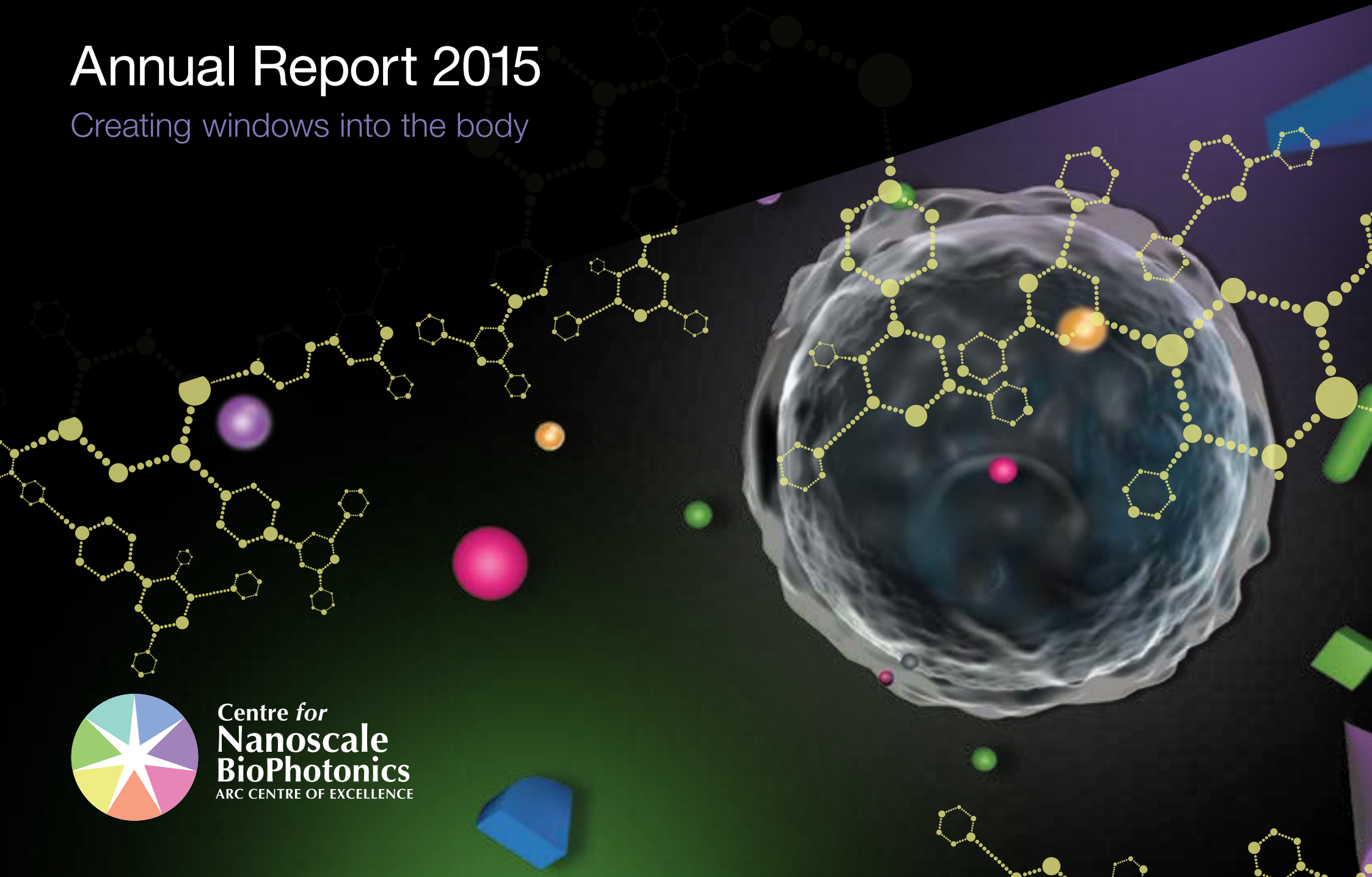


# Annual Report 2015

Creating windows into the body



Centre for  
**Nanoscale  
BioPhotonics**  
ARC CENTRE OF EXCELLENCE

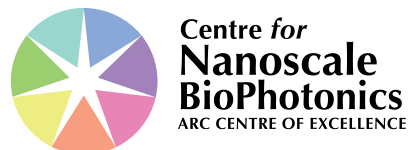


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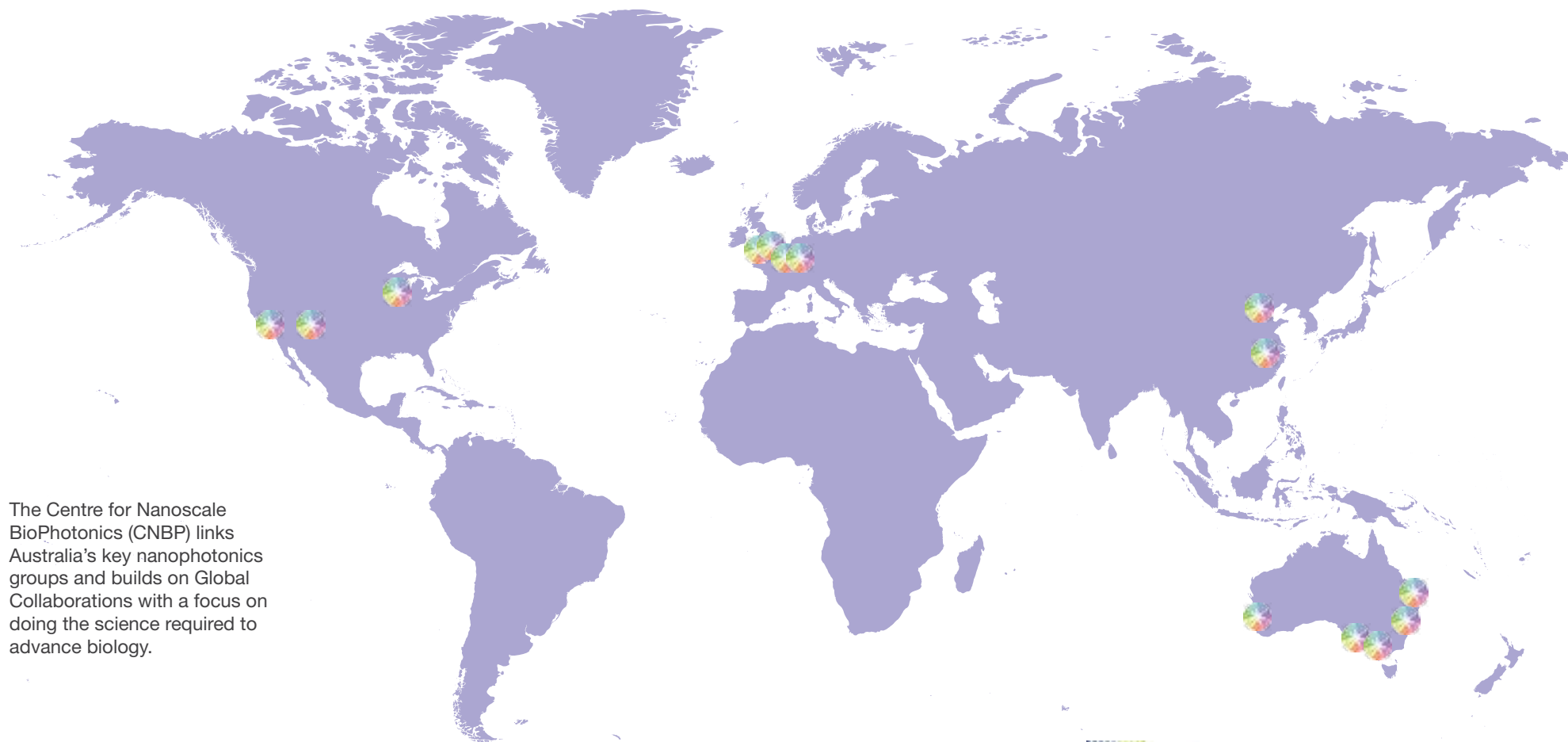
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As ambitious as man's flight to the moon, our journey is to an inward universe, inside the human body—at the nanoscale—with the power of light. This is a journey that will be truly transformational.

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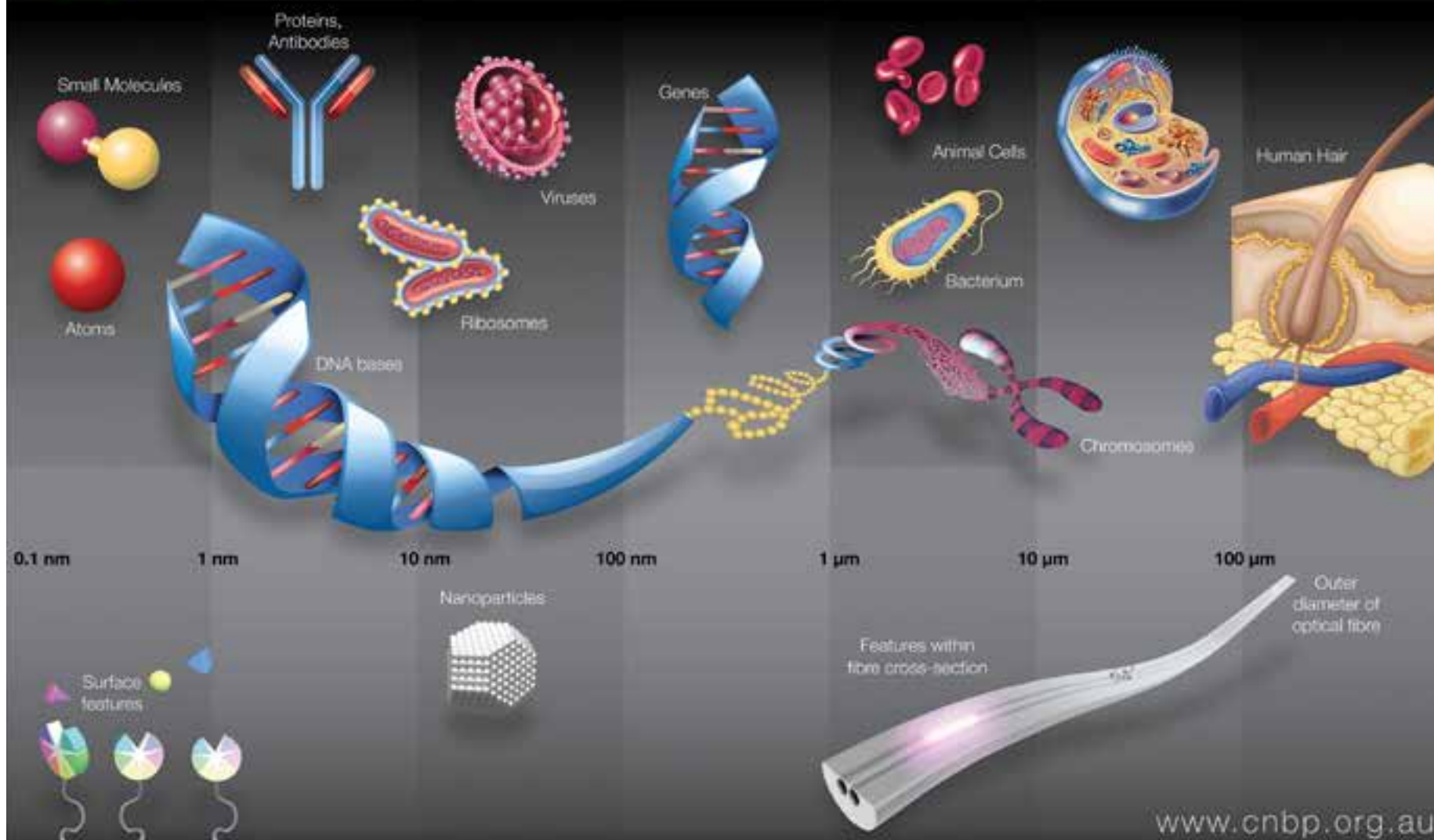
Australian Government  
Australian Research Council

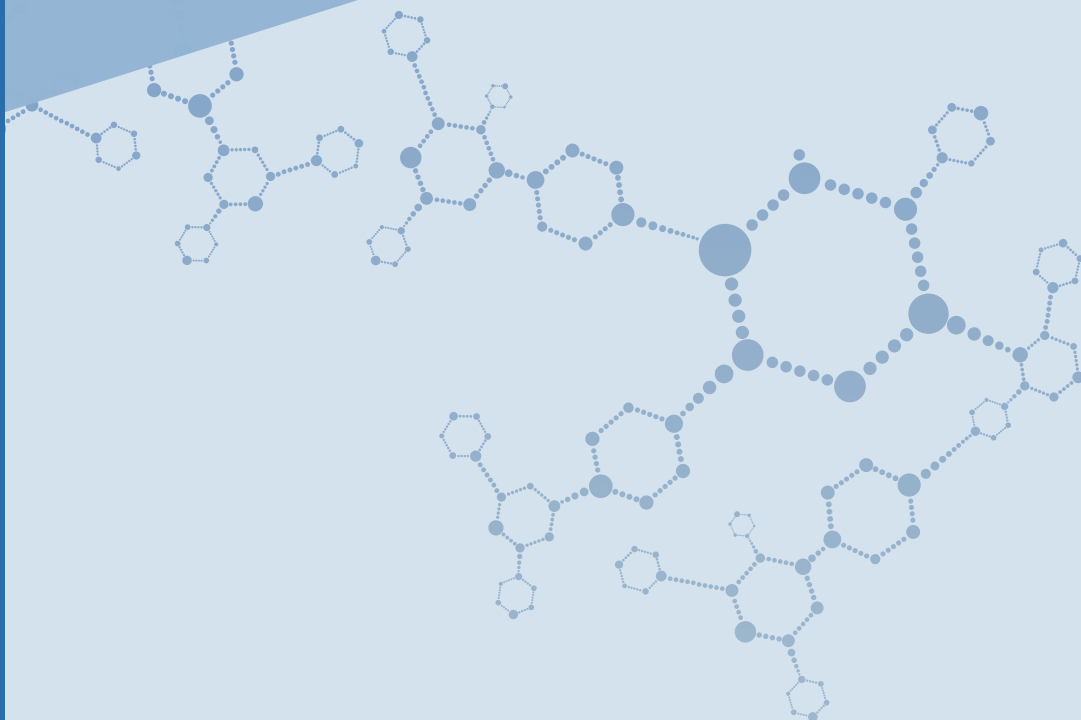


The Centre for Nanoscale BioPhotonics (CNBP) links Australia's key nanophotonics groups and builds on Global Collaborations with a focus on doing the science required to advance biology.



# A matter of scale



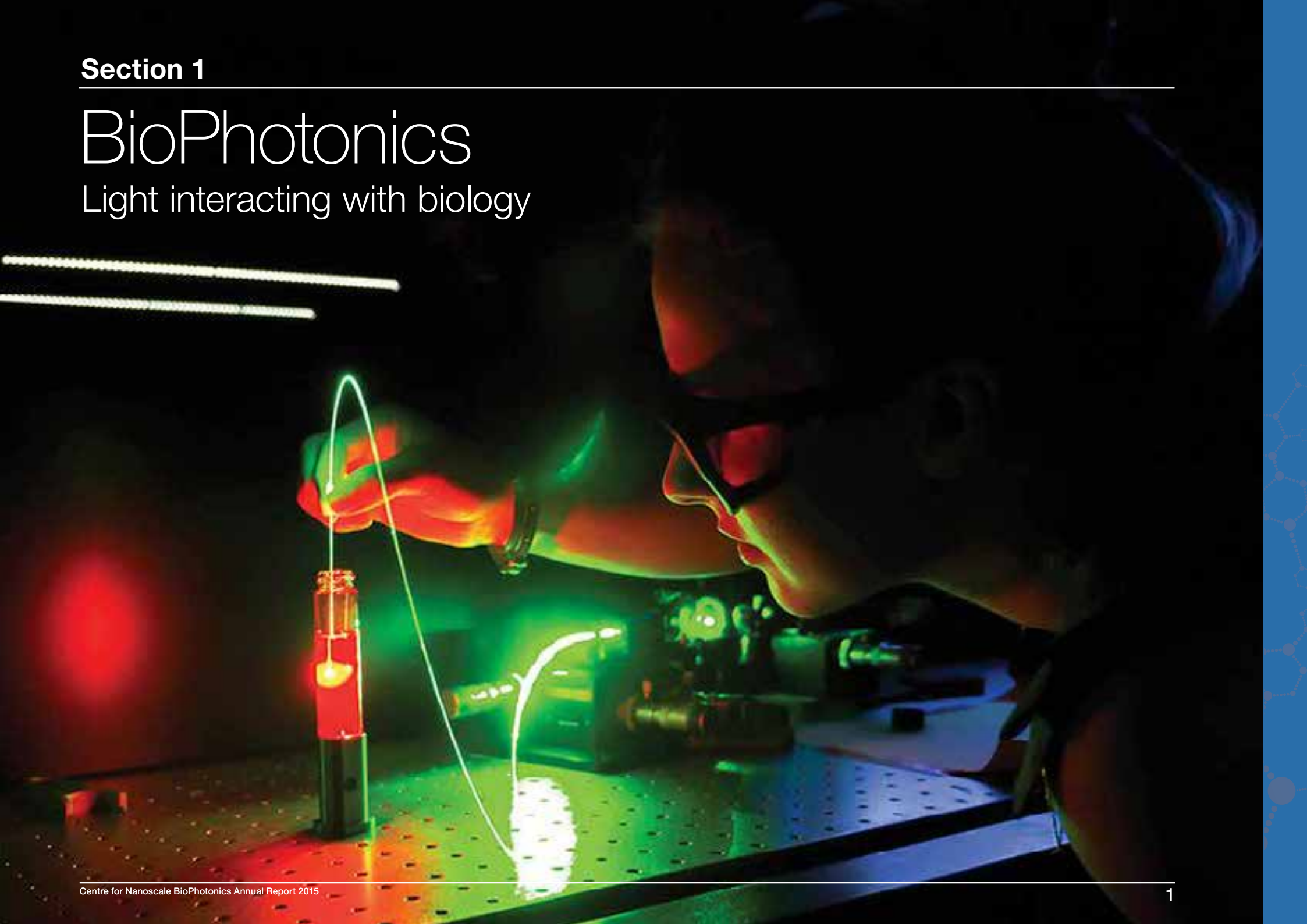


## Section 1

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# BioPhotonics

Light interacting with biology



## Director's report

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CNBP technologies and new knowledge will service multiple markets, from outback farms in animal production through to rural doctors treating their patients.



Prof. Mark Hutchinson, Director, CNBP

Welcome to the annual report of the Australian Research Council Centre of Excellence for Nanoscale BioPhotonics for 2015, a highlights package of our exciting scientific journey. In just our second year, 2015 continued to deliver an array of amazing firsts for our Centre and the consolidation of exciting activities from our inaugural year.

Within the science program of the CNBP we are asking questions at the nanoscale. For it is at the nanoscale that we can begin to guide light to interact with biology. It is at the nanoscale that we can create light where we need it. It is at the nanoscale that we can observe life beginning, watch the triggers of pain being activated, and heart disease evolving. I am very excited about the work conducted in our Centre in 2015 and what we have in store for the coming years.

Our first cohort of Centre postdoctoral scientists has been appointed and they are conducting breathtaking science. Many projects have matured beyond their infancy, with the growth of new Centre-generated publications flowing through during the year. It is exciting and encouraging to see these young inspiring scientists engaging across geographic, academic, language, scientific and knowledge boundaries to forge new programs of research activity, only possible in a dynamic and supportive environment like that of our Centre. An excellent example of the rapid translational impact of the CNBP scientific program is the licensing of CNBP

technology to Regeneus Ltd, derived from the Macquarie node, involving transdisciplinary collaborations across multiple nodes and scientific themes. This growth in academic excellence and commercial impact within the CNBP will be bolstered during 2016 with the addition of a new Chair of BioPhotonics joining the scientific team at the University of Adelaide.

Throughout 2015 we engaged extensively with our international partner organisations, triggering CNBP partner launches at: the South Australian Health and Medical Research Institute, CSIRO, Bioplatforms Australia, Olympus Australia, Heraeus Quarzglas in Germany, City University London, Huazhong University of Science and Technology, University of Southampton, and Peking University. Launches for our other international partners are planned for 2016. Additionally, we had the opportunity to launch the Centre at our nodes at Macquarie University and RMIT University. These launches were amazing events, with over 400 attendees at each, including representatives of the State Government, industry, members of the University communities and the general public.

Our CNBP scientists have featured heavily in the public domain for their outstanding academic and translational activities. Chief Investigators Prof. Jin Dayong and Prof. Tanya Monro, and the team from Minomic International, were jointly awarded the 2015 Eureka prize

### I would like to congratulate all of the Centre's personnel for a highly successful and productive year.

for Excellence in Interdisciplinary Scientific Research. Early-Career Researcher Hannah Brown was awarded the South Australian Young Investigator Award and Prof. Nicolle Packer was recognised through Macquarie University's 2015 Award for Excellence in Research—Innovative Technologies. These highlights, and the many other communication and outreach activities conducted in 2015, have seen the public profile of our new Centre grow, with an increasing appreciation for what nanoscale biophotonics is, and the opportunities our research provides in both academic and industry domains.

The second Centre scientific retreat at Lake Macquarie was a resounding success, with over 90 Centre scientists, Associate and Partner Investigators in attendance for the three-day event. The retreat drew upon the strengths of our international partnerships and blended rapid scientific updates with team building, speed networking, in-depth scientific discussions, professional development and mentoring. Once again, the retreat highlighted and strengthened the vibrant culture and nurturing environment we're providing for our scientists across all levels.

Two years into the CNBP our four key principles of Academic Excellence, Commercial Impact, Quality Communication and a Nurturing Environment have grown from an organisational initiative into meaningful actions. This can be seen in our amazing science programs.

But it also has been exemplified in the way that we have conducted this science through communication channels few use, such as directly engaging with our federally elected representatives. Importantly, our work continues to be externally motivated, with even closer ties with our current and future commercial partners to create disruptive technologies. As I have stated many times, the CNBP's technologies and new knowledge will service multiple markets, from outback farms in animal production through to rural doctors treating their patients. Our vision is to create economic and social value for all our communities and multiple industry sectors. Our high-impact science publications from the past year will only be part of our outcomes from this research, with industry translation and commercialisation intentionally evolving and facilitated within the CNBP.

CNBP scientists are out in the community and in the media, educating and exciting others about our science. Our Centre continues to be one in which our scientists can openly share and test new, raw and cutting edge hypotheses, where our scientists are mentored and equipped with the skills to be the next generation of science leaders. This means we have an environment where we are encouraged to practise and to take the big risks that sometimes fail, so that when the once-in-a-lifetime opportunities come around we are already equipped with the necessary skills to succeed.

I would like to congratulate all of the Centre's personnel for a highly successful and productive year. Thanks to our wonderful CNBP leadership team for all their hard work in 2015. These are exciting times!

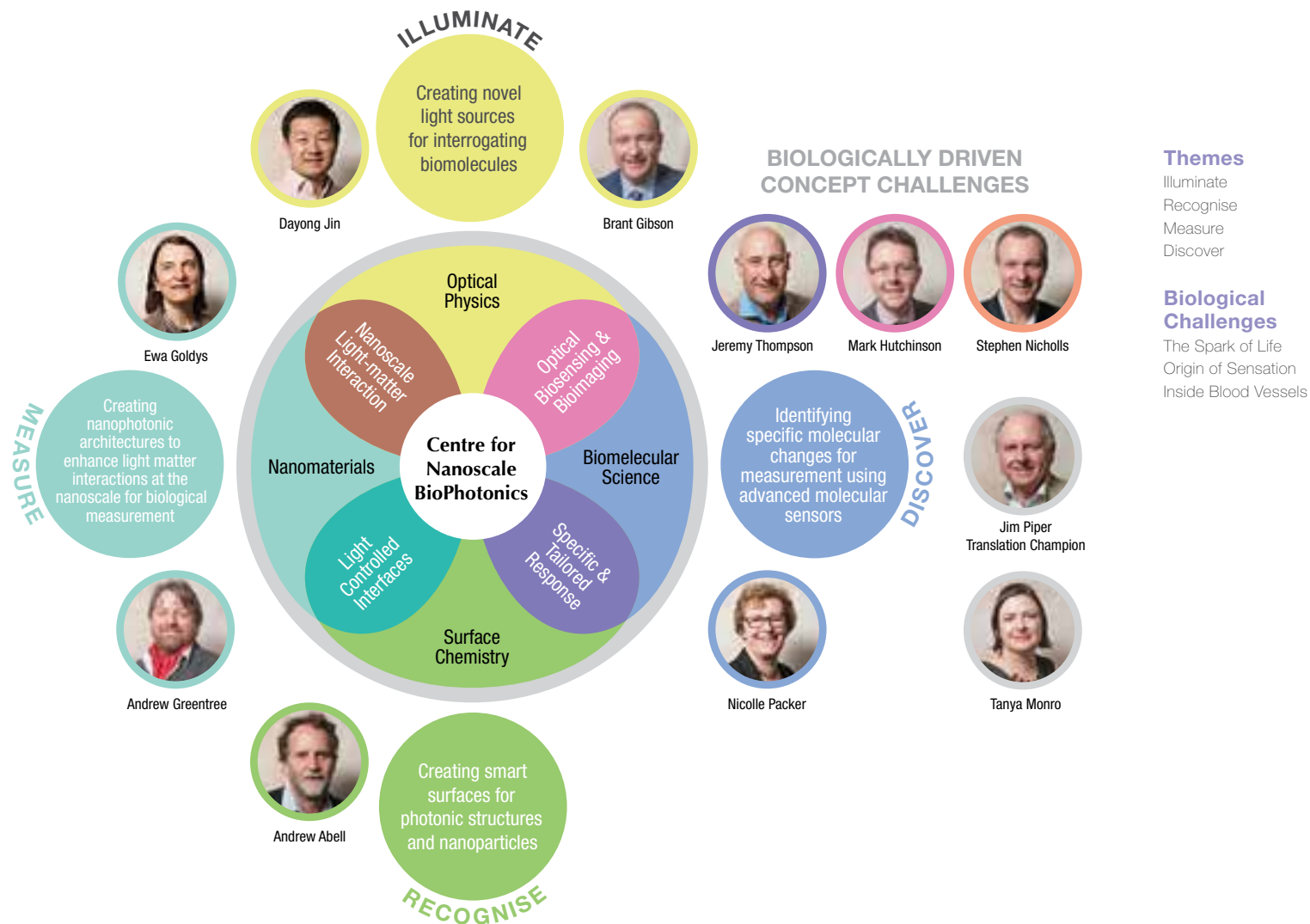


**Prof. Mark Hutchinson**  
Director, CNBP



# About us

Our vision will be delivered within four cross-connected science themes and three biologically driven challenges at the forefront of current research.



# Overview

CNBP researchers are driving the development of new devices to measure and sense at a nanoscale level—providing powerful new ways of understanding cellular processes within the human body.

## The broad objectives of the CNBP

1. Lead international research in nanobiophotonics—creating tools for understanding complex biological systems.
2. Empower and integrate fields of leading researchers across physics, chemistry and biology.
3. Pioneer approaches to transdisciplinary research training and nurturing entrepreneurship in emerging scientists.
4. Inspire children through to young adults to aspire to careers in science as a pathway to making a difference.
5. Engage with leading international centres and researchers to strengthen outcomes and raise the profile of Australian Research.
6. Seed industries by creating disruptive technology platforms and partnering with industry.

## The scientific aims of the CNBP

1. Reach the limits of light-based measurement within complex and dynamic biological environments.
2. Exploit physics and multiple scales—nanoscale to macro—using photons to bridge from nanomaterial to devices.
3. Create smart, tailored interfaces between these nanoscale systems and the biochemical environment.
4. Develop new ways to control molecular function in solution and on surfaces.
5. Establish new forms of assay measurement that can operate within living organisms.
6. Use these assays to study key problems associated with embryological development, and brain and blood vessel function.
7. Understand the molecular mechanisms, processes and functionalities in these biological systems.

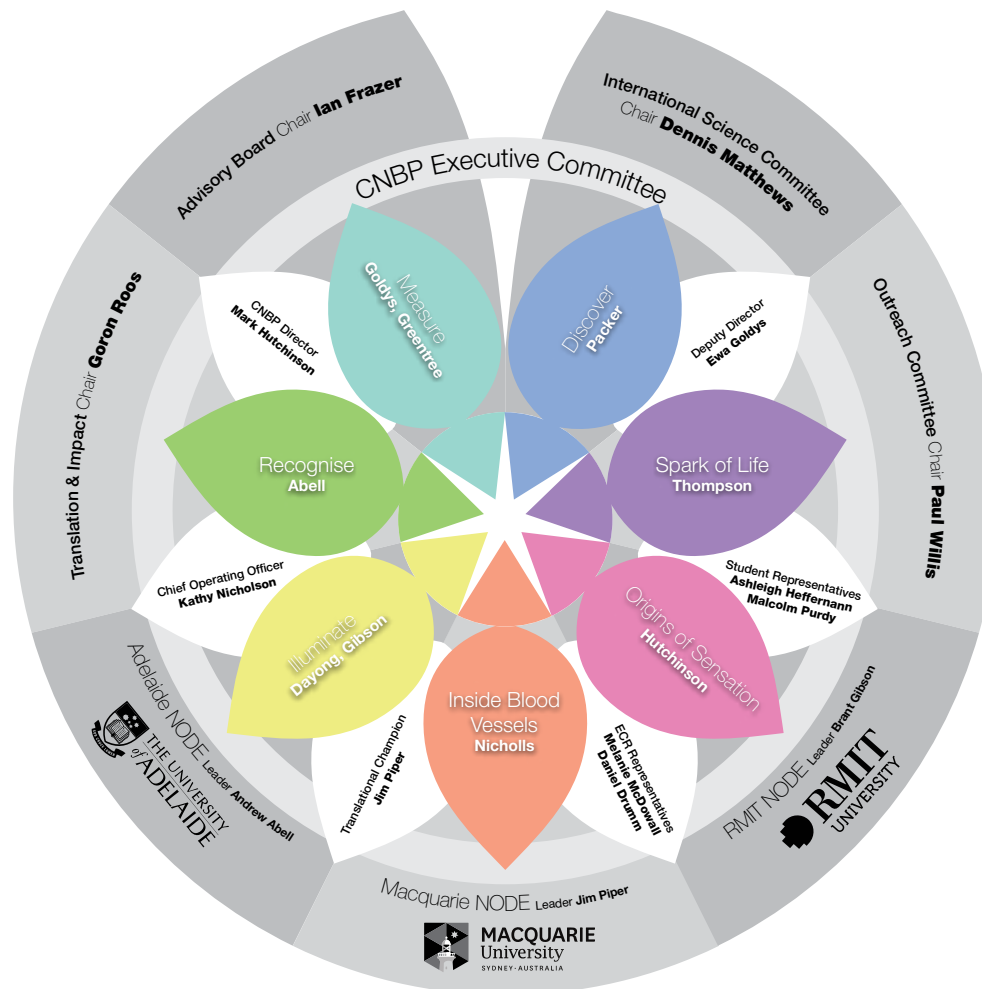
## CNBP values underpin all aspects of our work

- Academic excellence
- Commercial impact
- Quality communication
- A nurturing environment



## Structure and governance

The CNBP is a collaborative program with research focused within nodes at the University of Adelaide, Macquarie University and RMIT University.



The CNBP links into the broader Australian community through a selected web of Associate Investigators (AIs) from: University of Adelaide, Macquarie University, RMIT University, Melbourne University, Monash University, University of Technology Sydney, University of New South Wales and University of Western Australia.

The reach and capacity of the Centre will be enhanced by active links with Partner Organisations, providing Centre researchers with rich opportunities to work within leading international groups in areas that complement and extend the core capabilities in the Centre, both within Australia (CSIRO, SAHMRI) and overseas (Leibniz Institute of Photonic Technology, Peking University, Huazhong University of Science and Technology, University Health Network Toronto, Southampton University and City University London). Our corporate partners (Olympus Australia, Heraeus Quarzglas and Bioplatforms Australia) will help drive commercial outcomes from CNBP research.

A strong governance structure will enable us to marshal the enthusiasm and commitment of this team to the vision of the CNBP to pursue ambitious science goals.

# Executive Management Committee and Science Leadership Team

Regular meetings of the Executive Management Committee and Science Leadership Team ensure that Chief Investigators are actively engaged in all aspects of Centre activities.

The purpose of the Executive Management Committee (EMC) is to oversee all aspects of Centre activities. In addition, Senior Scientists work together as the Science Leadership Team (SLT) to oversee and steer the CNBP's scientific focus.

In 2015 the EMC met monthly, with meetings alternating between in-person and video conference. In-person meetings were scheduled across the nodes with accompanying science workshops.

The SLT met fortnightly via video conference, rotating content across the themes and challenges. Early- and mid-career researchers were invited to join for relevant meetings. SLT also provides professional development opportunities for Mid-Career Researchers (MCR), who are regularly asked to attend meetings on behalf of their team leader.



**Prof. Mark Hutchinson** (Chair) EMC & SLT

Director, Origin of Sensation Leader  
The University of Adelaide



**Prof. Ewa Goldys** EMC & SLT

Deputy Director, Measure Co-leader  
Macquarie University



**Emeritus Prof. Jim Piper** AM, EMC & SLT

MQ Node Leader  
Macquarie University



**A/Prof. Brant Gibson** EMC & SLT

RMIT Node Leader, Illuminate Co-leader  
RMIT University



**Heike Ebendorff** SLT

CNBP Senior Investigator  
The University of Adelaide



**A/Prof. Jeremy Thompson** EMC & SLT

Spark of Life Leader  
The University of Adelaide



**Prof. Andrew Abell** EMC & SLT

UA Node Leader, Recognise Leader  
The University of Adelaide



**Prof. Tanya Monro** EMC & SLT

The University of Adelaide  
University of South Australia

## Executive Management Committee and Science Leadership Team (continued)

“The technologies developed through the CNBP are likely to be paradigm-shifting in the development of the healthcare tools of the future, and I want to be involved in that process.”

—Professor Ian Frazer, Chair of the CNBP Advisory Boards



**A/Prof. Dayong Jin EMC & SLT**

Illuminate Co-leader  
Macquarie University



**Mr Ashleigh Heffernan EMC**

Co-Student Representative and CNBP  
Masters Student, RMIT University



**Dr Mel McDowall EMC**

Co-ECR Representative & CNBP Research  
Fellow, The University of Adelaide



**Mr Malcolm Purdey EMC**

Co-Student Representative and PhD  
Student, The University of Adelaide



**Dr Daniel Drumm EMC**

Co-ECR Representative & CNBP Research  
Fellow, The University of Adelaide



**Dr Kathy Nicholson (Secretary) EMC**

Chief Operating Officer  
The University of Adelaide



**Prof. Stephen Nicholls EMC & SLT**

Inside Blood Vessels Leader  
SAHMRI



**Prof. Andrew Greentree EMC & SLT**

Measure Co-leader  
RMIT University



**Prof. Nicolle Packer EMC & SLT**

Discover Leader  
Macquarie University

# Advisory Board

The Advisory Board works to strengthen CNBP linkages with academic, industry and government, identifying strategic engagement opportunities



**Prof. Ian Frazer (Chair)**

Director, Translational Research Institute  
University of Queensland



**Prof. Peter Nelson**

PVCR  
Macquarie University



**Mr Mick Reid**

Private Consultant



**Prof. Mark Hutchinson**

Director, CNBP  
The University of Adelaide



**Ms Catriona Jackson**

CEO  
Science Technology Australia



**Prof. Hugh Possingham**

Director ARC Centre of Excellence  
for Environmental Decisions (CEED),  
University of Queensland



**Prof. Michael Brooks**

DVCR  
The University of Adelaide



**Dr Paul Willis**

Director  
RiAus



**Dr Kathy Nicholson (Secretary)**

Chief Operating Officer, CNBP  
The University of Adelaide



**Prof. Calum Drummond**

DVCR  
RMIT University



**Prof. Goran Roos**

Advanced Manufacturing Board of SA

## International Science Committee

We are committed to ensuring that the CNBP engages in the very highest levels of scientific discovery and knowledge creation.

The purpose of the CNBP International Science Committee (ISC) is to advise on the strategic directions of the scientific endeavours of the Centre and support delivery of other Centre outcomes.

ISC members met at the 2015 SPIE Photonics West Conference (San Francisco), and the CNBP annual retreat. In addition, video conferences were hosted in July and December 2015. In 2016, ISC members will meet at SPIE BioPhotonics Australasia (to be hosted by CNBP in Adelaide), as well as the CNBP Annual Retreat.



**Prof. Dennis Matthews (Chair)**

Director, Centre of BioPhotonics,  
Science & Technology, UC Davis



**Prof. Mark Hutchinson**

Director, CNBP  
The University of Adelaide



**Prof. Katarina Svanberg**

Professor  
Lund University



**Prof. Paul French**

Professor  
Imperial College London



**Prof. Bob Grubbs**

Professor and Nobel Laureate  
Caltech



**Prof. Yafeng Guan**

Professor  
Chinese Academy of Sciences



**Prof. Francesco Pavone**

European Laboratory for  
Nonlinear Spectroscopy



**Dr Kathy Nicholson (Secretary)**

Chief Operating Officer, CNBP  
The University of Adelaide

# Education and Outreach Committee

We are passionate about nanotechnology and BioPhotonics, and aim to bring the wonders of science to the public with energy and enthusiasm.

## Education and Outreach Committee

Chaired by Dr. Paul Willis, our Education and Outreach Committee will guide CNBP researchers towards effective approaches to communicating the wonders of science to the broader community.

The committee met by video conference three times in 2015, with plans to continue regular meetings in 2016.



**Dr Paul Willis (Chair)**

Director  
RiAus



**Prof. Mark Hutchinson**

Director, CNBP  
The University of Adelaide



**Mr Mike Seyfang**

Private Consultant  
IT & Social Media



**Mr Nick Besley**

Senior Manager, Engagement  
RMIT University



**Dr Rachel Dunlop**

Medical Researcher  
and Sceptic



**A/Prof. Rod Lamberts**

Associate Director  
CPAS, ANU



**Mr Tony Crawshaw**

Communications and Outreach  
Coordinator, CNBP



**Dr Kathy Nicholson (Secretary)**

Chief Operating Officer, CNBP  
The University of Adelaide

## 2015 Centre personnel

THEME LEADER	CNBP RESEARCHERS	AFFILIATES AND AIs	STUDENTS - PhD	STUDENTS - MASTERS/HONOURS	VISITING FELLOWS
<b>ILLUMINATE</b>					
CI: Prof. Dayong Jin (UTS)	CI: Prof. Jim Piper (MQ)	Partner: Olympus (Jian Shen / Kim Everuss)	Yuijia Liu (MQ & Peking University)	Ashleigh Heffernan (RMIT) - Masters (2015)	
CI: A/Prof. Brant Gibson (RMIT)	A/Prof. Heike Ebendorff Heidepriem (UA)	PI: Peng Xi (Peking Uni)	Xianlin Zheng (MQ)	Elizabeth Camillieri (RMIT) - Masters (2015)	
	Dr Yong Liu (MQ)	AI: Prof. Dougal McCulloch (RMIT)	Deming Liu (MQ)		
	Dr Philipp Reineck (RMIT)	AI: Run Zhang (MQ)	Nafisa Zohonra (RMIT)		
	Roman Kostecki (UA)	AI: Yiquing Lu (MQ)	Zhihuang Zhou (MQ)		
	Dr Fan Wang (MQ)	Dr Xiaoxue (Helen) Xu (MQ) - nominated as AI	Lixin Zhang (MQ)		
	Dr Xue Bai (MQ)	Dr Bingyang Shi (MQ) - nominated as AI	Yunle Wei (UA) - 2015		
	Dr Alfonso Garcia Bennett (MQ)				
	Dr Anthony Orth (RMIT)				
	Xavier Vidal (MQ)				
	Denitza Denkova (MQ)				
	Lianmei Jiang (MQ)				
	Dr Desmond Lau (RMIT)				
	Thomas Lawson (MQ)				
<b>RECOGNISE</b>					
CI: Prof. Andrew Abell (UA)	Dr Sabrina Heng (UA)	AI: Jonathan George (UA)	Malcolm Purdey (UA) - (<2013)	Aimee Horsfall (UA) Masters (2015)	Dr Lina Geng (Hebei Normal University, China)
	Dr Jingxian Yu (UA)		Georgina Sylvia (UA) (2014)	Stephen Robert Kirby (UA) Honours (2015)	
	Dr Jenny Butler (UA)		Daniel Stubing (UA) - (<2013)	Aniket Kulkarni (UA) Honours (2015)	
	Dr John Horsley (UA)		Kwang Jun Lee (UniSA and Korea) - 2015	Yuan Qi (UA and Malaysia) Honours - 2015	
	Dr Xiaozhou (Michelle) Zhang (UA)		Dr Xiaozhou (Michelle) Zhang (UA)		
	Dr Victoria Peddie (UA)				
	Malcolm Purdey (UA) - (<2013)				

## 2015 Centre personnel (continued)

THEME LEADER	CNBP RESEARCHERS	AFFILIATES AND AIs	STUDENTS - PhD	STUDENTS - MASTERS/HONOURS	VISITING FELLOWS
<b>MEASURE</b>					
CI: Prof. Ewa Goldys (MQ)	CI: Prof. Tanya Monro (UA and UniSA)	Partner: Heraeus (Gerhard Schultz)	Anna Guller (MQ)	Irene Wilcocks (UA) Honours (2015)	Kai Zhang (CSC Fellow: Feb 2015 - Feb 2016)
CI: Prof. Andrew Greentree (RMIT)	A/Prof. Heike Ebendorff Heidepriem (UA)	PI: Brian Wilson (UHN, Canada)	Saabah Mahbub (MQ)	Michel Woy (UA) Masters (2015)	Christian Leiterer (DAAD Fellow: Jun 2014 - Jan 2016)
	Dr Georgios Tsiminis (UA)	PI: Yonggang Zhu (CSIRO)	Aziz Rehman (MQ) - (2014)	Xuanzhao Pan - Masters (2015)	Mushtaq Sobhan (Honorary fellow: May 2015)
	Dr Biju Clutus (MQ)	AI: Dr Varun Sreenivasan (MQ: MURF)	Tess Reynolds (UA)	Elizabeth Camilleri - Masters (2014)	Montarop Yamabhai (Endeavour Fellow: Mar - May 2015)
	Dr Daniel Drumm (RMIT)	AI: A/Prof. Shahraam Afar (UniSA)	Jonathan Hall (UA)	Yuan Qi Yeoh (UoA) - Honours Aug 2015	Jaimie Garcia (2015)
	Roman Kostecki (UA)	AI: Dr Alex Francois (UA)	Hong Ji (UA) - (2014)	Josef Worboys (RMIT) - undergraduate	
		AI: Tim Zhao (UA)	Kashif Islam (MQ)		
	Dr Erik Schartner (UA)	AI: David Inglis (MQ)	Sandhya Clement (MQ)		
	Dr Ivan Maksymov (RMIT)	Dr Nicolas Reisen (UA)	Zhara Kabir (MQ)		
	Dr Guozhen Liu (MQ)	Dr Martin Gosnell (MQ) (consultant)	Wan-Aziz Wan-Razali (MQ)		
	Dr Peipei Jia (UA)	AI: Wei Deng (MQ)	Wenje Chen (MQ)		
	Dr Yinlan Ruan (UA)		Piotr Wargocki (MQ)		
	Dr Ayad Anwer (MQ)		Meng He (MQ) - (2015)		
	Dr Herbert Foo (UA)		Fei (Felix) Wang (MQ)- (2015)		
			Kaixin Zhang (MQ) - (2015)		
<b>DISCOVER</b>					
CI: Prof. Nicolle Packer (MQ)	Dr Lindsay Parker (MQ)	Partner: BioPlatforms Australia (Andrew Gilbert)	Yu (Rain) Shi (MQ)		
	Dr Nicole Cordina (MQ)	AI: Peter Hoffman (UA)	Chris Ashwood (MQ)	Ishan Rastogi (MQ)	
	Dr Arun Dass (MQ)	AI: Dr Nima Sayyadi (MQ)	Luiien (Olivia) Liang (MQ)	Wei Ren (MQ)	
	Dr Andrew Care (MQ)	AI: Louise Brown (MQ)	Anna Guller (MQ)		
	Dr Adidali Mohamedali (MQ)	AI: Anwar Sunna (MQ)	Sameera Iqbal (MQ)		
			Shatali (Shaz) Abdulrahman (MQ)		

## 2015 Centre personnel (continued)

THEME LEADER	CNBP RESEARCHERS	AFFILIATES AND AIs	STUDENTS - PhD	STUDENTS - MASTERS/HONOURS	VISITING FELLOWS
<b>SPARK OF LIFE</b>					
CI: A/Prof. Jeremy Thompson (UA)	Dr Melanie McDowall (UA)		Hanna McLenna (UA) - 2015	Cheow Yuen Tan (UA) - Honours - 2014/15	
	Dr Hannah Brown (UA)			Emma Tregoweth (UA) - Honours 2015	
	Leslie Ritter (UA)			Mitchell Ross (UA) - Honours 2015	
<b>ORIGIN OF SENSATION</b>					
CI: Prof. Mark Hutchinson (UA)	Dr Sanam Mustafa (UA)	AI: Steven Maier (UC Davis)	Stefan Musolino (UA) - 2014		Jaime Garcia (2015)
	Vasiliki (Vicky) Staikopoulos (UA)	AI: Kevin Pfagler (UWA)	Jonathan Jacobsen (UA)		Yi Li
	Jacob Thomas		Azim Arman (UA) - 2015		
			JianJun (JJ) Li (UA) - 2015		
<b>INSIDE BLOOD VESSELS</b>					
PI: Prof. Stephen Nicholls (SAHMRI)	Dr Achini Vidnapthirana (UA & SAHMRI)	AI: Peter Psaltis (SAHMRI)			
	Dr Nisha Schwartz (UA & SAHMRI)	Affiliate: MyNgan Duong (SAHMRI)			
	Benjamin Pullen (UA & SAHMRI)				
	Dr Belinda Di Bartolo (SAHMRI)				

## 2015 Centre personnel (continued)

### CENTRE EXECUTIVE TEAM

Prof. Mark Hutchinson	Centre Director
Prof. Ewa Goldys	Centre Deputy Director
Dr Kathy Nicholson	Chief Operations Officer
Prof. Andrew Abell	Node Leader, The University of Adelaide
Emeritus Prof. Jim Piper AM	Node Leader, Macquarie University
A/Prof. Brant Gibson	Node Leader, RMIT University
Mrs Melodee Trebilcock	Business Development and Major Events Officer
Mr Tony Crawshaw	Communications and Outreach Officer
Mrs Sara Legatt	EA to the Director and Node Support, The University of Adelaide (Part Time)
Mrs Bronwyn Gibson	EA to the Director and Node Support, The University of Adelaide (Part Time)
Mrs Melanie Paull	Major Events and Node Support, The University of Adelaide (Part Time)
Mrs Leonie McKay	Node Support, Macquarie University
Ms Brooke Bacon	Node Support, RMIT University (Part Time)

### PARTNER INVESTIGATORS

Prof. Stephen Nicholls	Inside Blood Vessels Theme Leader, SAHMRI
Prof. Juergen Popp	Institute of Photonic Technology (IPHT) Jena
Prof. Sun Tong	City University London
Prof. Qingming Luo	Huazhong University of Science and Technology
A/Prof. Peng Xi	Peking University
A/Prof. Gilberto Brambilla	University of Southampton
Dr. Yonggang Zhu	CSIRO
A/Prof. Yujie Sun	Peking University, Beijing
Prof. Brian Wilson	University of Toronto
Prof. Steven Maier	The University of Colorado, Boulder

### ASSOCIATE INVESTIGATORS

Dr Alexandre Francois	The University of Adelaide
A/Prof. Andrei Zvyagin	Macquarie University
Dr Anwar Sunna	Macquarie University
Dr Bingyang Shi	Macquarie University
Prof. Bruce Hammock	UC Davis
Dr David Inglis	Macquarie University
Prof. David Gardner	University of Melbourne
Prof. Dougal McCulloch	RMIT University
A/Prof. Igor Aharonovich	University of Technology Sydney
Dr Jonathan George	The University of Adelaide
A/Prof. Kevin Pflieger	The University of Western Australia
Dr Louise Brown	Macquarie University
Prof. Marc Wilkins	The University of New South Wales
Dr Mark Prescott	Monash Uni
Dr Nima Sayyadi	Macquarie University
Prof. Paul Mulvaney	University of Melbourne
Dr Peter Hoffman	The University of Adelaide
Dr Peter Psaltis	SAHMRI
Mr Run Zhang	Macquarie University
Dr Shahraam Afshar	The University of South Australia
Prof. Steven Hill	University of Nottingham
Prof. Steven Weiderman	The University of Adelaide
Prof. Tiffany Walsh	Deakin University
Dr Tim Zhao	The University of Adelaide
Dr Varun Sreenivasan	Macquarie University
Ms Wei Deng	Macquarie University
Dr Xiaoxue (Helen) Xu	Macquarie University
Dr Yiqing Lu	Macquarie University



## Section 2

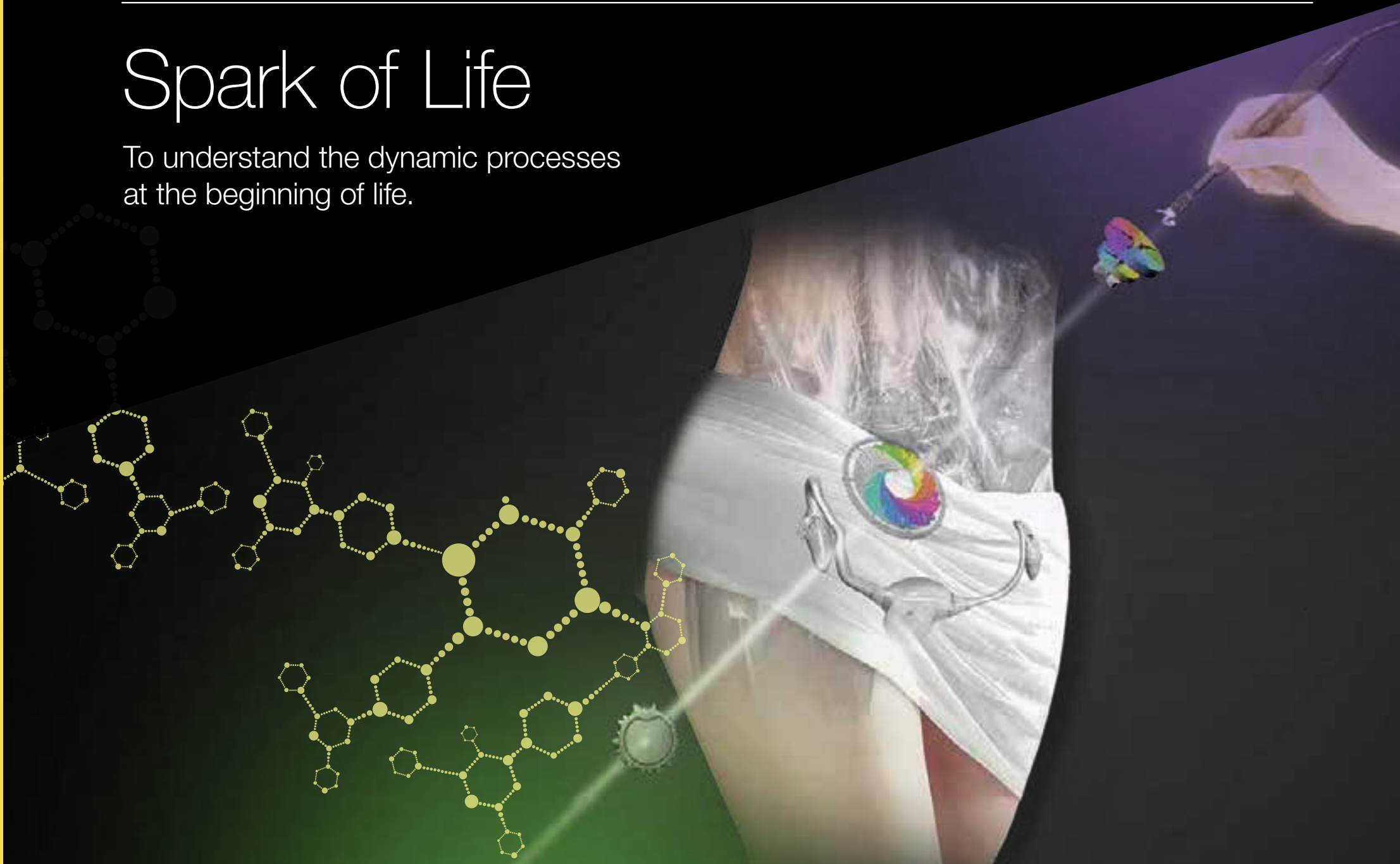
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# Research Themes

## Biological Challenge 1: Spark of Life

# Spark of Life

To understand the dynamic processes at the beginning of life.



## Challenge Leader: A/Prof. Jeremy Thompson



Spark of Life Biological Challenge Leader A/Prof. Jeremy Thompson

### Overview

Nanoscale BioPhotonics offers approaches to measuring ions and metabolites, DNA, RNA and associated proteins. This will reveal the causal pathways between maternal microenvironment and peri-conception programming, allowing us to work towards an improved understanding of the dynamic processes at the beginning of life.

### Summary

For all animals, life begins with an egg and sperm meeting within the reproductive tract. Each egg and sperm contains the genes that will shape much of the size, shape, appearance and health of a new life. Genes are therefore fundamental to the determination of the identity of a new individual, as the genetic code is a recipe for the developing life to form.

However, in many ways, the *environment* a developing new life encounters has a profound influence on determining the identity of the individual. In particular, we know that the environment within the mother's reproductive tract tinkers with the recipe, not by changing the code of genes, but by subtly adjusting when genes are turned off and on. We call this 'epigenetics', and it involves several different mechanisms that directly impinge on when genes are active and inactive.

This is especially so immediately after fertilisation, which represents a time of significant epigenetic change. The purpose of this is to inform the new life what kind of environment awaits it after birth, so that it can adapt to that environment in more ways than simply those contained within its genetic code.

Currently we view the dynamic nature of embryo development from a distance. We measure the products of gene expression and metabolism from embryos collected from the reproductive tract and examined in isolation, away from their natural environment. Measuring the precise epigenetic changes that occur at the single-embryo level is not feasible, and none of these can be measured within the reproductive tract, which in itself provides a dynamically changing, yet largely uncharacterised environment.

We want to know what are the metabolic adaptations and epigenetic consequences that occur in embryos when they encounter an adverse maternal environment (such as diabetes and obesity), which – even though the embryo keeps growing – result in an unhealthy offspring.

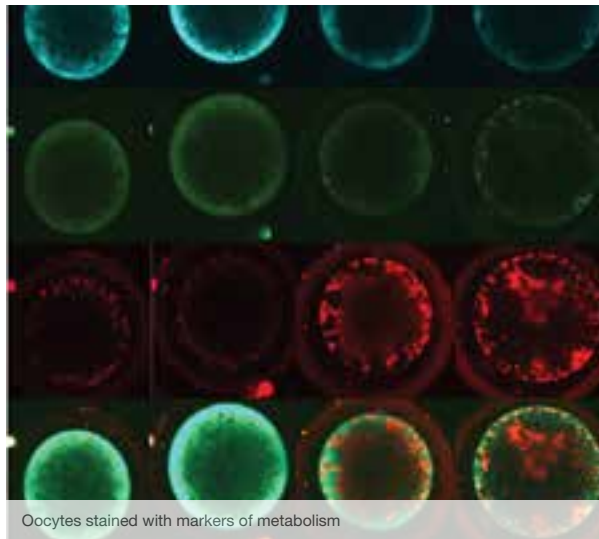
By engaging with the four themes, we will progressively measure these parameters on a single-embryo scale, as non-invasively as we can, ultimately aiming to do so within the reproductive tract.



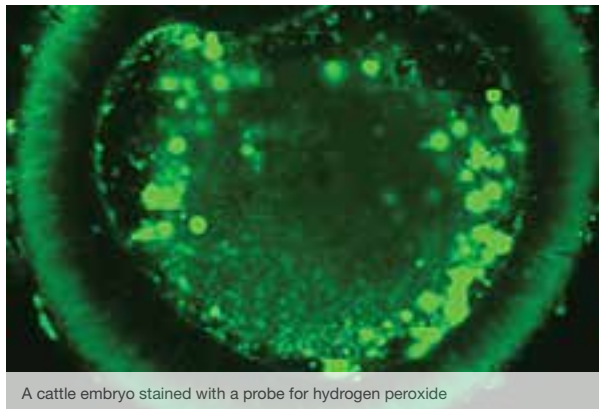
Dr. Mel McDowall reviewing stained bovine embryos

# Biological Challenge 1: Spark of Life (continued)

## What happens in the moments following conception?



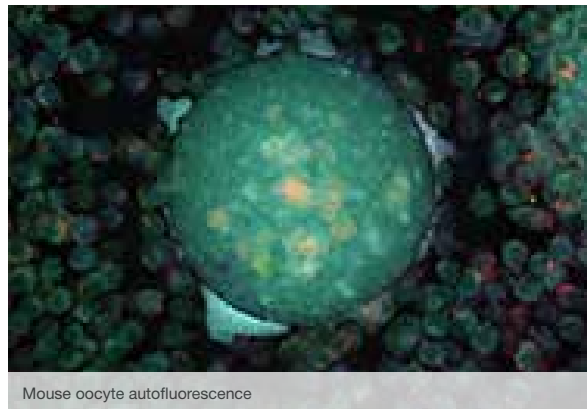
Oocytes stained with markers of metabolism



A cattle embryo stained with a probe for hydrogen peroxide

### We will:

- work towards understanding the dynamic processes at the beginning of life
- explore the capacity of autofluorescence to measure the dynamic nature of protein
- explore how we can use nanoparticle technology to measure epigenetic changes
- determine how to use photonics to measure changes in the female reproductive tract
- complete the picture of how the maternal environment influences early development.



Mouse oocyte autofluorescence

### 2015 scientific achievements

Selecting the 'best' embryo for transfer from an IVF cycle is critical in both animal breeding and clinical infertility treatment. However, microscopic morphology is a poor predictor, even by an experienced embryologist. We believe that non-invasive measures of early-embryo health are the only option. Led by Melanie McDowall (UA), who is collaborating with the Macquarie node and others in the Adelaide node, we are evaluating the auto-fluorescence of naturally occurring metabolic fluorophores to assess embryo health. Melanie has recently shown that: (a) cattle morula (Day 5 of development) examined with 2-excitation wavelengths can distinguish between those that will develop further to the next stage of development (Day 7 blastocysts) and those that won't, and; (b) In conjunction with Ewa Goldys and Martin Gosnell (MQ), hyperspectral autofluorescence analysis can demonstrate significant different spectral patterns between 'bad' and 'good' embryos created under different incubation systems.

Last year we determined haemoglobin is present in the mouse oocyte, and is likely involved in gas transport, be it O<sub>2</sub> or nitrogen oxide (NO). Hannah Brown's team (UA) established that haemoglobin mRNA is also expressed in early mouse embryos, peaking at the 4-cell stage and then declining thereafter. Furthermore, in vitro culture drastically reduced message levels. Low levels of protein were also determined. Along with Antony Orth (RMIT), we have identified an autofluorescence signature with a wide Stoke's shift on excitation of 650 nm, which may be a porphyrin ring; further evidence of a gas transport capacity in oocytes.

In conjunction with the Origin of Sensation and Measure themes, we began examining the capacity of the zona pellucida to act as a mini-bioreactor and sensor. Lesley Ritter (UA) has been developing the techniques to remove the oocyte from the zona pellucida, then injecting transformed cells into the remaining cavity left by the evacuated oocyte. This work has significant IP potential.

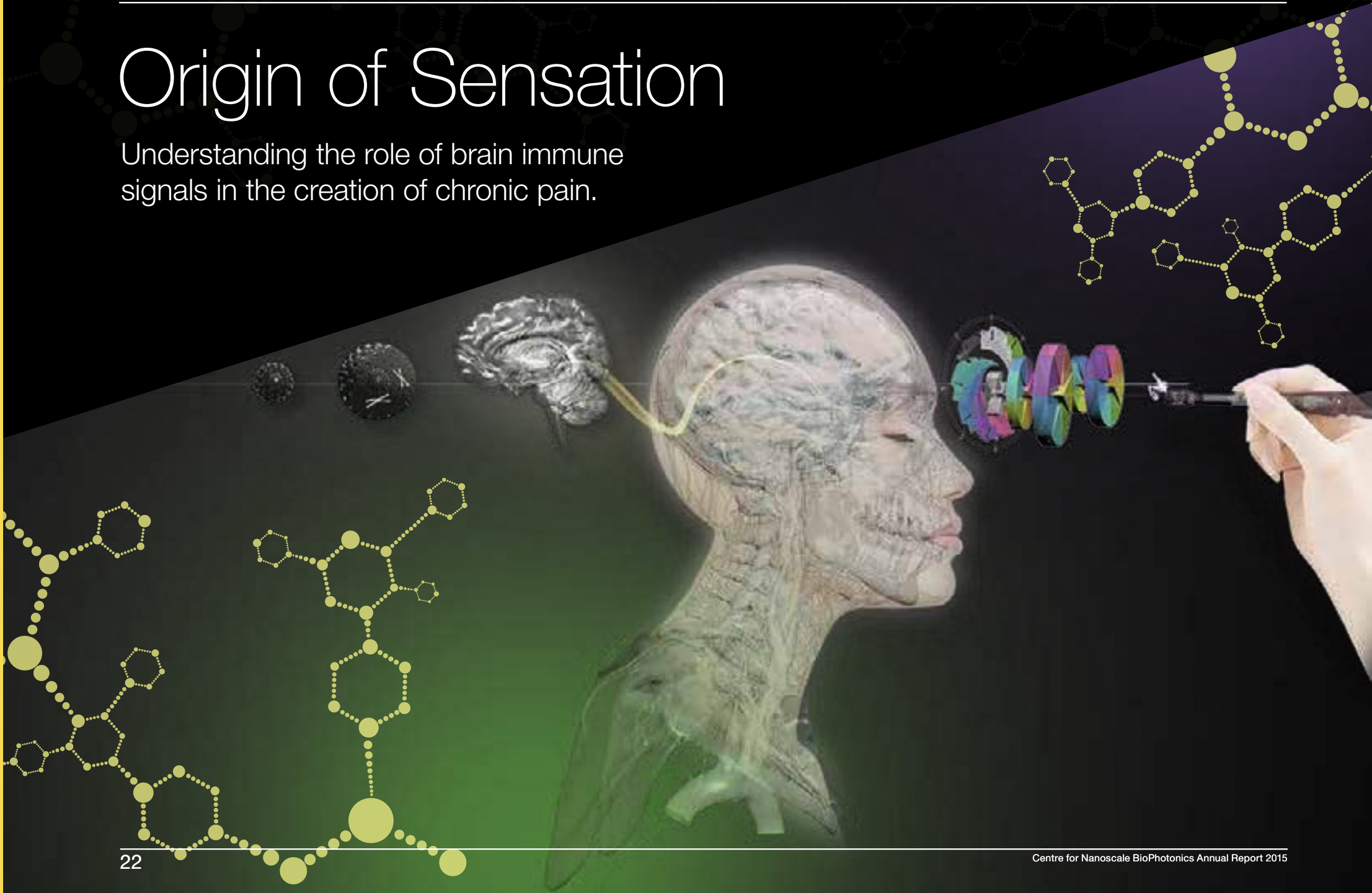
## Plans for 2016

- Both Melanie McDowall and Hannah Brown have forged strong links with an infertility company, Fertility SA, embarking on an investigation of analysis of micrographs of human embryos using GLCM analysis.
- Together with physicist Jonathon Hall (UA), Melanie will continue to investigate if zona pellucida, or the oocyte itself, can act as a sensor by behaving as a resonator within whispering-gallery-mode optics.
- Identifying the chemical and biological nature of the mysterious autofluorescence signal with an excitation at 650 nm and a peak emission at 800 nm is a priority, as this could be a valuable marker or novel fluorescence product.
- Extend the research on the zona as a bioreactor and sensor, by: undertaking a molecular characterisation of the cells in the zona compared with normal cultured cells and other cell types, and; studying the attachment of zona to fibres.
- Expand studies on autofluorescence and hyperspectral work, especially investigating events around fertilisation of mammalian eggs.

We are working with our colleagues in the Illuminate, Recognise, Measure, and Discover themes to customise solutions so we can find out what is happening moments after conception.

# Origin of Sensation

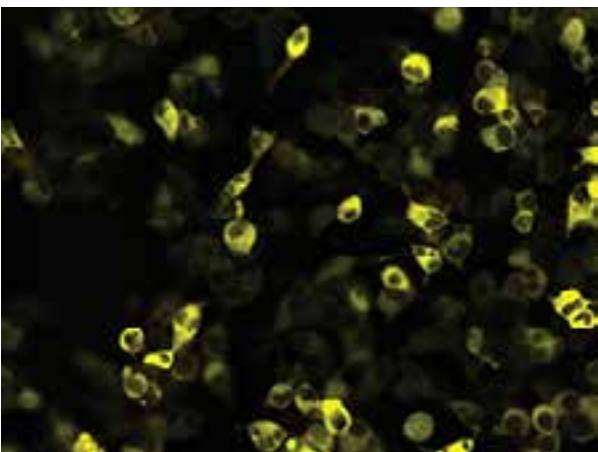
Understanding the role of brain immune signals in the creation of chronic pain.



## Challenge Leader: Prof. Mark Hutchinson



Biological Challenge Origin of Sensation Leader Prof. Mark Hutchinson



The origins of sensations team are engineering genetic constructs to create fluorescent signals in cells to provide real time measurements of the molecular origins of pain

### Overview

We will use new Centre-developed probes and techniques to identify the origin, actions and behavioural consequences of central nervous system (CNS) immune signals, and explore their role in the sensations of touch and pain.

### Summary

Over the past 30 years the evidence for glial immune-like signals in pain has grown from a trickle to a torrent. It is thought that immune signals, such as proinflammatory proteins, called cytokines, are critical for normal pain and the development of chronic pain states. Importantly, we are pioneering research examining sex differences in pain signalling, and demonstrating that females have a significantly heightened glial involvement in pain processing.

However, the exciting opportunities that this research affords remain blocked by the limitations of existing sensing tools for immune signals in the brain and spinal cord.

To advance our understanding of glial involvement in touch and pain processing, we need a new type of sensing technology that allows for precise and sensitive temporal and spatial resolution of classic immune signals.

These tools must be able to sense their targets at low concentrations, in small volumes and in discrete locations, and do this repeatedly over time.

Nanoscale biophotonic sensing tools--including innovative probes with functionalised optical fibre tips--look to be the answer. They have the power to go to places such as the brain, and can monitor small molecules and proteins in localised volumes of cerebrospinal fluid that could never be assessed before.

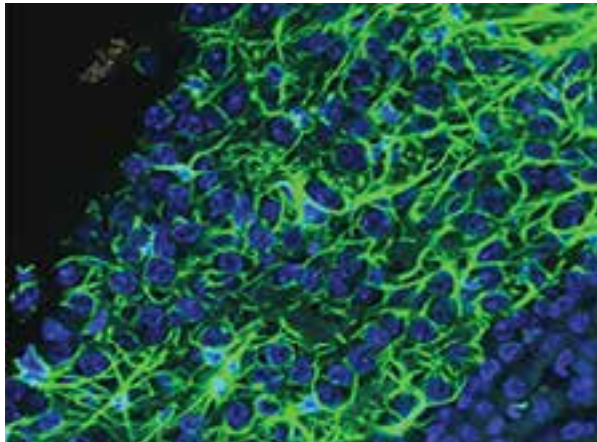
The lofty goals set by this Biological Challenge, built on the sensing tools being developed by the CNBP research themes, will address the needs of basic scientists, whilst simultaneously addressing the ethical considerations of the '3Rs': Replacement, Refinement and Reduction of animals in research.

Information will be produced by this challenge which will validate the use of these new sensing technologies, with Prof. Mark Hutchinson leading a team of medical scientists and PhD students through the complete stages of concept development, testing, rollout and release.

The ultimate aim is to provide researchers skilled in the science of neuroimmunology with access to emerging Centre-based sensing technologies and techniques.

## Biological Challenge 2: Origin of Sensation (continued)

Studying glial cells—the other 90% of the brain.



A section of clarified brain displaying the complex network of astrocyte cellular processes



Vicky Staikopoulos, Dr Sanam Musafa and Prof. Mark Hutchinson

### We will:

- identify the origin, actions and behavioural consequences of central nervous system (CNS) immune signals as they relate to pain
- work alongside Centre scientists as they develop their technologies from conceptual frameworks to tangible devices, using existing and new collaborations
- explore the application of the new Centre technologies to validate them against existing methods
- initiate new science projects upon finalisation of the new sensing technology, allowing for the testing of completely new scientific questions
- pioneer the testing of the new sensing technologies in a broad range of applications in both the spinal cord and brain.

### 2015 scientific achievements

The Origin of Sensation team has explored a range of exciting applications of nanoscale tools in the search for the molecular origins of exaggerated pain. A barrier in neuroimmune pain research is the limited ability to detect small changes in a handful of immune-like cells that neighbour the neuronal 'pain highways'. These small but extremely meaningful changes in neuroimmune cell function and signalling underpin the early phases of pain turning from a beneficial and protective signal to maladaptive and diseased. The team have tackled this problem five ways, through exciting collaborations with transdisciplinary and international teams of CNBP scientists.

In collaboration with CNBP partner organisation Huazhong University of Science and Technology and the team at the Wuhan National Laboratory for Optoelectronics, our scientists used state-of-the-art intra-vital 2 photon microscopy of the GFP-microglia in the allodynic mouse spinal cord to explore very early changes in glial reactivity following a nerve injury. This research continues as a PhD student project. Another novel imaging tool has been explored by the Origins of Sensation team looking at central nervous system tissues from chronic pain states through the use of label-free endogenous fluorescence. This hyperspectral and multispectral sample and image analysis has provided a new way to examine the diseased tissue, and has provided new research leads for our new PhD students.

Sometimes the rare signals we search for just aren't large enough on their own, so new tools have been created and are being used by the CNBP team to make the detection of these signals possible. Firstly, when normally imaged, the central nervous system tissue is opaque due to the fatty lipid membranes. When looking for rare signals we want as much of the light to penetrate the tissue, so the team are using the latest CLARITY and related whole-tissue-clearly methods, in combination with super-bright-labelling nanoparticles to detect cellular events that have never been observed before. This research has also led us to engineer fluorescing and luminescing cells to help us understand more about the protein-protein interactions that trigger the creation of chronic pain, or—as we think of it—'the cancer of the soul'.

Finally, the Origin of Sensation team has led the preparation of an invited review manuscript that examines the latest developments in imaging and sensing technologies, with specific relevance to the neuroimmune research field. This manuscript includes authors from across all CNBP themes and nodes and has proved to be a wonderful learning experience for all parties, examining each other's domain-specific knowledge in-depth. The work is currently under review and will be published early in 2016.

## Plans for 2016

The year ahead for the Origin of Sensation team is a very exciting one, with the promise of the completion of the first of several key projects using novel imaging techniques and sensing technologies to quantify the molecular changes in glial cells during chronic pain states. This work will see the team continuing to work extensively with the breadth of the CNBP scientists from Adelaide, Macquarie and RMIT Universities, together with those of our national and international partner organisations. For example, during 2016 the team at the University of Colorado at Boulder will begin working with the Origin of Sensation scientists on the collaborative translation of tools from the CNBP into their research projects in pain.

The team will also begin new external collaborations with our clinical colleagues at the Royal Adelaide Hospital. Supported by the securing of new funding from the NeuroSurgical Research Foundation we will take a new cellular tool developed in the CNBP to conduct a clinical trial in spinal cord injury patients in the first days after their injury. Whilst not a treatment for spinal cord injury, this new tool promises to give patients and clinicians greatly needed information about the current and future state of the injury and looks to provide the first quantitative guide to treatment selection.

We are working with our colleagues in the Illuminate, Recognise, Measure and Discover themes to build new tools so we can find out what the other 90% of the brain is doing.

# Inside Blood Vessels

Measuring nitric oxide in functional blood vessels to determine impact on heart disease.



## Challenge Leader: Prof. Stephen Nicholls



Biological Challenge Inside Blood Vessels Leader Prof. Stephen Nicholls

### Overview

Using new probes and sensors developed by the Centre, we will be able to explore blood vessels with greater precision in order to better understand the factors that regulate their function.

### Summary

Blood vessels regulate human health by delivering oxygen and nutrients to organs, removing metabolic waste products and by directing inflammatory and immune responses to microbes and foreign bodies. The vasculature also plays an important role as the site of formation of atherosclerotic plaque, the underlying cause of heart attacks and strokes. Our ability to image vessels is largely limited to characterising their anatomical burden and composition, yet the ability to sense the molecular events within has proven challenging. Our vascular biologists will collaborate with physicists and chemists to develop novel sensing approaches to detect molecular pathways involved in vascular health, with a number of specific aims:

- to develop more accurate approaches to detect and measure nitric oxide in biological systems – the major factor promoting vascular health
- to develop more effective approaches to monitoring inflammatory pathways in blood vessels, given their importance in vascular health and disease

- to develop effective approaches to sensing the endothelial cells that line the inside layer of blood vessels and play a critical role in orchestrating vascular function
- to better characterise the factors that influence the growth of new blood vessels, which is critical for human development and a range of states including vascular disease, cancer and transplantation.

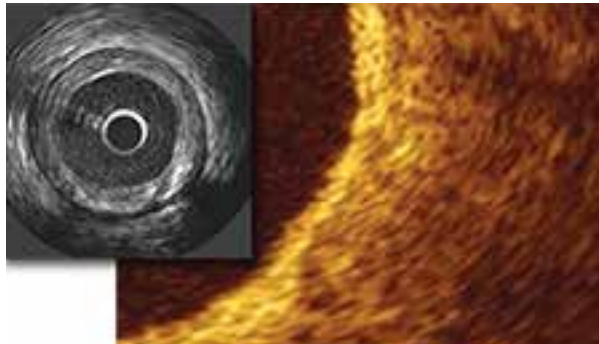
These collaborative projects have the potential to be transformative; to equip vascular scientists with novel approaches to studying the cellular biology underlying vascular health, while at the same time providing clinicians with better tools to develop more effective approaches to the detection, prevention and treatment of vascular disease.

### We will develop more effective approaches to:

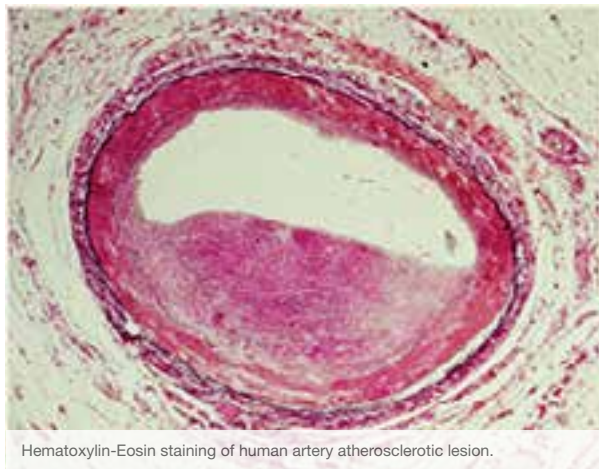
- measuring nitric oxide
- characterising vascular inflammation
- characterising endothelial function
- sensing new blood vessel formation.

## Biological Challenge 3: Inside Blood Vessels (continued)

Using new probes and sensors developed by the Centre, we will be able to explore blood vessels with greater precision.



*In vivo modalities to image human arteries: Intravascular Ultrasound (IVUS) and Optical Coherence Tomography (OCT)*



*Hematoxylin-Eosin staining of human artery atherosclerotic lesion.*

### 2015 scientific achievements

In the Inside Blood Vessels Challenge has focused their collaborative efforts in three primary areas.

We have attempted biological validation of numerous chemical sensors with the potential to detect and quantify nitric oxide in biological systems. Nitric oxide plays an important role in promoting vascular health, with evidence that its biological activity is reduced in the setting of heart disease. The major challenge is that we do not have reliable approaches to detecting and quantifying nitric oxide in biological systems. We have worked with our chemistry colleagues within the Centre and have found that a ruthenium-based sensor appears to detect nitric oxide and functional changes, particularly in biological fluids. Ongoing work is attempting to enhance the cellular targeting of these sensors. We have held a nitric oxide workshop to coordinate activities within the Centre to explore this challenge further. The ultimate plan will be to enhance chemical detection and then combine that with photonic approaches to deliver reliable and accurate nitric oxide sensing within cells and blood vessels.

We have embarked on collaborative efforts with our photonics colleagues to design and launch a study of a novel Raman spectroscopy-based approach to characterising plaque changes in the setting of dietary-induced regression in a well-validated animal model. This will provide an important opportunity to provide a chemical fingerprint of the vessel wall, which we can then use to characterise blood vessels in a range of physiological and pathological states.

We have collaborated with our Macquarie University colleagues to employ hyperspectral analysis to characterise changes in endothelial cells with senescence. Preliminary observations suggest a potential spectral fingerprint demonstrating the oxidative changes that occur with cellular aging, and this will undergo further exploration. We hope to be able to develop spectral fingerprints that study normal aging-related changes and to further extrapolate this to understand changes, and to extrapolate from this an understanding of what changes in settings accelerate the aging process. Ultimately, this process will enable monitoring of changes in response to preventive and therapeutic interventions.

## Plans for 2016

An expansion of activity over the next 12 months will prove to consolidate and increase the research activity within the biological challenge.

- We have welcomed the arrival of Malcolm Purdey, a chemist, to undertake part of his postdoctoral research activity based within our biological laboratory. We believe the co-localisation will enhance collaborative activity.
- We will expand the nitric oxide sensor activity in both biological fluids and within cell systems, and look to then combine our early experience with chemical sensors and photonic approaches to achieve the increased sensitivity of imaging required for development of a reliable biological sensor.
- Our plaque-regression study, employing a novel Ramen spectroscopy catheter will be completed.
- We will expand the activity in hyperspectral profiling of endothelial cells in the setting of a range of stimuli.
- We will commence work to develop effective approaches to the detection and quantification of endothelial cell apoptosis, which we believe will play an important role in both the maintenance of vascular health and promotion of vascular disease.



Dr Achini Vidanapathirana, Benjamin Pullen and Dr Nisha Schwarz

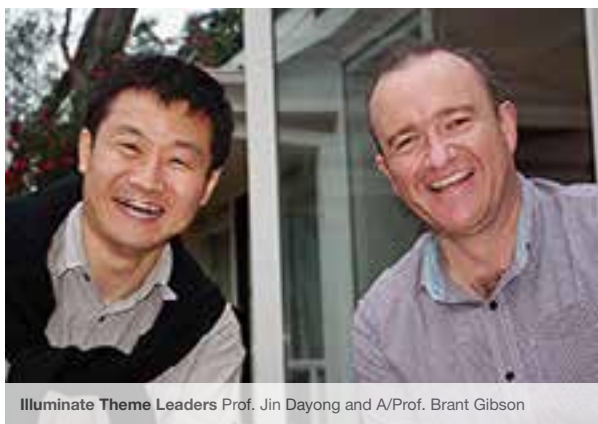
We are working with our colleagues in the Illuminate, Recognise, Measure and Discover themes to build new tools so we can discover what causes high blood pressure.

# Illuminate

Creating new light sources, such as nanoscale 'lamps', advanced optical fibres, and novel nanoprobe that deliver and collect light, targeting cells and molecules in the body.



## Theme Leaders: Prof. Jin Dayong, A/Prof. Brant Gibson



### Overview

The research theme of Illuminate explores advanced optical materials that efficiently deliver and collect light to and from cells and molecules locally. This allows us to non-invasively probe individual interacting biomolecules by using nanoparticle-based 'lamps'. Our explorations involve bio-compatible fluorescent nanoparticles, next-generation optical fibres, and nanoparticle-enriched hybrid materials.

### Summary

#### Novel nanoscale 'lamps'

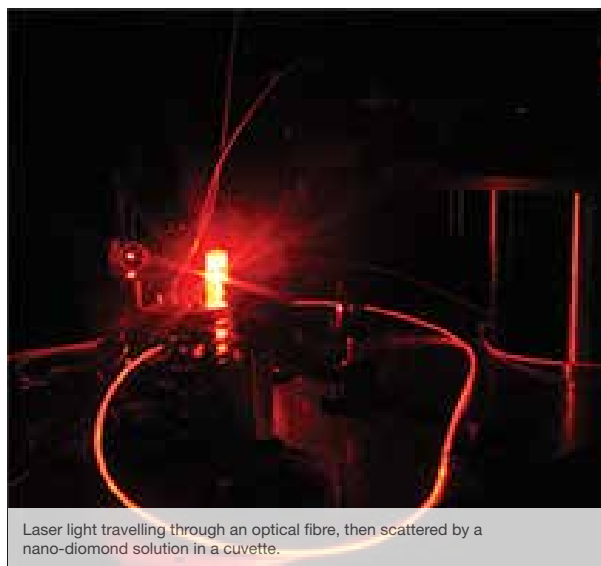
Fluorescent nanomaterials have enormous potential as nanoscale light sources and sensors operating as beacons within biological environments. We are building a tailored library of nanoparticles with the aim to interrogate target molecules down to the single-molecule level. This nanoparticle library consists of a broad range of fluorescent materials, including nanodiamond, upconversion particles, nanoruby, metal oxides and additional wide-optical-band materials. Within this library we are exploring a range of properties, including absorption and emission wavelengths, size, brightness (both single and ensemble emitters) and functionality. Our long-term aim is to create photon-switchable biocompatible nanoparticles sub-10 nm in size and with ultra-high brightness ( $> 10^8$  Hz).

In addition to controlling the growth of hybrid-multifunctional nanoparticles, this theme also focuses on building our expertise in the optical characterisation of luminescent nanoparticles.

#### Advanced optical fibres

We will improve the transmission of ultraviolet (UV) light in optical fibres by fabricating fibres suitable for light delivery and sensing from glasses that offer greater UV performance. The impact of fluorine doping, hydroxyl group content, fibre fabrication conditions, and laser power will be investigated to maximise UV transmission to and from cells. Furthermore, structuring concepts, such as Kagome lattices, will be explored to shift the UV edge of silica fibres and allow the transmission of light to extend further into the UV. By extending the reach of these fibres into the UV, using cross-sectional structuring and high-quality UV glasses, low-power UV light will be delivered to the cellular environment to probe cellular autofluorescence, particularly in the wavelength range of 270–350nm.

### Creating light when and where we need it.



Laser light travelling through an optical fibre, then scattered by a nano-diamond solution in a cuvette.

#### Nanoparticle-enriched hybrid materials

Nanoparticle-enriched active hybrid materials will serve as a bridge between nanoparticles and bulk materials, while conserving and enhancing nanoprobe functionality. We are currently exploring the physical and chemical interactions between the nanoparticles and the materials they are embedded in or attached to, with the ultimate aim of controlling the nanoparticles' properties and sensing performance. This area of research is being performed in the context of creating multi-functional nanomaterials with improved fluorescence and Raman sensing properties. We are also focusing on integrating nanoscale 'lamp' sensing elements with optical fibres, for the development of novel macroscopic sensing architectures.

#### We will:

- create photons designed to probe molecular-level systems
- progress novel nanoprobe with tailored emission characteristics
- develop advanced optical fibres for delivering light to and from nano environments
- produce nanoparticle-enriched materials and structures.

#### 2015 scientific achievements

In 2015, the Illuminate theme has achieved significant scientific research outputs in the areas of nanoscale 'lamps', advanced optical fibres, and nanoparticle-enriched hybrid materials.

Advanced nanomaterial processing procedures and synthesis protocols have been established across all three nodes. In addition, two custom-built re-configurable confocal microscopes have been established within new laboratories at the RMIT node. This has enabled a systematic analysis and comparison of the emission properties of a broad range of fluorescent nanomaterials which are of interest to the CNBP.

At the Macquarie node, a new conjugation method has been developed for upconversion superdots (published in *Analytical Chemistry*). Also, a review paper discussing the control of upconversion nanoparticle properties for emerging applications has recently been published in *Nature Nanotechnology*. A time-gated microscopy system has also been developed with a vitamin C-responsive probe for *in vivo* imaging (published in *Scientific-Reports*). And multifunctional lanthanide luminescent materials—with tunable decay lifetimes, emission colors, and enhanced cell viability—have also been developed (*Scientific-Reports*).

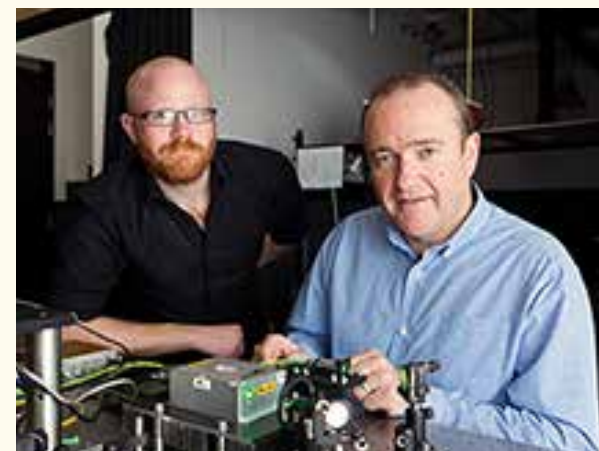
In addition, the Adelaide and RMIT nodes have collaborated to reduce the optical loss within nanodiamond-enriched tellurite glass optical fibres (published in *Optical Materials Express*) to a level that has enabled a novel sensing sphere architecture (Scientific Reports). Methods have also been developed to incorporate both upconversion and gold nanoparticles in tellurite glass for future imaging and sensing applications.

## Plans for 2016

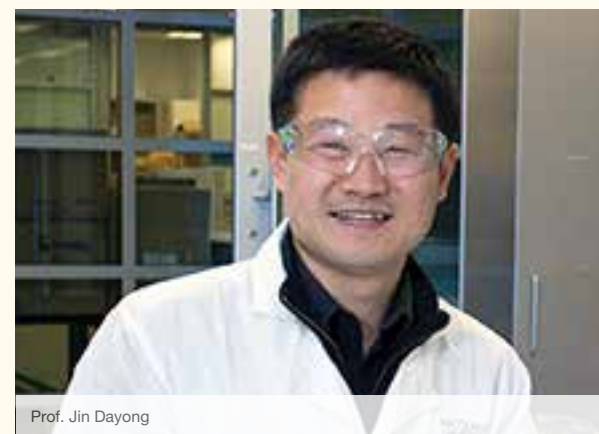
All three nodes will collaborate to identify endogenous fluorescent markers in mouse oocytes (eggs). Autofluorescent compounds, typically seen as a nuisance, will be investigated as potential signatures of oocyte quality for improved in vitro fertilisation.

In collaboration with the Adelaide and Macquarie nodes, the RMIT node will advance the study of fluorescence photophysics. The response of fluorophores to variable pulsed optical excitation at multiple wavelengths will be leveraged as a contrast mechanism to separate fluorophore species. These experiments will aim to shed light on the physical nature of photobleaching, possibly leading to new multi-modal imaging protocols.

In 2016, the Illuminate research program will continue to focus on developing smaller, brighter photostable particles. Hybrid multifunctionality of nanomaterials will be explored for their integration into biological samples for next-generation diagnostic applications. In addition, super-resolution imaging of emerging fluorescent nanomaterials will be studied, along with their bioconjugation, for controlled specific binding applications. Furthermore, a research program will be established on conductive hybrid materials for the sensing of electric and magnetic fields.



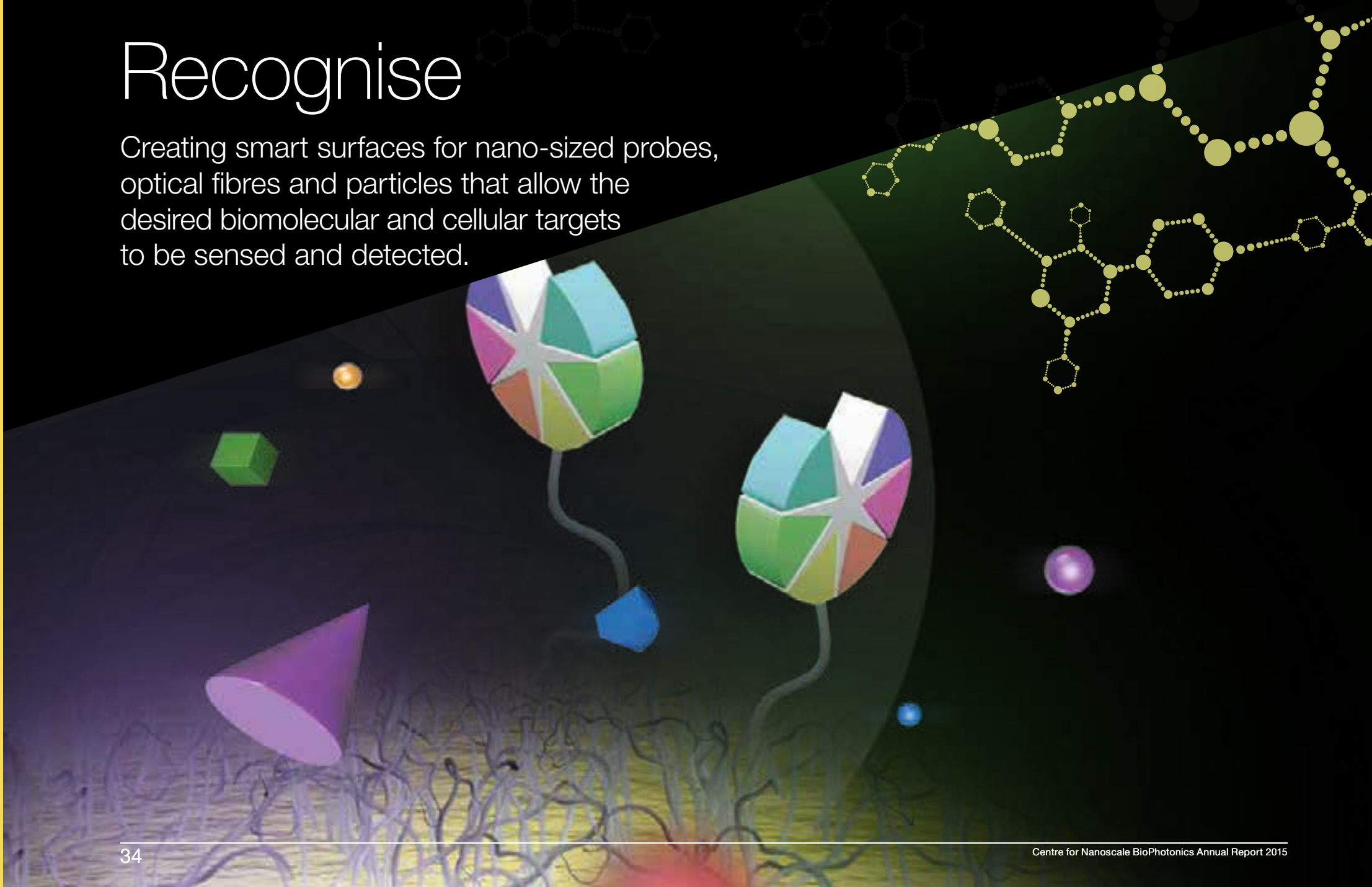
Ashleigh Heffernan and A/Prof. Brant Gibson



Prof. Jin Dayong

# Recognise

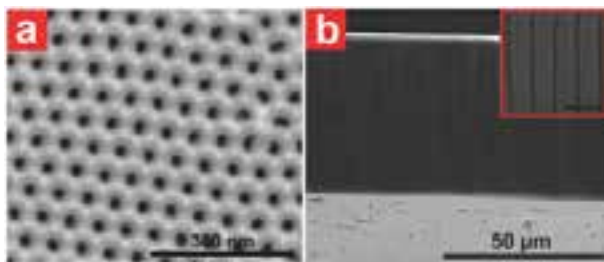
Creating smart surfaces for nano-sized probes, optical fibres and particles that allow the desired biomolecular and cellular targets to be sensed and detected.



## Theme Leader: Prof. Andrew Abell



Recognise theme leader Prof. Andrew Abell



Typical SEM images of NAAM (nanoporous anodic alumina membranes) prepared in sulfuric acid electrolyte. (a) Top view with self-organized pores. (b) Cross-sectional view showing entire thickness of the NAAM with a magnified view inset (scale bar: 100 nm)

### Overview

To design and develop new biocompatible sensing platforms for the reversible detection of reporter molecules that will drive our fundamental understanding of CNBP's three biological challenges—Spark of Life, Origin of Sensation and Inside Blood Vessels.

### Summary

The interaction of key biomarkers with more complex biological receptors drives cellular function. These interactions generate a signal, at the molecular level that drives key metabolic processes essential to life. The ability of these biomarkers to bind to their receptor is defined by a mutual complementarity of molecular shape and electronic properties.

Understanding these processes at the most fundamental molecular level requires us to first identify key biomarkers that interact within cells, but also the signal molecules that are subsequently liberated. We need specific tools to study these processes and their associated downstream effects. All this must be done with probes that operate at an exact cellular location and on a precise time frame. The generation of such a biological sensor requires us to develop new ways to control and measure molecular function in solution and on the surfaces to allow precise and repeated measurement.

This last point necessitates that the probe can be switched on and off on demand, to allow repeated and timely measurement. We propose to develop the tools to create such sensors that are capable of continuous monitoring of specific biomolecules, rather than single one-off measurements.

The component molecular switches of the probes are activated photochemically, or by some other external stimulus, to bring about a molecular change that is able to modulate binding and interaction with a target biomolecule. We are developing novel ways to detect these changes, for example through the detection of an associated electrochemical response. We are particularly interested in modular approaches to allow the assembly of versatile switchable sensing platforms that can be tailored to a given application, much like one might construct a Lego structure from its component building blocks or parts. A key part of our endeavour is to then exploit these sensing platforms within the arena of the three biological challenges. We are particularly interested in the detection of metal ions, such as  $\text{Zn}^{2+}$  and  $\text{Ca}^{2+}$ , reactive oxygen species, nitrous oxide, glutathione, and GPCRs.

## Research Theme 2: Recognise (continued)

### Building surfaces to identify specific molecules.



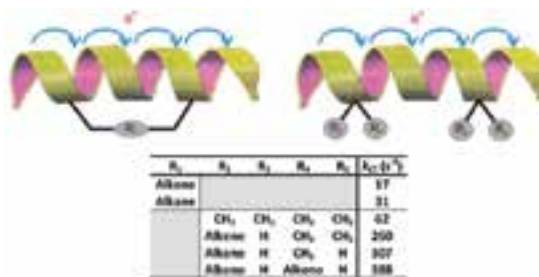
CNBP Researcher Malcolm Purdey performing synthesis of fluorescent sensors



A reversible and highly sensitive platform for the detection of zinc in biology

#### We will:

- develop optically controlled surfaces to recognise molecules in living systems
- develop new ways of sensing molecular interactions and conformational changes
- produce novel reporter molecules of importance to the three biological challenges
- advance strategies for surface attachments
- advance our fundamental understanding of the three biological challenges.



Controlling and switching electron transfer in peptides

#### 2015 scientific achievements

A new spiropyran-based molecular switch has been developed, with improved biocompatibility and a red shift in its emission profile, to provide a general scaffold for a new generation of on-off switchable biosensors (manuscript in preparation). In related work, a new class of protease inhibitor has been developed where a spiropyran acts as both a light-activated switch and a peptide backbone mimic. The activity of the inhibitor can be switched on and off in solution and also when bound to an optical fibre (published in *Chemistry - A European Journal*).

Work is underway to incorporate a light-activated photoswitch into peptides of well-defined secondary structures. The switch will then control the geometry of the peptide and hence its ability to promote electron transfer. Once attached to an electrode, this will provide a biosensor that functions by recognising and binding other bioactive peptides and proteins that possess a complementary shape. A clear link between the rigidity of a peptide backbone and its ability to undergo electron transfer has also been defined. This then provides a basis of new bioelectronics devices and switches (published in *Journal of the American Chemical Society* and *Chemistry - A European Journal*).

A new nanoporous material has been developed that contains a light-activated switch or 'gate' that can reversibly control the passage of solutes. This membrane mimic has applications in drug delivery and as a basis of new nano-devices (published in *Advanced Materials* (cover) and featured in *Chemistry in Australia*).

A new biosensor device has been developed, in collaboration with the Spark of Life bio-challenge and Cook industries, that is capable of dual pH and hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) measurements, for use in IVF applications (manuscript in preparation).

Work continues in collaboration with the Spark of Life bio-challenge and also Laureate Prof. John Aitken (Newcastle) to exploit our hydrogen peroxide biosensors (published in *Free Radical Biology & Medicine* and also *Molecular Reproduction and Development*).

Work has also begun on nitrogen oxide (NO) biosensors for use in all three bio-challenges. Initial studies will exploit biosensors provided by Prof. Steve Lippard at MIT.

## Plans for 2016

Work will continue on developing and exploiting biosensors for  $\text{H}_2\text{O}_2$ , NO, GPCR's, glutathione, and a range of metal ions of significance to the three biological challenges. Significant time will be invested in studying the potential of these new sensors *in vivo*.

A new chemistry-focused post-doctoral fellow is to commence in our theme (Malcolm Purdey), who will spend half his time directly embedded within the laboratories of Prof. Stephen Nicholls at SAHMRI. This will provide a wonderful opportunity for true multidisciplinary development.

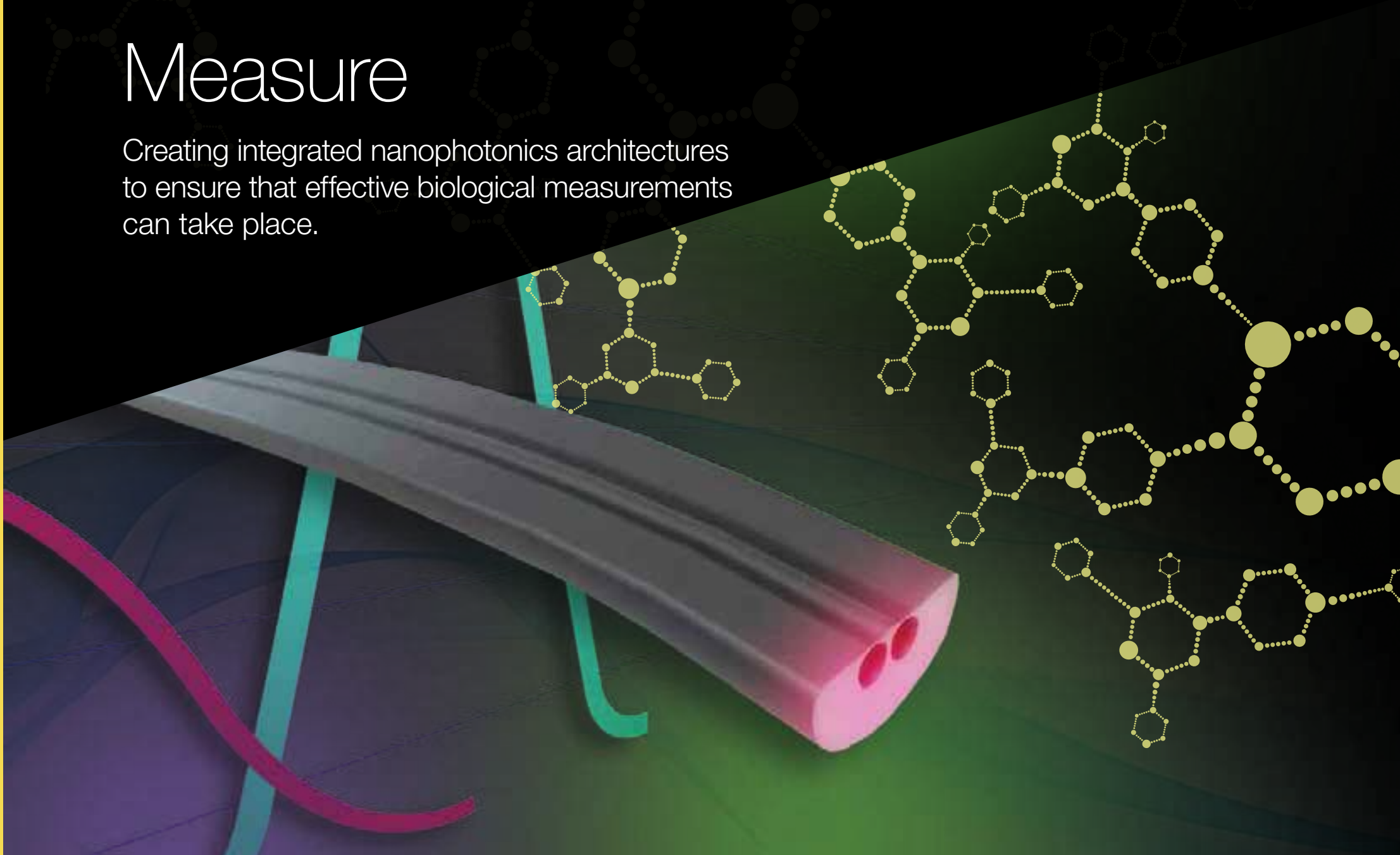
A significant effort will also be invested in our fundamental studies on developing an electrochemical approach to studying protein-protein interaction. We anticipate developing our sensing systems further with the incorporation of other fluorophore platforms, such as nano dots and the like. This will pave the way for further collaboration across all themes and capabilities within the CNBP.



Prof. Tanya Monro and Dr. Sabrina Heng

# Measure

Creating integrated nanophotonics architectures to ensure that effective biological measurements can take place.



## Theme Leaders: Prof. Ewa Goldys, Prof. Andrew Greentree



### Overview

The theme 'Measure' focuses on technology integration and using the developed technology for producing new understandings of real biological systems, with emphasis on *in vivo* sensing inside the body. It draws on the Illuminate and Recognise themes, which are providing the building blocks for molecular detection.

### Summary

We develop new 'windows to the body' with two complementary approaches of non-invasive label-free and invasive labelled detection of selected biomolecules in cells and tissue.

Our main emphasis is label-free characterisation of fluorescent compounds that are native to cells. We carry out a careful quantitative analysis of fluorescent colour of cells and tissues with specific emphasis on cell population properties. Colour is a supremely sensitive indicator of biological processes and its quantification enables us to non-invasively identify cell groups and analyse biochemistry. We have been able to access key cell and tissue characteristics, such as the levels of surface biomarkers, reactive oxygen species, genetic modification and outcomes of chemical interventions. With this quantitative analysis, we have been able to test biological hypotheses, such as whether a medical treatment has been effective.

Current projects in this area focus on characterisation of the embryos within the 'Spark of Life' challenge, the analysis of neuronal cell populations for 'sensing sensation', and the function of the epithelium. We have been able to apply CNBP technologies to projects with our external partners in the area of ophthalmology, diabetes and cancer. Our most immediate plans focus on early diagnostics of motor neuron disease and monitoring of photodynamic therapy (PDT).

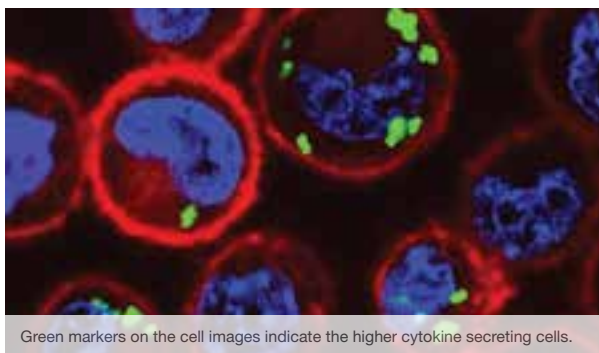
Raman sensing is another non-invasive biomolecular detection modality where we work together with our partner investigators. The program on real-time detection of inflammation in blood vessels (with PI Prof. Stephen Nicholls from SAHMRI) uses a Raman probe to provide non-invasive diagnostics of vulnerable plaque via Raman signatures.

Our program on labelled detection of key molecular species centres around micro- and nanoparticle-based probes and supplements our work on label-free technologies. Here, the focus is on the development of nanoscale assays, to enable localised sensing and repetitive sensing of small animals. Our emphasis is on two types of molecular species: cytokines, where we combine nano- and microparticle sensors with remote detection and; metalloproteases. Here we build on the achievements of the themes Illuminate and Recognise and we employ ultra-bright fluorescent particles and tailored surfaces developed elsewhere in the Centre.

### Exploring the fundamental limits of detection.



Prof. Ewa Goldys



Green markers on the cell images indicate the higher cytokine secreting cells.

#### We will:

- create nanoscale photonic sensing architectures
- develop remote nanoscale assays
- develop novel spatially distributed measurement schemes and novel assay platforms, including for in-vivo applications
- explore the fundamental limits of detection of key analytes for CNBP, including cytokine molecules.

#### 2015 scientific achievements

Key achievements have included the development of a novel method to sense cytokine secretion in living cells, in a cross-node team led by Guozhen Liu, for which a provisional patent was lodged in 2015 ('Cell selection method'). This work has attracted the attention of a company called Regeneus Ltd, with which we have now signed a research contract.

The label-free detection technology has been significantly advanced as well. Key results obtained by Martin Gosnell and the Macquarie team, led by Ewa Goldys, in partnership with Jeremy Thompson and Mel McDowall from the Adelaide node, included the establishment of the method to distinguish healthy from compromised embryos. We have early results with Mark Hutchinson in the area of pain, where we discovered subpopulations of TLR4 cells and significant distinctions in brain tissue in animals with and without pain.

We have also finalised the design of a hyperspectral retrofit to fluorescence microscopes currently rolled out at Macquarie and in parallel at Adelaide University. The graphical user interface for the unmixing software was finalised in December 2015. We also lodged a PCT 'Cell characterisation method'.

In collaboration with the group of Stephen Nicholls, Ivan Maksymov has developed a new approach to the detection of ultrasound, using nanoplasmonic antennae suitable for use in intra-vascular imaging. Daniel Drumm has also developed new code for the determination of the optimal search of single photon emitters using top-hat function imaging with realistic noise sources, performed with project student Josef Worboys. In addition, Jan Jeske with Andrew Greentree theoretically predicted a new methodology for optically detected magnetic resonance—using nitrogen-vacancy diamond—that has been demonstrated by Yinlan Ruan, Brant Gibson and teams at Adelaide and RMIT.

With our CSC Visiting Fellow from Jilin University, Dr. Kai Zhang, we have been able to develop a methodology of silica coating of nanorubies, which will enable easy conjugation of targeting moieties through established methods.

## Plans for 2016

We have major aspirations for 2016. In the area of label-free detection technology, we aim to determine key characteristics of pain in animal experiments and bring to fruition early results from 2015 concerned with TLR4 cells. We wish to take this technology to human embryos in collaboration with an IVF clinic in Adelaide.

In the area of nanoparticle sensors, we are planning a major development of commercial technologies with Regeneus, and major research manuscripts in high-impact journals. The cytokine sensing will be taken to *in vivo* devices and we will also develop needle-biased microfluidic devices, to sense cytokines and other analytes of interest to CNBP.

Both hyperspectral and cytokine sensing technologies will be targeting our new partnerships with the University of Colorado, and possibly with future Canadian research partners. This work will be focusing on the brain.

In 2016 we expect Dr Ploschner to bring his fibre imaging technologies to the fields of CNBP interest. Theory programs will be looking at translating their concepts to realisation, with proof-of-concept experiments on the optimal search for nanoparticles and construction of plasmonic antennae on optical fibres for ultrasonic detection.

There will be diverse activities in various Fellow, postdoctoral and PhD projects, mostly oriented at cementing our ties with the area of health and translational medicine.

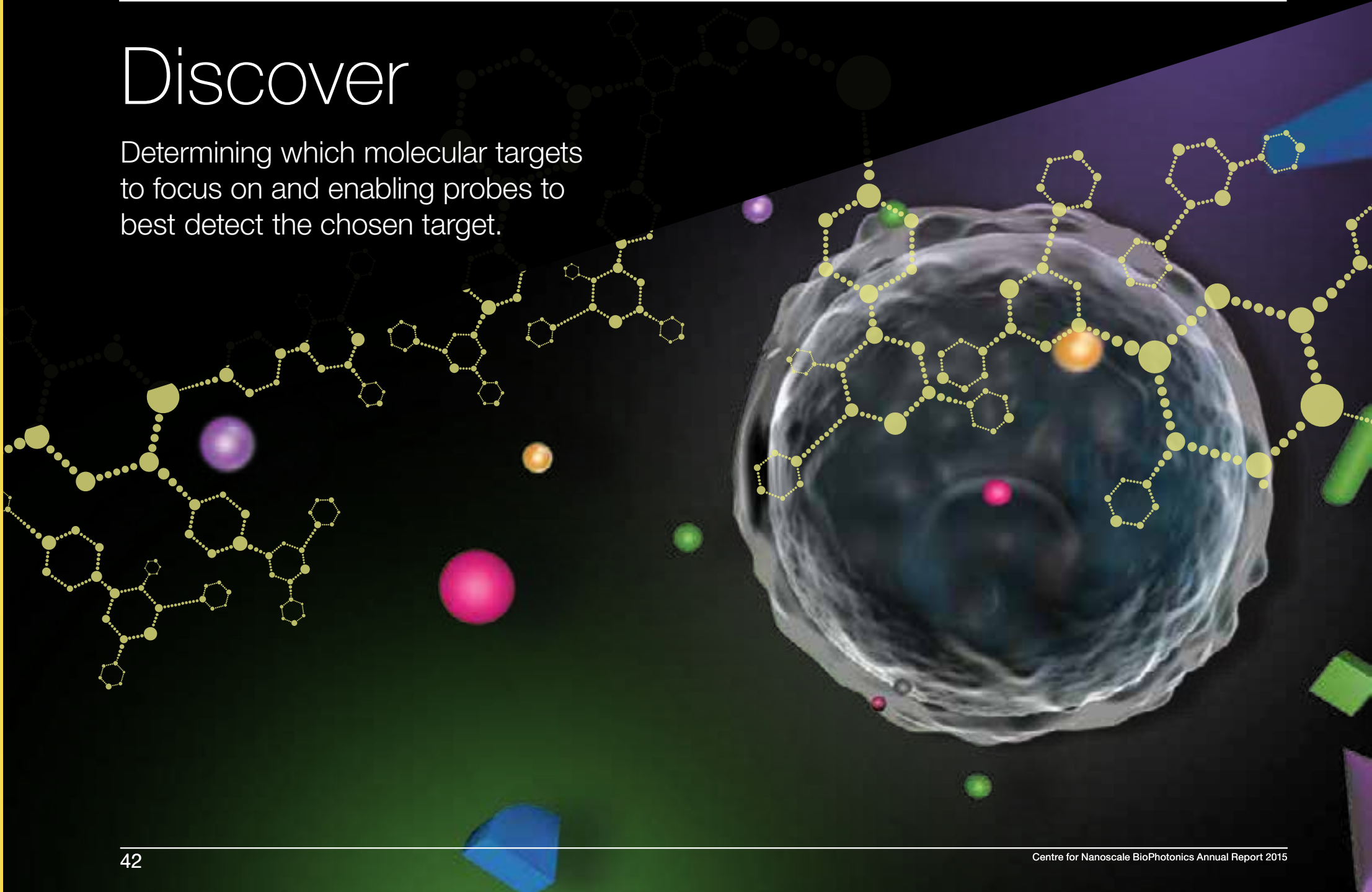


Prof. Andrew Greentree

Measure focuses on technology integration and using the developed technology for producing new understandings of real biological systems with emphasis on in-vivo sensing inside of the body.

# Discover

Determining which molecular targets to focus on and enabling probes to best detect the chosen target.



## Theme Leader: Prof. Nicolle Packer



Prof. Nicolle Packer (Photo: Chris Stacey at Macquarie University)

### Overview

The Discover theme bridges the physics, chemistry and biology aspects of the Centre by not only discovering relevant molecular targets to answer our biological questions, but also to enable purpose-built probes to detect these targets, and importantly, to measure the effects of putting these probes into the biological systems.

### Summary

It is one thing to have high-sensitivity, super resolution detection instruments and another to make these work in the biological applications that we have identified as being of human interest to understand.

We will use state-of-the-art technologies to discover new, and further develop known, molecules that alter in response to cellular perturbations, such as pain transmission, fertilisation and development, and arterial plaque formation. The molecules will be the targets of purpose-built tools to measure the molecular changes that occur in these systems. Platforms will be developed that bioconjugate the probes developed in the Centre to enable the sensitive detection of such molecular targets as RNA, protein and glycan at the *in vitro*, *ex vivo* and *in vivo* cellular level.

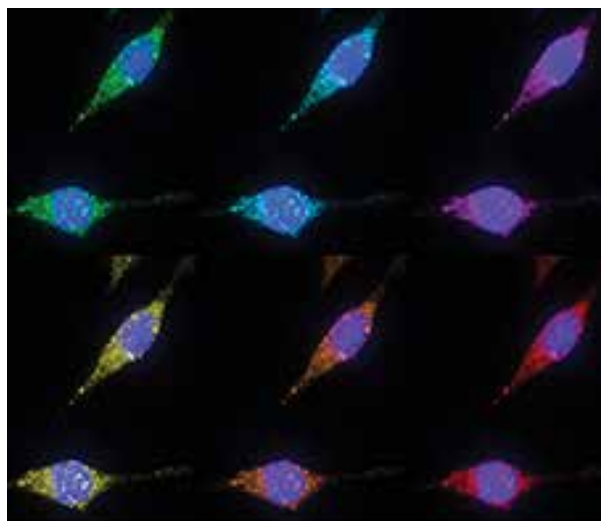
These probes will be trialled in test tubes and under microscopes, in fixed tissue and live cells, but our ultimate aim will be to allow simultaneous measurement of molecular changes *in vivo*, in real time, at a single location in the body. On the other hand, the use of these types of nanophotonic platforms applied to biological systems will also be monitored for any effects they may have on the cells and tissues, both for understanding the measurements as well as for the safety of future *in vivo* applications.

These outcomes will be achieved by working together with the physicists that develop the photonic probes, the chemists that modify the surfaces of the probes and conjugate the biomolecules to them, and the biologists who understand the cellular mechanisms.

### We will:

- use advanced molecular analysis to monitor changes in/around cells
- quantify newly discovered and existing target molecules by -omics technologies
- attach a variety of specific detector molecules to a range of nanophotonic platforms
- visualise and measure changes at the molecular level in cells to answer the biological questions posed.

### Exploring the fundamental limits of detection.



RMIT processed 35nm nanodiamonds conjugated with streptavidin attached to CD36 biotin mRNA in mouse macrophage cells

#### 2015 Discovery theme progress report and plans for 2016

##### 2015 scientific achievements

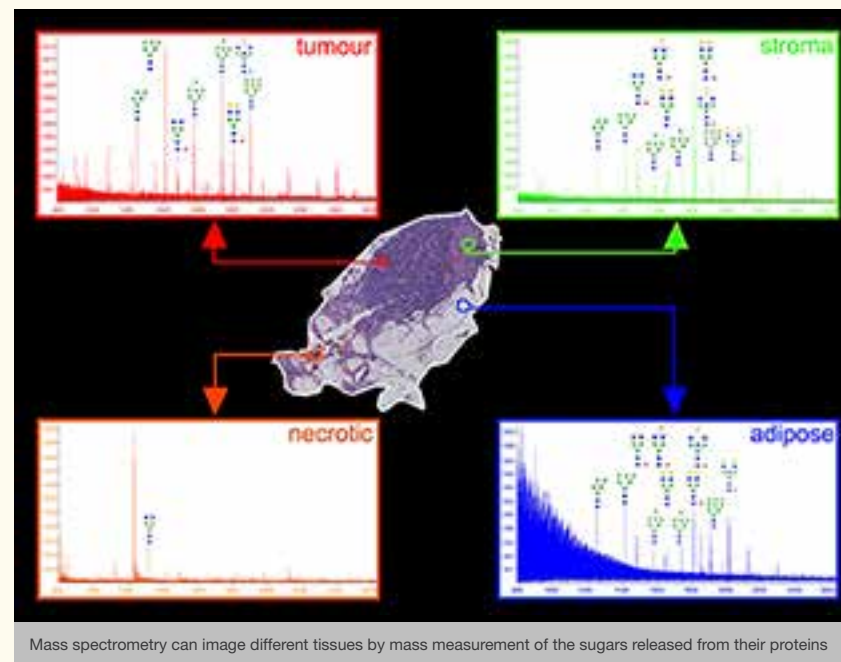
The initial aims of the Discovery team are to develop general platforms of attachment of biomolecules to available nanoparticles that will specifically recognise molecules of biological interest, so that these can be followed in the areas of pain, embryology and arterioplague formation. Three different platforms of bioconjugation of antibodies, ligands, nucleic acids to nanodiamonds, upconversion nanoparticles and new chemical chelates have been progressed, as Discovery Theme projects are based on molecular targets that have been identified by the three Biological Challenges. The platforms involve both direct chemical conjugation as well as biotin and our novel Linker-Antibody Binding Protein (L-ABP) attachment of specific antibodies, ligands and mRNAs to the different types of nanoparticles. An initial review has been published in *Trends in Biotechnology*. Cell membrane proteins such as CD36, TLR4, TNF alpha, selectin and CTB have been identified as being of interest to target across the biological systems, and probes to these at the protein and RNA level are being progressively developed. A NanoBlock database has been initiated as a CNBP information resource on the available probes.

The discovery of new molecular targets in the perception of pain is being investigated by the analysis of polysialic acid (PSA) on proteins in the central nervous system, and a probe to target PSA in different regions of the brain is being developed at the same time by one of the PhD students. The role of TLR4 in pain signalling in the brain is the subject of another student-based discovery project that is correlating proteomic, glycomic and metabolomics targets with TLR4 expression. In the reproductive biology area, mucins will be studied as a target for the visualisation of changes that occur in the endometrial lining of the uterus in diabetic women. Effects of high glucose on embryo implantation will be monitored.

In a novel tissue imaging approach, the use of Matrix Assisted Laser Desorption Ionisation (MALDI) Mass Spectrometry in molecular imaging is proving to enable differentiation of tissues (e.g. tumour from non-tumour) in formalin-fixed pathology specimens. A paper on this technique has been published in *Analytical and Bioanalytical Chemistry* journal. This advanced molecular-imaging technique will be applied to brain and embryological tissues to spatially locate biomarkers.

## Plans for 2016

- Optimise and quantitate the platforms for attachment of the available probes (nanodiamonds, UNCPS, Eu Chelates) to antibodies, proteins, mRNA, microRNA, small molecule ligands and ZPs by direct conjugation, biotin/streptavidin and/or linker peptides. Extend the bioconjugation of detector molecules to the fibre-based probes. Analyse the protein corona that forms on UNCPS and nanodiamonds in various biological fluids (e.g. serum, urine, by proteomic analysis), and determine effect on particle uptake and localisation.
- Move the detection platforms from fixed-cell to live-cell visualisation.
- Identify those platforms that have commercial potential and patent, and/or approach relevant biotechnology companies, including reagent distributors.
- As each platform is optimised, transfer the technology to the relevant applications in the Biological Challenges.
- Differentiate short-term goals from longer-term goals and ensure postdocs carry out these in parallel.
- Launch interactive NanoBlock building blocks database, populate with information and test functionality across CNBP.
- Discover properties of new biological markers of pain, embryo implantation and arterial plaque.
- Maintain current, and initiate new, collaborations across various CNBP disciplines at intra- and inter- node level and with other Associate Investigator and Partner Organisations.
- Publish papers both at the discipline level (students) and transdisciplinary level (postdocs) in high-impact journals.
- Prepare applications for CNBP-associated research grants and encourage postdoc Fellowship applications.





## Section 3

# CNBP in the community



# CNBP in the community – CNBP

“Sometimes we need to let scientists make mistakes.” —Cathy Foley

## CNBP community

### Workshops: March/July/September

The CNBP hosted regular internal workshops at each of the three nodes over the course of 2015.

Workshops focused on core capabilities at each node, as well as presentations from local researchers about new and existing projects, with lots of discussion about opportunities for new transdisciplinary collaboration.

Researchers left each workshop with new transdisciplinary vocabulary, as well as an increased understanding of the breadth of expertise and potential contained within the CNBP research community.



Poster session at the CNBP Annual Retreat

### Annual Retreat — November 9-11 2015

The CNBP hosted its second annual retreat at Lake Macquarie, NSW from 9-11 November 2015.

Almost 100 researchers from all nodes and many Partner Organisations gathered for three days of scientific interaction, networking and team building.

With a strong focus on scientific discussions and building new collaborations, attendees were excited to witness how far the CNBP had grown over the past 12 months.



Plenty of discussion and engagement at the Annual Retreat

### SLACK

Working across three geographically spaced nodes with 11 Partner Organisations across the globe, CNBP has implemented an online communication tool (SLACK) to enable Centre-wide announcements and discussions to occur and be archived in a secure environment. Popular SLACK channels include: Centre Broadcasts; Centre Comms Tool Box; Science News; ECR News; and 2015 Retreat.

### ECR and Graduate Network

Early Career networks have now been established at each node, with informal "no boss allowed" meetings. These meetings combine scientific discussion and seminars with transdisciplinary discussions and peer-driven mentorship and support.

A graduate network was established in 2015 to support CNBP postgraduate students. With the goal of complementing (not competing with) existing member-university programs, this network has identified opportunities to support CNBP students in non-traditional ways, such as a financial literacy workshop.

### Mastermind Network

Established in 2015, the CNBP Mastermind Network connects CNBP researchers to a professional mentor, with the goal of supporting individuals beyond the scientific mentorship received from their supervisors and colleagues. A number of Centre personnel have embraced this opportunity, with mentors stemming from science, business and communication backgrounds.

### Professional development workshops

Centre-wide Professional Development workshops on the topics of: 'Getting the most from Power-point'; 'Grant Writing' and 'Media Training' were hosted in 2015. In addition, local activities were hosted at individual nodes on topics such as media, commercialisation and science writing.

### Women and families in science

A family-friendly approach has been implemented for all CNBP activities. The policy includes a travel fund for children to accompany primary carers to Centre workshops, and scheduling of major meetings between 10am and 4pm with the opportunity to join via video or teleconferencing.

A CNBP 'Mums Group' has also been established to support researchers who are pregnant or caring for young children. Incorporating video conferencing to link across the nodes, discussions range from managing the family-work balance and childcare options, to documentation of missed opportunities for inclusion in fellowship applications.



## CNBP in the community: Scientists

“Most of the things worth doing in the world had been declared impossible before they were done.” —*Louis D. Brandeis*



Spark of Life team examining cellular fluorescence

CNBP researchers are working on complex scientific problems – drawing on expertise from collaborators and partners across the world. Together with peer review publications CNBP researchers attend international conferences and have hosted scientific symposia and workshops to increase visibility of CNBP and showcase CNBP research excellence.

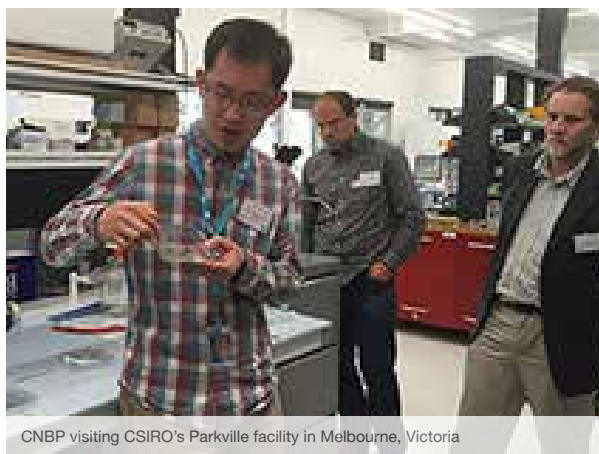
### Scientific Publications

Centre personnel have published in a range of high impact journals across diverse scientific disciplines including: Optics Express, Scientific Reports, Advances in Optics and Photonics, Chemistry – A European Journal, Analytical Chemistry and Journal of Comparative Neurology.

For a full list of Centre Publications please see Appendix 2.

### SPIE Photonics West – San Francisco

CNBP hosted a workshop on International Engagement at the Annual SPIE Photonics West Conference in San Francisco. Speakers discussed International funding opportunities, followed by informal discussions and the opportunity for building new collaborations over drinks and nibbles. With over 20,000 attendees attending multiple concurrent sessions at the Congress, CNBP were happy to host over 100 people for this important workshop.



CNBP visiting CSIRO's Parkville facility in Melbourne, Victoria

## CNBP in the community: Scientists (continued)

### ANZCOP

CNBP were proud exhibitors at the 2015 Australian and New Zealand Conference on Optics and Photonics, hosted in Adelaide.

### Macquarie BioFocus Research Centre Conference

Hosted at Macquarie University, this workshop brought together academics from physics, chemistry, biology and medicine from within Macquarie University and other local institutions.

### Other conferences

CNBP researchers were on organising committees, participated as key-note and invited speakers, and delivered oral and poster presentations, at a range of international, national and local meetings throughout 2015.



Dr Martin Gosnell introducing cellular auto fluorescence imaging at a meeting of the ARC Centre of Excellence in Convergent Bio-Nano Science

# CNBP in the community: Engagement

“We live in a society exquisitely dependent on science and technology;  
in which hardly anyone knows anything about science and technology.” —*Carl Sagan*

CNBP researchers are focused on using the Centre to showcase amazing science, in encouraging the community to engage with scientific thinking and to inspire future generations to be excited by the wonders of science. CNBP has embraced a range of communication technologies to showcase CNBP activities.

## Engagement

Many scientists remember the moment that they were inspired to pursue a career in science, and CNBP hopes to provide that inspiration for future scientists. Some of this year's highlights follow:

### CNBP in schools

In 2015 CNBP visited Belmont High School for a fun-filled day of outreach, incorporating a 75-minute live stage show for 80 Year 8 and 9 students. A leaf-blower, table tennis balls, lasers, strobe lights and running water were all used to demonstrate the dual nature of light and its reflective, refractive and diffractive properties. Nanodiamonds, iPhones, invisibility cloaks and glow sticks also made an appearance, with the challenges and opportunities of looking deeply into the body, and CNBP's research mission, clearly outlined. The team also spent time talking with Year 12 chemistry students and Belmont High School science teachers, especially regarding ongoing science education opportunities and potential careers in the science field.

### Kids Navigate Neuroscience

The CNBP Adelaide node was proud to sponsor and participate in the National Science Week activity 'Kids Navigate Neuroscience', hosted and coordinated by the University of Adelaide Medical School. Around 250 children aged 6-12 explored how the brain and nervous system work in a fun and hands-on way by participating in a series of interactive neuroscience exhibits.

### Seeing into the Body, one Photon at a Time

Supported by RMIT University, Centre CI Prof. Andrew Greentree delivered a fun and entertaining public lecture discussing the nature of light, quantum physics and how new understandings are leading to new biological insights. Also explained was the nano biophotonic research that CNBP is currently undertaking, based on this innovative interdisciplinary research. Over 200 members of the public attended and experienced first-hand the passion that Andy brings to his work.

### Researchers get fresh

CNBP researchers Daniel Drumm and Philipp Reineck participated in this year's Fresh Science Victoria program, which encourages public and educational engagement from early-career scientists. Both undertook presentation training, spoke to media and described their work to students and members of the public over a two-day period of intensive activity.

### Up Close and Revealed: Life at the Nanoscale

The CNBP RMIT node hosted a panel discussion on nanoscale technology as part of Melbourne Knowledge Week. The discussion focused on nanoscale optical sensors, quantum technology and next-generation computational devices. Following the entertaining and informative panel dialogue, members of the public were provided with tours of CNBP's new research laboratories, and provided with further information on CNBP's current research activities.



CNBP researchers Lindsay Parker, Denitza Denkova and Andrew Greentree taking CNBP research to Belmont High School



Kids Navigate Neuroscience at the University of Adelaide during National Science Week

# CNBP in the community: Engagement (continued)

## CNBP website and social media platforms



In this new communications age, more and more people are getting their news and information via the web and social media, and social networking and media sharing is on the rise. So the CNBP devoted considerable effort during 2015 to further developing its website and social media presence, and developing engaging and professional content that allows us to directly engage with our audiences and to project desired messages.

As part of these efforts, our website was restructured to better inform and engage with users. This included updated news, media, resources and communities sections, with a focus on improved prominence of new and updated content. The website saw pleasing traffic: 17,006 sessions; 10,428 users, and; 48,594 page views.

The CNBP news blog, which aims to capture and communicate key CNBP-related activity, was also a high priority and saw significant focus and effort—262 news items were posted online during 2015.

Likewise, audience engagement via the CNBP Facebook and Twitter channels has been significant, with research, seminar, outreach, event and other CNBP-related activity regularly posted online. Popular Facebook posts have reached 500-800 views, with top-rating posts hitting in

excess of 2000 views. CNBP's Twitter channel (@CNBPscience) has been equally successful, with followers in 66 locations from around the world, with a potential network reach of 374,201.

CNBP's YouTube and Flickr channels were also updated with relevant CNBP video and imagery.

## Traditional media

CNBP have been delighted to see our research achievements and other activities showcased by a variety of media channels. Some of the highlights follow.

### Use your smartphone for biosensing

A string of print and online articles and radio interviews, including in the *Sydney Morning Herald* and *The Age*, and on *Radio National*, discussing research from the Macquarie University node about converting your smartphone into a bio-sensing readout device.

### Regeneus licensing deal—New agreement to open the door to next generation cell therapies

Showcasing research and a licensing deal from the Macquarie node, this story received visibility through online, print and television coverage, including on *Ten News* and in *The Australian*.

### Chronic pain—media briefing undertaken by CNBP Director Mark Hutchinson with AusSMC

The briefing resulted in online, radio and television coverage, including on *7 News* and in *The Huffington Post*.

### Lost in Science

RMIT node CIs Andrew Greentree and Brant Gibson were both interviewed on Melbourne radio station 3CR, promoting CNBP science and a public panel discussion linked to Melbourne Knowledge Week.

### A focus on fatty eggs

CNBP senior researcher Dr Mel McDowall featured in *The Advertiser* and was interviewed by radio for her work on fat levels in oocytes and their resulting impact on fertility.

### Dr Hannah Brown

Dr Hannah Brown engaged in a significant number of media interviews throughout the year, on topics ranging from the ethics relating to genetic modification of human embryos, to gene-edited micro-pigs, to her fertility research on methodologies to repair damaged eggs.

# CNBP in the community: Partner launches

“The whole is greater than the sum of its parts.” —*Aristotle*

## CNBP Partner Launches

The strength of the CNBP is founded on the breadth of strong National and International Partners who bring a wealth of knowledge and expertise to the CNBP. To acknowledge their importance and to continue to grow these relationships, CNBP is committed to hosting an official ‘CNBP Launch’ at the home of each CNBP Partner.

Following the successful Centre-wide launch hosted at the University of Adelaide in November 2014, 2015 saw official CNBP Launches with all National Partners (Macquarie University, RMIT University, CSIRO, SAHMRI and Bioplatforms Australia) and six CNBP International Partners (Olympus (Japan), Heraeus (Germany), Huazhong University of Science and Technology (HUST, China), Peking University (China), City University London (England) and University of Southampton (SOTON, England).



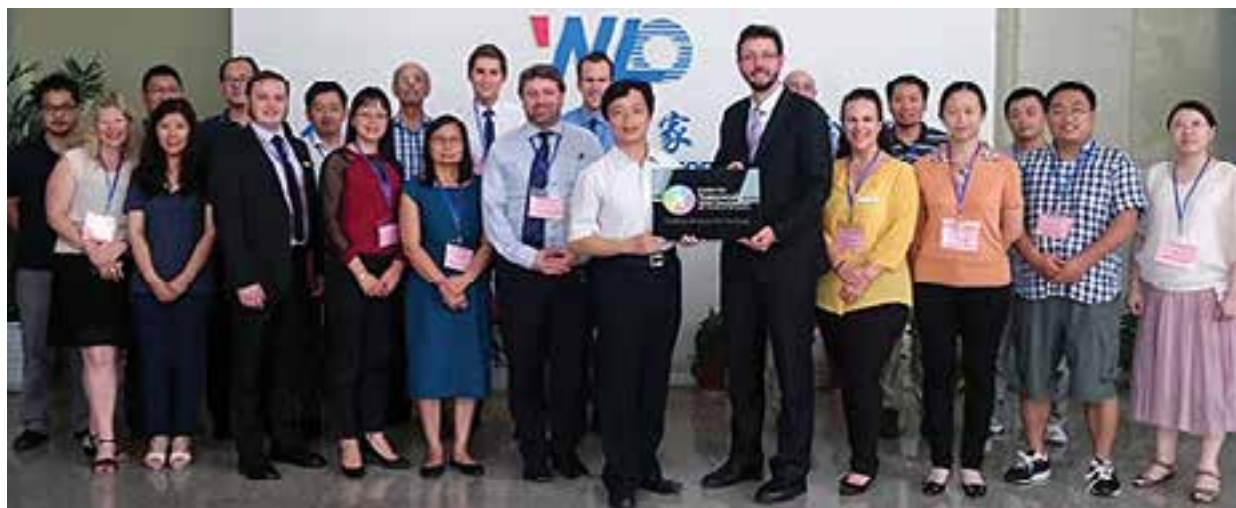
CNBP launches its partnership with BioPlatforms Australia

While the official ‘plaque giving’ ceremony was consistent across launches, the general format for each Partner Launch varied across events, including a combination of scientific workshops, public lectures and/or boardroom meetings.

In 2016, Partner Launches will be hosted with our remaining International Partners, IPHT (Germany) and University Health Networks (Canada).



CNBP Director Mark Hutchinson presents a Partner plaque to Prof. Tony Sun at City University, London.



CNBP in China launching its partnership with the Huazhong University of Science and Technology

# CNBP in the community: end-users and commercialisation

Translational outcomes cannot be achieved as an afterthought of research.

CNBP science is focused on creating scientific breakthroughs that will have long-term economic and societal benefits, as well as attracting and nurturing CNBP researchers seeking to make a difference.

## Engaging with end-users

Under the 'Promoting population health and wellbeing' National Health Care Priority challenge, the CNBP is working towards delivery of research outcomes aligned with the priority: *Optimise effective delivery of health care and related systems and services.*

CNBP researchers are working with potential end-users to understand the existing systems, including their limitations, to ensure that CNBP science is directed towards real world problems. By educating potential end-users, CNBP researchers are also looking to increase their knowledge and appetite to implement new CNBP technologies.

In 2015, CNBP engaged with a broad range of researchers, clinicians, patients and policy makers working in fields relevant to the CNBP Biological Challenges. This engagement happened in a variety of ways, such as: hosting an interactive workshop with the SA Dementia Study Training Centre; organising a symposia at the Annual Scientific Meeting of the Endocrine Society of Australia and the Society for

Reproductive Biology for 2015; speaking at a Pain Adelaide workshop; delivering the keynote address at a Canberra Health Annual Research Meeting; and delivering seminars and boardroom discussions with a host of companies working with the health industry.

## Commercialisation of Centre outcomes

Under the 'Lifting productivity and economic growth' National Research Priority challenge, the CNBP is conducting fundamental research to underpin the development of new industries and transform the way some established industries operate; the benefit of which is the provision of increased high-value jobs and greater diversity and resilience to the Australian economy.

To achieve this goal, CNBP researchers are focused on using the Centre to pioneer the fundamental science required to facilitate translational outcomes. The CNBP is building translational thinking and strategy into all stages of project development, with the goal of creating an outcomes-based culture—one that celebrates and nurtures innovation.

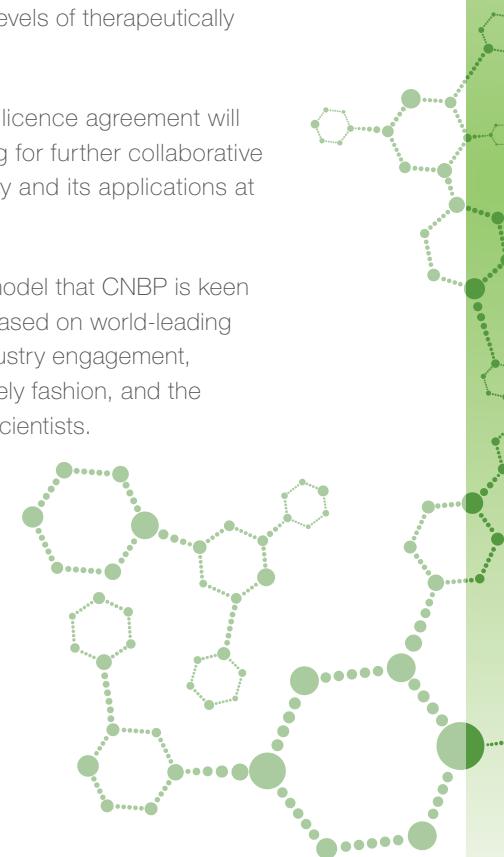
2015 saw CNBP achieve its first commercialisation success. A new collaboration and licensing agreement was formalised between Macquarie University and a clinical-stage regenerative medicine company, Regeneus, to commercialise an innovative cell selection

and identification technology that will support the manufacture of next-generation cell therapies.

The technology allows researchers for the first time to identify and select individual live stem cells based on their capacity to secrete high levels of therapeutically powerful cytokines.

An exciting component of the licence agreement will see Regeneus provide funding for further collaborative development of the technology and its applications at the CNBP.

The agreement represents a model that CNBP is keen to continue to develop—one based on world-leading science, quality academic-industry engagement, commercial outcomes in a timely fashion, and the mentoring of up-and-coming scientists.



### Engaging with government

CNBP researchers are committed to educating all Australians about the value of science to society. By engaging with government officials we have the opportunity to share our excitement regarding the disruptive potential of upcoming CNBP technologies, and reinforce the value of the blue-sky research that makes these breakthroughs possible.

A selection of CNBP researchers were fortunate to attend the annual Science meets Parliament event, coordinated by Science Technology Australia, in March 2015. The event brought together 200 working scientists for a two-day program of professional development and networking, aimed at helping them better communicate their science to the media, policymakers and Parliamentarians.

CNBP Chief Investigators and researchers met with Malcolm Turnbull (at that time, Minister for Communications), Nick Xenophon (Independent Senator for South Australia), Christine Milne (then Leader of the Australian Greens) and Julie Owens, MP. The undoubted highlight of the event, however, was the opportunity for two CNBP ECRs, Sabrina Heng and Philipp Reineck, to meet with then Prime Minister Tony Abbott, where they gave a broad overview of their research and the activities of the CNBP more generally.

The CNBP nodes have also hosted visits from a range of government officials. The Adelaide node was visited by Karen Andrews MP, Parliamentary Secretary to the Minister for Industry & Science, Christopher Pyne MP, Minister for Industry, Innovation and Science, and Senator Simon Birmingham, Minister for Educational Training. The RMIT node was visited by Wyatt Roy MP, Assistant Minister for Innovation.



University of Adelaide and CNBP visit by Ministers as part of newly released innovation statement



Assistant Minister for Innovation Wyatt Roy is shown around CNBP laboratories at RMIT by A/Prof. Brant Gibson

# CNBP in the community: Awards

## Select awards and honours

External recognition for CNBP personnel in 2015 demonstrates the versatility and strengths of our talented team. Awards have been granted from our scientific peers and the wider community, with some of the highlights as follows:



Dr Hannah Brown receiving the 2015 South Australian Young Investigator Award

### **Prof. Dayong Jin and Prof. Tanya Monro**

The 2015 Eureka Prize for Interdisciplinary Research

### **Dr Hannah Brown**

2015 South Australian Young Investigator Award and People's Choice Award

### **Mr Ashleigh Heffernan**

'Walter Boas Memorial Prize' and Nanotechnology Award, RMIT University

### **Prof. Mark Hutchinson**

2015 James McWha Award of Excellence, The University of Adelaide

### **A/Prof. Heike Ebendorff-Heidepriem**

Women's Research Excellence Award  
The University of Adelaide

### **Wan Azizuddin Wan Razali**

Travel award for attendance at CYTO 2015

### **Prof. Stephen Nicholls**

Elected as a fellow of the Australian Academy of Health and Medical Sciences

### **Dr John Horsley**

Dean's recommendation for doctoral thesis,  
The University of Adelaide

### **Prof. Nicolle Packer**

2015 Award for Excellence in Research—Innovative Technologies, Macquarie University

### **Dr Mel McDowall**

Best publication in the Society for Reproduction Biology's journal *Reproductions, Fertility and Development*

### **Dr Sabrina Heng**

Barbara Kidman Fellowship

## Partner Organisations

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The CNBP has 11 official partners who contribute significant cash, in kind support and infrastructure to CNBP activities.



### **SAHMRI**

PI Prof Stephen Nicholls and the SAHMRI Heart Health Program is working closely with the Adelaide Node of the CNBP. SAHMRI employs the inside blood vessels challenge leader and hosts three University of Adelaide part-time researchers working on this challenge. In addition to this substantial in kind contribution of research support and infrastructure, SAHMRI contributed \$50k cash towards research consumables, staff travel and communication activities. CNBP researchers working at SAHMRI are active members of the CNBP community attending local or on-line workshops, professional development activities and the annual science retreat. In September 2015 SAHMRI's partnership with CNBP was acknowledged by way of a Public Lecture and Launch at SAHMRI.



### **Bioplatforms Australia**

BioPlatforms Australia have made a 3 year commitment of \$100k per annum to leverage BioPlatform facilities to generate omics data in support of the CNBP strategy. Bioplatforms Australia support for the Centre has been accessed by Prof Nicki Packer. This module of work is critical to the application of centre developments in biologic models. Bioplatforms Australia has been active in engaging the Centre Director to investigate on going scientific and applied opportunities for closer collaboration. In November 2015 CNBP and BioPlatforms partnership was formally acknowledged and celebrated by way of a Launch at Macquarie University engaging external CNBP stakeholders including, partners, industry bodies and Chief Scientist Mary O'Kane.



### **Olympus Australia**

Olympus Australia have made a \$40k cash contribution annually to CNBP activities which CNBP have allocated towards salary and expenses for a CNBP research fellowship working towards shared goals. In addition \$160k in kind contribution provides CNBP with access to Olympus Engineers and access to Olympus facilities. In July 2015 a CNBP delegation of around 12 researchers, the executive team and Olympus Australia Managers travelled to Olympus Headquarters in Tokyo to securing a management meeting to discuss CNBP's capabilities develop strategies to work with Olympus Tokyo within their scientific solutions division. CNBP delegates also travelled to Olympus Research and Development site in Tokyo, where CNBP researchers presented to Olympus R&D, CNBP's transdisciplinary research providing further engagement and strengthening the industry engagement.

## Partner Organisations (continued)

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### Heraeus

With expertise in high purity silicon glass, Heraeus has committed \$10k in kind to provide custom built materials for CNBP researchers and to support Dr Gerhard Schotz (General Manager Photonics and specialty Fibre Optics) in working with the CNBP Community. In March 2015 Professor Heike Ebendorff-Heidepriem visited Heraeus and acknowledged CNBP's partnership with Heraeus presenting a CNBP plaque, together with providing a seminar to Heraeus researchers.

### CSIRO

The CSIRO Biosecurity flagship program with PI Prof Yonggang Zhu is working with the CNBP Measure team. An in kind commitment of \$52k per annum has been spent in part of PI's salary, facilities and travel. In September 2015 a representation of CNBP researchers and executive team visited CSIRO at the Clayton South site in Melbourne for engagement of science presentations, networking and formal acknowledgement of the CNBP and CSIRO partnership with the presentation of a CNBP plaque.

### Huazhong University of Science and Technology (HUST)

With a focus on collaborative research and student education HUST have committed \$14k per year (for 7 years) to support 4 students over the life of the centre to spend time in Australia working at CNBP nodes. HUST also provide \$10k in kind towards the salary and other costs for PI Prof Qingming Luo and other staff. CNBP delegation visited Wuhan National Laboratory for Optoelectronics in July 2015. Prof. Zhihong Zhang and Qingming Luo in WNLO collaborated with Prof. Mark Hutchinson and Ms. Vicky Staikopoulos on intravital imaging of Chronic Constriction Injury (CCI), and collaborated with Prof. Jeremy Thompson on photoacoustic imaging of hemoglobin in the oocytes. Subsequently four PhD and Master students are working on these collaboration projects. In 2015 Prof. Zhihong Zhang attended the CNBP annual scientific retreat in Sydney and gave a report about "Intravital Imaging of Immune response". HUST and CNBP's formal partnership was also acknowledged during this visit.

# Heraeus





### Peking University

With a strong commitment in student education and collaborative research, Peking University have committed \$18k per annum (for 7 years) to support a 1 year living allowance for 10 Peking University students to spend time at CNBP labs in Australia over the life of the centre. Peking University is working closely with the MQ Node of the CNBP and PI Prof Peng Xi is joint supervisor for PhD student Yujie Lu. In addition Peking University is providing in kind support of \$20k relevant to salary and support for Partner Investigators. In July 2015 CNBP delegation travelled to Peking University and presented together with Peking University academics a science seminar and acknowledged the partnership and continued collaboration between CNBP and Peking University.



### Institute of Photonic Technology (IPHT)

CNBP collaborates with the Leibniz Institute of Photonic Technology (IPHT) in Germany in order to develop Raman fiber probe technology, as well as application of the new technology to test the potential for spectroscopy supported diagnoses based on chemical analysis. Raman spectroscopy in combination with modern fiber probe technology allows a spectroscopic characterization of atherosclerotic plaques and has been demonstrated to be applicable under *in vivo* conditions. In September 2015 CNBP researchers, Georgios Tsiminis and Erik Schartner visited the group of Professor Jürgen Popp in Jena in order to set the conditions for routine based *in vivo* studies that can be performed at the CNBP. Raman fiber probes were tested on exerted rabbit aortas. Further *in vivo* testing is anticipated and will be performed in Adelaide to investigate the long term effects of localized drug treatment as well as further improvement of the probe design. Current challenges are the fabrication of very thin flexible fibers for catheter based intravascular applications. Stephen, from the Leibniz Institute of Photonic Technology (IPHT) in Jena, Germany, has been collaborating with the Centre for Nanoscale Biophotonics on using focused ion beam milling to fabricate optical micro-cavities into microstructured optical fibers. The optical fibers are known as exposed-core fibers due to their unique geometry where a portion of the optical core is open to the external environment for sensing. These fibers were provided by the CNBP while the cavity fabrication and characterisation was performed at IPHT. This forms part of a larger body of work where Stephen is fabricating micro-scaled optical sensors for use as biological sensors. IPHT have committed \$172k cash to support 1 postdoc and 2 PhD students per annum ongoing for the life of the Centre. In addition, IPHT have committed \$14k per annum in kind to support salary for PI Professor Juergen Popp and access to technology. Professor Juergen Popp attended the CNBP 2015 annual scientific retreat.

## Partner Organisations (continued)

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### City University London

With a commitment towards student education and collaborative research City University London has committed \$63.5k to support 2 CNBP PhD students. These students will spend time at CNBP labs in Australia during their PhD. CNBP Director, Prof Mark Hutchinson travelled to City University London in March 2015 and presented a seminar, together with launching the partnership of CNBP and City University of London. In November 2015 Professor Tong Sun and Professor Ken Gratton travelled to Australia and visited Macquarie University node and attended the annual CNBP scientific retreat at Lake Macquarie.



### University of Southampton (Soton)

With a focus on collaborative research and student education Soton have committed \$23k per annum cash (over 7 years) to the CNBP to support 2 students over the life of the Centre. It is the expectation that these students will spend up to 1 year working at the CNBP nodes in Australia. Soton have also committed \$45k in kind to support Professor Brambila's time and other expenses associated with this collaboration. March 2015 saw RMIT Node Director, A/Prof Brant Gibson travel to University of Southampton and discuss collaborations with Professor Brambila, together with presenting the CNBP plaque acknowledging the CNBP and Soton partnership ongoing for the life of the Centre.



### University Health Network, Toronto (UHN)

With a focus on productive joint research UHN have committed \$15k per annum to support a .3FTE postdoctoral researcher working on a CNBP project. In addition, UHN are providing in kind support of \$15k per annum to support salary, infrastructure and other costs for PI Brian Wilson who travelled to Australia and visited Macquarie University and then attended the CNBP science retreat at Lake Macquarie in November 2015.



## Other partners and grants

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We are grateful for the significant financial and infrastructure support provided by other CNBP partners



### **NSW Trade & Investment's Research Attraction and Acceleration Program (RAAP)**

CNBP Chief Investigators Piper, Jin, Goldys and Packer have secured a \$500,000 commitment over three years (2014-2016) to support industrially relevant research at the CNBP.



### **SA Collaboration Pathways Program – Premiers Research and Industry Fund**

Chief Investigators Monro, Hutchinson, Abell, Thompson and Nicholls have secured \$300,000 over three years (July 2014 – June 2017) to support technical salaries, outreach activities and Node travel for Adelaide based centre personnel.



### **National Computational Infrastructure (NCI)**

The CNBP has been awarded 800,000 (\$32,000) core hours of computing time annually, commencing in 2015. In addition the CNBP will have entitlement to persistent storage totaling 8 TBytes.



### **Pancreatic Cancer Canada Innovation Grant**

This is a joint grant between CNBP and our International Partner University Health Network, Toronto. Synchronous radiotherapy enhancement of pancreatic cancer with X-ray induced photodynamic therapy and oxygen generating nanoparticles: Dr. Ralph Da Costa, Professor Shirley XY Wu (University Health Network, Toronto) and Professor Ewa Goldys (CNBP CI).



### **Optofab Node of ANFF**

The CNBP is underpinned by the state of the art fabrication facilities of the Optofab Node of the ANFF. These enable CNBP researchers to make the optical fibre sensors that will drive the research forward.

# Legacy partners

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## The Society for Optics and Photonics (SPIE)

CNBP have pleasure in announcing a joint partnership with The Society for Optics and Photonics (SPIE) to co-host the inaugural SPIE BioPhotonics Australasia Conference in October 2016 in Adelaide. This conference will provide an opportunity for a broad-ranging exploration of the use of interactions between light and biological systems, and applications of these approaches to provide advances in biomedicine and imaging. SPIE BioPhotonics Australasia will connect people across scientific disciplines and will incorporate presentations of plenaries, themed sessions, speed science discussions and industry engagement forums. It is envisaged the inaugural conference will attract an international presence with the view to building the conference to be biennial with the view to a 1000+ meet in 2018.

The logo for SPIE (The Society for Optics and Photonics) features the word "SPIE" in a bold, black, sans-serif font, followed by a small red dot.

## Science and Technology Australia (STA)

CNBP's 2nd year of membership with Science and Technology Australia (STA) provides a greater networks of connection for CNBP and strengthens communication of our interdisciplinary research amongst politicians, business leaders and the wider community. STA Membership enabled our researchers to attend Science Meets Parliament in March 2015 at Parliament House in Canberra, where they were chosen to spend 15 minutes with the then Prime Minister, Tony Abbott discussing the science, research and key outcomes of the Centre.



## Australian Science Media Centre (AusSMC)

CNBP's membership with Australian Science Media Centre (AusSMC) connects CNBP to the most up to date science news in the media. Our membership with AusSMC also enabled us to engage their services and expertise with presenting professional development workshops to our researchers in the area of Media Training.





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