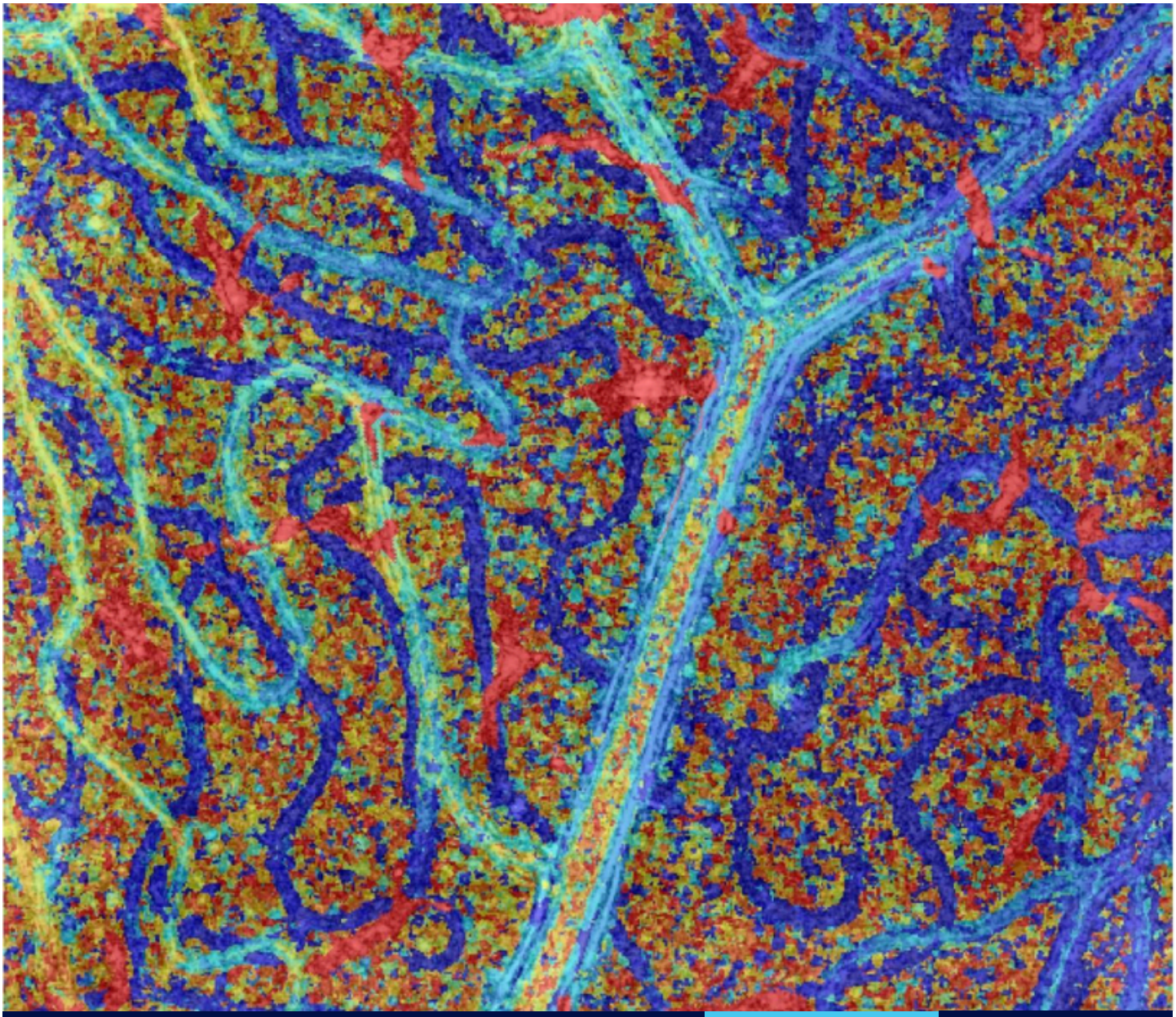


Research Projects 2026

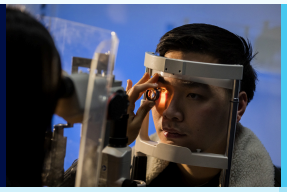
(Honours, Masters and PhD)

Department of Optometry and Vision Sciences

THE UNIVERSITY OF MELBOURNE

Scan to read or download the brochure.

Contents



Page number

Cover illustration: *Phase contrast imaging in the living human retina using adaptive optics scanning laser ophthalmoscopy. Colour coding shows the relative depth of structures. Resident immune cells, in red, patrol the inner surface of the retina and play a key role in coupling the activity of retinal neurones to local changes in capillary blood flow.*

RESEARCH IN THE DEPARTMENT OF OPTOMETRY AND VISION SCIENCES

The Department of Optometry and Vision Sciences is based in the Faculty of Medicine, Dentistry and Health Sciences (MDHS). Vision science research is multidisciplinary in nature and spans topics from understanding the fundamental workings of the living retina on the microscopic scale to the testing of new therapies in clinical trials. No matter what your major, there are vision research pathways for you. In this brochure we highlight some of the projects available for research students within our Department. If you have a passion for vision science that is not covered specifically in this project set, please contact our researchers to discuss further.

For students who have completed an undergraduate degree a research pathway though an Honours or Master of Biomedical Science is an appropriate research path. For students with a BSc (Hons) or BBiomed (Hons) further scientific training through a three-year PhD, or a 1.5-year Master of Philosophy would be appropriate.

You can also contact the Departmental Honours and Master of Biomedical Science Coordinators, Dr Livia Carvalho (livia.carvalho@unimelb.edu.au) and Prof Trichur Vidyasagar (trv@unimelb.edu.au) or the Departmental Graduate Researcher Coordinator for PhD and Master of Philosophy related queries, A/Prof Andrew Anderson (aaj@unimelb.edu.au).

For further information

Honours
http://mdhs-study.unimelb.edu.au/degrees/honours/overview

Master of Biomedical Science
https://study.unimelb.edu.au/find/courses/graduate/master-of-biomedical-science
https://handbook.unimelb.edu.au/2025/courses/mc-bmedsc

Master of Philosophy
https://study.unimelb.edu.au/find/courses/graduate/master-of-philosophy-mdhs-biomedical-science/

PhD
https://study.unimelb.edu.au/find/courses/graduate/doctor-of-philosophy-medicine-dentistry-and-health-sciences

Department of Optometry and Vision Sciences
https://healthsciences.unimelb.edu.au/departments/optometry-and-vision-sciences

ANTERIOR EYE, CLINICAL TRIALS AND RESEARCH TRANSLATION UNIT

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Key Project Co-supervisor

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Summary of research interests:

The Anterior Eye, Clinical Trials and Research Translation unit adopts an integrated and innovative approach to research that combines laboratory, clinical and implementation science, as a basis for improving patient outcomes.

Our team possess advanced expertise in the **anterior eye** (including the development and translation of novel ocular diagnostic devices and therapeutics) and **research translation** (to develop and test interventions to improve research dissemination and its implementation in practice). Our collaborators include industry, national and international research groups (including researchers in neurology, endocrinology, immunology, neuroscience and engineering) on projects that combine preclinical and clinical science.

Focus Area #1: Using tears as a platform for advancing the understanding of disease. This program of research investigates using tears (Figure 1) to provide new insights into human health. We combine sophisticated clinical and laboratory technique to characterise how various features of the tear film, including tear biology and behaviour, are altered in eye and systemic disease. These investigations are the basis for our team developing new diagnostic and prognostic tests to inform the management of clinical conditions. Some of our recent studies have identified new tear biomarkers for diabetes, dry eye disease and contact lens discomfort, leading to patents and subsequent projects focussed on the commercialisation of these discoveries.

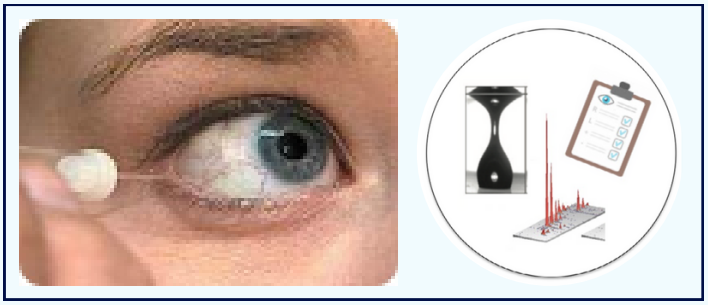

Figure 1: *After non-invasive collection using a capillary tube, human tears are analysed using a range of cutting-edge techniques, to quantify parameters such as viscoelasticity (stretchiness), protein composition and lipid content. These studies are the foundation for developing novel lab-on-a-chip tests for ocular and systemic disease.*

Focus Area #2: Functional in vivo confocal microscopy (Fun-IVCM) as a window to the human immune system. As a transparent tissue, the cornea is the only site in the body where sensory nerves and different types of immune cells can be non-invasively imaged in living humans, using high-resolution in vivo confocal microscopy (IVCM). Corneal IVCM uniquely provides capacity to assess the immunological effect of eye and systemic conditions, as well as other factors (such as contact lens wear) on an intact physiological system.

Our team has recently developed Fun-IVCM as a non-invasive imaging method to dynamically track corneal immune cell subsets in living humans. Using Fun-IVCM we recently captured the first-ever live cell imaging of corneal T cells, dendritic cells and macrophages in response to immune-active stimuli in humans. This research has redefined scientific understanding of corneal immune cell populations, including identifying the presence of T cells in healthy human corneas, and demonstrated changes to their dynamics in

acute and chronic inflammation (Downie et al., 2023 *PNAS*).

Changes to corneal immune cell morphology and behaviours, captured using Fun-IVCM show utility as new biomarkers of ocular and systemic disease, and have the capacity to inform the development of targeted therapeutics for these conditions.

Project 1: "Seeing" the dynamics of immune cells in the eyes of humans

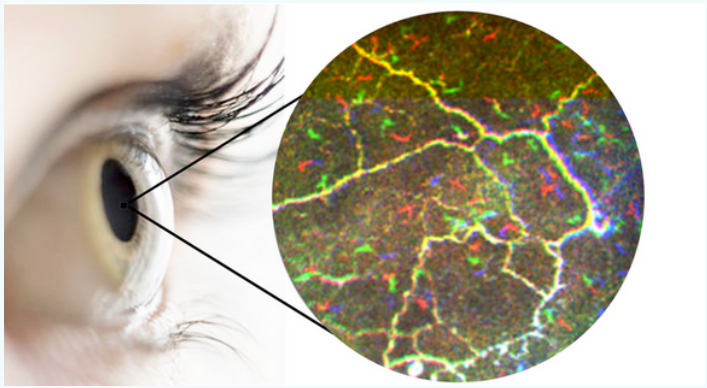

Figure 2: *Fun-IVCM image of the human corneal epithelium. The colour-coded time-lapsed image shows stable immune cells and nerves (white) and motile immune cells (coloured).*

Using Fun-IVCM, we have shown that human corneal immune cells are dynamic cell populations, however currently little is known about how various stimuli affect their behaviours in vivo.

This project will investigate how various factors, including different disease states (such as multiple sclerosis, keratoconus and other conditions), modify the behaviours of the different types of corneal immune cells (T cells, dendritic cells, macrophages). This research will provide new insights into the immunology of the human eye. This project will involve participant recruitment, clinical examinations, and digital image analysis. It is suitable for Honours, Masters and PhD students.

Project 2: Exploring the effects of omega-3 fatty acid supplementation on the retinal vasculature in type 1 diabetes

Building on our previous studies showing that omega-3 fatty acid supplements promote corneal nerve regeneration in people with type 1 diabetes, this project will investigate the effects of these supplements on the retinal microvasculature.

High-resolution images of the retinal vasculature were captured using optical coherence tomography angiography (OCT-A) from participants with type 1 diabetes who participated in a randomised, placebo-controlled clinical trial. Omega-3 fatty acids modulate systemic inflammation, and high dietary intakes can reduce the risks of severe diabetic retinopathy. However, the effects of this supplementation on the retinal vasculature architecture have not yet been comprehensively studied. This project will involve development and implementation of new image analysis protocols, to investigate whether omega-3 fatty acids modulate retinal vascular density and architecture in people with type 1 diabetes. It is suitable for Honours students.

Selected related publications from our team:

1. Downie LE, Zhang X, Wu M, … Mueller SN, Chinnery HR. Redefining the human corneal immune cell compartment using dynamic intravital imaging. *Proc Natl Acad Sci U S A* 2023; Aug;120(31):e2217795120
2. Britten-Jones AC, Kamel JT, et al. Investigating the neuroprotective effect of oral omega-3 fatty acid supplementation in type 1 diabetes (nPROOFS1): a randomized, placebo-controlled trial. *Diabetes* 2021;70(8):1794-1806.
3. McDonnell A, Lee JH, Makrai E, Yeo LY, Downie LE. Tear film extensional viscosity is a novel potential biomarker of dry eye disease. *Ophthalmology* 2019;126(8):1196-8.
4. Gad A, Vingrys AJ, Wong CY, Jackson DC, Downie LE. Tear film inflammatory cytokine upregulation in contact lens discomfort. *Ocul Surf* 2019;17(1):89-97.

OCULAR BIOMARKER LABORATORY

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https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/ocular-biomarker-laboratory

Summary of lab interests: The eye affords a unique opportunity to gain insights into what is occurring in the brain. It is the only place in the body where neurons and blood vessels can be directly visualised. Moreover, neurological diseases such as Alzheimer's disease, Parkinson's disease and multiple sclerosis have been shown to exhibit changes in the eye which can be measured with currently available clinical tools and emerging technologies.

Project 1: Treating Parkinson's disease with Vitamin B3

Imagine a world where a screening eye test at your local optometrist could tell you your risk of developing or progressing with Parkinson's disease and whether you could then prevent or delay symptoms by taking a safe and inexpensive vitamin. This study uses an animal model as a proof-of-principle to test whether Vitamin B3 exhibits neuroprotective properties in Parkinson's disease brains and whether retinal imaging can track this response. In this manner it lays the critical stepping-stones of developing and validating the tools to make this vision into a reality.

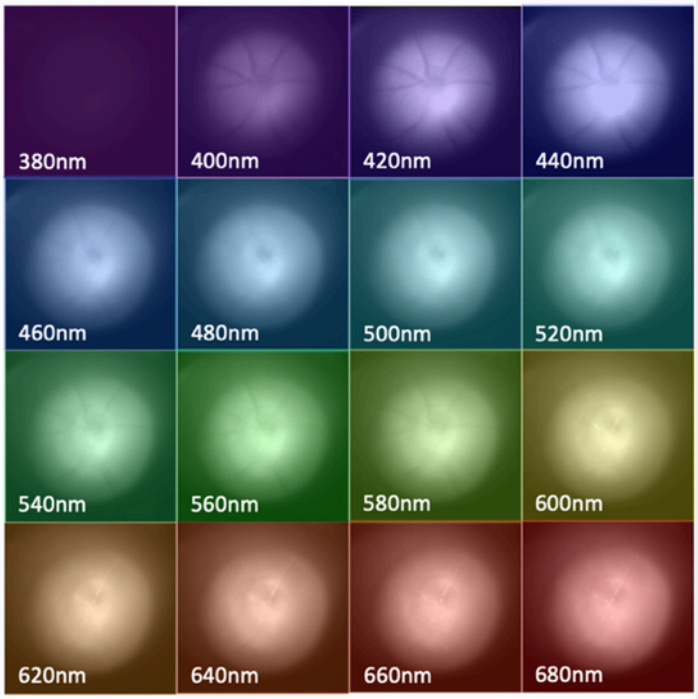

Figure 3: *In vivo hyperspectral imaging in a live mouse eye.*

Project 2: An eye on Parkinson's disease: Characterising toxin-induced changes in the retina

Exposure to environmental toxins can increase an individual's risk of Parkinson's disease. Given the neuronal similarities in the eye and brain it is not surprising that these toxins also affect the retina. Our group has shown that a toxin that modifies energetic demand (MPTP) can modify retinal measures that can also easily be conducted in patients. The current project will build on this work and characterise retinal imaging changes in another toxin-induced mouse model (rotenone) of oxidative stress. In this manner, the project will form the building blocks for testing whether common clinical retinal assessments (optical coherence tomography, hyperspectral imaging, electroretinography) may be useful for early detection of Parkinson's disease.

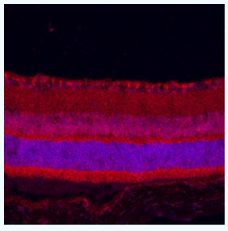

Figure 4: *A metabolic marker (DJ1) is elevated in the retina in Parkinson's disease*

Project 3: Eye as a window to Parkinson's disease: human data analysis

Parkinson's disease needs to be detected earlier in order for new treatments aimed at neuroprotection to be effective. The eye can serve as a "brain on a stalk" and provide a window into cortical changes whilst being simple and inexpensive to measure. This project will analyse visual measures conducted on control and Parkinson's disease patients in order to examine which may be the most sensitive to differentiate between the two groups. This will pave the way for early biomarkers of Parkinson's disease that can assist with future development of novel treatments.

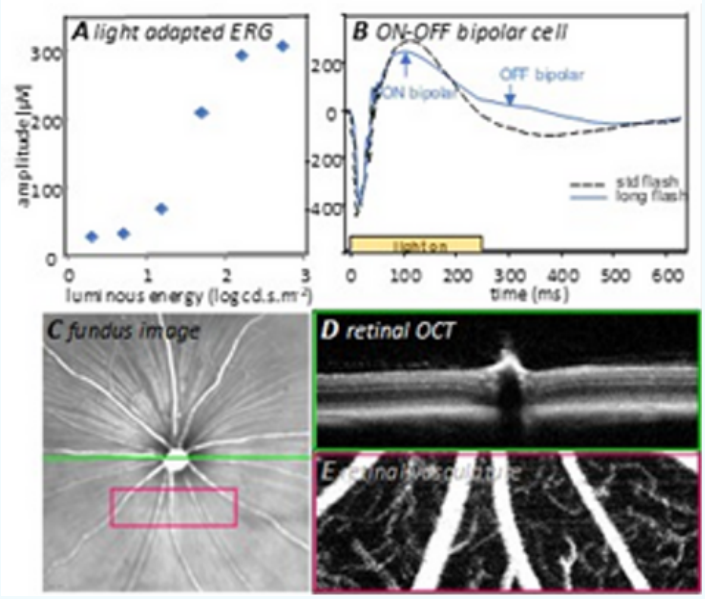

Figure 5: *Functional and structural assessment of retinal health in Parkinson's disease*

Project 4: An eye on Parkinson's disease: Characterising alpha-synuclein changes in the retina

A hallmark of Parkinson's disease is deposition of a key protein, alpha-synculein in the brain. These proteins are also found in the eye, and our group has shown their presence can modify retinal measures which can also easily be conducted in patients. The current project will build on this work and characterise retinal imaging changes in a mouse model of alpha-synculein overaccumulation at early and late stages of disease. In this manner, the project will form the building blocks for testing whether common clinical retinal assessments (optical coherence tomography, hyperspectral imaging, electroretinography) may be useful for early detection of Parkinson's disease.

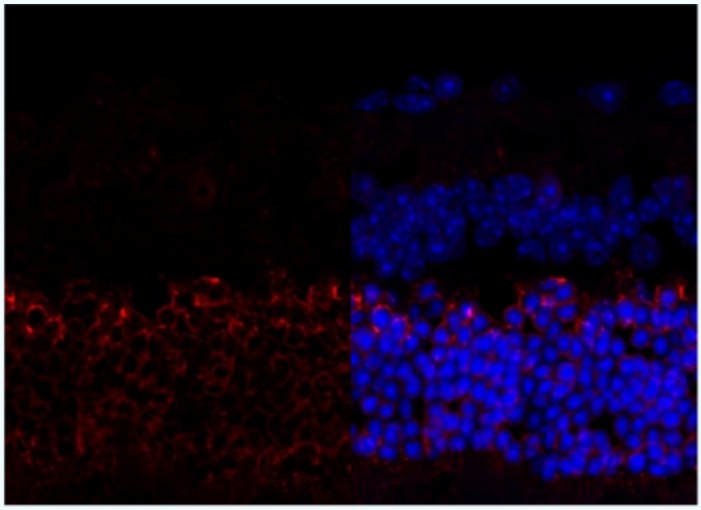

Figure 6: *Alpha-synuclein (red) a hallmark of Parkinson's disease in the retina*

Project 5: Parkinson's disease: Using a retinal stress test to uncover early metabolic changes

One of the earliest pathological changes in Parkinson's disease is change to metabolism. Retinal photoreceptors are the most highly metabolic tissue per weight in the body and hence they form a logical location to examine early Parkinson's changes. By challenging the retina with light (akin to a photographic flash) retinal metabolism can be probed in mice with or without Parkinson's at various disease stages. This will shed light on whether retinal metabolic changes may be an early marker of Parkinson's disease and improve our understanding of its pathogenesis. The capacity to develop early, specific biomarkers for Parkinson's disease is pivotal for the development of treatments.

Recent related publications from our team:

1. Trlin P, Gong J, Tran KKN, Wong VHY, Lee PY, Hoang A, Beauchamp LC, Lim JKH, Metha A, Barnham KJ, Finkelstein DI, Bui BV, Bedggood P, Nguyen CTO. Retinal hyperspectral imaging in mouse models of Parkinson's disease and healthy aging. Sci Rep 2024
2. Tran KKN, Lee PY, Finkelstein DI, et al. Altered outer retinal structure, electrophysiology and visual perception in Parkinson's disease. J Parkinsons Dis 2023.

OCULAR PHYSIOLOGY LABORATORY

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https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/ocular-physiology-laboratory

Summary of lab interests: We are interested in understanding the causes of retinal and optic nerve injury in eye diseases. We are also interested in developing new ways to clinically detect eyes at risk of vision loss from these and other neurological conditions.

Project 1: Understanding how pressure affects ganglion cells in glaucoma

Our investigations of glaucoma hope to shed light on how the cells that connect the eye to the brain, the retinal ganglion cells, adapt to stress such as changes in pressure in and around the eye. We hope to more fully understand how adaptation mechanisms decline with ageing. To study risk factors for glaucoma we have developed acute and chronic model of eye pressure elevation. We study ganglion cell responses to stress by relating their function (electroretinography), structure (imaging) and cell morphology in relation to a range of cellular processes that keep ganglion cells healthy (e.g., communication with support cells, autophagy for self-repair, energy supply).

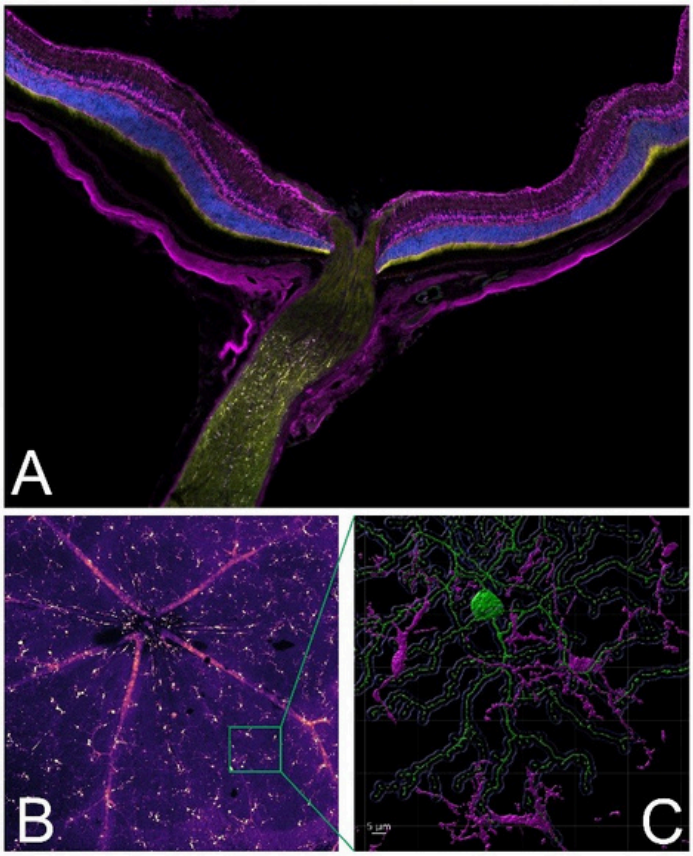

Figure 7: *Using a transgenic mouse line where the process of autophagy is fluorescently labelled (yellow) we study how injury affects autophagy in different regions of the retina and optic nerve (A). Panels B/C shows reporter mice used to study how immune (microglia = pink) and ganglion cells interact (green).*

Project 2: Clinical studies of retinal vascular autoregulation

The retina and brain are the most highly energy demanding tissues in the body. The need for optical clarity means that little energy is stored and as such the retina is completely dependent on a stable blood supply for oxygen and glucose. Local autoregulation mechanisms stabilise flow to three major vascular beds (superficial, intermediate and deep). Vascular autoregulation involves cells lining the blood vessel walls (endothelial cells) as well as neurons and supporting glia (astrocytes and microglia). Failure of autoregulation can lead to vision loss in diabetes and glaucoma. In these studies, we will employ tools such as optical coherence tomography imaging to assess autoregulation in diabetes and glaucoma.

Project 3: Developing ocular biomarkers of epilepsy

Epilepsy is a chronic neurological condition that causes an individual to experience recurrent seizures. It is the most common neurological disorder, affecting about 4% of Australians. Many of the channels that are dysfunctional in the brain are also manifest in other sensory systems, which accounts for significant co-morbidities including, hearing and vision deficits, sleep disturbance, digestive problems and cardiac issues. The presence of deficits in sensory organs can be leveraged to develop biomarkers. For example, the eye and its response to light might be useful to detect and monitor some forms of epilepsy. in this project we will assess the electrical response of the eye to light, called the electroretinogram, in murine models of epilepsy to establish the optimal protocol for assessing channel dysfunction in subtypes of epilepsy. We will use these protocols to assess the effect of standard of care and new drugs. This work is critical in developing a laboratory platform for drug testing with significant potential to inform the development of clinical tools for children with epilepsy.

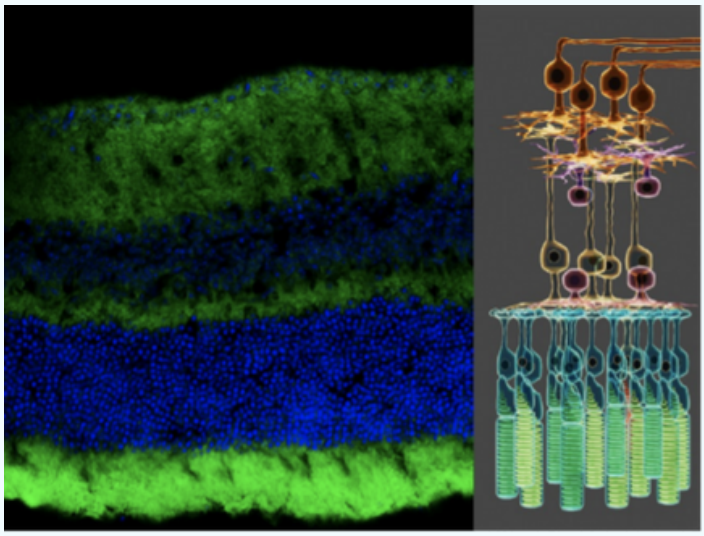

Figure 8: *Applying a non-invasive measure of retinal function, the electroretinogram, we can use the retina to better understand and test drugs for epilepsy, in this case when it arises from HCN1 epilepsy.*

Recent related publications from our team:

1. Ganearachchi SN, van Koeverden AK, Nguyen CTO, He Z, Wong VHY, Bui BV, Zhao D. Rat retinal function attenuation with IOP elevation is impacted by both blood pressure and intracranial pressure. *Front Physiol*. 2025;16:1566032.
2. Lee PY, Greferath U, Zhao D, Huang JY, Wang AYM, Vessey KA, Chrysostomou V, Fletcher EL, Crowston JG, Bui BV. Systemic TRPV4 inhibition worsens retinal response to acute intraocular pressure elevation in older but not younger mice. *Optom Vis Sci.* 2025 Feb 1;102(2):78-89
3. Jobling AI, Greferath U, Dixon MA, Quiriconi P, Eyar B, van Koeverden AK, Mills SA, Vessey KA, Bui BV, Fletcher EL.Microglial regulation of the retinal vasculature in health and during the pathology associated with diabetes. *Prog Retin Eye Res.* 2025 May;106:101349.
4. Tribble JR, Wong VHY, Stuart KV, Chidlow G, Nicol A, Rombaut A, Rabiolo A, Hoang A, Lee PY, Rutigliani C, Enz TJ, Canovai A, Lardner E, Stålhammar G, Nguyen CTO, Garway-Heath DF, Casson RJ, Khawaja AP, Bui BV, Williams PA. Dysfunctional one-carbon metabolism identifies vitamins B6, B9, B12, and choline as neuroprotective in glaucoma. *Cell Rep Med.* 2025 May 20;6(5):102127.
5. Afiat BC, Zhao D, Wong VHY, Perera ND, Turner BJ, Nguyen CTO, Bui BV. Age-related deficits in retinal autophagy following intraocular pressure elevation in autophagy reporter mouse model. *Neurobiol Aging.* 2023 Nov;131:74-87.
6. Zhao D, Pinares-Garcia P, McKenzie CE, Bleakley LE, Forster IC, Wong VHY, Nguyen CTO, Scheffer IE, Reid CA, Bui BV. Retinal Dysfunction in a Mouse Model of HCN1 Genetic Epilepsy. *J Neurosci.* 2023 Mar 22;43(12):2199-2209.
7. Heriot WJ, Metha AB, He Z, Lim JKH, Hoang A, Nishimura T, Okada M, Bui BV. Optimizing retinal thermofusion in retinal detachment repair: achieving instant adhesion without air tamponade. *Ophthamol Sci.* 2022 2:100179.

OPTOLOGICAL LABORATORY

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https://findanexpert.unimelb.edu.au/profile/19811-andrew-anderson

Figure 9: *Optometry research students*

The Optological Laboratory non-invasively investigates how the human eye and brain function, both in normal observers and those with eye disease.

Our laboratory uses psychophysical methods (techniques to investigate the relationship between physical stimuli and the sensations they produce) to determine how the eye and brain behave. Sometimes our investigations involve visual targets used in clinical tests of vision, allowing us to better understand how such tests work and allowing more effective clinical tests to be developed. Other investigations use customised visual stimuli and special experimental protocols to examine how the eye transmits information to the brain, and also how the brain processes this information in order to make decisions. The laboratory also has several methods to allow us to measure eye movements, and so determine where people direct their attention.

Project 1: Why doesn't the world jiggle about?

Even when we stare intently at a small target, our eyes are constantly in motion. This results in images that continuously move on our retinas. Powerful perceptual stabilisation mechanisms prevent our noticing this motion, however. Whilst this means our world doesn't appear to incessantly jiggle around, does this actually improve our ability to do things? This project investigates whether perceptual stabilisation mechanisms improve our ability to do a very common task – accurately reaching towards something we see.

(Honours & Masters, with scope for MPhil/PhD extension)

Figure 10: *Deborah Mailman: feature location analysis in a portrait (Evert Ploeg, 1999: National Portrait Gallery, Australia) and photograph (www.aacta.org/aacta-award/winners-and-nominees/2nd-aacta-awards/: accessed 24/7/25)*

Project 2: Is all art caricature?

Caricaturing exaggerates distinctive features in a face. It has been argued that artists employ caricature, even unconsciously, to make those areas of our brains that would normally respond to a particular person's face respond even more strongly to their portrait. As such, our aesthetic

response to the portrait is enhanced. But is this true? This project will compare features in painted portraits to those in photographs, to see if artist truly do employ a degree of caricature in their work, particularly when not explicitly creating a caricature.

(Honours & Masters)

Project 3: Can flickering lights be used to reliably measure fatigue?

There is an upper limit to how fast a light can flicker before it appears continuous (i.e. non-flickering) to an observer (the Critical Flicker-Fusion Frequency, or CFF). Measures of CFF have been used for many decades to monitor how "fatigued" our visual systems become over time. But how robust are the methods used to assess CFF? This project will investigate some basic aspect of CFF measurements, to determine just how trustworthy such measures are.

(Honours & Masters)

Recent related publications from our team:

1. Anderson AJ, Livingstone MS. The effect of caricaturing on the esthetic appeal of familiar faces, and its relation to simple proportion judgments. *iPerception* 2024; 15(6):20416695241300099.
2. Mahjoob M, Anderson AJ. Effect of cognitive mental load on attended and non-attended visual stimuli. *Optom Vis Sci* 2023;100(3):201-206.
3. Singh S, Downie LE, Anderson AJ. Is critical flicker-fusion frequency a valid measure of visual fatigue? A post hoc analysis of a double-masked randomised controlled trial. *Ophthal Physiol Opt* 2023;43(2):176-182.
4. Sepulveda JA, Wood JM, Lacherez P, Anderson AJ, McKendrick AM. The relationship between central and mid-peripheral motion perception and the hazard perception test in younger and older adults. *Ophthalmic Physiol Opt* 2023;43(5):1211-1222.

HUMAN FACTORS VISION LABORATORY

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Summary of lab interests: The human factors vision lab takes a keen interest in how visual science can be leveraged and applied in an occupational context. Our work includes validation of new clinical vision testing for visual standards, contextual application of vision science to visual displays and exploration of gaps in basic visual science which underpin these applications.

The lab has expertise in eye movements and assessment of colour perception.

Project 1: Improving testing for blue cone colour vision deficiency

Colour vision testing is being modernised from pigmented paper tests to specialised computer programs. In order for these tests to be useful clinically and in an occupational setting they need to have their test-retest reliability and correlation with traditional colour tests investigated. There are currently no validation results for those with blue cone colour deficiencies. This study seeks to provide validation data for the Konan CCT-HD for blue cones in those with a colour vision deficiency.

Project 2: Eye movements in colour vision deficiency

Alterations in colour perception change the way we view the world, but does this change the way in which we interact with it? This project seeks to examine eye movements in those with dichromatic colour vision deficiencies to determine if the way they interact with visual scenes is altered.

Project 3: Effect of myopia control treatments on eye movements

Spectacle lenses specifically designed to control myopia are now available and being prescribed by Optometrists. The lens design includes a blur region in the mid-periphery of the lens. This project seeks to determine if this treatment alters eye movement behaviour.

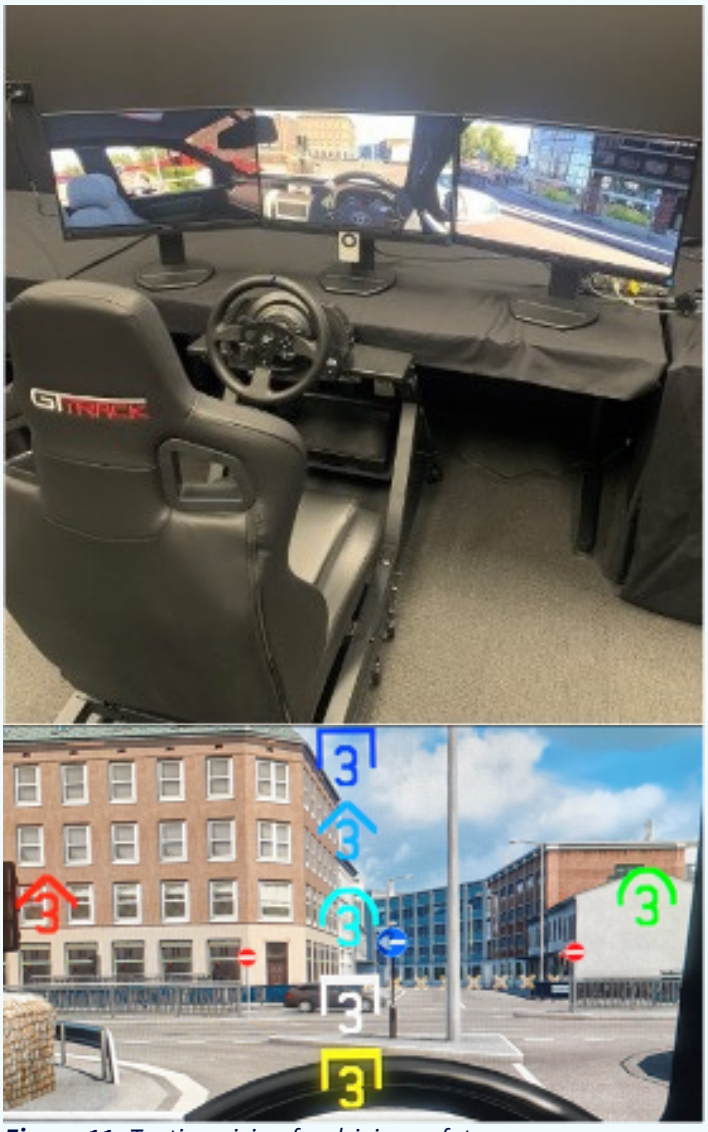

Figure 11. *Testing vision for driving safety.*

Recent related publications from our team:

1. Murphy TI, Abel LA, Armitage JA, et al. Effects of tracker location on the accuracy and precision of the Gazepoint GP3 HD for spectacle wearers. *Behav Res* 2024;56:43-52.
2. Coffey K, Abel L, Karas R, Gavrilescu M, Douglass A. Effect of laser eye protection devices on color perception. *J Opt Soc Am A Opt Image Sci Vis* 2023;40(3):A9-A15.

THE RETINAL OBSERVATORY

(Imaging cellular structure and function in the living human retina)

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The broad research aim of the Retinal Observatory is to observe the structure and function the living retina on the microscopic scale, so as to figure out what it is doing and how. We work collaboratively with other groups in the Department and throughout the University to observe how the retina works under normal circumstances, and how this becomes compromised in sight-debilitating diseases such as diabetes and inherited retinal degenerations. To achieve these aims, we combine a range of investigative tools including high-resolution non-invasive retinal imaging, psychophysics, and computational modelling.

Our current research projects make use of high speed, multi-spectral adaptive optics to visualize the smallest neurons and blood vessels that is possible to see in in living human eyes. We study the dynamics of blood flow and oxygen exchange at the level of individual red and white cells, and the cascade of optical and physiological events that occur when a photoreceptor interacts with light.

This requires a multi-disciplinary approach and so we welcome motivated students across **all fields** (e.g., **Mathematics, Physics, Computer Science, Engineering, Biology, Psychology**), who are interested in contributing to our innovative programs of research.

Project 1: Keeping the eye alive: characterizing the pulsatile nature of single red and white blood cell flow through retinal capillary networks

With newly-developed adaptive optics (AO) retinal imaging, it is now possible to visualise the finest capillaries in the eye and watch the passage of single red and white blood cells through its fine web of vascular pipes. These are the networks that keep your retina healthy, and which fail in diseases such age-related macular degeneration and diabetes. The exact details of blood flow patterns have not yet been fully documented – even in healthy eyes – because blood flows very quickly. Also, because the retina is designed to be transparent, it has been difficult to obtain high contrast images without risking light damage. However, with the recent lifting of these technical issues, a novel project emerges to characterize aspects of normal flow such as: cell deformability during flow; variation in flow velocity through different parts of the network; and the influence of the cardiac cycle on flow pulsatility.

This project would suit Honours Students and Graduate Researchers who wish to learn about and apply optical and image processing skills to questions of basic human physiology with immediate clinical applicability.

Project 2: Wiring the retina for human vision - a single-cell behavioural approach

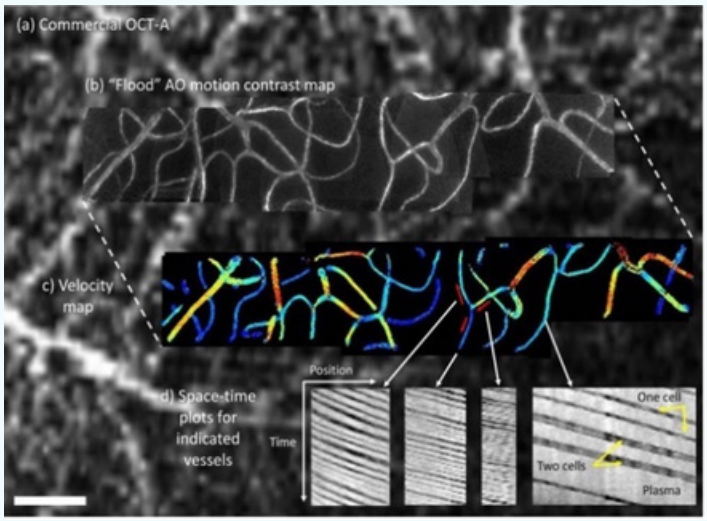

Figure 12: *Tracking single-file blood cell flow though the retinal capillary network*

The normal human retina is tiled with a mosaic of about 110 million rods and 6 million cone photoreceptors of 3 types that are sensitive to long (L), middle (M) and short (S) wavelengths of light. These 116 million photoreceptors converge to a mere 1 million axons that form the optic nerve connecting the eye and brain. The retina itself is responsible for much more than image detection, but is involved in substantial processing of visual information as well!

Using psychophysical methods to record behavioral responses to stimulating either single cells or specific cell arrangements, this project aims to establish precisely how signals from 3 types of cone photoreceptor are organised within the receptive fields of retinal ganglion cells whose fibers exit the eye, and how this impacts the information conveyed for spatial and colour perception.

Project 3: Improving the efficiency, accuracy and robustness of human visual performance measures

Measurements of human visual performance are important both to understand the basic science behind vision and for diagnosis of blinding eye diseases. The methods currently used to measure visual performance in the clinic and laboratory are time-consuming, which limits the amount of information that can be gained in a given test session.

This Honours project will evaluate the use of alternate testing strategies designed to improve test efficiency, and determine whether such improvements can be obtained whilst avoiding the introduction of inaccuracy or bias. Specifically, the project asks whether: **1)** the reported degree of certainty of participant's responses be used to determine visual threshold more quickly than assessing the accuracy of responses alone; and **2)** the degree to which cueing participants to direct their attention to a smaller part of the visual field can improve the reliability of their responses. This information may have immediate clinical applicability for improving standard clinical perimetry (visual field testing) for diseases such as glaucoma and maculopathy, and also for making more efficient laboratory investigations of precise retinal cell sensitivity.

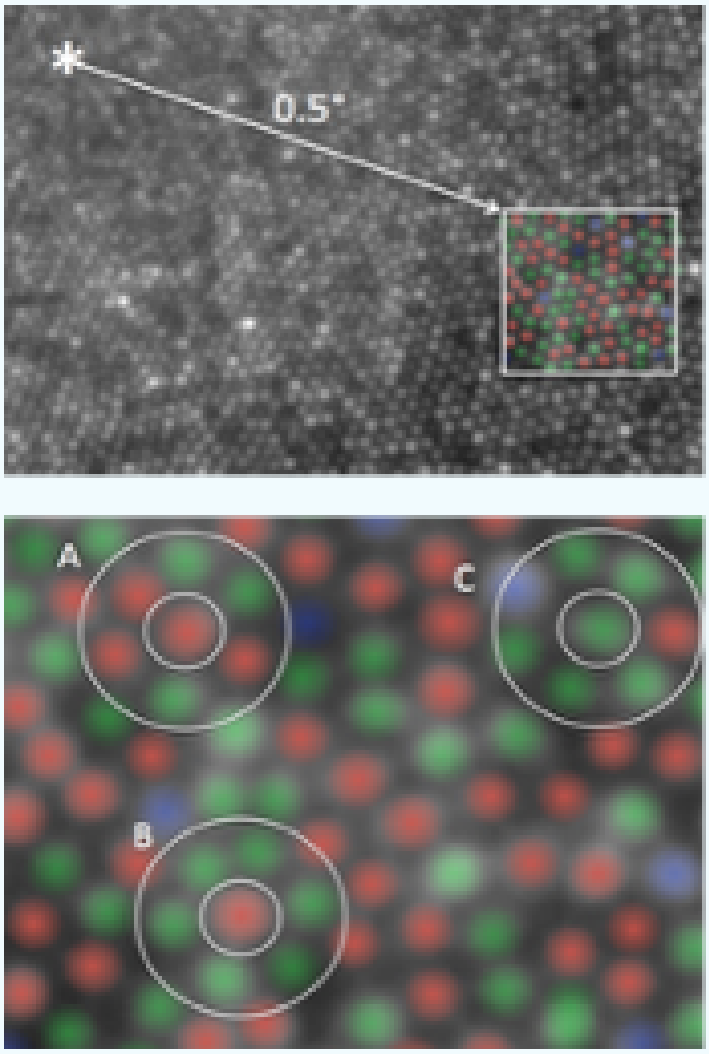

Figure 13: *Targeting single cone photoreceptors to investigate inputs to midget ganglion cells.*

Recent related publications from our team:

1. Bedggood, P., & Metha, A. (2020). Adaptive optics imaging of the retinal microvasculature. *Clin Exp Optom* 103(1): 112-122.
2. Duan, A., Bedggood, P. A., Metha, A. B., & Bui, B. V. (2017). Reactivity in the human retinal microvasculature measured during acute gas breathing provocations. Sci Rep 7(1), 2113.
3. Bedggood, P., & Metha, A. (2013). Optical imaging of human cone photoreceptorsdirectly following the capture of light. *PloS One* 8(11).

VISUAL AND COGNITIVE NEUROSCIENCE LABORATORY

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Our laboratory is interested in understanding the neural basis of visual perception, attention, memory, how they affect complex functions such as reading, and their relations to diseases such as migraine. We are also investigating surprising ways in which light can modulate neuronal circuits regulating bodily functions in sleep and wakefulness and applying that to create a better way to address conditions such as epilepsy and depression. To these ends, we use a variety of techniques to study the brain in humans and living animals, including electrophysiological methods to measure neuronal activity and behavioural studies.

In these studies, we use a combination of single electrodes, multi-electrode arrays and optical imaging of intrinsic signals to examine responses of individual neurons and groups of neurons and interactions between brain regions.

Project 1: Functional microcircuitry of the visual cortex and formation of migraine aura

In our lab, we have examined over the years the microcircuit of the visual cortex in cats and macaques, to understand how the brain makes sense of and interacts with the external world.

We now aim to apply this information to assess differences in visual perception between migraine patients and healthy controls to improve understanding of migraine-related visual disturbances.

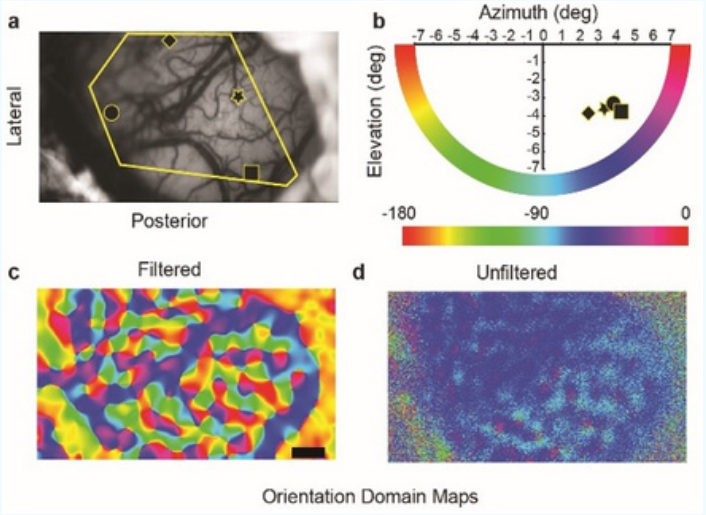

Figure 14. *Imaging and functional studies to understand how vision is organised in the brain.*

The primary visual cortex is organized to process various orientations of visual stimuli, transforming a bias for radial orientations (i.e., for contours pointing to the fovea) in its retino-thalamic inputs into a broad spectrum of preferred orientations. This transformation is presumed to rely on effective intracortical inhibition. In migraine patients, a deficiency in intracortical inhibition has been hypothesized to limit this capacity, resulting in abnormal perception during visual aura that often precedes the headaches. A common aura is a set of zig-zag lines ('fortifications') that seem dominated by the radial orientations and its orthogonal orientations.

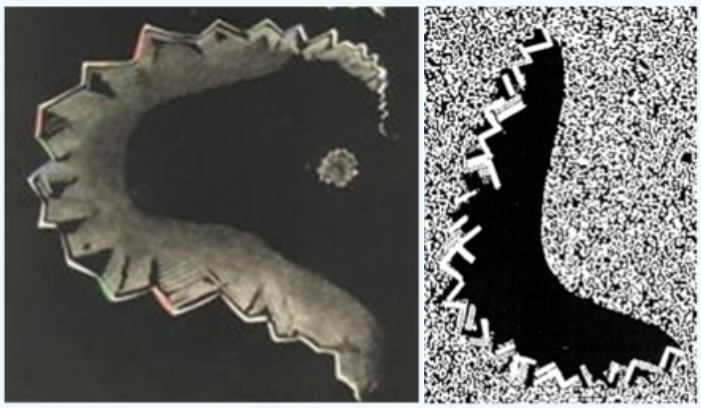

Figure 15. *Zig-zag lines, known as 'fortifications' are some of the typical visual auras that are reported in migraine. The one on the left was done by Airy (1865). The one on the right is from Grüsser and Landis (1991). The auras typically start at the fovea and move out to the periphery.*

The project aims to assess differences in orientation perception between migraine patients and healthy controls in central vision and the periphery. This study may provide insight into the link between cortical inhibition, orientation sensitivity, and visual aura in migraine, critically evaluating a novel mechanistic hypothesis and potentially leading to improved understanding of migraine-related visual disturbances.

Project 2: Role of a class of special light sensitive cells in the retina in epilepsy modulation

Light regulates our circadian rhythm by engaging a type of retinal cells - intrinsically photosensitive retinal ganglion cells (IPRGCs). These cells transmit information regarding the light exposure to the brain area which regulates circadian rhythm – the suprachiasmatic nucleus.

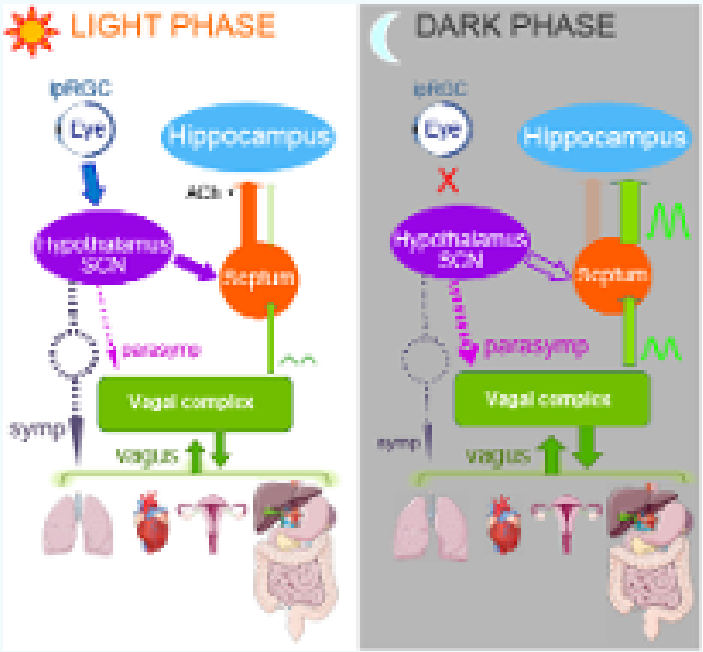

Figure 16. *Light can possibly modulate development of hippocampal seizures.*

Interestingly, the circadian signals driven by the ipRGCs arrive also in parts of the brain that receive visceral inputs via the autonomic nervous system - in particular in hippocampus. This provides a basis for why some cases of pharmacoresistant epilepsy arising in hippocampus can be treated by electrical stimulation of the vagus nerve (VNS), the nerve carrying information between the internal organs and the brain. However, mechanisms of VNS actions are largely unknown. We have developed a model (see Fig 16) that explains the propensity of hippocampal of seizures to occur in sleep and why VNS can abort them. We aim to study response to different VNS patterns in the brain areas involved in regulation of bodily functions, and test how light exposure modulates these responses. We aim to develop a system that can predict and improve VNS effects in the brain.

Selected related publications from our team:

1. Esghaei M, Treue S, Vidyasagar TR. (2022) Dynamic coupling of oscillatory neural activity and its roles in visual attention. *Trends in Neurosci*. 45(4):323-335.
2. Vidyasagar, T. R., & French, C. (2025). A Novel Framework Linking Cortical Circuitry, Visual Auras, Neurovascular Coupling and Migraine. *Preprints*, 202505.0236.v1. https://doi.org/10.20944/preprints202505.0236.v1
3. Levichkina E, Kermani M, Saalmann YB, Vidyasagar TR. (2021) Dynamics of coherent activity between cortical areas defines a two-stage process of top-down attention. *Exp Brain Res.* 239, 2767-2779.
4. Mohan YS, Jayakumar J, Lloyd EKJ, Levichkina E, Vidyasagar TR. Diversity of Feature Selectivity in Macaque Visual Cortex Arising from a Limited Number of Broadly Tuned Input Channels. *Cereb Cortex*. 2019 Dec 17;29(12):5255-5268.
5. Vidyasagar TR & Pammer K. (2010) Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. *Trends Cognitive Sci*. 14(2):57-63.
6. Saalmann YB, Pigarev IN, Vidyasagar TR. (2007) Neural mechanisms of visual attention. *Science* 316: 1612-1615.
7. Levichkina, E., Grayden, D. B., Petrou, S., Cook, M. J., and Vidyasagar, T. R. (2025). Sleep links hippocampal propensity for epileptiform activity to its viscerosensory inputs. *Front. Neurosci*. 19:1559529. doi:10.3389/fnins.2025.1559529

VISION OPTIMISATION LABORATORY

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Summary of lab interests: In recent years, there have been a number of interventions developed for vision loss and blindness. From gene therapy to bionic eyes, all treatments require thorough evaluation of visual function pre- and post-intervention, as well as an understanding of the impact of the treatments on a person's life.

Our team works on clinical vision and psychosocial assessments of people who receive such vision interventions. We have developed and run clinical studies for retinal prostheses (bionic eyes), gene therapy, and other low vision aids (including sensory substitution devices). Our aim is to ensure that every person is able to make the most of the vision they have.

The lab maintains strong collaborations with engineers, ophthalmologists, visual function experts and basic scientists globally to assist in the development of new treatments. This includes of membership of the Foundation Fighting Blindness global consortium.

Currently, we run several industry-sponsored clinical trials for inherited retinal disease (including gene therapy); design new software algorithms for electronic and audio-based low vision aids; develop novel imaging techniques to identify raised intracranial pressure and run natural history studies to identify biomarkers of retinal degenerative disease. Dr Britten-Jones leads a program on ocular genomics, investigating novel genetic testing methods (such as long read and genome sequencing) to better diagnose inherited retinal diseases.

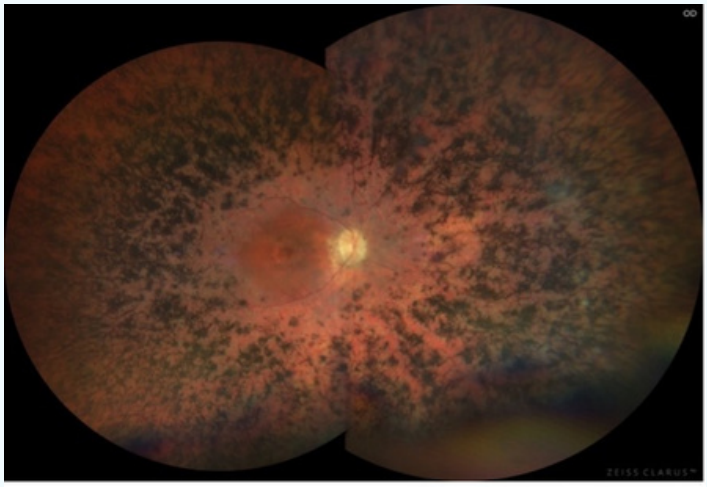

Figure 17: *A retinal fundus photo of a person with X-linked retinitis pigmentosa, a form of inherited retinal disease that we focus on in our research.*

Project 1: Development of New Vision Tests for Vision Restoration Clinical Trials

This project, in collaboration with clinicians in the United Kingdom and ophthalmologists from the Centre for Eye Research Australia, will develop and validate new methods of measuring low vision in patients who may be eligible for treatments such as gene therapy and stem cells. At present, there is a lack of gold standard test protocols for low vision testing, and this project will provide important data on the validity of new tests.

Project 2: Natural History of Inherited Retinal Diseases (VENTURE Registry)

A large study in our group is focusing on the collection of data on the natural history of inherited retinal diseases in Australia and New Zealand. A number of research projects into imaging biomarkers, genotype/phenotype correlations and visual function measures in this population are available.

Project 3: Stickler syndrome

In collaboration with Dr Rosie Dawkins (Royal Victorian Eye and Ear Hospital), we are running a number of projects on a multi-system disease called Stickler syndrome. These clinical studies investigate how ocular and systemic features present in this syndrome and how genetic factors contribute to disease expression.

Project 4: Cerebrospinal fluid leak

In collaboration with Biomedical Engineering and colleagues in the Melbourne School of Health Sciences, we are interested in exploring the perspectives, behaviours, and understanding of conditions where intracranial pressure may be abnormal (as part of our device development work). This study will explore the awareness of cerebrospinal fluid leak among Australian allied health care professionals.

Recent related publications from our team:

1. Gocuk SA, Edwards TL, Jolly JK, McGuinness MB, MacLaren RE, Chen FK, Taylor LJ, McLaren TL, Lamey TM, Thompson JA, Ayton LN. Retinal characteristics of female choroideremia carriers: Multimodal imaging, microperimetry and genetics. *Ophthalmology Retina* 2024; Accepted 19 June 2024.
2. Jin R, Petoe MA, McCarthy CD, Stefopoulous S, Battiwalla X, McGinley J, Ayton LN. Functional performance of a vibro-tactile sensory substitution device in people with profound vision loss. *Optometry and Vision Science* 2024; Accepted 1 May 2024.
3. Britten-Jones AC, Ayton LN, Graydon K, Boyce JO, Braden R, Dawkins R, Cham KM and the Stickler Syndrome Awareness Study Group. Clinician awareness of Stickler syndromes among Australian allied health professionals. *Journal of Multidisciplinary Healthcare* 2024; Accepted 8 April 2024.
4. Britten-Jones AC, McGuinness MB, Chen FK, Grigg J, Mack HG, Ayton LN. A multinational survey of potential participant perspectives on ocular gene therapy. *Nature Gene Therapy* 2024; Accepted 13 March 2024.
5. Johansen L, O'Hare F, Shepard ER, Ayton LN, Pelentsov LJ, Kearns LS, Galvin KL. Exploring the support needs of parents of young children with Usher syndrome: A qualitative approach. *Orphanet Journal of Rare Diseases* 2024; Accepted 4 March 2024.
6. Britten-Jones AC, Schultz J, Mack HG, Kearns LS, Huq AJ, Ruddle JB, Mackey DA, Hewitt AW, Edwards TL, Ayton LN. Patient experiences and perceived value of genetic testing in inherited retinal diseases: A cross-sectional survey. *Scientific Reports* 2024; Accepted 1 March 2024.

NATIONAL VISION RESEARCH INSTITUTE, AUSTRALIAN COLLEGE OF OPTOMETRY

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Project Supervisors

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Summary of lab interests: The core goal of NVRI work is to identify problems and create solutions that can improve eye care, access to eye care, and/or vision outcomes (functional and quality of life). Serving this goal, we work on 5 themes: epidemiology, health economics, improving children's vision, improving vision in complex/vulnerable communities, and eye care education.

Project 1: Describing the impact of ACO Eye Health and the Victorian Eyecare Service

There is very little evidence quantifying the value of optometry within any community. How often do we prevent or treat vision impairment from refractive or ocular health causes? What is the impact of managing a non-vision impairing condition such as dry eye or convergence insufficiency? How do we change systemic health management via comprehensive eye exams for people with diabetes and other conditions? The ACO has recently embarked on a data coding and patient reported experience/outcome measures (PREMs and PROMs) project that will enable more detailed answers to these and other critical questions in the Victorian community. This project will contribute to both the questions and the answers.

Project 2: Predicting community prevalence of eye/vision conditions from clinic data

The NVRI has recently been part of a consortium that completed the Australian Eye and Ear Health Survey – the most detailed population-based quantification of eye/vision and ear/hearing epidemiology ever. In addition to the rich, direct data on sensory health, the AEEHS also reinforced that large-scale population-based surveys are very expensive and declining in representativeness (community trust in governments and institutions has declined, translating to declining participation rates in surveys). Globally, the World Health Organization has adopted effective cataract surgical coverage and effective refractive error coverage as mandatory indicators – meaning all countries must report them. If every country invests in population-based research to quantify eCSC and eREC, that will divert a significant amount of funding to quantifying the problem that could (arguably, and particularly in resource-limited communities) be better spent on solving the problem. This project will contribute to models estimating community prevalence of eye/vision conditions from clinic data, which could potentially circumvent the need to choose between either data OR solutions, by enabling both.

Project 3: Designing, optimizing and measuring eye care interventions and their impacts in the humanitarian settlement journey in Victoria

The ACO has a number of collaborations with organisations who work with refugees and asylum seekers. We, and the organisations we work with, believe that providing eye care to those who need it is an essential part of the humanitarian settlement journey. It can facilitate access to learning language, education that is provided to help people adapt to their new situations, and community engagement, leading to improved outcomes. However, none of these programs

have assured, long-term funding, making them vulnerable to yearly budgeting decisions. This project has several stages. We have a basic service design (with multiple years of data). We are currently optimizing service delivery via a co-design project with communities. Next, we are seeking to measure eye care interventions in these communities – do they have the same refractive and eye health profile and needs as the rest of the Victorian community? Then we will measure the impact of eye care interventions on the humanitarian settlement journey via mixed quantitative/qualitative methodology.

Recent related publications from our team:

1. Lee L, De Angelis L, Barclay E, Tahhan J, Saunders K, McConnell L, Ghorbani-Mojarrad S, Dahlmann-Noor A, Jaselsky O, Leveziel N, Bremond-Gignac D, Resnikoff S, Fricke T. Factors affecting the lifetime cost of myopia and the impact of active myopia treatments in Europe. *Am J Ophthalmol* 2025;278:212-221.
2. Bourne RRA, Cicinelli MV, Fricke T, et al; Vision Loss Expert Group of the Global Burden of Disease Study. Effective refractive error coverage in adults: a systematic review and meta-analysis of updated estimates from population-based surveys in 76 countries modelling the path towards the 2030 global target. *Lancet Glob Health* 2025.
3. Cardona M, Lee L. Eye care interventions that reduce access inequities for women, rural residents and older people in low-middle-income countries. *Front Public Health* 2025;13:1578848.
4. Kha J, Macken L, Mitchell P, Liew G, Keay L, Waddell A, Yang J, Do T, Fricke T, Newall F, Gopinath B. The Australian Eye and Ear Health Survey (AEEHS): Study protocol for a population-based cross-sectional study. *PLoS One* 2024;19(5):e0301846.

RETINAL GENOMICS AND THERAPY LABORATORY

Laboratory Head and Project Supervisor

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Project Co-supervisors

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Summary of lab interests: Our lab focuses on understanding the cellular and molecular mechanisms behind photoreceptors degeneration in inherited retinal diseases, testing of novel treatment strategies, including gene therapy and neuroprotective drugs, and the effect of disease-causing mutations on retinal development. With a focus on cone photoreceptor health and disease mechanisms, we use unique mouse models of inherited retinal degeneration to elucidate the drivers of cone-mediated vision loss. Our long-term goal is to develop a comprehensive research program that will offer a roadmap for the molecular and cellular events behind the onset and progression of inherited retinal degeneration and help us develop more efficient gene therapy and neuroprotective treatment strategies.

Project 1: Targeting AMPK as a gene-agnostic treatment for inherited retinal diseases

The genetic, molecular, and clinical heterogeneity of IRDs presents a significant challenge for developing comprehensive treatments. Most ongoing clinical trials focus on gene-specific interventions, overlooking common disease pathways that could benefit multiple IRD types regardless of their genetic cause. By targeting a common disease pathway disrupted in photoreceptor degeneration, we can circumvent the need for 280+ individual gene therapies.

Our research and others have identified metabolic collapse as a common driver of photoreceptor loss across multiple IRDs. Research shows a metabolic shift in photoreceptors from aerobic glycolysis to oxidative phosphorylation preceding photoreceptor cell death in mouse and human IRD models. This led to the identification of a novel therapeutic target: the key energy sensor AMP-activated protein kinase (AMPK), which could potentially shift photoreceptor metabolism back to aerobic glycolysis. Preliminary data in our lab shows AMPK activation via drug treatment can preserve short-term photoreceptor survival and function in two IRD mouse models.

This project aims to:

1. Expand treatment modalities within the eye to assess prolonged AMPK activation on photoreceptor health,
2. Define the therapeutic mode of action of AMPK-targeting therapies.

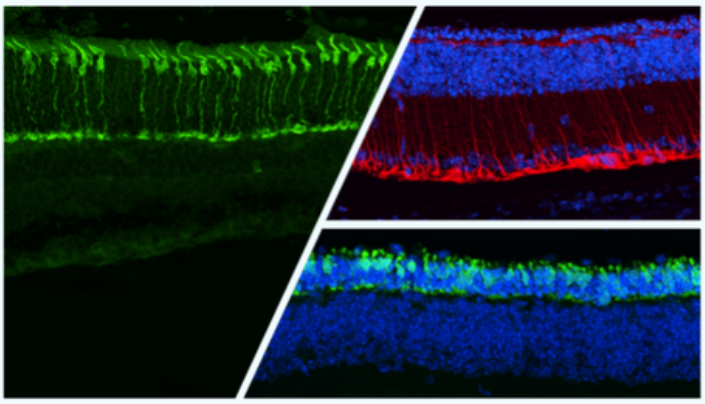

Figure 18. *Confocal microscopy images of mouse retinal sections showing (A) wildtype healthy cones; (B) IRD retina with active gliosis, and (C) IRD retina after treatment.*

Project 2: Identifying pyroptosis as the main culprit for cone degeneration in inherited retinal diseases

Inherited retinal disease (IRDs) are a diverse group of visual disorders that affect approximately 1 in 2,000 people worldwide and

are the leading cause of blindness in working-age adults. In Australia alone, it is estimated the economic burden of IRDs is $781 million to $1.56 billion [1]. Over 280 disease genes have been identified, with majority of mutations affecting rod and cone photoreceptors. Cones are essential for daylight vision, visual acuity, and colour visions, and their degeneration has the greatest impact on patients' quality of life. However, the cellular mechanisms underlying cone degeneration are poorly understood, severely impacting the advancement of developing therapies to save cones from dying. Pyroptosis is a relatively newer form of cell death that has been identified, with currently limited research linking pyroptosis to photoreceptor degeneration. Using mouse models of IRDs, our lab has identified upregulation of pyroptosis markers through transcriptomic sequencing. The proposed project aims to validate that pyroptosis is a key contributor to cone photoreceptor death in IRDs.

This project aims to:

1. Confirm pyroptosis activation during cone degeneration
2. Define the upstream triggers of pyroptosis activation in degenerating cones
3. Determine whether inhibition of pyroptosis attenuates cone degeneration

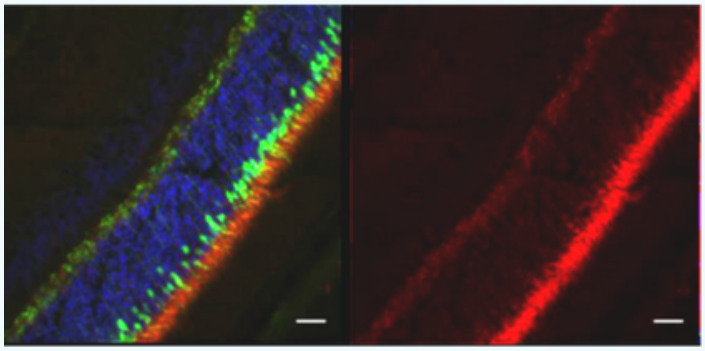

Figure 19. *HK2 staining (red) in outer segments of photoreceptors. Green shows cones*

Recent related publications from our team:

1. Miller AL, Fuller-Carter PI, Masarini K, Samardzija M, Carter KW, Rashwan R, Lim XR, Brunet AA, Chopra A, Ram R, Grimm C, Ueffing M, Carvalho LS, Trifunović D. Increased H3K27 trimethylation contributes to cone survival in a mouse model of cone dystrophy. *Cell Mol Life Sci.* 2022 Jul 10;79(8):409.
2. Brunet AA, Harvey AR, and Carvalho LS. (2021) Primary and Secondary Cone Cell Death Mechanisms in Inherited Retinal Diseases and Potential Treatment Options. *Int J Mol Sci.* 2022 Jan 10;23(2):726
3. Brunet AA, Hunt DM, Mellough C, Harvey AR, Carvalho LS. (2021) Compensatory Cone-Mediated Mechanisms in Inherited Retinal Degeneration Mouse Models: A Functional and Gene Expression Analysis. *Adv Exp Med Biol;* published 19 Jul 2023
4. Brunet AA, Fuller-Carter PI, Miller AS, Voigt V, Vasiliou S, Rashwan R, Hunt DM, Carvalho LS. (2020) Validating fluorescent Chrnb4.EGFP mouse models for the study of cone photoreceptor degeneration. *Translational Vision Science & Technology*, 2020 Aug 18;9(9):28.
5. Carvalho LS, Xiao R, Wassmer S, Langsdorf A, Zinn E, Pacouret S, Shah S, Comander JI, Kim LA, Lim L, Vandenberghe LH. (2018) Synthetic adeno-associated viral vector efficiently targets mouse and non-human primate retina in vivo. *Hum Gen Ther.* 29(7).
6. Carvalho LS, Xu J, Pearson RA, Smith AJ, Bainbridge JW, Morris LM, Fliesler SJ, Ding XQ & Ali RR. (2011) Long-term and age-dependent restoration of visual function in a mouse model of CNGB3-associated achromatopsia following gene therapy. *Hum Mol Genet*, 20(16):3161-3175.

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Poster Day

See posters showcasing the latest research and collaborative work from our Department, and speak to our team.

Monday 8 September 2025, 12.30-2.00pm

Ground Floor, Kenneth Myer Building, 30 Royal Parade Parkville.

Research Projects 2026

(Honours, Masters and PhD)

Department of Optometry and Vision Sciences

THE UNIVERSITY OF MELBOURNE