MONASH University

MONASH
Biomedical Imaging

Human brain modification technologies in 2040: *Implications*

Gary Egan
Professor & Director
Monash Biomedical Imaging

Monash University at a Glance

- Established 1961
- Named after Sir John Monash
- Ranked in the top 80 worldwide (THE, AWRU)
- 6 Australian campuses
- International footprint: 6 campuses in Asia & Europe

Sir John Monash - Outstanding Leadership

- innovation & entrepreneurship
- methodology & structure
- a sense of purpose & individual empowerment
- *commander of the Australian Imperial Forces in WW1*
- knighted on battlefield by King George V - August 1918
- Sir John Monash Centre opening in France - 25 April, 2018

Presentation Outline

1. **Introduction**
2. The past - where we've come from
3. The present - what we have now
4. The future - some possibilities
5. Summary

Monash Biomedical Imaging and Australian Synchrotron

Research dedicated imaging & procedures

MONASH University

Staffed Reception Area

3T Skyra MRI

simultaneous EEG - TMS

Consulting & Procedure rooms

Simultaneous 3T MR-PET

- Scans performed by qualified radiographers & nuc med techs
- Reported by MR & MR-PET neuroradiologists & physicians
- PET-tracers dispensed by nuclear medicine pharmacists
- MR & PET engineering & physics support
- MR & PET data analysis support
- research patient data management work flows

Pre-Clinical Imaging

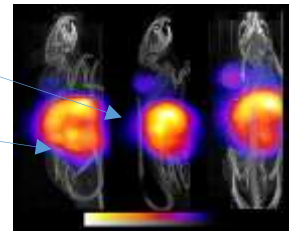
MONASH University

Mediso SIEMENS Australian Synchrotron

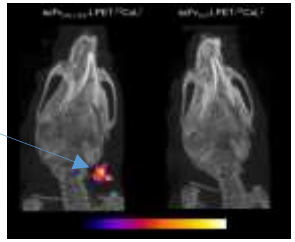
FUJIFILM | VISUALSONICS

PET-SPECT-CT

FDG murine tumors

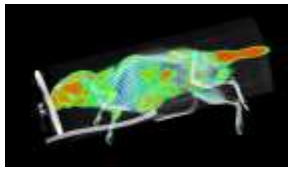


Inflammation/vascular injury



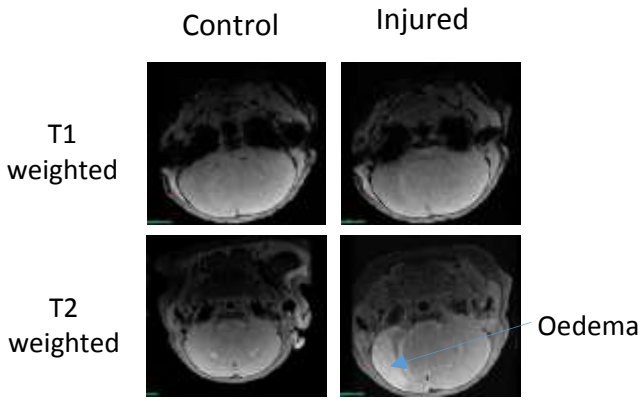
PET-Cu^{64}-platelet accumulation

Metabolic activity - FDG



MRI – 9.4T

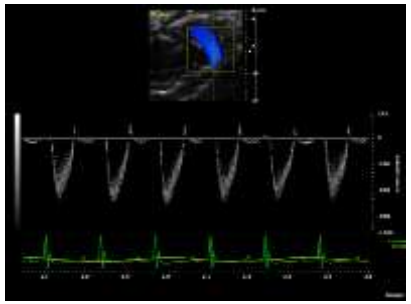
Brain Injury



Brain vasculature mapping

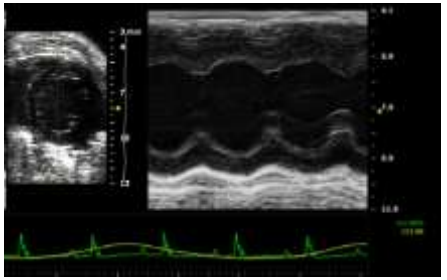
Rodent Ultrasound

Blood flow



PW Doppler PA

Aortic wall thickness



M-mode

2. The past - where we’ve come from

Imaging brain structure & function

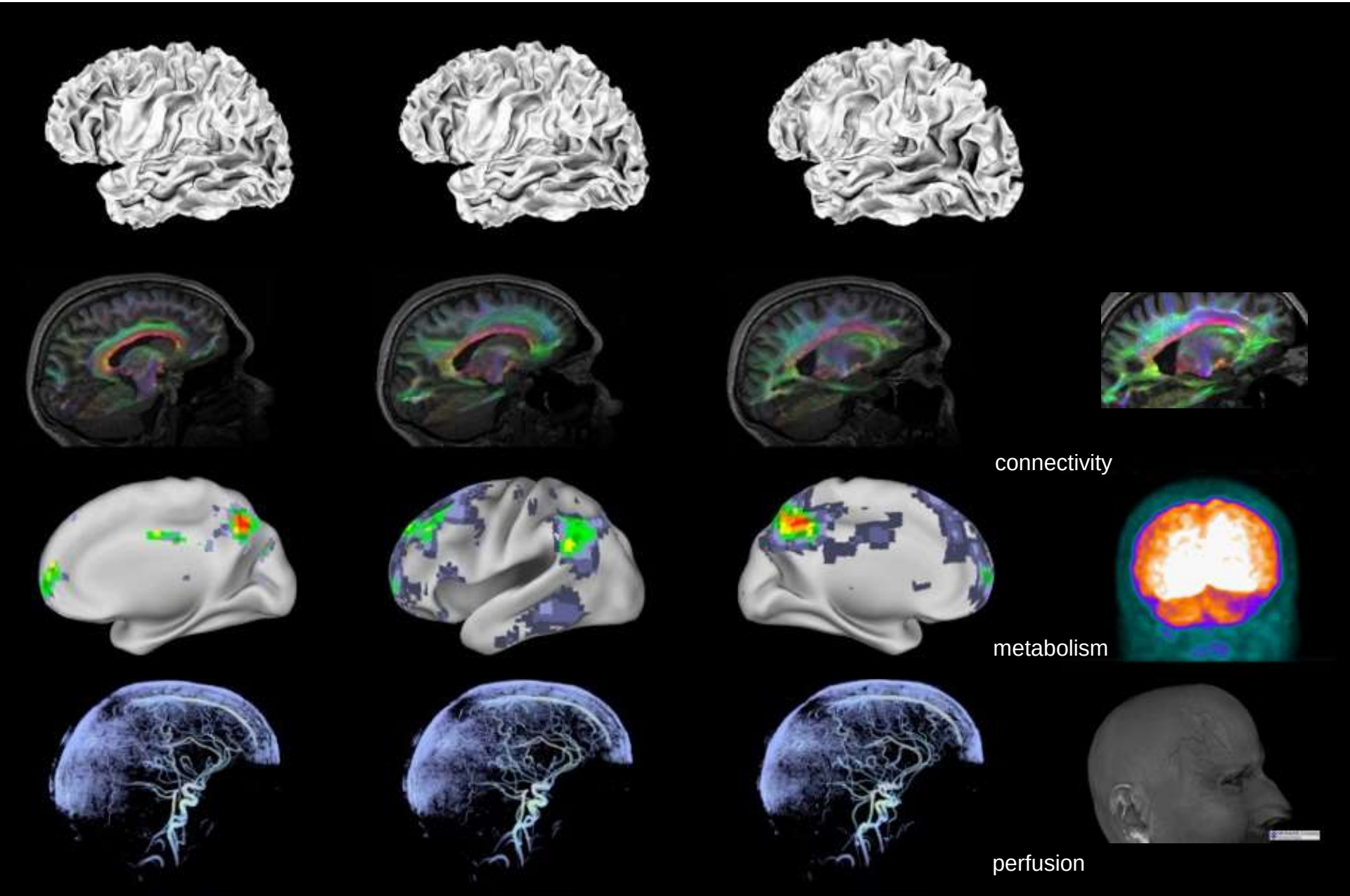
MRI studies brain anatomy.

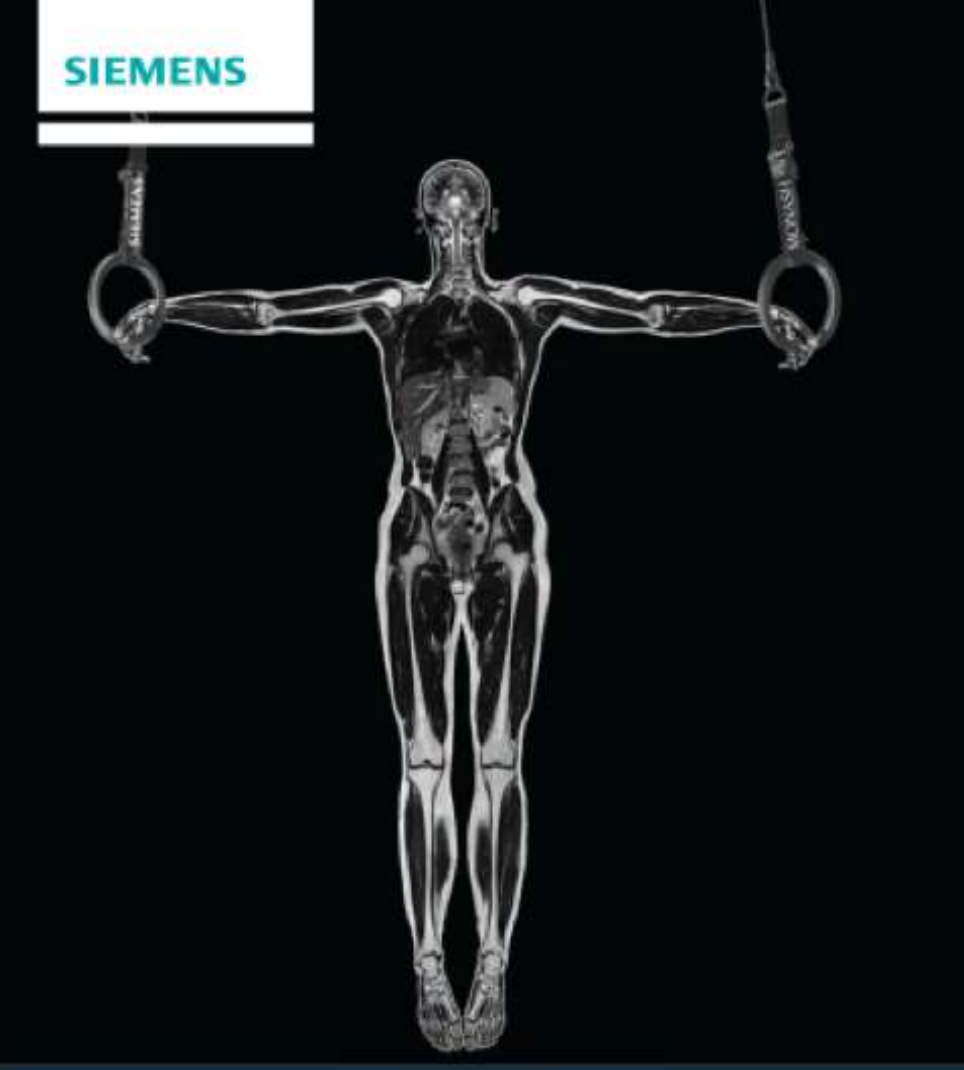
Functional MRI (fMRI) studies brain function.


HOWARD FLOREY INSTITUTE


Ultrahigh resolution 7Tesla
MRI of human brain

Imaging the human brain with MR-PET





Partnering globally to advance biomedical imaging research

MONASH University
Biomedical Imaging

Answers for life.

Collaborating to develop next generation medical imaging technologies

MONASH University
Biomedical Imaging

Answers for life.

CIBF

Australian Research Council

Centre of Excellence for Integrative Brain Function

MONASH University

The University Of Queensland AUSTRALIA

The University of Melbourne

The University of Sydney

ANU The Australian National University

UNSW The University of New South Wales

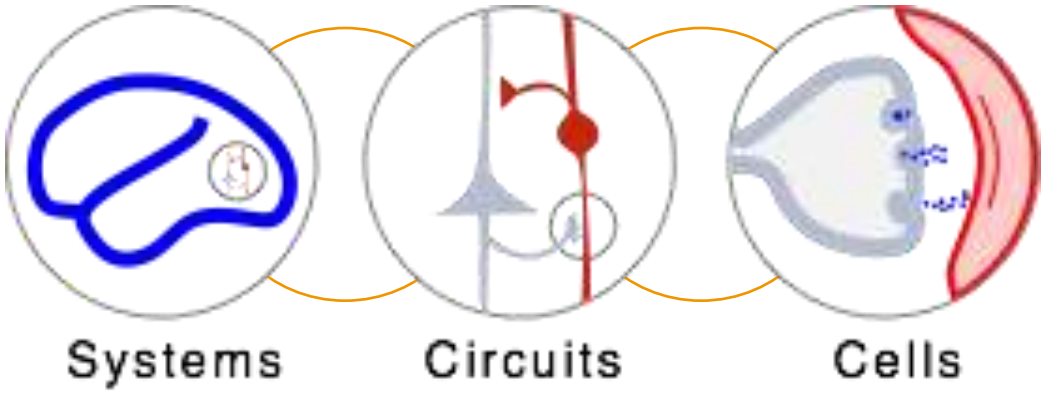
CoE for Integrative Brain Function

CIBF

Discovering how the brain interacts with the world.

ATTENTION → PREDICTION → DECISION

Models



Software & Technology

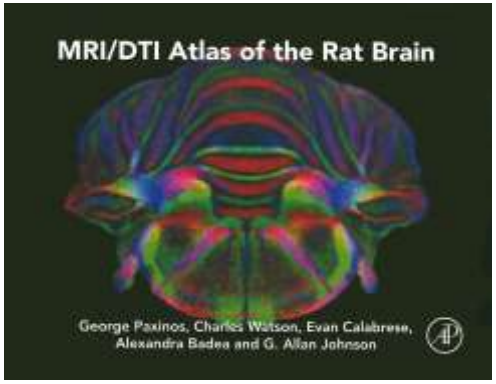
A multi-scale and multi-disciplinary research program.

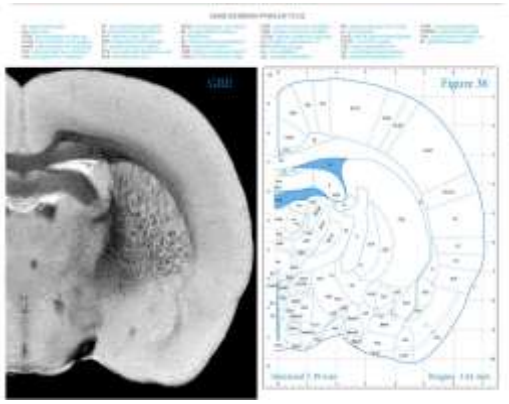
Discovery Tools - neuroatlases

Australian Research Council
Centre of Excellence for
Integrative Brain Function

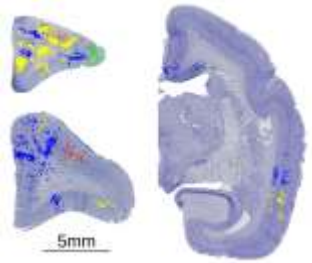
1. Development of MRI/DTI atlas of the rat brain

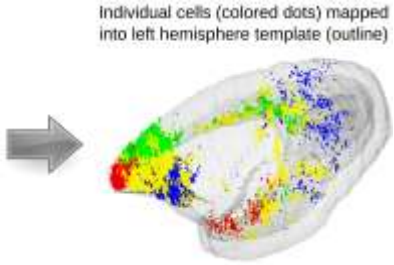
- MRI GRE scanning techniques - higher resolution than all prior published data
- current work - MRI GRE human brain atlas

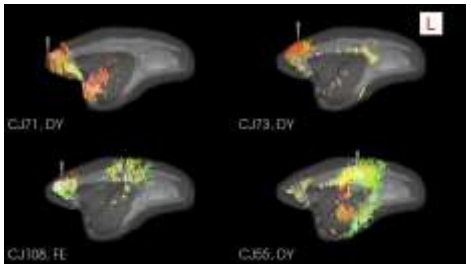




2. Digital atlas of neuronal connections in primate cortex







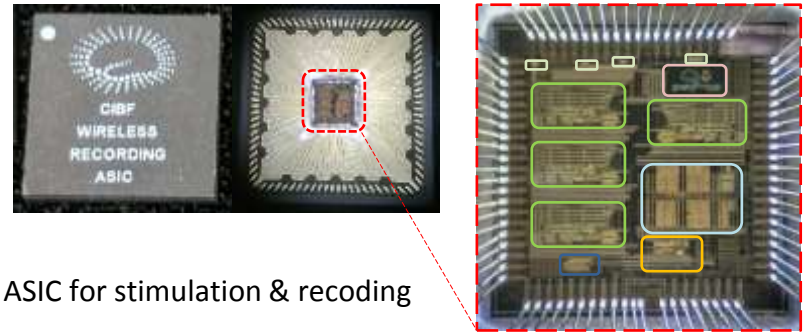
development of platforms for integration, visualisation, sharing and analysis of anatomical data

Significance:
digital maps to localise brain function to brain structure in rodents, marmosets & humans

Discovery Tools - neurotechnologies

Australian Research Council
Centre of Excellence for
Integrative Brain Function

1. Development of a wireless ASIC microchip

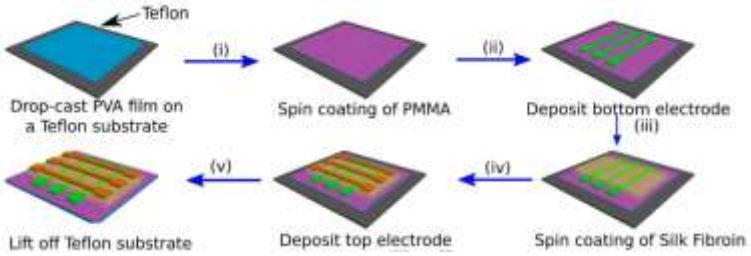


ASIC for stimulation & recoding

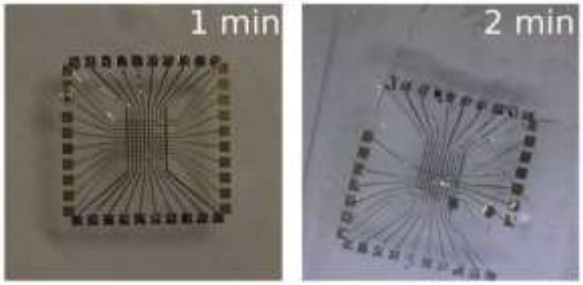
implantable tiles

implants under craniotomy

2. Development of flexible, printable, biocompatible active electrodes



fabrication process



biodegradable

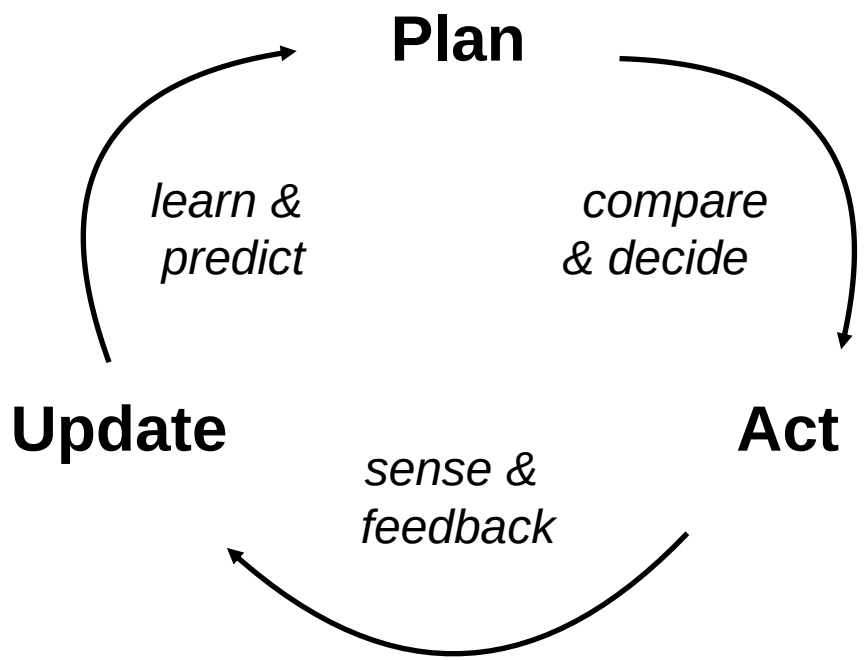
Significance:

implantable wireless stimulation & recording devices for awake rodent & marmoset experiments

CoE for Integrative Brain Function 2.0

Australian Research Council
Centre of Excellence for
Integrative Brain Function

Discovering how the world interacts with the brain



- plan - how the brain models the world
- action - how the brain changes the world
- update - how the world changes the brain

Both predator and prey must:

- generate a model of the world with the best path to approach/avoid the other,
- navigate the terrain, and
- attain their goals: food for the predator and survival for the prey.

Partner Investigators welcome


MONASH
University
BrainPark
A NEW APPROACH
TO ADDICTIVE
AND COMPULSIVE
BEHAVIOURS

A WORLD-FIRST APPROACH AND RESEARCH CLINIC
FOR THE TREATMENT OF ADDICTIVE AND COMPULSIVE DISORDERS

BrainPark is a research-driven solution to fast-track knowledge

from the brain sciences into the community

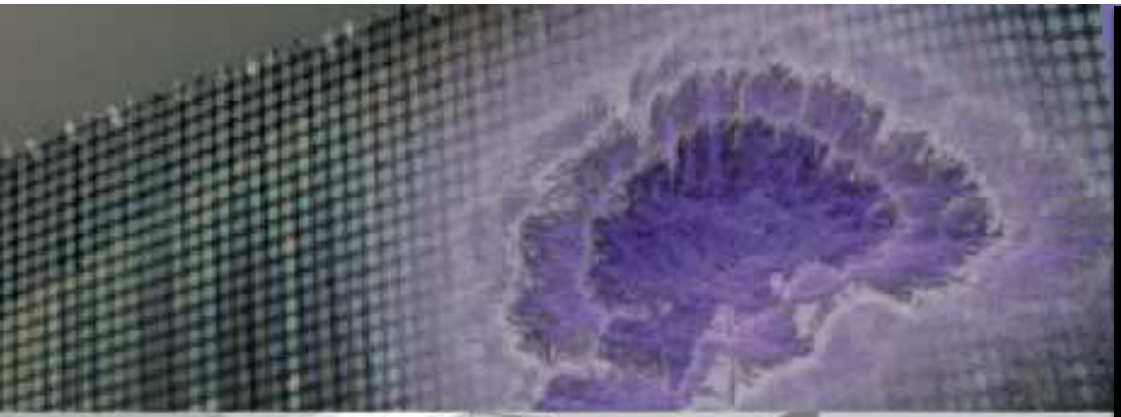
and help improve brain health of Australians

PROFESSOR MURAT YÜCEL, Head of Addiction
Monash Institute of Cognitive and Neuroscience (MICN)

VIRTUAL REALITY with two virtual reality studios,
including therapeutic VR and exergaming capabilities

THE PHYSICAL EXERCISE with indoor and outdoor gyms,
immersive spin studio, and an exercise physiology lab

MEDITATION with indoor and outdoor meditation studios



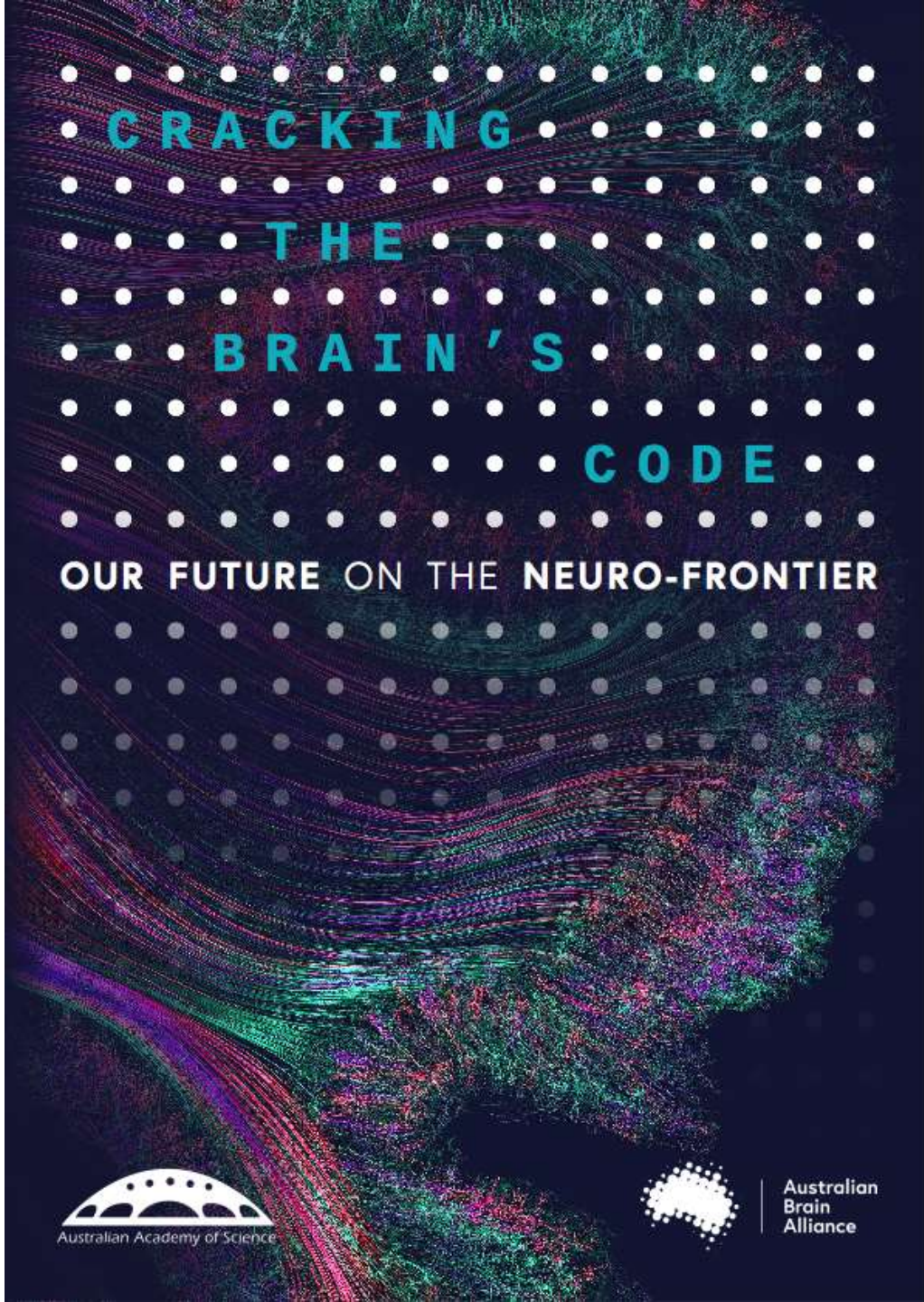
BrainPark will...

- **Immerse people** in an interactive and energising environment
- **Deliver safe**, effective and accessible interventions
- **Focus on empowerment** and wellness not just illness
- **Research the underlying drivers** of addictive and compulsive behaviours
- **Bring brain scientists** and the community together to share scientific knowledge
- **Conduct research** to understand the power of brain plasticity
- **Co-locate with MBI** to determine intervention mechanisms and effectiveness
- **Form new partnerships** between technology, neuroscience, & other sectors

Brain Modification Technologies - Decoding the Brain

Australian Brain Alliance

- Founded in February 2016, under the auspices of the **Australian Academy of Science** to transform the brain research sector in Australia.
- The Alliance aims to secure a commitment to an **Australian Brain Initiative**.
- Supported by **major scientific societies, brain research institutes** and **neurotechnology companies**.



Brain Modification Technologies - Decoding the Brain

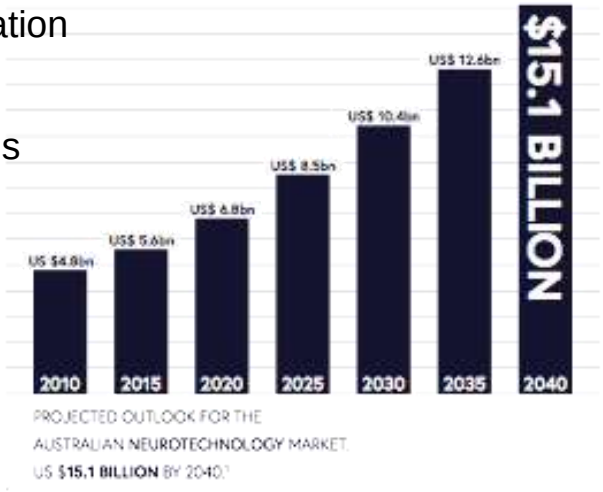
The Australian Brain Initiative will:

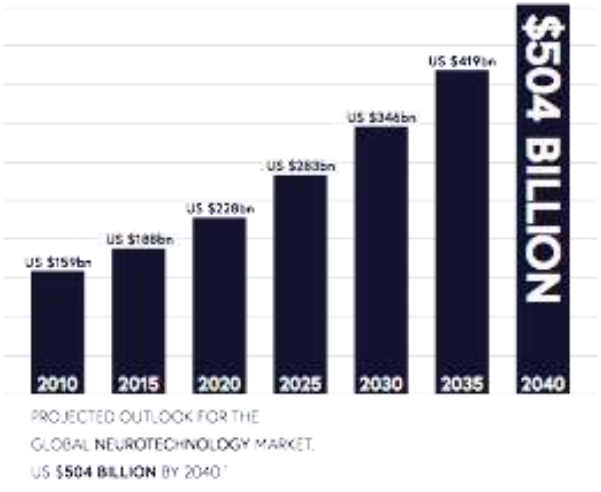
- make major advances in understanding healthy, optimal brain function
- create advanced industries based on this unique understanding of the brain
- identify causes and develop novel treatments for debilitating brain disorders
- produce sustainable, collaborative networks of brain researchers for the social, health and economic benefit of Australians

Neurotechnologies

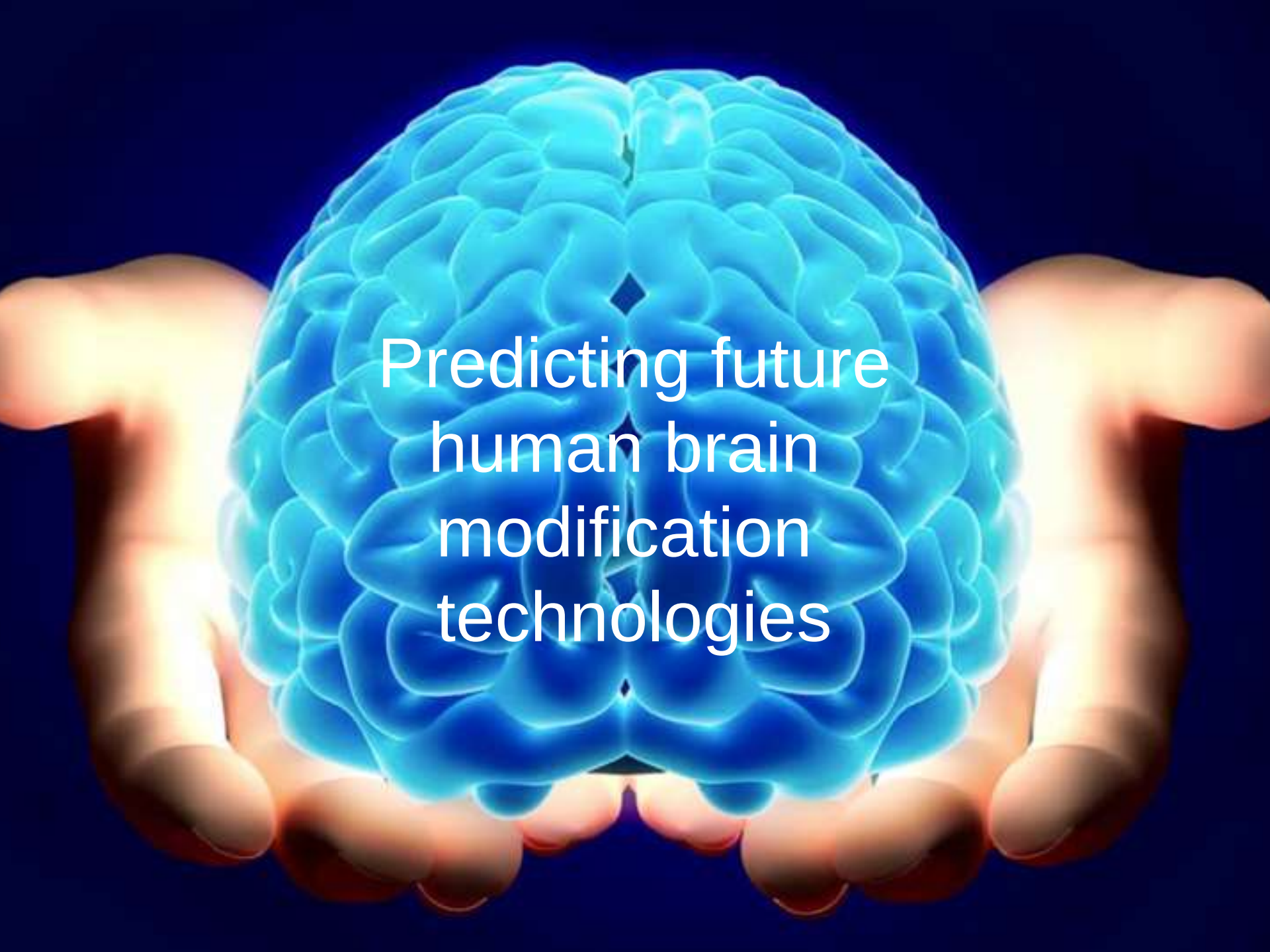
As we improve our understanding of the brain, we can develop ways to stimulate, mimic and augment its functions using:

- neurostimulation & neuromodulation
- neuromorphic computing
- brain inspired learning algorithms





www.brainalliance.org.au


Predicting future
human brain
modification
technologies

World Economic Forum 2015

Five emerging technologies that offer a glimpse into the future of brain science:

1. **Mind mapping**

Neural circuits are intricately linked to normal behaviour & how behaviour goes awry in brain diseases.

2. **Brain-like computers**

The next generation of computers informed by brain science may reason, predict and react just like the human neocortex.

3. **Brain prosthetics for patients**

As our understanding of the brain improves we can directly control and tap into brain networks using brain-computer interfaces (BCIs).

4. **Brain interfaces for the rest of us**

Brain directly connected devices are finding applications in the automobile, education, gaming, and security industries.

5. **Automated brain testing**

Technology will replace 80% of time doctors spend on decision making using portable devices and apps to diagnose, track and even treat ailments.

weforum.org/agenda/2015/08/5-brain-technologies-future/

Three Brain Technologies to Watch in 2018

1. Neural dust/neurograins - *DARPA's $65 million neural engineering program*
Aim - to develop a brain implant that can communicate digitally with the outside world.

Detect neuronal signalling using salt-grain-sized "neurograins" containing an electrode to detect neural activity and stimulate neurones, using radio frequencies.

2. Thought-Powered Typing - *could you type directly from your brain?*
Aim - turn thoughts into text at 100 words per minute.

… Facebook is developing its "silent speech" program assuming "There is signal in there [the brain] that you can harness."

3. Mini-brains
Aim - to create organoids that mimic the brain.

Create three-dimensional organoids from human stem cells to grow functional neurones, distinct layers of cortex, and other architectures that mimic the brain.

scientificamerican.com/article/3-brain-technologies-to-watch-in-2018/

Human brain modification technologies in 2040

Summary 1

A perspective of the technical and societal trends, barriers and drivers relevant to the implications of Human Modification Technologies in 2040.

- **technical trends**

- multi-disciplinary research teams & integrative approaches
- non-proprietary standards & real time automated information processing

- **societal trends**

- multi-disciplinary teams with diversity (gender, ethnic, cultural)
- neuroethics programs with community engagement

- **possible barriers**
  - lack of rigorous scientific evidence
  - community concerns & apprehension of technologies

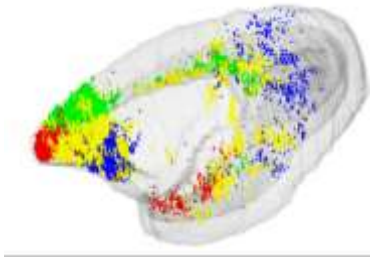
- **drivers for change**

- personal & workplace productivity improvements
- augmentation of specific brain functions - sensing, moving, remembering

Summary 2

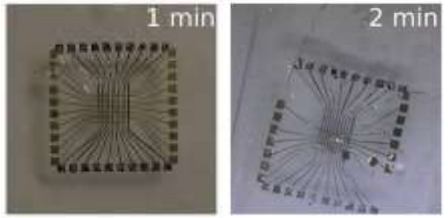
Current gaps in scientific knowledge that are an essential to bridge in order for Human Modification Technologies to have broad impact in 2040.

- knowledge of the circuits and pathways in the brain that underpin integrative behaviours - ***the brain's circuits***



- an understanding of how the brain decodes and codes information - ***the neural code***

- biocompatible technologies to interface devices to the brain - ***the interfaces***



- evidence based research to determine the mechanisms of action and efficacy of technologies - ***the evidence***

Summary 3

How the technology and methods of application for Human Modification Technologies may change over the next 10 and 20 year time frames.

- mobile wearable devices - ***for continuous recording & modification***

- ultrahigh density sensing (electrode) arrays

- ***with embedded realtime processing***

- implantable neural devices - ***extending deep brain stimulation***

- continuous monitoring of performance - ***for real time feedback***

- brain machine interfaces - ***expanding neural control mechanisms***

Acknowledgements & Funding Sources

MEMBERS

Monash MedTech

National Imaging Facility

VBIC

Australian Research Council Centre of Excellence for Integrative Brain Function

Australian Government
Australian Research Council

SUPPORTERS

SCIENCE AND INDUSTRY ENDOWMENT FUND

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

ARMI
AUSTRALIAN REGENERATIVE MEDICINE INSTITUTE

VICTORIA
State Government

Australian Government
Department of Industry, Innovation and Science

Australian Government
National Health and Medical Research Council

CSIRO

Science and Industry Endowment Fund

COLLABORATORS

CSIRO

MonashHealth

ASPREE
ASPirin in Reducing Events in the Elderly

JÜLICH
FORSCHUNGSZENTRUM

Australian Synchrotron

MASSIVE
Multi-modal Australian ScienceS Imaging and Visualisation Environment
NCI Specialised Facility in Imaging and Visualisation

PARTNERS

BRUKER

SIEMENS Healthineers

"THEN IT'S AGREED – YOU CAN'T HAVE A MIND WITHOUT A BRAIN, BUT YOU CAN HAVE A BRAIN WITHOUT A MIND."