-driven research by providing support, training and expertise in statistics, data science, AI, software engineering, simulation, visualisation, bioinformatics and research computing to University researchers and external collaborators.

Find out more

sydney.edu.au/sydney-informatics-hub

New gateways to agricultural data

Challenge

Australian agriculture is valued at $71 billion dollars and relies on data to drive optimisation. In 2021 with funding from the Australian Research Data Commons (ARDC), the Agricultural Research Federation (AgReFed) platform was launched to share agricultural data and benefit the sector. The project team was confronted with the task of managing and extracting insights from vast, diverse sets of spatiotemporal data such as climate, satellite and soil observations. Existing manual processes were time-consuming and difficult to reproduce, hampering potential for machine learning and other advanced analytical approaches. A rethink of the architecture was needed.

Research

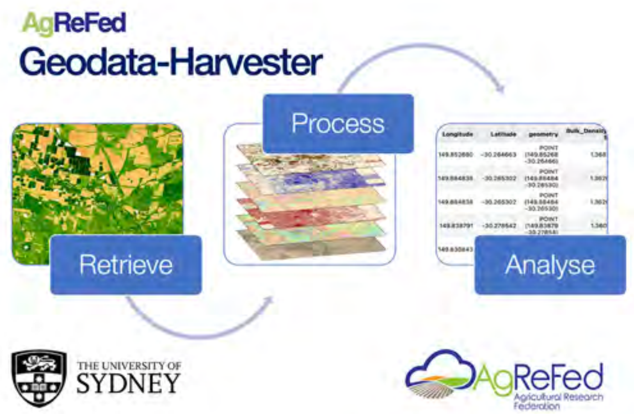
Led by Dr Sebastian Haan, Sydney Informatics Hub data scientists and high-performance computing experts developed two powerful reusable tools, Geodata-Harvester and the AgReFed Machine Learning Model, to improve accessibility. The Geodata-Harvester tool provides open-source software and machine learning to easily extract and align data for specific regions and time periods, while its counterpart uses AI to map environmental properties and their uncertainties from spatial and temporal data.

Results

The tools are now freely available online, enabling access to more intuitively aggregated geospatial, climate and soil data for use in research and decision-making. The software has been published as open-source packages, allowing other developers to build upon the models, and the outcomes have led to further funded research engagement with AgReFed.

Funding sources include:

- Australian Research Data Commons
- Grains Research and Development Corporation



Above: Concept map for the AgReFed Geodata-Harvester AI tool, developed by Sydney Informatics Hub.

Improving children's oral health

Challenge

Poor oral health can impact a child's development, and in adulthood is associated with chronic disease. Dr Christina Adler (School of Dentistry, Faculty of Medicine and Health) and her team designed a ground-breaking study to examine the links between oral microbiome development and oral health in childhood. To complete the study, the team needed a process for analysing longitudinal data from over 200 children to identify antimicrobial resistance in each child's microbiota and its influence on tooth decay.

Research

Sydney Informatics Hub drew on expertise across three teams to offer a data analysis solution. First, Dr Cali Willet from the bioinformatics team built a scalable bioinformatics workflow to create data on the relative abundance of different microbiota. Statistical consultants including Dr Kathrin Schemann then enabled the research group to develop their analysis plan and implement advanced statistical modelling, leading to better and more precise model parameter estimates. Finally, analysis by Dr Henry Lydecker and the data science team generated statistical insights into the diversity and temporal evolution of microbiota and antimicrobial resistance, as well as heritability, composition and impacts on tooth decay.

Left: Dr Christina Adler, School of Dentistry, Faculty of Medicine and Health.

Results

Sydney Informatics Hub's data analysis support enabled the completion of a successful $4.3m US National Institutes of Health grant application, high-impact publications including a 2023 paper in *Nature Communications*, and promising findings for the development of probiotics to improve children's oral health. The study has also advanced understanding of links between the oral microbiome and antimicrobial resistance, which is a major threat to human and animal health globally.

Funding sources include:

- Channel 7 Children's Research Foundation
- Financial Markets Foundation for Children
- Intersect
- National Health and Medical Research Council
- National Institute of Dental and Craniofacial Research
- Multiple Births Association
- Twin Research Australia

Training

Upskilling researchers

On top of its data analysis services, Sydney Informatics Hub nurtures research excellence through training in advanced analytical techniques. Its rich program shares the expertise of its highly skilled data specialists in short, modular workshops with downloadable course content.

In 2022, Sydney Informatics Hub ran 64 workshops, upskilling 1100 researchers across the University with over 95% satisfaction from the attendees.

sydney.edu.au/informatics-hub/training

64 workshops

1,100 researchers upskilled

95+% satisfaction

Accelerating wildlife conservation research

Challenge

Australia has more than 500 threatened animal species, and non-invasive wildlife monitoring with motion-activated cameras is crucial to their conservation. However, a single study can generate millions of images, and identifying the animal in each picture is time-consuming and costly. Dr Aaron Greenville (School of Life and Environmental Sciences, Faculty of Science) and NSW National Parks were keen to develop a fast, efficient way of identifying animals in images to maximise the benefit of camera data for wildlife conservation and management.

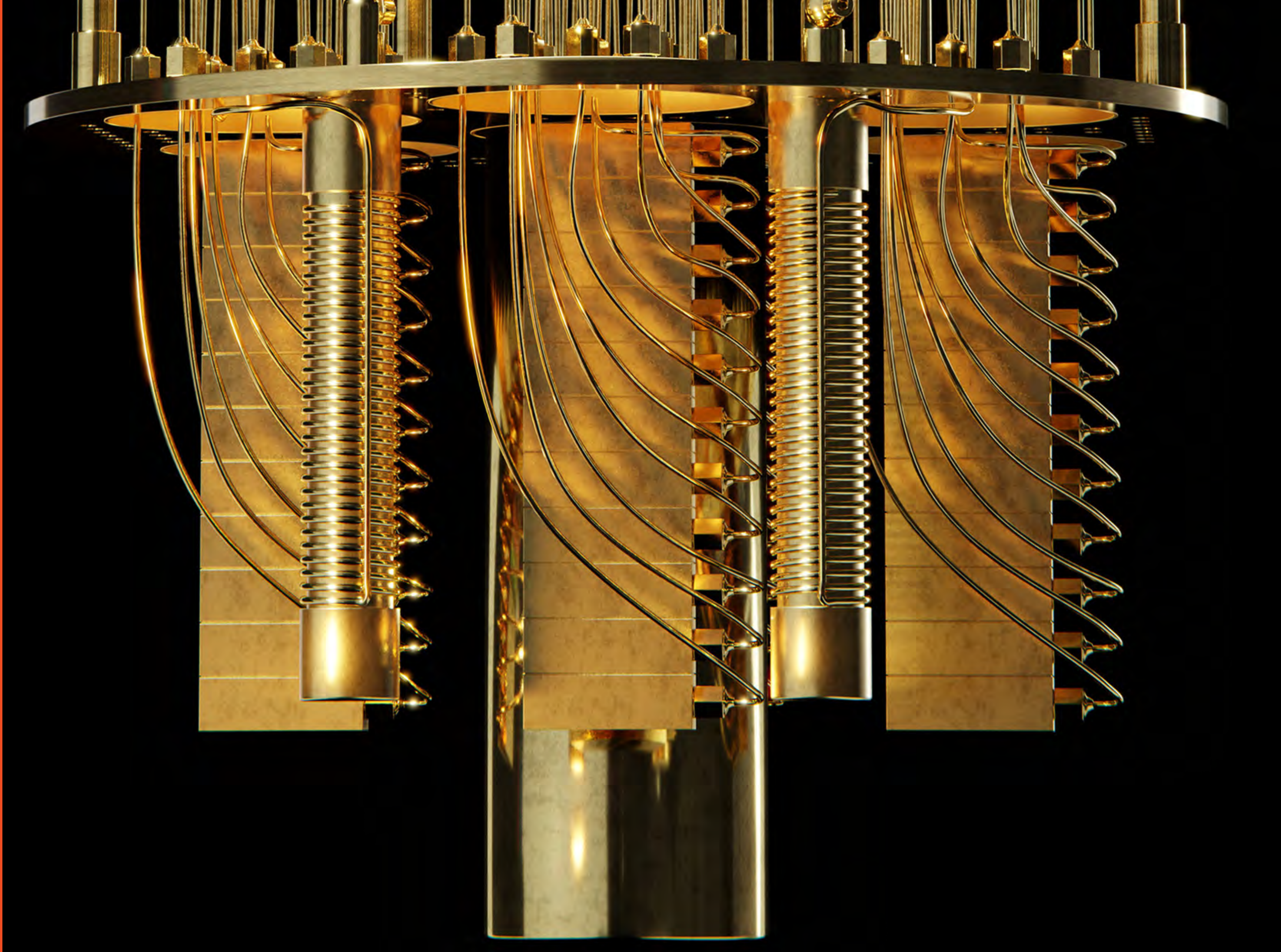
Research

Data scientists including Dr Henry Lydecker at Sydney Informatics Hub set out to create Marsupial.AI, a visual AI prediction tool to support automatic identification of 72 native and invasive species. They trained a state-of-the-art visual AI model using over two million labelled images of Australian wildlife from the dataset of WildCount, NSW National Parks' long-term animal monitoring program.

Results

Marsupial.AI can label tens of thousands of images per hour, compared with an estimated 450 images per hour for experts and around half that for citizen scientists. Precision is high at 94% for the most common half of species and 88% overall. With results 1,000 times faster and 5,000 times cheaper than manual approaches, it's a game-changer for Australian conservation research. Says Dr Greenville, "The time gained can be used for on-ground species conservation management" – a win for all.

Above: Marsupial.AI in action.



Research and Prototype Foundry

Fabrication at micro and nano scale

The Research and Prototype Foundry, based in Sydney Nanoscience Hub, offers instruments for the fabrication of devices and structures with features on the micro and nanoscale, with specialised processes allowing users to prototype new optical, electronic, microfluidic, and quantum science and technology devices.

Producing qubits in electronic devices

Challenge

Quantum computing has the potential to solve problems of enormous complexity and scale. The catch? The components are so heat-sensitive that they need to be kept at temperatures close to -273°C.

Through work conducted at the Research and Prototype Foundry, quantum tech start-up Archer Materials developed ground-breaking components with potential for quantum computing at room temperature. This was a major milestone, but there was a barrier to scalability: they relied on a 40-nanometre carbon particle which proved extremely sensitive to physical manipulation. For a scalable product, Archer needs quantum bits, or qubits, that maintain integrity during and after circuit assembly.

Research

The R&D team at Archer ran extensive process development within the Research and Prototype Foundry cleanroom, making use of the facility's focused ion beam and scanning electron microscopes to understand the material's properties and their interactions at nano scale.

The ability to manoeuvre qubits with nanometre precision is crucial to quantum circuit assembly. With the help of technicians and instrument scientists from the Research and Prototype Foundry, including Senior Process Engineer Steven Moody, the team discovered that they could use custom focus-ion-beam-milled nanosized metal tips to 'pick up' and move the individual carbon nanoparticles successfully.

Results

The outstanding positional accuracy and control achieved through process development at the Research and Prototype Foundry enabled Archer to build scalable chip prototypes. The new process also allowed them to quickly build and test quantum information processing devices incorporating different qubit components, which is vital in building a chip for a practical quantum computer.

This breakthrough sets the stage for potential commercialisation and further advancements in quantum computing using carbon-based materials. The work was announced to investors and shareholders through the ASX platform (which is done routinely), underscoring the importance of ready access to research facilities in supporting innovation and shaping the future of technology.

Archer Materials is the only ASX-listed semiconductor company that is advancing quantum computing in electronic devices. Archer has a base in the Sydney Knowledge Hub.

ANFF

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

Find out more

sydney.edu.au/research-and-prototype-foundry

Advancing solar cell efficiency

Challenge
Solar photovoltaic (conversion of sunlight into electricity) power capacity is predicted to surpass that of coal by 2027, becoming the largest energy source in the world and generating hundreds of billions of dollars globally as it becomes a vital pillar in the transition to a net-zero society. With standard silicon solar cells approaching their efficiency limit (29%), new approaches are needed to support the continued growth of this renewable power source.

Research
Silicon cells are good at converting lower-energy light to electricity but are not so good with higher-energy light. Tandem solar cells hold the most promise for overcoming the efficiency limit of silicon solar cells because they involve the stacking of a solar cell that is better at converting high-energy light to electricity onto a silicon cell. This allows the two cells to work in tandem, each converting light from different parts of the solar spectrum to electricity more efficiently.

Professor Anita Ho-Baillie (School of Physics, Faculty of Science; ARC Future Fellow) and her team explored an elegant approach to tandem silicon solar cells with metal halide perovskites using an ultra-thin indium tin oxide layer. The team experimented with the new tandem cell designs at the nanoscale to maximise efficiency gains.

The Research and Prototype Foundry provided access to the specialised facilities and technical support, led by Process Engineer Dr Yun Li, for part of the process sequence for the high-performance cell fabrication.

Results
As published in *Energy & Environmental Science*, Professor Ho-Baillie and her team broke new ground in terms of perovskite-silicon tandem solar cell efficiency with the new cell design using nanoscale indium tin oxide. Their champion cell achieved 27.2% power conversion efficiency, exceeding that of the best research silicon cell demonstrated to date, at 26.8%.

Funding sources include:

- Australian Centre for Advanced Photovoltaics
- Australian Renewable Energy Agency
- Australian Research Council
- University of Sydney

Above: The many layers of Professor Ho Baillie's silicon-perovskite tandem solar cells.

Towards early detection of cardiovascular disease

Challenge
Cardiovascular disease is the leading cause of death globally and can cost Australia around $12 billion in a single year. Early detection could deliver enormous benefits but clinical prediction can be complex and challenging. Associate Professor Arnold Lining Ju (School of Biomedical Engineering, Faculty of Engineering) is working on a device for detecting changes in the blood associated with cardiovascular disease in hope of improving health outcomes.

Research
Cardiovascular disease is characterised by blood clots, which are often preceded by subtle changes in the blood that are best observed at microscopic volume and scale. Dr Ju and his team wanted to develop a simple, effective tool to monitor for these changes by simulating clotting conditions. To do this, they designed a microscopic device with ultra-fine channels that act like blood vessels, and with protrusions in the channels to mimic clots.

With the assistance of Process Engineer Ethel Ilagan, the team fabricated the device at the Research and Prototype Foundry, where cutting-edge light exposure techniques allowed fast and accurate creation of the required structures with micron-level resolution.

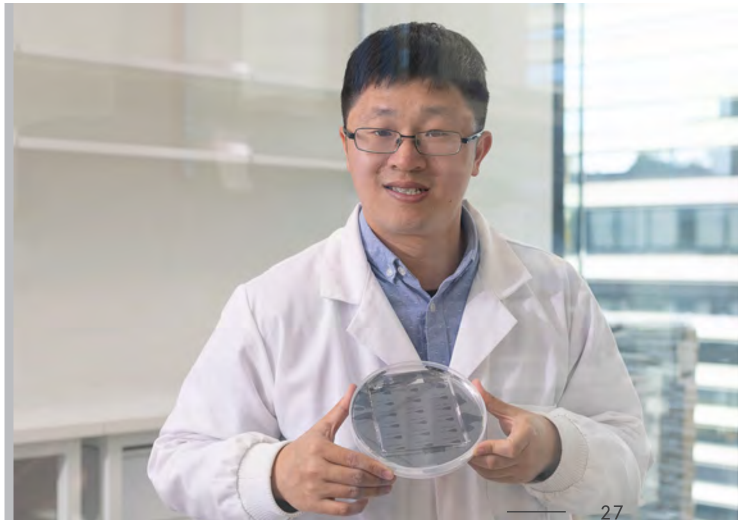
Results
The microfluidic device successfully enabled the study of clot formation in a small, convenient platform, and is extremely promising for both medical and research use. This achievement brought Dr Ju and team closer to their goal of creating a test for detecting cardiovascular disease within minutes, using a single drop of blood. Dr Ju was recently awarded a highly prestigious $8 million Snow Fellowship in recognition of the importance of this research, which has the potential to uncover new cellular mechanisms within the body. Dr Ju's work has received major media coverage and been published in journals including *Royal Society of Chemistry*.

Funding sources include:

- Australian Research Council
- National Health and Medical Research Council
- National Heart Foundation of Australia
- NSW Health
- Ramaciotti Foundation
- University of Sydney

Did you know

At the Research and Prototype Foundry, micro and nano-scale devices are made in a 'cleanroom'. A cleanroom is a laboratory where the environment is strictly controlled to eliminate contaminants such as humidity and dust. The Research and Prototype Foundry's cleanrooms appear yellow because they filter out blue light, which can cause certain materials to harden.



Right: Associate Professor Arnold Lining Ju with his groundbreaking microfluidic devices produced at Research and Prototype Foundry.

Making

Sydney Manufacturing Hub

Additive manufacturing and materials processing

Sydney Manufacturing Hub specialises in cutting-edge additive manufacturing AM and materials processing of metals, ceramics and polymers, and offers researchers and industry access to concept-to-production capabilities supported by design and technical expertise.

GE Additive

3RDAXIS

Find out more

sydney.edu.au/manufacturing-hub

Investigating copper-tin alloys for 3D-printing

Challenge

Copper and its alloys are used in applications where materials with high conductivity, corrosion resistance, strength and ductility are needed. Additive manufacturing (AM) increases opportunities for these materials to be used due to its design flexibility and structural complexity. More knowledge of the properties of copper-tin alloys is needed to harness these opportunities.

Research

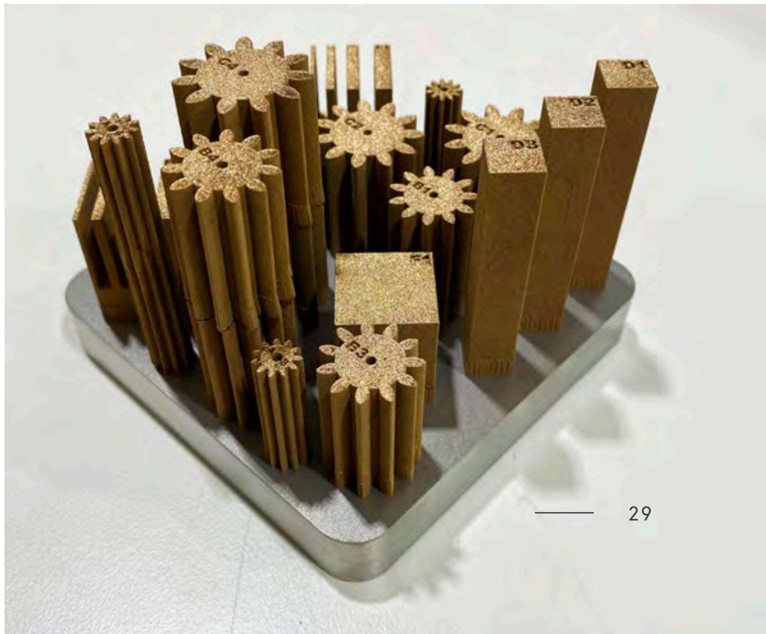
A University of Sydney team including ARC DECRA fellow Dr Keita Nomoto and PhD student Kangwei Chen (School of Aerospace, Mechanical and Mechatronic Engineering, Faculty of Engineering) are working to understand the microstructure-property relationships of AM tin-bronze (Cu-10Sn) alloys to achieve more superior mechanical and electrical properties than are possible with conventional manufacturing. A series of fully dense parts with varying specifications were successfully 3D-printed at Sydney Manufacturing Hub using the laser powder bed fusion process. Technical experts including Dr Mehdi Eizadjou from Sydney Manufacturing Hub worked with the team to develop a wide range of printing parameters with the aim of increasing strength while maintaining ductility.

Results

The team identified parameters which allowed them to successfully increase strength without compromising ductility in 3D-printed copper-tin alloy parts, exceeding the performance of conventionally cast samples using the same material. These pathfinding results are leading the team towards stronger, more conductive copper-based alloys via AM that will be a critical underpinning of the electrification revolution.

Funding sources include:

- Australian Research Council



Right: Fully dense parts 3D-printed from copper-tin alloy, using the laser powder bed fusion process. Compared with conventional casting, the additively manufactured samples achieved higher strength while maintaining ductility.

Developing musculoskeletal implants with ceramic 3D printing

Challenge

Additive manufacturing can produce intricate structures which are challenging to fabricate with conventional manufacturing techniques, and this level of precision offers enormous potential for biomedical implants. Ceramic 3D-printing is an important frontier in this area, and emerging research aims to determine optimal designs for implants.

Research

Postdoctoral researcher Dr Chi Wu from Professor Qing Li's research group (School of Aerospace, Mechanical and Mechatronic Engineering, Faculty of Engineering) harnessed novel computational modelling and machine learning techniques to develop implantable devices for the treatment of musculoskeletal disorders. The device designs incorporated complex surface geometries and intricate structures to enhance load-bearing capacity and promote tissue growth in a long-term fashion.

Working with Dr Katja Eder at Sydney Manufacturing Hub, Dr Wu used a ceramic 3D printer to produce the devices using a variety of biocompatible ceramics, such as hydroxyapatite, alumina, and zirconia. The ability to 3D-print in high resolution with these materials is important, as they possess the properties needed for successful implants: biocompatibility and excellent thermal and chemical stability.

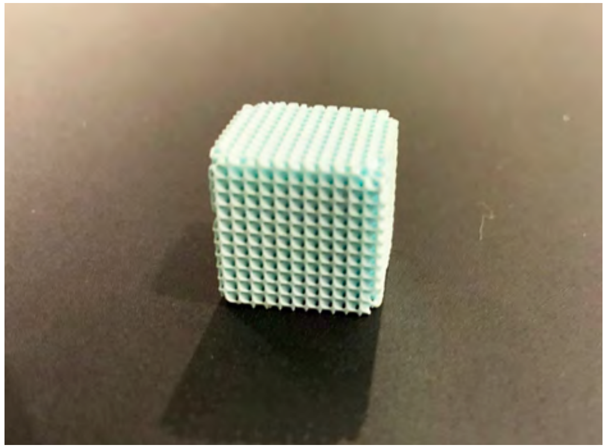
After sintering the parts at Sydney Manufacturing Hub, they were imaged using a microCT at Sydney Microscopy and Microanalysis to ensure the integrity of the structures, and then mechanically tested.

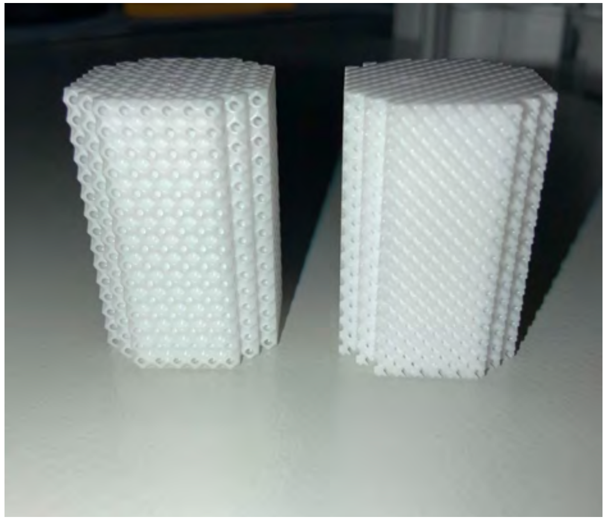
Results

Using this combination of innovative design approaches and advanced ceramic 3D-printing capabilities, Dr Wu developed load-bearing implants with rationally tailored properties capable of withstanding harsh conditions. Further, Dr Wu drew on this success to produce a comprehensive framework for creating next-generation implantable devices with enhanced long-term treatment outcomes. This work opens the way for practical new treatment options to improve quality of life for patients with musculoskeletal injury and disability. The findings were published in *Science Direct* and presented at the 12th International Conference on Structural Integrity and Failure, where it won Best Paper Award.

Funding sources include:

- Australian Research Council





Above: Dr Chi Wu's ceramic 3D-printed implantable samples,

Additive manufacturing propels rocket science

The USYD Rocketry Team is a group of students from the School of Aerospace, Mechanical and Mechatronic Engineering (Faculty of Engineering) who design and build rockets. In 2022, they entered the Spaceport America Cup intercollegiate rocketry competition, the world's largest event of its kind. Sydney Manufacturing Hub sponsored the team by 3D printing the bulkhead of a rocket nose cone from titanium for their entry. The team won the 2022 competition, placing first in three categories!

Advantages of additive manufacturing

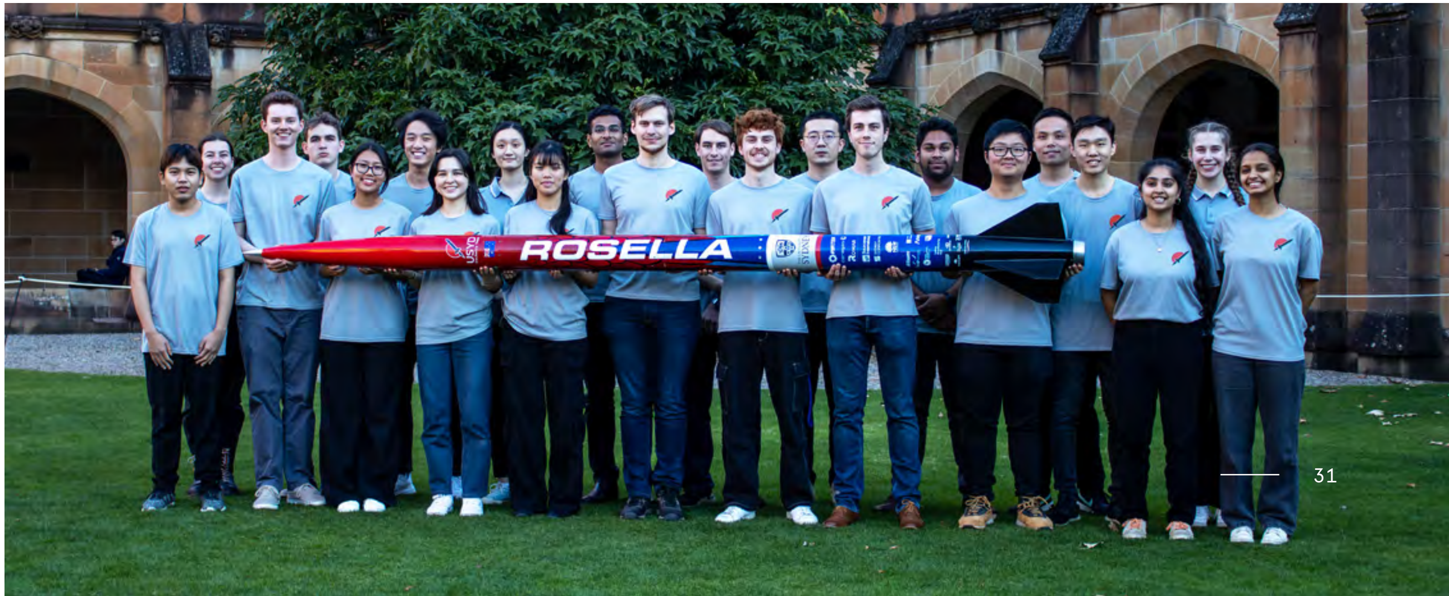
The USYD Rocketry Team are now designing their next-generation rocket. Chief Engineer Bruce McLean, Dr Wen Hao Kan and other engineers at Sydney Manufacturing Hub have been working closely with the team throughout the design process to help them better leverage the advantages of metal additive manufacturing such as rapid prototyping, fabrication of highly complex shapes, and substantial weight reductions. As a result, the latest design iterations use complex part geometries with intricate internal hollow structures to maximise aerodynamic performance and weight-savings for better fuel efficiency.

Design expertise increases efficiency

For example, Sydney Manufacturing Hub recently 3D printed the end cap for a rocket's boat tail out of F357 aluminium alloy. The end cap was originally designed for conventional manufacturing processes, so while the design could be easily produced with additive manufacturing, it did not fully leverage the advantages of the technology. Sydney Manufacturing Hub worked with the Rocketry Team on a new design for a largely hollow part supported by intricate lattice structures, achieving a weight reduction of 40%. Additionally, because unused raw material can be recycled and the volume of a part is directly correlated to the manufacturing time, the updated design was both cheaper and faster to additively manufacture compared with the initial design.

Gains like these put the USYD Rocketry Team in a prime position to excel again in their future projects.

Above: End cap samples: Sydney Manufacturing Hub worked with the USYD Rocketry team to produce an additively manufactured version with an intricate lattice structure (left), achieving a 40% weight reduction compared with the conventionally



Sydney Analytical

Chemical, biological and materials analysis

Sydney Analytical is the University's flagship facility for chemical, biological and materials analysis, supporting capability in vibrational spectroscopy, magnetic resonance, X-ray diffraction and scattering, protein production and characterisation, and drug discovery.

Anti-viral research for COVID-19

Challenge

According to the World Health Organisation, by mid-2023 almost 770 million COVID-19 cases had been reported globally, causing close to 7 million deaths and post-viral health problems in an estimated 10–20% of infected individuals. Anti-virals that work effectively against the SARS-CoV-2 virus are needed to reduce the ongoing impact of the COVID-19 pandemic.

Research

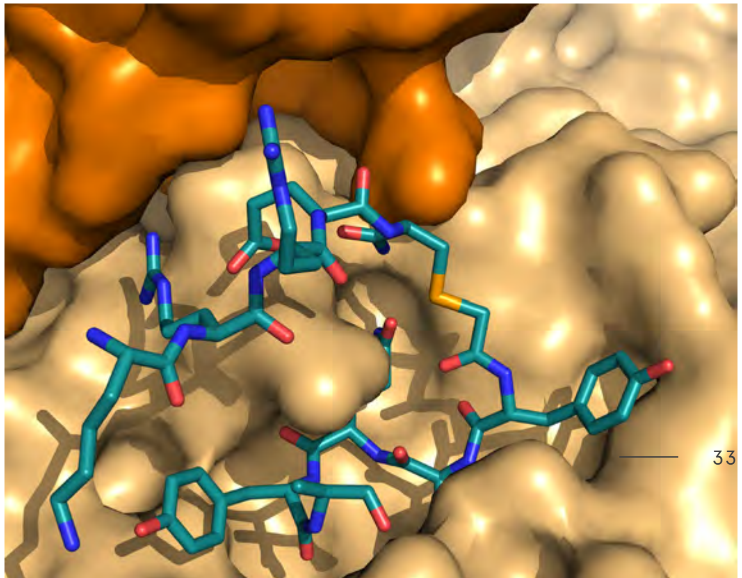
A team led by Professor Richard Payne (School of Chemistry, Faculty of Science), in collaboration with researchers from Sydney's School of Medical Sciences and School of Life and Environmental Sciences, Australian National University, Kirby Institute and University of California San Diego, sought to address this challenge by identifying novel inhibitors of the SARS-CoV-2 main protease, a key protein in the viral lifecycle that is required for productive infection. To achieve this, the researchers made use of Sydney Analytical's cyclic peptide display screening platform, the only university-based platform of its kind in the world, established by staff scientist Dr Toby Passioura.

Results

The team identified several molecules that potently inhibited the main protease target. They also showed that at least some of these molecules acted by binding to the active site of the viral protease. Perhaps most importantly, though, several of the identified molecules were able to prevent SARS-CoV-2 infection of cultured human cells, demonstrating their potential as starting points for the development of new drugs to treat COVID-19. The findings were published in the journal *Chemical Science*.

Funding sources include:

- Australian Research Council
- University of Sydney



Right: One of the novel molecules identified in the study.

Australian Government | ANSTO

Find out more

sydney.edu.au/sydney-analytical

Understanding cultural heritage through science

Challenge

In museum records, the materiality of collection items is often based on visual inspection alone. This can result in an incomplete understanding of an object's history and significance. When the University's Chau Chak Wing Museum was preparing for its *Chinese Toggles: Culture in Miniature* exhibition, it built on a long-running collaboration with Sydney Analytical to enhance knowledge about the exhibits and better communicate their cultural heritage value.

Research

Technical experts from Sydney Analytical, led by Vibrational Spectroscopy facility manager Dr Elizabeth Carter, undertook scientific analysis of early modern Chinese belt toggles to determine their materials of origin. This work used the capabilities of Sydney Analytical's Vibrational Spectroscopy arm and its state-of-the-art near-infrared and Raman spectroscopy equipment. The analysis largely covered objects on loan from Sydney's Powerhouse Museum, which includes one of the world's largest collections of Chinese ornamental belt toggles.

Results were combined with close visual and multivariate data analysis to shed light on ivory and jade toggles. Curators from both the Powerhouse and Chau Chak Wing Museum then worked with the Sydney Analytical scientists to confirm or revise records in preparation for the exhibition.

Results

The analysis led to the revision of a number of collection records. For example, an object once thought to be elephant ivory was confirmed to be mammoth ivory, offering evidence that mammoth ivory extracted from Siberian ice circulated as raw material in the 19th century. Further, an ivory toggle was found to have been dyed green to pass for more expensive jade. This multidisciplinary study demonstrates the value of harnessing science to further cultural heritage research.

The scientific characterisation of materials enabled nuanced identification, empowering the institutions to interpret and exhibit the works to the public with confidence. Sydney Analytical's characterisation work will be included in a forthcoming book from Power Publications on Chinese toggles, and featured in collaborative programming with Chau Chak Wing Museum for National Science Week.

Left: Scientists from Sydney Analytical characterised early modern belt toggles from the Powerhouse Museum collection for the Chau Chak Wing Museum's exhibition, *Chinese Toggles: Culture in Miniature*.

The future of data storage

Challenge

Humanity's ever-increasing output of digital information demands denser methods of information storage. The next frontier in this quest involves reducing data cell size to the molecular scale, and increasing the dimensionality of storage devices from 2D to 3D. Crystal lattices hold potential for data storage, but their high degree of ordering means their storage capacities are inherently low. Disorder is required to increase potential for data storage.

Research

Professor Cameron Kepert (School of Chemistry, Faculty of Science) is an expert in the design of metal-organic frameworks, which are ordered arrays of metal-containing clusters interconnected by organic molecular linkers. Professor Andrew Goodwin (University of Oxford) is an expert in the theory and characterisation of disordered materials. Ongoing collaboration between their research groups saw the development of a new metal-organic framework material incorporating disorder.

The material was first synthesised by Dr Lisa Cameron, Professor Kepert's former student, and Professor Goodwin's student Emily Meekel travelled to Sydney to study it. With the assistance of Sydney Analytical staff including diffraction specialist Dr Sam Duyker, she used the facility's single-crystal and powder X-ray diffraction capabilities to investigate the material's structure.

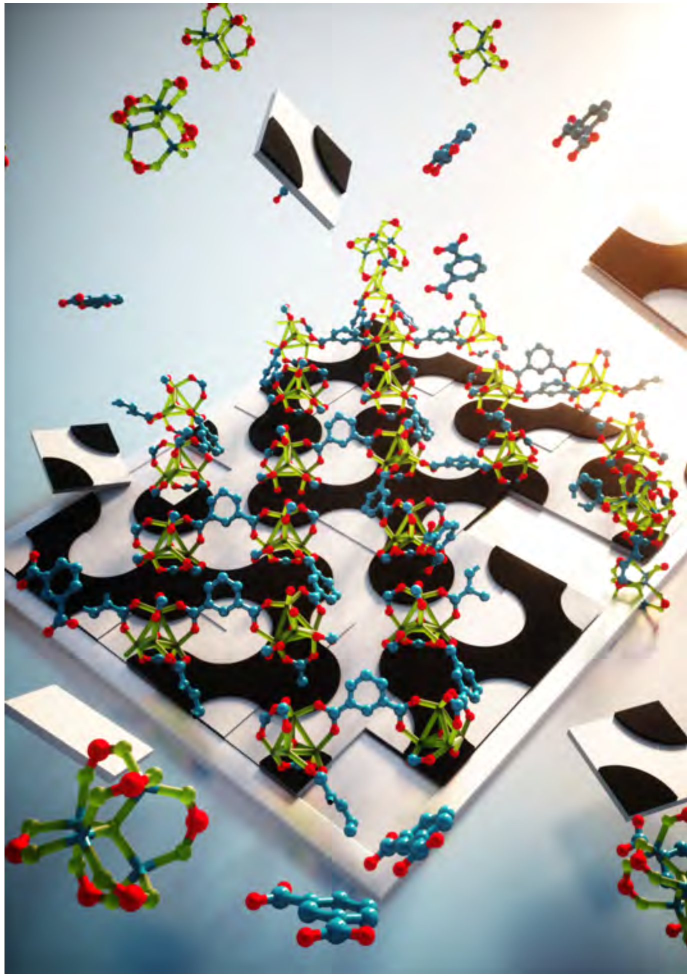
International collaborators also contributed to the work. The material was named TRUMOF-1 because the 3D tiling of its sub-units is analogous to a 2D tiling set discovered by French monk Sébastien Truchet in 1704 which underpins the encoding principles of barcodes and QR codes.

Results

Detailed analysis revealed that TRUMOF-1 contains clusters that are uniformly coordinated by six linkers, but asymmetric linkers used in its construction connect the clusters in a disordered fashion that never repeats, generating a labyrinthine network bearing "complex order". The porous nature of the material may also give rise to other emergent properties due to its periodic/aperiodic structure. The discovery was recently published in *Science* and offers a glimpse at what 3D-encoded data on the molecular scale might look like.

Funding sources include:

- Australian Research Council
- European Research Council
- The Royal Society



Right: A visualisation of the parallels between the structure of TRUMOF-1, revealed using capabilities at Sydney Analytical, and a Truchet tile set.


532R

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sydney.edu.au/cytometry

Developing better vaccines to protect our community

Challenge

Vaccination against SARS-CoV2 using mRNA vaccines saved tens of millions of lives globally. However, the length of protection of mRNA vaccines is limited and the need for storage at low temperature remains an issue in remote areas. Despite the multiple vaccines developed against SARS-CoV-2 there is still a need for safe, transportable, prophylactic and therapeutic vaccines.

Research

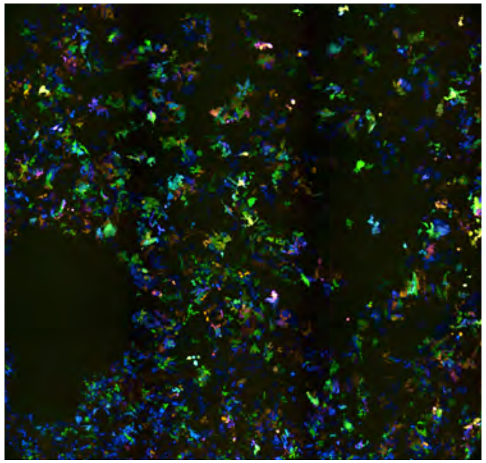
Professor Jamie Triccas (School of Medical Sciences, Faculty of Medicine and Health), along with collaborators from the University of Sydney and Centenary Institute, undertook the challenge of developing a novel-type vaccine. They combined the protein spike (expressed by SARS-CoV-2) with a specific adjuvant (the function of the adjuvant is to boost the immune response) to create a subunit vaccine, then tested its efficacy when directly delivered in the lung mucosal area or in the muscle in a preclinical model. This work was enabled by Sydney Cytometry's cutting-edge flow cytometry analyser and high-content imaging cytometer, and was funded by major funding agencies including NHMRC and NIH.

Results

The administration of the new vaccine induced an effective immune response against SARS-CoV-2. The team also found that intratracheal administration (to reach the lung mucosal area) was the most effective as it elicited a stronger immune response and had a longer-lasting effect. This work was published in *Mucosal Immunology* and the successful team now lead an international consortium that has received US$19.3 million to develop a variant-proof SARS-CoV-2 vaccine.

Funding sources include:

- Medical Research Future Fund
- National Health and Medical Research Council
- National Institutes of Health
- Sydney Institute for Infectious Diseases
- University of Sydney Drug Discovery Initiative



Above: ACE-2 expressing HEK293T cells transduced with SARS-CoV-2 pseudotyped lentiviruses fluoresce blue, green or orange. Captured via the Opera Phenix® Plus High-Content Screening System at Sydney Cytometry. Image courtesy Caroline Ashley.

Discovering pathways for tuberculosis treatment

Challenge

Tuberculosis is the source of a significant public health burden worldwide, with 1.6 million dying from the disease in 2021 alone. This is in part because the bacteria *Mycobacterium tuberculosis* which causes tuberculosis has adapted to escape the human immune response, posing a challenge to treatment and recovery. Effective treatments are needed to reduce the toll of this deadly disease.

Research

For the past 25 years, Professor Carl Feng (Central Clinical School, School of Medical Sciences, Faculty of Medicine and Health) and his team have strived to support the development of effective tuberculosis treatments by focussing their research on the impact of *Mycobacterium tuberculosis* on the immune response.

The immune response can occur in multiple sites and the activation of specific immune cells happens in the lymph node, a highly organised structure in which T cell and B cells will proliferate and then migrate back into tissues to kill infected cells and pathogens respectively. Some pathogens can survive within immune cells and alter the structure of the lymph nodes, compromising the immune response.

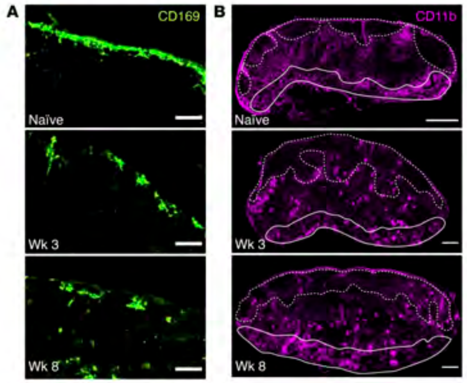
In a recent study, the team used Sydney Cytometry flow cytometry analysers to characterise the impact of *Mycobacterium tuberculosis* on the mediastinal lymph node, draining the lungs.

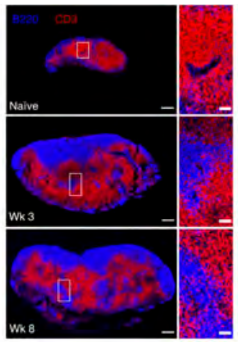
Results

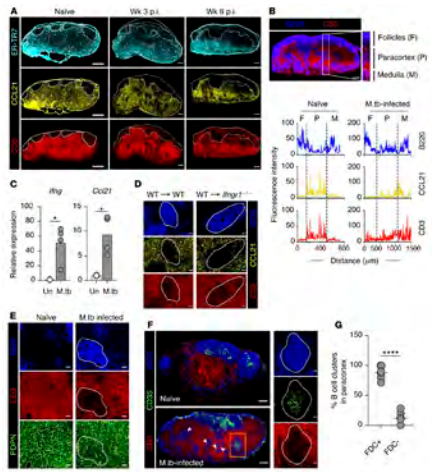
The team discovered that *Mycobacterium tuberculosis* uses a specific cell subset as a Trojan horse to enter the mediastinal lymph node. Once there, they found that *Mycobacterium tuberculosis* altered B cells and identified this cell subset as a novel therapeutic target in tuberculosis infection. The research was published in *The Journal of Clinical Investigation*, and Professor Feng along with Chinese and US collaborators have received US $2.5 million in National Institutes of Health funding to pursue their work on *Mycobacterium tuberculosis*. This new project will also be enabled by Sydney Cytometry's flow cytometry analyser and imaging mass cytometry.

Funding sources include:

- Centre of Research Excellence in Tuberculosis Control
- National Health and Medical Research Council
- Natural Science Foundation of China







Harnessing sunlight to fight disease

Challenge
Multiple sclerosis is an acquired disease which affects the central nervous system. Almost 3 million people live with the disease worldwide, with no cure yet available. Professor Scott Byrne (School of Medical Sciences at The Westmead Institute for Medical Research, Faculty of Medicine and Health) and his team are exploring the use of UV light to treat multiple sclerosis, as part of the Charles Perkins Centre's "Living Healthier Lives Under the Australian Sun" collaborative network.

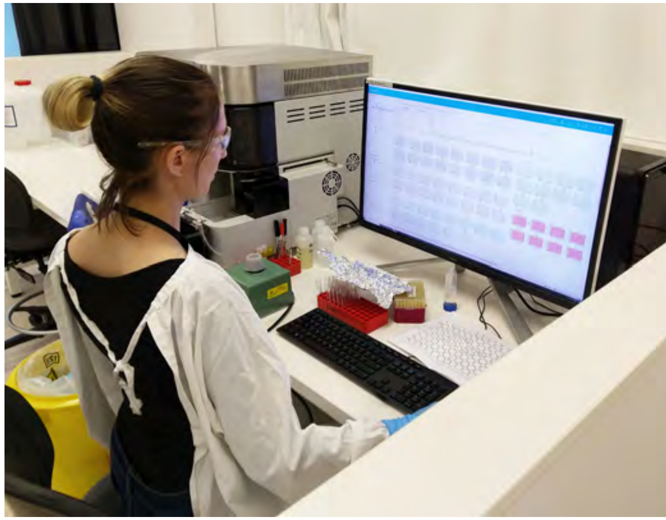
Research
UV light is notorious for causing skin damage, leading to high incidences of melanoma in Australia and elsewhere. However, it can also benefit our health by supporting the generation of Vitamin D and modulating the immune response. Professor Byrne and his collaborators designed a study to improve understanding of how UV light affects the immune response, with the aim of identifying how best to harness UV light for health benefits.

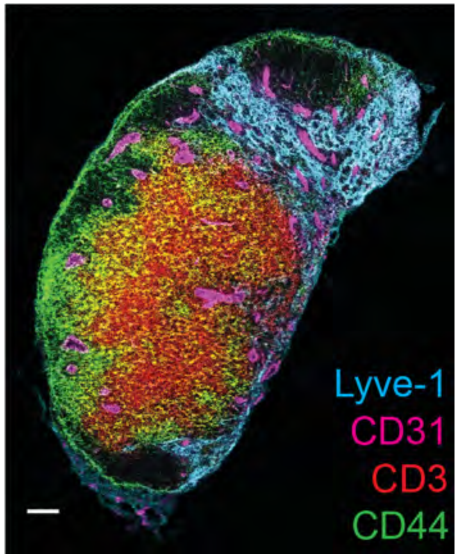
Using a preclinical model, the team characterised the impact of UV light on the skin draining lymph nodes as well as on immune cell function. The project used Sydney Cytometry's flow cytometry analyser to study large vesicles and immune function, and mass imaging cytometry to visualise immune cells in lymph nodes. It also drew on capabilities at Sydney Mass Spectrometry to visualise lipids in the lymph node.

Results
The team found that UV light upregulated 6 unique lipids in the skin draining lymph node, and that these lipids could inhibit immune cell function. Interestingly, the skin produced large vesicles in response to UV light and these vesicles carried the lipids to the draining lymph nodes. This work unravelled novel effects of UV on the immune system and identified new immunomodulatory candidates. The results were published in *Frontiers in Immunology*, taking the researchers one step closer to their treatment development goal.

Funding sources include:

– Multiple Sclerosis Research Australia





Bottom right: Mass cytometry imaging of immune cells in mouse skin-draining lymph nodes post-UV exposure. Image courtesy Benita Tse (*Lipids in Ultraviolet Radiation-Induced Immunomodulation*, PhD thesis, 2020)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3D-printed implants for bone reconstructive surgery

Challenge

People who require surgery for treatment of oral cancer often are left with large bone deficits in the jaw, which are reconstructed using bone from other areas of the person's body. While autologous bone is effective in restoring jaw function, there are negative aspects for the patient which could be improved by using 3D-reconstructed biocompatible implants.

Research

Professor Jonathan Clark AM (Central Clinical School, Faculty of Medicine and Health; Chris O'Brien LifeHouse) and his research group, Integrated Prosthetics and Reconstruction, are designing and manufacturing 3D implant/scaffolds for reconstructive surgery. The implants use bone tissue engineering techniques to promote bone ossification with the implant, with the aim of improving patient outcomes.

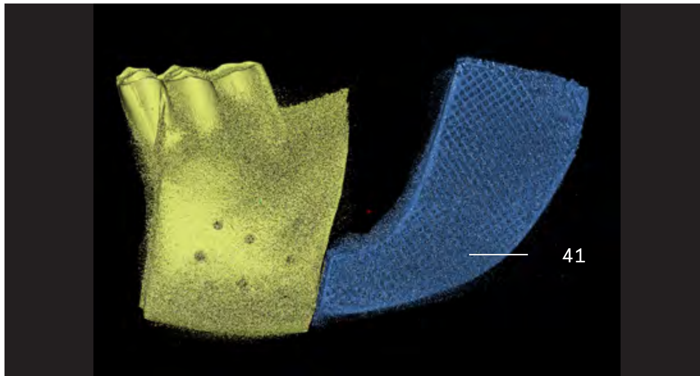
Undertaken using a sheep model, this multi-faceted project centres on the use of a porous 3D-printed hybrid polymer-ceramic scaffold. This scaffold is integrated with different biomaterials, left in-situ over a clinically relevant period and then imaged in vivo at different time points using the Siemens Artis Pheno robotic C-arm in Sydney Imaging's Hybrid Theatre to track implant and bone integration rates. At the completion of the in vivo part, the implants are removed and studied using microCT at Sydney Imaging's Preclinical Imaging facility to evaluate bone ingrowth and the material's suitability as an implant. The work is being aided by the invaluable technical expertise of Lisa Partel, Senior Technical Officer and Veterinary Technician Specialist, and Pranish Kolakshyapati, Senior Technical Officer in the Hybrid Theatre facility.

Results

The project has identified the superiority of 3D-printed plasma-treated polymer scaffolds for bone reconstruction. The findings were published in *Plasma Processes and Polymers*, and further publications are in the pipeline. The researchers can now build on this discovery to identify the most suitable bioactive materials to combine with the 3D hybrid scaffold, bringing this emerging biotechnology one step closer to improving the lives of oral cancer patients.

Funding sources include:

- Ato-Hardy Family Foundation
- Cancer Institute NSW
- Lang Walker Family Foundation
- Sydney Local Health District



Right: The team utilised micro-CT for in-depth analysis of tissue integration between the native healthy tissue (bone integration

Mending broken hearts

Challenge

Heart disease was the leading cause of death for men and the second-leading cause for women in Australia in 2022, with one Australian experiencing a heart attack every ten minutes. After a heart attack, the body replaces damaged heart muscle with stiffer scar tissue. This leads to a mechanical mismatch between the scar and healthy tissue, resulting in abnormal levels of stress and impacting heart function. Solutions for healing heart scarring promise to improve heart function and quality of life in heart attack survivors.

Research

Associate Professor Robert Hume and Dr James Chong (Westmead Institute for Medical Research and Sydney Medical School, Faculty of Medicine and Health) ran a preclinical trial of a novel treatment to reduce heart scarring using the protein tropoelastin. Tropoelastin haspreviously shown efficacy in wound healing applications but has not been significantly investigated in cardiac repair. The researchers sought to test whether tropoelastin injected into a damaged heart could boost healing in rats.

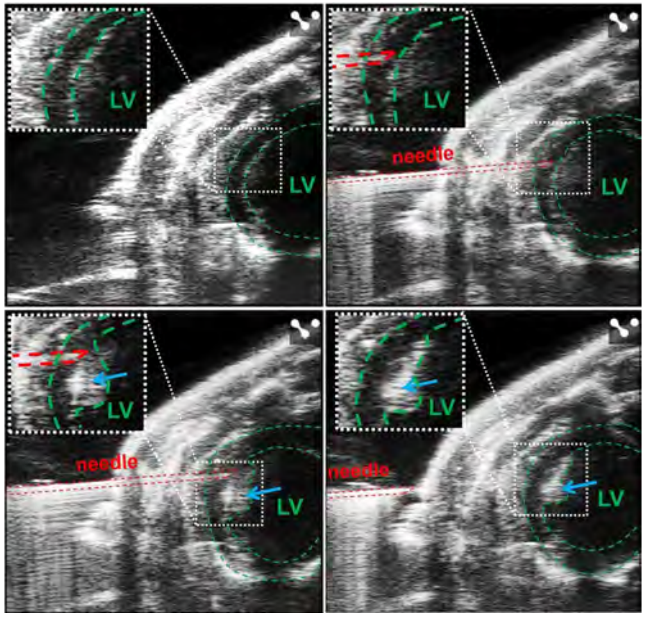
Working in Sydney Imaging's world-class preclinical imaging facility, the researchers applied the VisualSonics ultra-high-frequency ultrasound system in two ways. First, they administered treatment to animal hearts using a novel ultrasound-guided intramyocardial injection protocol, which is less invasive than conventional techniques. Second, they assessed post-treatment heart recovery using echocardiogram. The group that received injections survived the entire study, with echocardiography assessments showing that the tropoelastin had significantly improved heart function.

Results

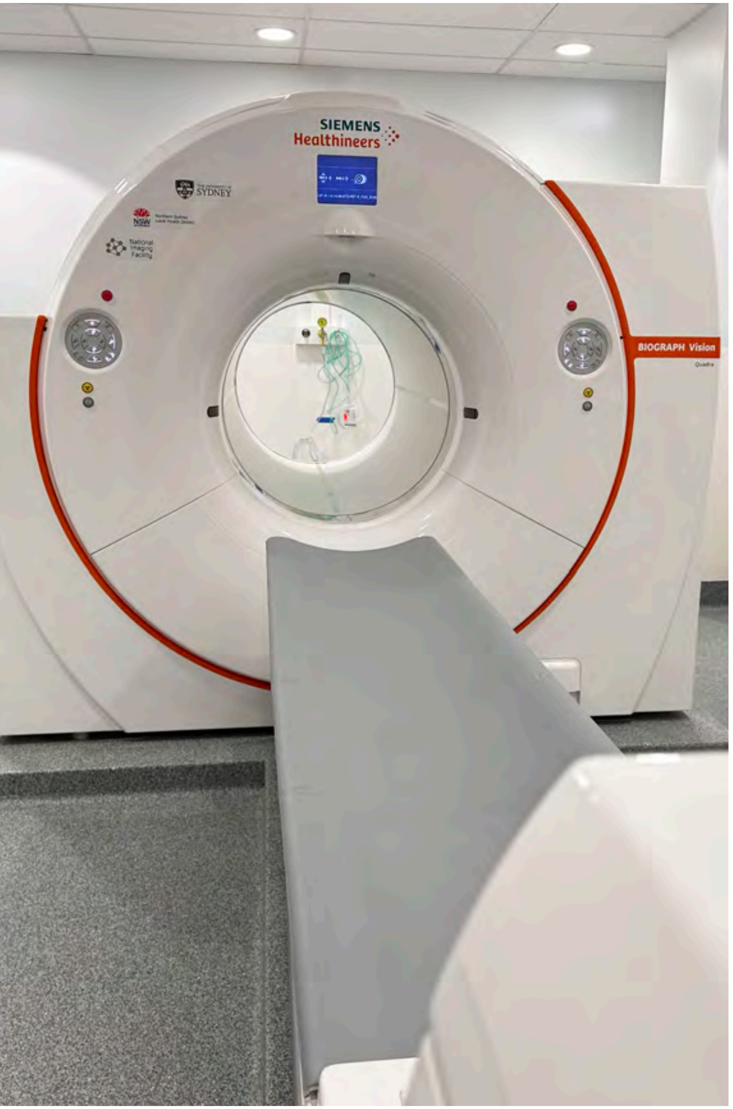
For the first time, the researchers demonstrated that purified human tropoelastin can significantly repair infarcted hearts in rodents by reducing scar expansion and increasing scar elastogenesis. The findings received major media coverage and provide evidence for potential clinical translation of tropoelastin to treat and improve the lives of millions of heart failure patients, literally mending broken hearts. This work was published in *Circulation Research*.

Funding sources include:

- National Health and Medical Research Council
- National Heart Foundation of Australia
- NSW Health



Right: Short axis echocardiograms showing intramyocardial delivery of tropoelastin in the myocardium of the Left Ventricle (LV). Ultrasound imaging permits a less invasive intramyocardial therapeutic delivery of tropoelastin. Source: Hume et al., Circulation Research. 2023; 132: 72-8642



Above: The Australian National Total Body PET Facility is located at Royal North Shore Hospital and opened in August 2023.

Australian National Total Body PET Facility Accelerating Biomedical Research

Strategic partnership

Sydney Imaging has established a new flagship platform, the Australian National Total Body PET Facility, in partnership with Northern Sydney Local Health District (NSLHD) and the National Imaging Facility (NIF), under the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS).

Australian-first research capability

The Australian National Total Body PET Facility is pioneering a hybrid model of open-access research-oriented capability alongside rigorous clinical applications service at the Royal North Shore Hospital (RSNH). This $15 million facility aims to accelerate biomedical research by providing unique insights into the complex molecular mechanisms of human physiology.

Advantages and applications

Total Body PET (Positron Emission Tomography) technology represents a remarkable advancement in molecular imaging, unlocking novel experimental paradigms and creating new research opportunities. The extended axial field of view enables acquisition of comprehensive whole-body dynamics and pharmacokinetics. This facilitates systemic disease pathway investigations, identification of novel therapeutic targets, and exploration of multi-organ signalling, including vital connections such as the brain-gut axis. The exceptional sensitivity of the facility's scanner, a Siemens Biograph Vision Quadra, produces diagnostically superior images in substantially less time and with reduced radiation exposure than conventional PET scanners, enabling research on vulnerable populations such as children and the elderly. In addition, the improved statistical power of imaging studies may accelerate clinical trials, helping researchers to reach surrogate endpoints earlier.

Funding sources include:

- National Imaging Facility, under the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS)
- Northern Sydney Local Health District
- University of Sydney

sydney.edu.au/research/total-body-pet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Evaluating deep learning for protein analysis

Challenge

Proteins are the core building blocks of life, performing a diverse array of essential functions through an almost infinite variety of shapes and structures. Some proteins work in isolation, and others work in conjunction with other proteins. When protein-protein interactions go astray, it can lead to devastating effects such as Creutzfeldt-Jakob disease (CJD), a neurodegenerative affliction resulting in dementia and death. Therefore, mapping protein structures and protein-protein interactions is of critical importance in the study of many biological processes in health and disease.

In 2021, a neural-network-based deep-learning algorithm called AlphaFold was released, transforming protein structure prediction by allowing researchers to predict the structure of almost any protein from its sequence alone. However, learning material for the model is scarce, as only 6% of human protein-protein interactions have experimentally determined structures. This means that the accuracy of its predictions for protein complexes (and those of its successor, AlphaFold 2) is unclear.

Research

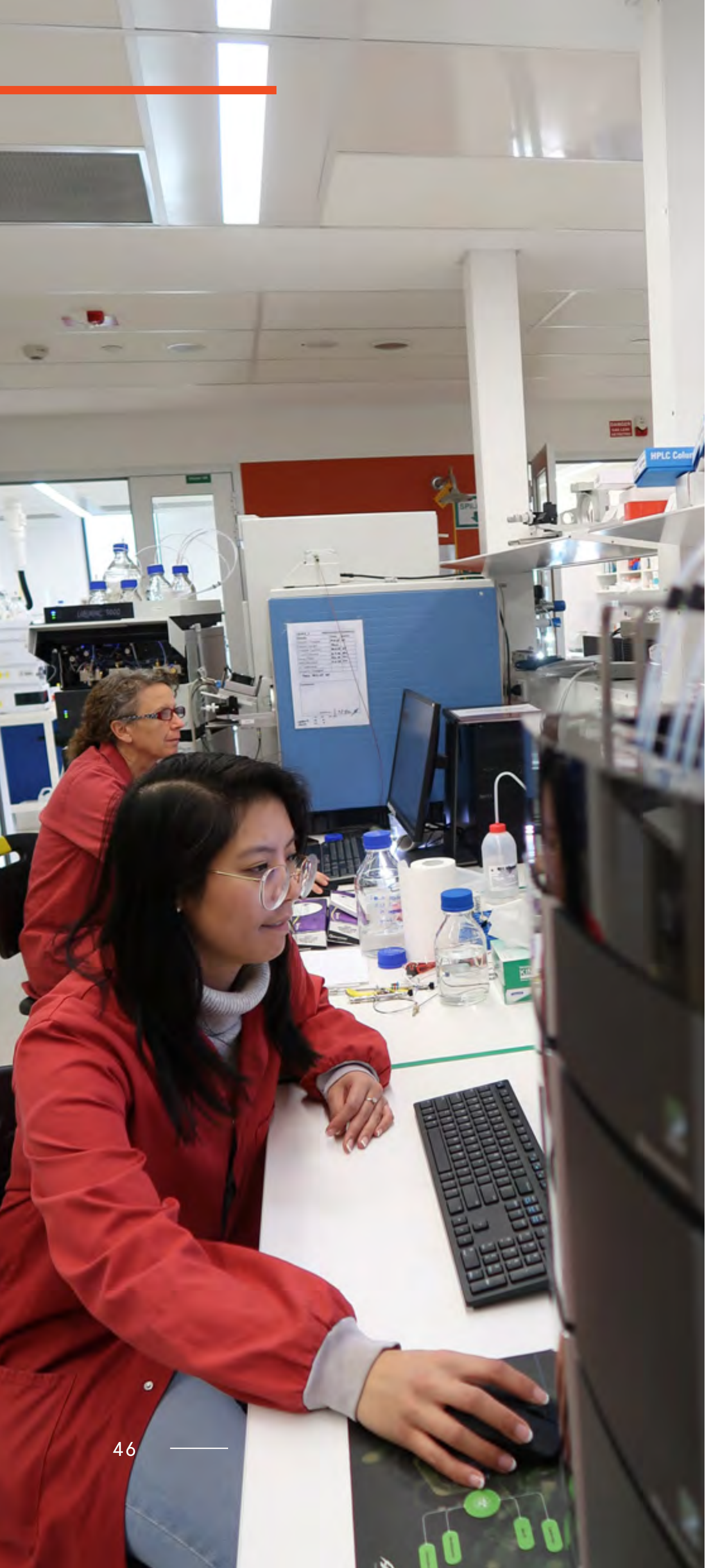
To address this challenge, Dr Jason Low (School of Life and Environmental Sciences, Faculty of Science) and his team began a large-scale cross-linking mass spectrometry project, with the aim of providing a deep-coverage characterisation of cultured human cell lines. This work was made possible by the latest generation of mass spectrometers at Sydney Mass Spectrometry, and the proteomics and mass spectrometry expertise of Angela Connolly and the proteomics team.

Results

Published in *Proceedings of the National Academy of Sciences*, the project yielded in the largest-ever cross-linking mass spectrometry dataset, which has been a powerful asset in evaluating, validating and supporting structures modelled using machine-based learning programs such as AlphaFold. The dataset represents a significant leap for the field of functional proteomics and interactomics, as it will enable the identification of protein-protein interactions that are upregulated or downregulated in a disease, potentially leading to the design of more targeted approaches to cure or treat illness.

Funding sources include:

- Australian Research Council
- National Computational Infrastructure
- National Health and Medical Research Council of Australia
- NSW State Government
- UNSW Sydney



Combating chronic disease with nutrition

Challenge

Diabetes, obesity, and cardiovascular disease are major health concerns in Australia and elsewhere, leading to a high rate of morbidity and mortality. Professor Stephen Simpson AC (School of Life and Environmental Sciences, Faculty of Science; Academic Director, Charles Perkins Centre; Executive Director, Obesity Australia) and colleagues have been investigating the intersection between Western diets and their health implications.

Research

Professor Simpson is a globally recognised entomologist and nutritional biologist who co-developed an integrative modelling framework for nutrition known as the Geometric Framework. Building on this work, he and his team wanted to determine whether changes in the macronutrient composition of the diet could potentially enhance lifespan and improve metabolic health during middle age in animal models.

Sydney Mass Spectrometry has one of the largest collections of liquid-chromatography mass spectrometry available to academic researchers in the country. Offering excellent capabilities and capacity, Sydney Mass Spectrometry assisted the research team in processing hundreds of samples from their landmark study of 33 isocaloric diets on 700 mice to quantify a variety of metabolites. The work was enabled by targeted metabolomics specialist Dr Atul Bhatnagar and the metabolomics team from Sydney Mass Spectrometry utilising the QTRAP mass spectrometer platforms.

Results

The study, published in *Nature Metabolism*, led to insights on how different carbohydrate types can have a profound effect on metabolic health. For example, they found that a low-protein high-carbohydrate diet can result in improved glycaemic status, plasma biochemistry, metabolic status and gut microbiota health if complex carbohydrates rather than simple carbohydrates are used. These findings suggest that nuanced nutritional advice may lead to better outcomes than simply recommending calorie-restricted diets, charting a course to address population health burdens.

Funding sources include:

- Ageing and Alzheimers Institute
- Australian Research Council
- Diabetes Australia
- National Health and Medical Research Council of Australia

Linking the gut microbiome and auto-immune disease

Challenge
Autoimmune diseases such as rheumatoid arthritis, multiple sclerosis or coeliac disease are chronic conditions that affect 3-5% of the general population. While these conditions have been linked to environmental factors, there is growing evidence that gut dysbiosis contributes to onset and severity. Could a healthy gut microbiome help treat autoimmune disease?

Research
Advances in understanding of host-microbiota interactions have highlighted that metabolites, especially short-chain fatty acids, released by gut bacteria play a key role in immune cell development and function. Research by Professor Laurence Macia (School of Medical Sciences, Faculty of Medicine and Health) and others has shown that short-chain fatty acids are central players in immune tolerance as they promote the activation of anti-inflammatory regulatory T cells.

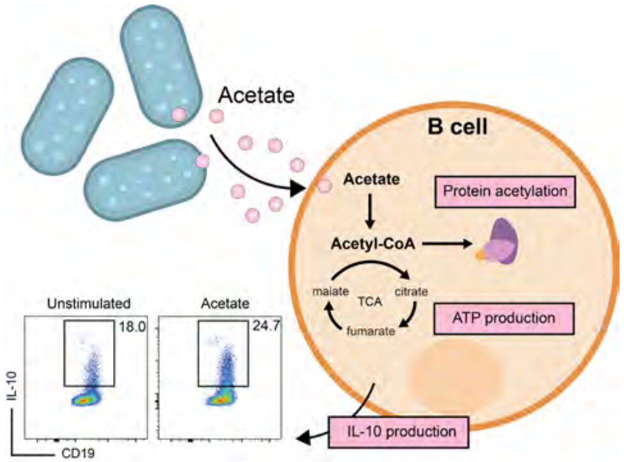
Professor Macia coordinated a study to elucidate the immunosuppressive mechanism of short-chain fatty acid acetate. Using a QTRAP 5500 mass spectrometer, and with the assistance of the Sydney Mass Spectrometry metabolomics team led by Dr Lake Ee Quek, the researchers used stable isotope labelled acetate to show how acetate stimulated the production of anti-inflammatory cytokine interleukin-10 in B cells.

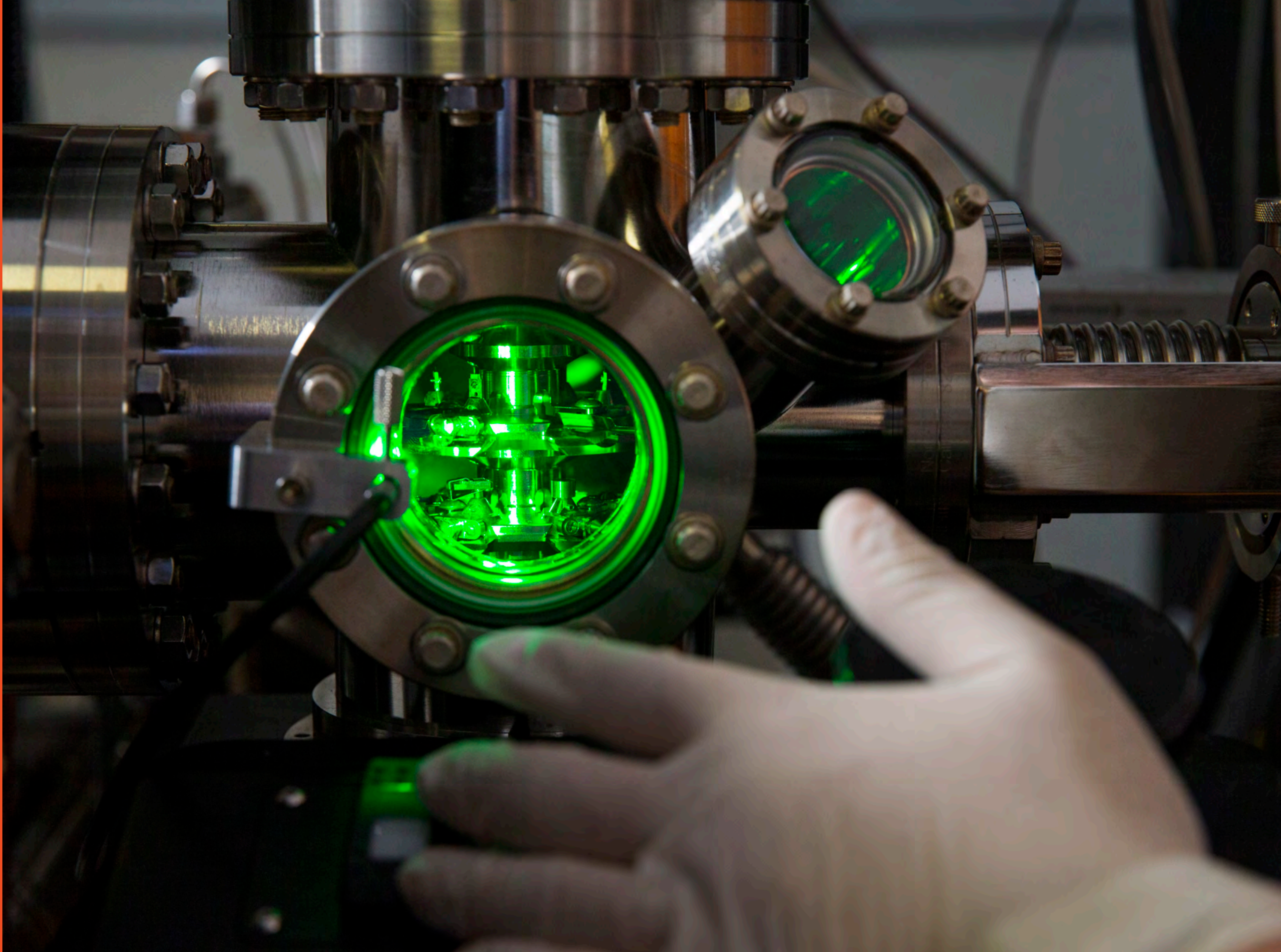
Results
The findings were published in a recent *Journal of Clinical Investigation* paper, and may explain the rise in inflammatory diseases in fiber-underconsuming Western populations. The study highlighted how a healthy gut microbiome can combat chronic inflammation, opening a path for safe and cost-effective dietary intervention to tackle autoimmune disease.

Funding sources include:

- Australian Research Council
- Cancer Institute NSW
- Cooper Foundation
- National Health and Medical Research Council
- The Medical Foundation of the University of Sydney
- University of Sydney

Below: Source: Daïen et al., JCI Insight. 2021 Apr 8; 6 (7): e144156.





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sydney.edu.au/microscopy-microanalysis

Reducing drag to save fuel

Challenge

With growing imperatives to reduce fossil fuel consumption globally, both governments and industry have an active interest in improving the efficiency of their fleets across air, water and land. Australian start-up MicroTau has been conducting research and development in this area with the aim of boosting efficiency by reducing surface drag in transport.

Research

Microscopic patterns found on many plants and animals have functional properties that have evolved over millions of years. For example, sharks have thousands of microscopic overlapping ‘scales’ that reduce drag, allowing them to glide swiftly and silently through the water. Inspired by this phenomenon, MicroTau developed an innovative technique to create drag-reducing microstructures using UV curable coatings that can be applied to aeroplanes and ships. The company is also collaborating with Professor Chiara Neto (School of Chemistry, Faculty of Science; ARC Future Fellow) and her team to investigate the use of functional microstructures for ship anti-fouling. This work also aims to reduce drag by deterring marine life from attaching to ships. Both projects have been enabled by Sydney Microscopy and Microanalysis, where scanning electron microscopes were used to examine and compare different microstructures.

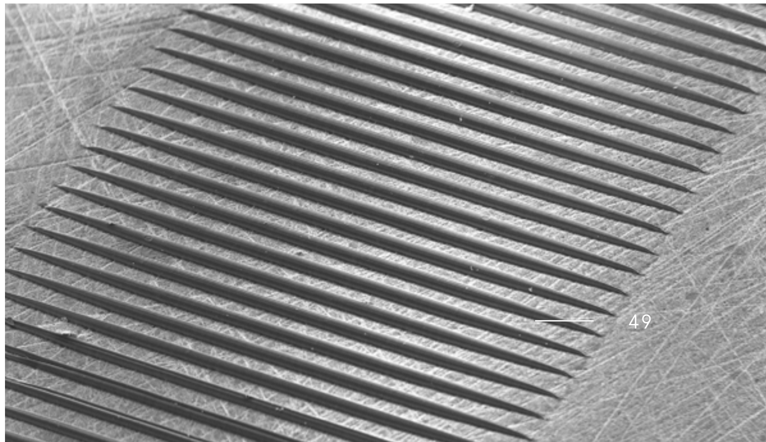
Results

MicroTau’s technique for producing functional microstructures, known as Direct Contactless Microfabrication (DCM), is now patented. While initially developed for the US Air Force, MicroTau’s drag reduction products have the potential to save commercial aviation and shipping over US$34 billion in fuel costs and 225 million tonnes of CO_2 emissions annually. Meanwhile, MicroTau’s ship anti-fouling work with Professor Neto’s team is progressing, and a full-time PhD student was recently engaged to enable this ongoing collaboration. Sydney Microscopy and Microanalysis continues to support MicroTau’s development of new microstructures and techniques.

Funding sources include:

- Australian Research Council
- Defence Innovation Network

Story assistance from Microscopy Australia.



Right: Scanning electron microscope image of MicroTau's riblets taken at Sydney Microscopy and Microanalysis.

Defending ourselves against COVID-19

Challenge
Since the emergence of COVID-19, researchers have been working to determine the mechanisms behind clinical variance in severity and outcomes for infected patients. Understanding the basis for these differences could help to predict outcomes and potentially lead to new COVID-19 treatments.

Research
A team of researchers, led by Professor Greg Neely (School of Life and Environmental Sciences, Faculty of Science; Charles Perkins Centre), set out to explore factors influencing how SARS-CoV-2 interacts with cells, hoping to shed light on the body's innate defence system.

When a person becomes infected with COVID-19, the SARS-CoV-2 virus uses its spike protein to attach to the outside of a host cell via a protein called ACE2. However, they found that the virus can also bind to a naturally occurring protein called LRRC15. When it does this, the virus can no longer bind to ACE2, taking it out of circulation. The team used confocal microscopy at Sydney Microscopy and Microanalysis to help demonstrate this binding, with the assistance of platform scientist Dr Neftali Flores Rodriguez.

Results
Data from the study show that expression of LRRC15 on cells that are not susceptible to SARS-CoV-2 infection could protect neighbouring ACE2+ SARS-CoV-2 target cells.

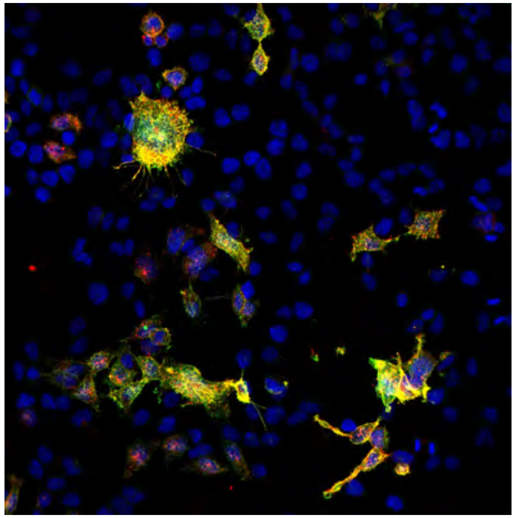
LRRC15 is found at protective immune barriers in the body, such as the placenta, skin, mouth, throat and lymph nodes, but it isn't present in high levels in healthy lungs. However, the team also found that during COVID-19, the amount of LRRC15 in the lungs increases, sticking to the viruses and creating a barrier that prevents them from infecting cells.

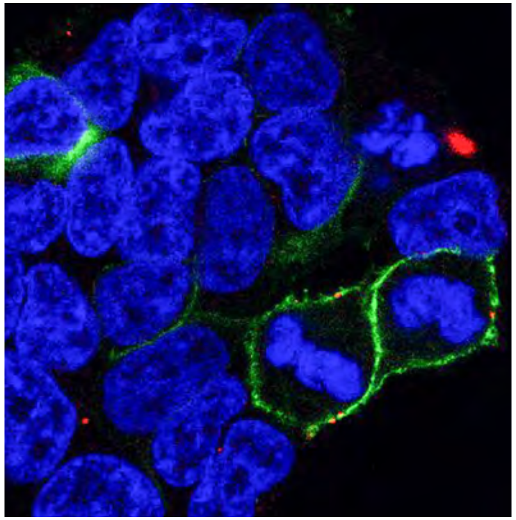
Similar results were also reported by two other research groups at the same time, which provides a robust confirmation of this study. Moreover, in an independent patient-focussed study that was also published at the same time, the authors reported that out of all proteins in the blood, LRRC15 levels were the most important for predicting patient outcomes. High levels of blood LRRC15 indicate less severe disease, and decreasing LRRC15 levels indicate more severe COVID-19. Said Professor Neely, "We can now use this new receptor to design broad-acting drugs that can block viral infection or even suppress lung fibrosis." The study was published in *PLOS Biology*.

Funding sources include:

- National Health and Medical Research Council
- Swiss National Science Foundation
- University of Sydney

Story assistance from Microscopy Australia.





Above: Confocal image from the project showing cultured cells with LCCR15 in yellow and green and the SARS-Cov-2 spike protein in red. Taken by Dr Cesar Moreno at Sydney Microscopy and Microanalysis.

Strengthening Australia's nano-biotechnology capability

Thanks to nano-biotechnology, samples as tiny as single cells or clusters of molecules can lead to medical diagnoses, and development of bespoke treatments can increase their efficacy. This emerging field is called precision medicine, and it is set to be a game-changer for treating cancer – the second-biggest killer globally – as well as infectious diseases. Precision medicine is now poised to take a significant stride forward thanks to a new research partnership with Bruker, a world-leading manufacturer of high-performance scientific instruments.

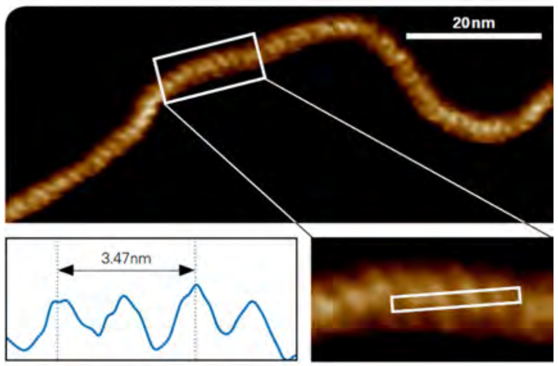
Australian-first research capability

Under the partnership, Sydney Microscopy and Microanalysis will acquire two new-generation atomic force microscopes made by Bruker – the first of their kind in Australia. The microscopes are customised to perform highest-resolution imaging of living biological samples, visualise dynamic molecular mechanisms and quantify cellular and biomolecular interactions. Advanced automation capabilities make them ideal for biomedical and preclinical research. The partnership will place Sydney Microscopy and Microanalysis in a leading position internationally to enable advances in nanomedicine, gene therapies and the early detection, treatment and prevention of disease.

Research applications

The driving force behind the partnership is Dr David Martinez Martin (School of Biomedical Engineering; Deputy Director, Sydney Microscopy and Microanalysis), who has had a long-standing collaboration with Bruker in atomic force microscopy. As part of the partnership, Bruker will support nano-biotechnology research driven by Dr David Martinez Martin.

Further projects are set to follow. Atomic force microscopy allows scientists to analyse and manipulate live cells and materials at the nanoscale, even molecule by molecule, using a laser to measure the physical interaction of the microscope's sensor with a sample at the scale of a billionth of a metre. These cutting-edge capabilities will enable unprecedented exploration of biophysical properties of tissues, cells and molecules with the aim of developing the next generation of diagnostics and treatments.



Left: The profile of a DNA molecule seen through a Bruker atomic force microscope, showing the grooves of the double helix structure (represented by the troughs in the graph). The diameter of human DNA is approximately 2.5 nanometers, which is up to 72,000 times smaller than that of a human hair.

Left: Dr David Martinez Martin (third from left) and colleagues in a lab at Sydney Microscopy and Microanalysis, where the new atomic force microscopes will be located.

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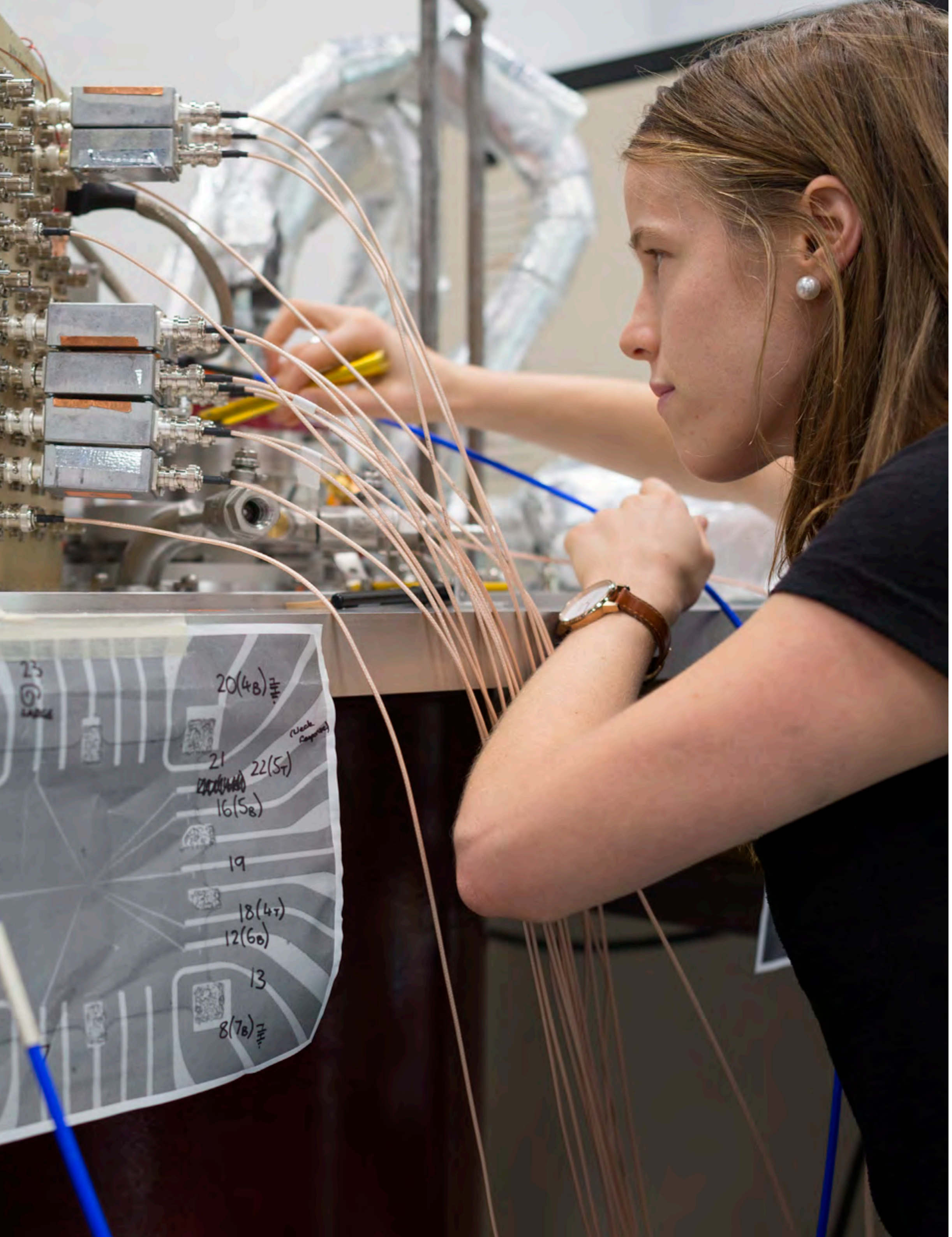

Icon glossary

Critical Technologies in the National interest

- Advanced manufacturing and materials technologies
- AI technologies
- Advanced information and communication technologies
- Quantum technologies
- Autonomous systems, robotics, positioning, timing and sensing
- Biotechnologies
- Clean energy generation and storage technologies

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