THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

Centre for Advanced Imaging

cai.centre.uq.edu.au

The Centre for Advanced Imaging (CAI) is a strategic initiative of The University of Queensland (UQ), reflecting the growth in biotechnology, biomedical and materials research requiring advanced imaging capabilities.

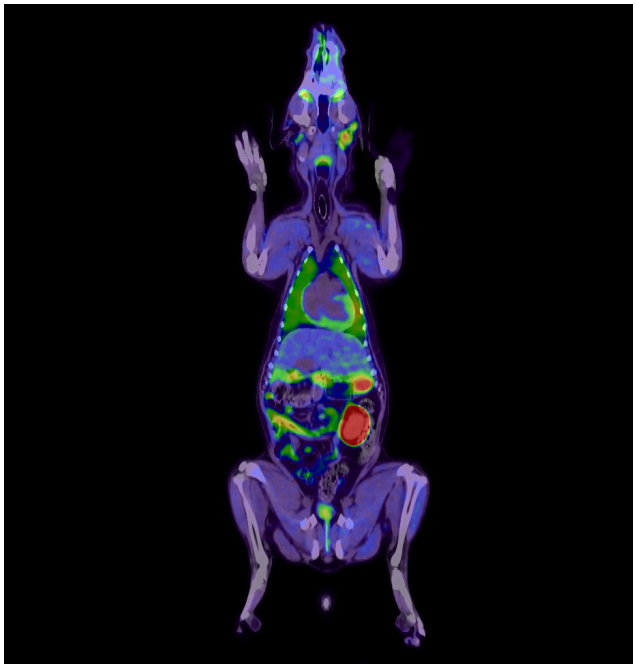
As a leading imaging research facility in Australia, CAI brings together researchers who are leaders in their fields and state-of-the-art, world-first or Australian-first research imaging instruments.

CAI offers postgraduate and research programs and students benefit from highly skilled researchers and strong links to MR industry leaders.

NMR, EPR, MRI, PET, CT and optical imaging are now key platform research technologies for studying structure and function from biomolecules to living organisms including humans.

CAI conducts research across a broad spectrum from development of new imaging technologies, analysis of molecular structure, synthesis of PET tracers targeting fundamental biological processes, to studies of major diseases affecting a range of organ systems. Such diseases include dementia, epilepsy and other brain diseases, cancer, and cardiovascular disease. CAI instruments are also used for research on economically significant agricultural animals and plants, minerals and construction materials.

The University of Queensland is the lead organisation of the National Imaging Facility and a founding partner of the Queensland Nuclear Magentic Resonance (NMR) Network, funded by the Federal and Queensland State Governments.



PET-CT scan of a dog using radiotracer 68Ga-PSMA (prostate-specific membrane antigen). Imaged by the Biograph Horizon PET/CT, Centre for Advanced Imaging.

Did you know?

CAI is the only facility of its type in Australia and one of only a handful in the world.

The 5,500 m^2, $55 million CAI building was funded by the Federal Education Investment Fund in 2010.

It contains over $50 million of imaging and spectroscopy equipment, including

- the first commercial small animal PET-MRI scanner in the world
- the first ultra high-field human MRI scanner (7T) in the Southern Hemisphere
- the most powerful small animal MRI scanner (16.4T) in Australia
- the highest field NMR spectrometer in Australia (21T)


UQ
CENTRE FOR
ADVANCED IMAGING
inVision 256

How is CAI used by researchers?

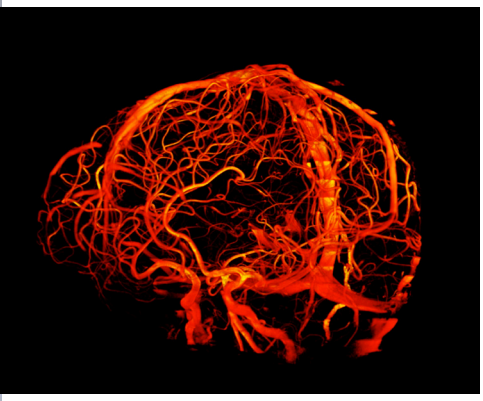
Imaging is used to

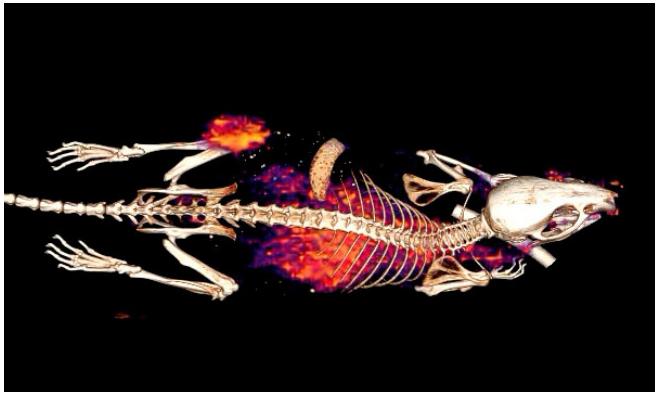
- better understand brain function and development
- study neurological disorders such as dementia, epilepsy, stroke, multiple sclerosis, Parkinson's and motor neurone disease and cancers, including those affecting the brain, breast, liver and pancreas
- evaluate the healthy musculoskeletal system and disorders of bones, joints, muscles and other soft tissues

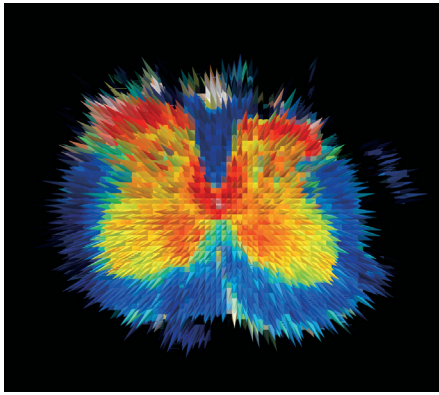
Many of these studies involve the development of new imaging agents and biomarkers to detect disease earlier and to monitor its response to treatment.

CAI facilities are used

- to increase understanding of how biologically important molecules such as proteins, enzymes and receptors behave and interact, allowing us to design targeted imaging agents in combination with therapeutic delivery systems (theranostics). This means therapy can be delivered to a disease, alongside its diagnosis
- for research programs that span basic science through preclinical to biomedical imaging, forming a translational imaging pathway from the benchtop to the bedside.





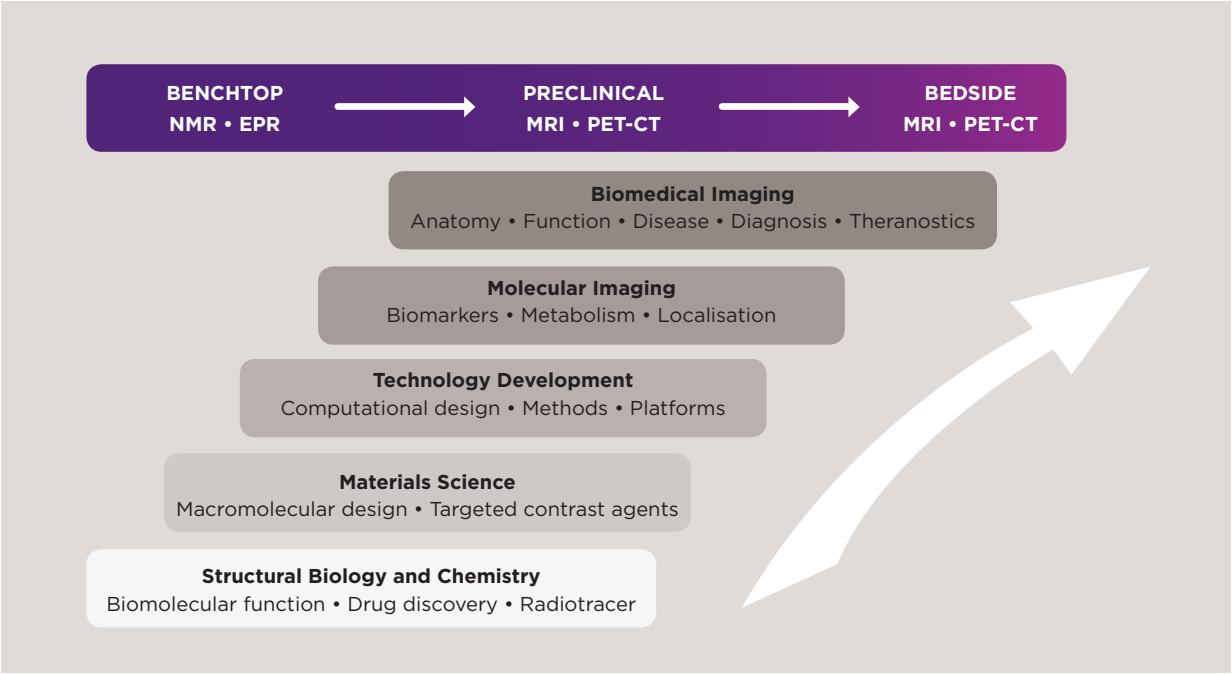


Translational imaging science at CAI

Collaborating researchers at UQ and many other institutions in Australia and overseas use the facilities in a range of programs including:

- Advanced imaging of structure, function and disease
- Advanced imaging, diagnostic and spectroscopic technologies
- Advanced molecular characterisation and design

Imaging is a key platform technology for research studies of the structure and function at the molecular, cellular and whole organism levels in healthy and diseased humans, animals and plants.



What imaging is done at CAI?

A number of instruments are used to image people, animals, plants and objects for scientific research to generate images containing different types of information.

Different imaging techniques and technologies are used to find out distinct details. The imaging method can depend on the material structure being imaged, (such as bone or soft tissue), and the level of image detail required.

Our capabilities include

- Magnetic Resonance Imaging (MRI)
- Cyclotron and Radiochemistry
- Positron Emission Tomography (PET)
- Computed Tomography (CT)
- Nuclear Magnetic Resonance (NMR)
- Electron Paramagnetic Resonance (EPR)
- Optical Imaging
- Optoacoustic Imaging
- Ultrasound

Magnetic Resonance Imaging (MRI)

MRI is a scanning technique that uses magnetic fields and radio waves to generate images of internal organs. The magnetic field acts on protons in water molecules within soft tissue. Magnetised protons in soft tissue produce a signal when radio waves are applied. A computer reconstructs these signals into images.

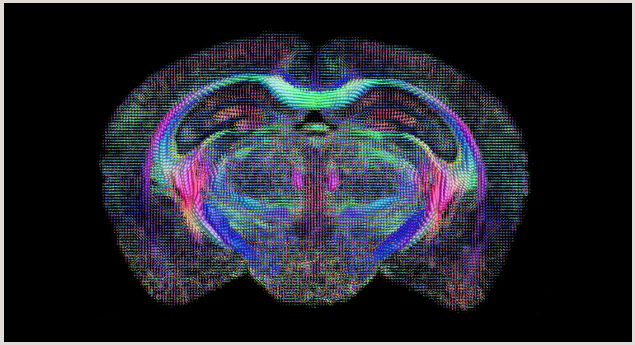


Image top right: An MRI image of a mouse brain displays the high level of detail that can be achieved using MRI technology. This image shows fibre orientation distribution of high angular resolution diffusion-weighted images, imaged at 100 micron resolution by CAI's 16.4T MRI scanner.

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Human imaging

- **Siemens Magnetom 7T MRI scanner**
  The first 7T scanner in the Southern Hemisphere, this $11 million instrument allows imaging of the human body with unprecedented detail.
- **Siemens 3T MRI scanner**
  A high performance human MRI scanner optimised to study human cognition and this $3 million scanner is also equipped for musculoskeletal and organ imaging.

Animal and plant imaging

- **Bruker 9.4T preclinical MRI scanner**
  A state-of-the-art, $3.6 million, animal MRI scanner optimised to provide ultra high resolution images of small animal models of disease.
- **Bruker 16.4T preclinical MRI scanner**
  One of the most powerful MRI scanners in the world, this $3.5 million scanner is capable of producing MRI images at microscopic resolution (down to 5 microns) in specimens such as fixed tissue, disease models and plant samples.

Radiochemistry and Cyclotron

The cyclotron is used to produce short-lived radioisotopes that emit positrons. These radioisotopes are then incorporated into biologically active molecules to form an imaging probe or radiopharmaceutical that can be used to image molecular markers in the living organism.

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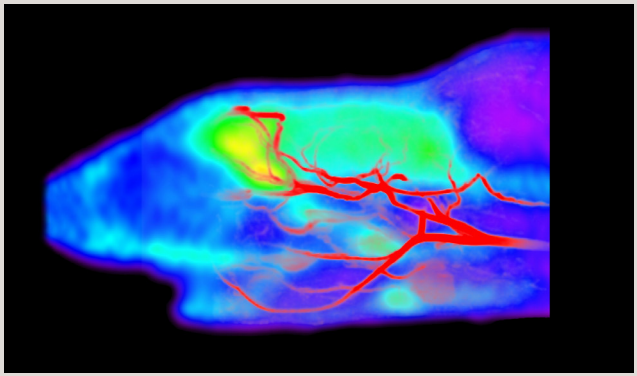
- CAI's $12 million radiochemistry facility consists of an **IBA 18/18 MeV cyclotron** capable of making a wide range of radioisotopes including carbon-11, fluorine-18, copper-64 and iodine-124. In addition to these isotopes, the facility is capable of using a wide range of isotopes including gallium-68, zirconium-89, technetium-99m and lutetium-177.
- With access to **14 hot cells** and **four fume hoods**, the facility provides a unique environment for performing novel drug discovery, preclinical research and translation of tracers to human imaging.
- The facility also has dedicated **synthetic chemistry laboratories** for synthesis of precursor materials for labelling.

Positron Emission Tomography (PET)

PET involves the injection of tracer amounts of a positron-emitting radiopharmaceutical. The accumulation of the radiopharmaceutical is detected by the PET scanner (for example, in fast-growing tumour cells).

Autoradiography capabilities enable visualisation of the distribution of radiolabelled probes in tissue sections.

Image top right: A PET/MR image of a rodent head, using CAI's PET-MR scanner. PET/MR technology combines positron emission tomography (PET) and magnetic resonance (MR) technologies to produce detailed images with the ability to show different biological information. This figure shows an FDG-PET image of the brain overlaid with red blood vessels acquired simultaneously using MR angiography – an imaging technique used to image blood vessels.



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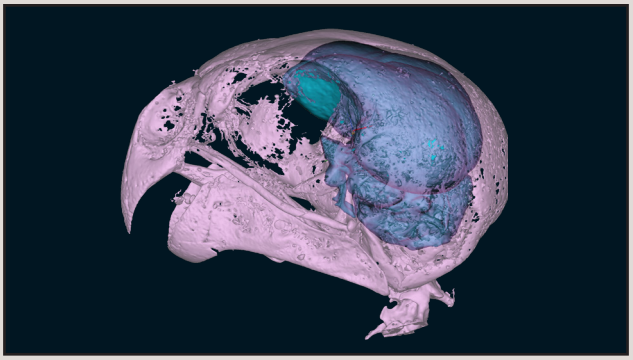
- **Bruker Clinscan 7T preclinical PET-MR scanner**
  The first of its kind in the world, this scanner combines MRI and PET imaging modalities to provide simultaneous structural, functional and metabolic images for translational research in animal models of disease. This cutting edge $4.5 million technology puts Queensland and Australia at the forefront of molecular imaging research.
- **Siemens Inveon preclinical PET-CT**
  The $1.3 million small animal PET scanner at CAI is combined with a CT scanner allowing CT images that provide detailed structural information to be overlaid with metabolic and functional information obtained from the PET scan. This technology aids the development of new diagnostic imaging agents for diseases such as cancer and dementia.
- **Siemens Biograph Horizon large bore PET-CT**
  The large bore combined PET and CT scanner allows scanning of humans and companion animals. This technology is part of the Australian Cancer Research Foundation Facility for Molecular Imaging Agents in Cancer and facilitates the clinical translation of new cancer drugs, devices and imaging procedures.

Computed Tomography (CT)

A CT scan uses X-rays and digital technology to create detailed two- or three-dimensional images. CT scans provide images of internal organs and are particularly useful for imaging bone and blood vessels when using contrast agent.

CAI's CT scanners are part of the **Siemens Inveon preclinical PET-CT** and the **Siemens Biograph Horizon large bore PET-CT** systems.

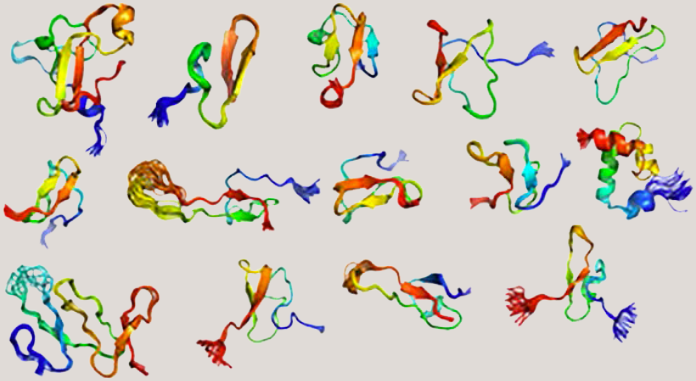


CT image of a night parrot (*Pezoporus occidentalis*) skull. Imaged by Dr Karine Mardon (pictured below), in collaboration with the Queensland Museum.

Nuclear Magnetic Resonance (NMR)

NMR is a powerful non-destructive analytical tool that enables the researcher to identify and determine the structure of molecules ranging from small organic compounds to biologically important proteins and enzymes.

NMR applications include chemistry, drug discovery, systems biology, medical diagnostics, biotechnology, nutritional and material sciences.



3D structures of peptides isolated from the venom of spiders. The structures were solved in solution to atomic resolution using the high field NMR facilities at the Centre for Advanced Imaging (credit: M Mobli).

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- **Bruker 900 MHz NMR spectrometer**
  Optimised for biomolecular NMR studies, this spectrometer at 21T, is the highest field strength MR system and the only one of its kind in Australia. The $10 million equipment provides high resolution, three dimensional structures of proteins, nucleic acids and complex carbohydrates and maps of biomolecular interaction.
- **Bruker 700 MHz NMR spectrometer**
  This $2.5 million system is dedicated to chemical and life science research. It is optimised for high-throughput sample handling for metabolic profiling and for determination of chemical structure and function.

Electron Paramagnetic Resonance (EPR)

EPR can detect any material containing unpaired electrons, either intrinsic to the sample or added as a probe for sample characterisation. EPR is the only technology that can detect unpaired electrons unambiguously.

It has applications in chemistry, drug discovery, structural biology, biotechnology, materials science and analytical chemistry. It can be used for imaging free radicals – key mediators in biological processes such as in signalling and disease.

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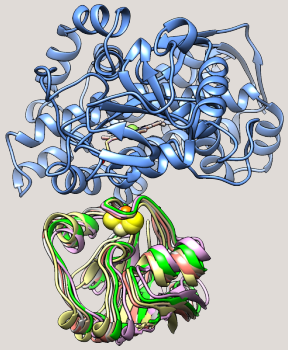
- **Bruker Elexsys imaging and CW EPR spectrometer**
  Part of the suite of over $5 million in EPR equipment at CAI, this EPR imaging system provides images of free radicals in biological tissue, with applications in cancer, neurodegeneration and vascular disease.
- **Bruker Elexsys E580 X-/Q-band CW and pulse EPR spectrometer**
  The spectrometer is optimised with resonators, high-power microwave amplifiers and a cryostat down to 1.7 K and is the only one of its kind in Australia. The system enables high-resolution spectroscopy to determine the structure of paramagnetic systems including organic and inorganic radicals, metal complexes, metalloenzymes, and solids containing paramagnetic centres. Examples include battery materials and solar cells. Spin labelling of diamagnetic proteins and their complexes enables structural biology applications including for drug discovery.

An EPR spectrometer detects unpaired electrons using continuous wave and pulsed microwave irradiation to manipulate the spin system and thus interrogate the sample.



A structural model of a P450-Ferredoxin complex from double electron-electron resonance spectroscopy.

Figure: Bowen, A. M., Johnson, E. O. D., Mercuri, F., Hoskins, N. J., Qiao, R. H., McCullagh, J. S. O., ... Harmer, J. R. (2018). A Structural Model of a P450-Ferredoxin Complex from Orientation-Selective Double Electron-Electron Resonance Spectroscopy. *Journal of the American Chemical Society, 140*, 2514-2527. doi: 10.1021/jacs.7b11056

Optical Imaging

Optical imaging utilises light in the visible and near-infrared spectrum to detect the presence of molecules of interest within samples, tissues, or animals.

Optical imaging is a rapid and low cost imaging technique commonly used for preliminary assessment of the distribution and targeting of novel molecules (such as nanomedicines).

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- **IVIS Lumina X5 Imaging system**
  The IVIS® Lumina™ X5 high-throughput 2D optical imaging system combines high-sensitivity bioluminescence and fluorescence with high-resolution x-ray. This instrument is a workhorse for those undertaking preclinical assessment of novel therapeutics or imaging agents, with rapid screening of up to five mice simultaneously.

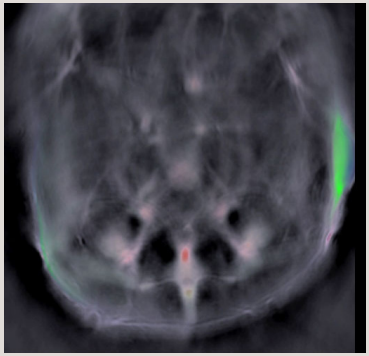
Optoacoustic Imaging

Optoacoustic or photoacoustic imaging uses non-ionising near-infrared laser pulses to deliver energy to a sample or biological tissue. The energy that is absorbed is converted into heat and leads to thermoelastic expansion, which is detected as an ultrasonic emission.

Optoacoustic imaging can be used to image endogenous molecules such as haemoglobin and melanin, as well as exogenous agents that absorb near-infrared light (for example the optoacoustic image below shows an exogenous agent – a polymer highlighted green).

FLAGSHIP EQUIPMENT

- **Multispectral Optoacoustic Imaging – iThera MSOT inVision 256-TF system**
  The inVision 256-TF MSOT system offers unique imaging capabilities, combining tomographic acoustic imaging with optical sensitivity. The exquisite spectral resolution offered by this instrument provides a powerful methodology to elucidate the presence of both endogenous and exogenous probes.



Optoacoustic image of gold nanoparticles surface coated with a polymer (highlighted green). Imaged by Nick Westra van Holthe, CAI Thurecht Group.

Interested in learning about imaging science? Study with CAI

CAI offers postgraduate and research programs covering all aspects of imaging research from hardware engineering to biomedical imaging, and molecular imaging to spectroscopy.

Learn within a multidisciplinary environment and benefit from researchers who are leaders in their fields.

All CAI programs reflect the teaching team's vast experience as medical practitioners, chemists, radiochemists, radiographers, radiopharmacologists, radiophysicists, medical physicists, biologists and engineers.

To find out more, visit
cai.centre.uq.edu.au/study

We offer the following study opportunities, as well as short courses and traineeships:

Undergraduate Programs

- Summer Research Program
- Winter Research Program
- Honours Research

Postgraduate Programs

- Postgraduate Coursework in Magnetic Resonance Technology
- Master of Molecular Imaging Technology
- Graduate Certificate in Magnetic Resonance and Positron Emission Tomography (MR-PET)

Research Programs

- Doctor of Philosophy (PhD)
- Master of Philosophy (MPhil)

The Centre for Advanced Imaging (CAI) is a foundation partner in

QNN
QUEENSLAND NMR NETWORK

National Imaging Facility

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