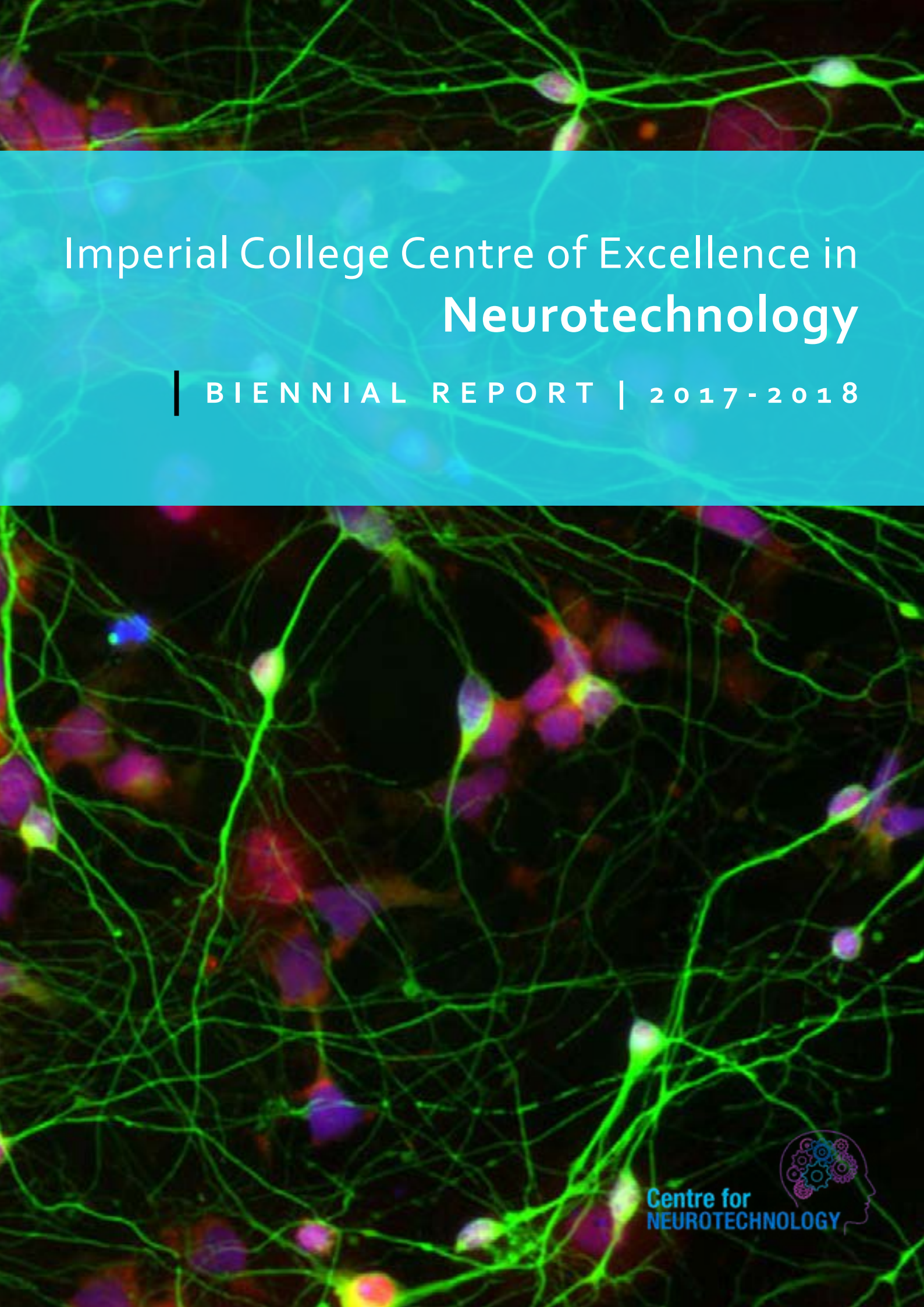


Imperial College Centre of Excellence in **Neurotechnology**

BIENNIAL REPORT | 2017-2018

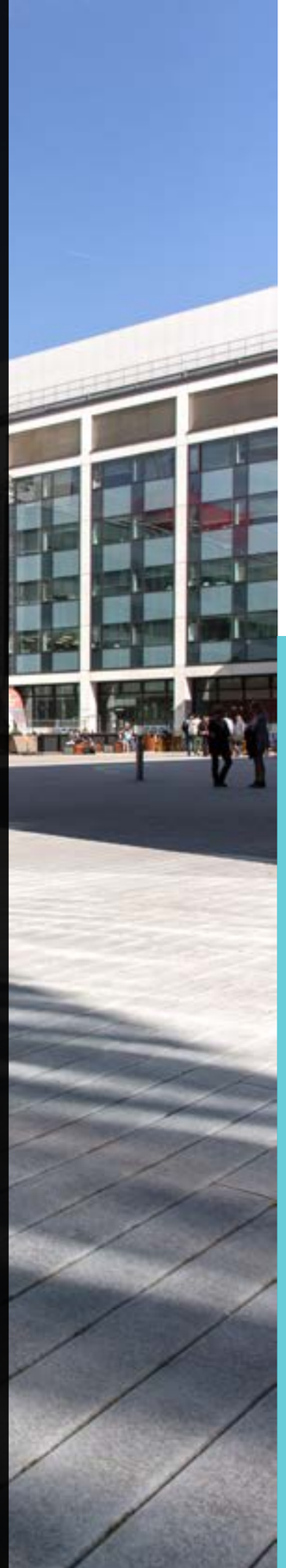
Centre for NEUROTECHNOLOGY

CENTRE FOR

NEUROTECHNOLOGY

IMPERIAL COLLEGE LONDON

www.imperial.ac.uk/neurotechnology



DIRECTOR'S FOREWORD

ONE OF THE MAIN AIMS OF THE CENTRE FOR NEUROTECHNOLOGY has been to drive new collaborative research projects that span the range of disciplines represented at Imperial College and beyond, to improve our understanding of the brain and its disorders. PhD studentships have been one of the primary vessels for achieving this. The EPSRC Centre for Doctoral Training in Neurotechnology has taken two (or more) supervisors who bring complementary training expertise focussed at the intersection of neuroscience and engineering, and matched them with a stellar young PhD student to solve a difficult problem of real benefit to society. By any measure, this has been wildly successful, generating numerous new interdisciplinary collaborations, and providing these young scientist/engineers with a unique skillset which we expect to have great impact on the world. The new research collaborations generated by the Centre involve 31 principal investigators from 11 departments across the Faculties of Engineering, Life Sciences and Medicine. They have also spanned beyond Imperial, notably with the emergence of a strong collaboration on advanced closed-loop technology for deep brain stimulation, between Imperial, the University of Oxford, and Medtronic.

THE CDT IS NOW IN ITS FIFTH YEAR, with the first cohort of students in the process of graduating – it gives me great pleasure to congratulate our first doctoral graduates, Cher Bass, Tamara Boltersdorf and Peter Quicke. The fifth and final cohort of students funded under this award began their research training in October 2018; they will graduate in 2022. Where next for the Centre? That is a question we are asking, and one thing we can say for certain is that it will remain true to our original goals of stimulating new interdisciplinary collaborations to develop the technologies that will advance our understanding of the brain in health and disease.

SIMON SCHULTZ
Director, Imperial Centre of Excellence in Neurotechnology
Professor of Neurotechnology, Department of Bioengineering
Imperial College London

CENTRE FOR NEUROTECHNOLOGY

ABOUT US

The Centre for Neurotechnology fosters collaborative research at the interface of neuroscience and engineering.

Our Centre spans the three faculties (Engineering, Life Sciences and Medicine) at Imperial College London, and is complemented by satellite members based at the Brain Network Dynamics Unit at Oxford University, the Francis Crick Institute, and the Sainsbury Wellcome Centre at UCL. The addition of new research projects in 2017 and 2018 has increased our membership to 51 academic staff, and over 50 student members, working across 15 academic departments at Imperial.

The Centre hosts the EPSRC Centre for Doctoral Training in Neurotechnology for Life and Health (the CDT), which is training a new generation of researchers to develop and harness new technologies for understanding and treating brain disorders. In 2017 the Centre was formally recognised by Imperial College London as a Centre of Excellence in Neurotechnology.

PEOPLE

CENTRE DIRECTORS

Simon Schultz, *Professor of Neurotechnology, Royal Society Industry Fellow, Dept. of Bioengineering*.
The Schultz Lab works at the interface between engineering and neuroscience. Our aim is to understand how information is processed by mammalian neural circuits underlying perception, action and memory. Understanding how "cortical circuits" process information may help us to understand how it dysfunctions in neurodegenerative disorders such as Alzheimer's Disease, and also aids in the design of novel computational devices. www.schultzlab.org/

Paul Matthews, *Edmond & Lily Safra Chair of Translational Neuroscience & Therapeutics, Dept. of Medicine.*
Paul Matthews, OBE, MD, DPhil, FRCP, FMedSci is Head of the Division of Brain Sciences in the Department of Medicine of Imperial College, London. He has recently been named as Director of the UK Dementia Research Institute at Imperial College. His research is directed towards novel approaches for human therapeutic target validation, low cost clinical trial design and stratified medicine. www.imperial.ac.uk/people/p.matthews

Bill Wisden, *Professor of Molecular Neuroscience, Dept. of Life Sciences*.
Research interests and techniques include: Neuroscience: molecular biology; transgenics, neuroanatomy, physiology, behaviour; Mechanisms of sleep; Hypothalamic function: the regulation of neurons which make histamine: the tuberomammillary nucleus and sleep regulation; other neuromodulators which regulate sleep. http://www.imperial.ac.uk/life-sciences/research/research-themes/anaesthesia-sleep-and-pain/

MANAGEMENT GROUP

Simon Schultz	Director (Engineering)
Paul Matthews	Co-Director (Medicine)
Bill Wisden	Co-Director (Natural Sciences)
Martyn Boutelle	Research Board member (Engineering)
Stephen Brickley	Research Board member (Natural Sciences)
Dario Farina	Research Board member (Engineering)
Magdalena Sastre	Research Board member (Medicine)
David Sharp	Research Board member (Medicine)

ADMINISTRATIVE STAFF

Kate Hobson	Centre and CDT Manager
Robert Ferguson	Industrial Liaison Manager (Bioengineering)

EXTERNAL ADVISORY BOARD

John Daniel	Vice President, Research & Development, Stryker Neurovascular
Caroline Hargrove	Technical Director, McLaren Applied Technologies
Stéphanie Lacour	Chair in Neuroprosthetic Technology, EPFL
Keith Mathieson (chair)	Director of Institute of Photonics, University of Strathclyde
John O'Keefe	Professor of Cognitive Neuroscience, University College London
Tim Shuttleworth	Portfolio Manager, EPSRC
Thomas Stieglitz	Head of Biomedical Microtechnology Laboratory, Bernstein Centre
Keith Wafford	Principal Research Scientist, Eli Lilly Research Laboratories UK
John White	Professor of Biomedical Engineering, University of Boston

CENTRE MEMBERS

Mauricio Barahona	(Mathematics)
Sam Barnes	(Medicine)
Anil Bharath	(Bioengineering)
Martyn Boutelle	(Bioengineering)
Stephen Brickley	(Life Sciences)
Etienne Burdet	(Bioengineering)
Alasdair Campbell	(Physics)
James Choi	(Bioengineering
Claudia Clopath	(Bioengineering)
Tim Constandinou	(Electrical & Electronic Engineering)
Vincenzo De Paola	(Clinical Science)
Simone di Giovanni	(Medicine)
Manos Drakakis	(Bioengineering)
Aldo Faisal	(Bioengineering/Computing)
Dario Farina	(Bioengineering)
Amanda Foust	(Bioengineering)
Nick Franks	(Life Sciences)
Mazdak Ghajari	(Design Engineering)
Giorgio Gilestro	(Life Sciences)
Dan Goodman	(Electrical & Electronic Engineering)
Rylie Green	(Bioengineering)
Nir Grossman	(Medicine)
Adam Hampshire	(Medicine)
Thomas Knopfel	(Medicine)
Mirko Kovac	(Aeronautics)
Andrei Kozlov	(Bioengineering)
Holger Krapp	(Bioengineering)
Huai-Ti Lin	(Bioengineering)
Nick Long	(Chemistry)
Danilo Mandic	(Electrical & Electronic Engineering)
Paul Matthews	(Medicine)
Dipankar Nandi	(Medicine)
Mark Neil	(Physics)
Kenji Okuse	(Life Sciences)
Alexandra Porter	(Materials)
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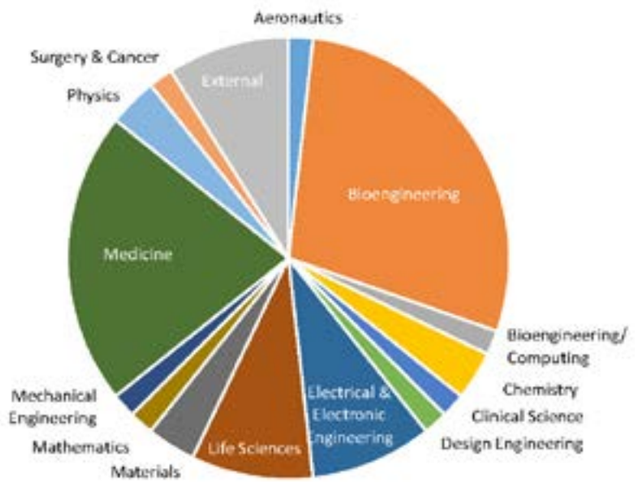
Richard Reynolds	(Medicine)
Esther Rodriguez-Villegas	(Electrical & Electronic Engineering)
Chris Rowlands	(Bioengineering)
Magdalena Sastre	(Medicine)
Simon Schultz	(Bioengineering)
Barry Seemungal	(Medicine)
David Sharp	(Medicine)
Molly Stevens	(Materials)
Paul Strutton	(Surgery & Cancer)
Richard Syms	(Electrical & Electronic Engineering)
Mengxing Tang	(Bioengineering)
Ravi Vaidyanathan	(Mechanical Engineering)
Ramon Vilar	(Chemistry)
Bill Wisden	(Life Sciences)

SATELLITE MEMBERS (EXTERNAL)

Peter Brown Peter Magill	MRC Brain Network Dynamics Unit, University of Oxford
Ede Rancz Andreas Schaefer	Francis Crick Institute
Troy Margrie	Sainsbury Wellcome Centre, UCL

AFFILIATE MEMBERS

Ann Go	(Bioengineering)



CENTRE AFFILIATIONS

RESEARCH STUDENTS

Grace Ang	Richard Daws	Diana Lucaci	Kaja Ritzau-Reid
Claire Baker	Hristo Dimitrov	Amadeus Maes	Thomas Robins
Cher Bass	Patrycja Dzialecka	Carlos Mancero Castillo	Navjeevan Soor
Oscar Bates	Lewis Formstone	Thomas Martineau	Nathan Steadman
Tamara Boltersdorf	Patricia Gallego	Irene Mendez-Guerra	Jonathan Taylor
Tunvez Boulic	Giuseppe Gava	Gerald Moore	Dan Terracina Barcas
Mario Bracklein	Pierre Guilleminot	De-Shaine Murray	William Trender
Tiffany Chan	Bryan Hsieh	Filip Paszkiewicz	James Tyrrell
Chiara Cicatiello	Mikolaj Kegler	Konstantinos Petkos	Matteo Vinao-Carl
Alexander Clarke	Gillian Koehl	Sam Podmore	Lotte Weerts
James Clarke	Alessandra Lo Fiego	Sebastian Popescu	Hugo Weissbart
Matthew Copping	Rajinder Lotay	Seigfred Prado	Isabell Whiteley
Darije Custovic	Sihao Lu	Martin Priessner	Aidan Wickham
Sofia Dall'Orso	Carl Lubba	Peter Quicke	Georgios Zafeiropoulos

CENTRE FOR NEUROTECHNOLOGY

RESEARCH

Research themes in the Centre include ***bioelectronics*** (microelectronic devices and biosensors), ***neurophotonics*** (including optogenetic technology), ***computational modelling and neural data analysis***, ***neural interface technology*** (including biomaterials for novel electrodes), ***brain-machine interaction***, and ***robotic automation for the neurosciences***.

These are directed towards solving problems in neuroscience and neurology including ***functions of brain circuits in health & disease***, ***diagnostics and clinical monitoring***, ***neuromodulation therapeutics***, ***neuroprosthetics***, ***brain repair & neuroregeneration***, and systemic therapeutics through control of the ***autonomic nervous system***.

Many disease conditions are being addressed by the Centre, including Alzheimer's Disease, Parkinson's Disease, motor neuron disease, neurotrauma, epilepsy, sleep disorders, stroke, and movement and balance disorders. As well as longstanding translational strengths in neurorehabilitation, there is an increasing focus on neurotechnology for dementia research and treatment, linking to the formation of the new UK Dementia Research Institute.

RESEARCH HIGHLIGHTS

Some of the research highlights, successes and achievements of our Centre members in 2017 and 2018 include:

- Development of a **ROBOTIC PROSTHETIC ARM** that detects signals from nerves in the spinal cord (Farina, 2017)
- Winning bid to host new **UK DEMENTIA RESEARCH INSTITUTE**, with the IC Centre led by Centre for Neurotechnology co-Director Paul Matthews (2017)
- **EPSRC IMPACT ACCELERATION AWARD** to work on Clinical Impact of Quantification of Symptoms of Parkinson's Disease (Angeles, Vaidyanathan, 2017)
- Creation of a **3D BRAIN MODEL** to reconstruct the moment of impact in sports collision, in a study to investigate the link between traumatic brain injury (TBI) and chronic traumatic encephalopathy (CTE) (Ghajari, Sharp, 2017)
- **£1M EPSRC AWARD** to develop the next generation of novel plastic-based medical implants (Green, 2017)
- **"SEEING ROBOT"** Robotic patch clamping technique used to study brain cells named as one of *The Scientist's* top technical advances of 2017 (Schultz, 2017/18)
- CDT Neurotechnology-affiliated student Chris Caulcrick featured as one of **5 YOUNG ENGINEERS** in Royal Academy of Engineering #ThisisEngineering campaign (2018)
- **£320K DUCHENNE RESEARCH FUND AWARD** to develop a bodysuit to monitor symptoms of Duchenne (Faisal, 2018)
- **£150K RUTHERFORD FELLOWSHIP AWARD** to work with Australian academics to develop new technologies to treat brain disorders (Schultz, 2018)
- **$50,000 MOBILITY UNLIMITED CHALLENGE DISCOVERY AWARD** to develop eye-controlled AI wheelchair (Faisal, 2018)
- Centre researchers use **ARTIFICIAL INTELLIGENCE TO IMPROVE STROKE AND DEMENTIA DIAGNOSIS** in brain scans (Bentley, 2018)
- Centre researchers invited to present work on human-robot interface at **PRIME MINISTER'S ROUND TABLE EVENT WITH TECH INDUSTRY** (Vaidyanathan, Wilson, 2018)
- Researchers use **MACHINE LEARNING TO IMPROVE THE PERFORMANCE OF PROSTHETIC HANDS** (Farina, 2018)
- Award of **2018 SCIENCE & PINS PRIZE FOR NEUROMODULATION** for development of method of non-invasive brain stimulation to treat brain disorders (Grossman 2018)
- **€10M ERC GRANT** awarded to team led by Dario Farina to "launch prosthetic technology into a new era" (Farina, 2018)

- Development of 3D printed device to study **BRAIN RESPONSES TO THE SENSE OF TOUCH IN BABIES' FACES** (Burdet, 2018)

RESEARCH FUNDING

More than £40M in research funding was awarded to Centre for Neurotechnology members in 2017-2018. Some of the research grants awarded to our members include:

- **Alzheimer's Research UK**: *Ultrasound delivery of BACE1 inhibitors across the blood-brain barrier in a model of Alzheimers disease* (2017-2020), CHOI, James J, SASTRE, Magdalena
- **Alzheimer's Research UK**: *Imperial College London Network Centre Grant* (2018-2019), CHOI, James J, GHAJARI, Mazdak, SASTRE, Magdalena, SCHULTZ, Simon R
- **Alzheimer's Research UK**: *Predicting neurodegeneration after traumatic brain injury: a longitudinal study of axonal injury* (2018-2021), SHARP, David J
- **Biogen Idec Ltd**: *Biogen Pharmacovigilance Study - OPTIMISE* (2018-2025), MATTHEWS, Paul M
- **Biogen MA Inc**: *Pilot - AI for Translational Myelin Imaging* (2018-2020), BARAHONA, Mauricio, MATTHEWS, Paul M
- **Biotechnology and Biological Sciences Research Council**: *How is diverse sensory information encoded within the simple circuitry of the thalamus?* (2018-2021), BRICKLEY, Stephen G
- **Biotechnology and Biological Sciences Research Council**: *Dopamine induced hippocampal plasticity: synaptic model of foraging in mice* (2017-2020), CLOPATH, Claudia
- **Biotechnology and Biological Sciences Research Council**: *Two-photon Light Field with Neuro-active Sensing for Fast Volumetric Neural Microcircuit Readout* (2018-2021), FOUST, Amanda J
- **Biotechnology and Biological Sciences Research Council**: *Fly-by-feel: the neural representation of aeroelasticity in insects* (2018-2021), LIN, Huai-Ti
- **Biotechnology and Biological Sciences Research Council**: *Noninvasive, ultrasound-mediated viral delivery of gene products to targeted brain regions* (2018-2020), CHOI, James J, SCHULTZ, Simon R
- **Bracco Suisse S.A**: *Therapeutic Microbubbles and Ultrasound Pulse Sequences for Noninvasive and Localised Drug Delivery* (2018-2020), CHOI, James J
- **Brain Research UK**: PhD studentship - *Acquired brain damage/spinal cord damage* (2018-2021), DI GIOVANNI, Simone
- **Commission of the European Communities**: *"EXTEND" - "Bidirectional Hyper-Connected Neural System"* (2018-2021), FARINA, Dario
- **Commission of the European Communities**: *From Neurons to Robots: Non-Invasive, General-Purpose Interfacing With Human Spinal Motor Neurons (INTERSPINE) - H2020 ERC* (2017-2018), FARINA, Dario
- **Commission of the European Communities**: *H2020 - ICT - INPUT - Intuitive Natural Prosthesis UTilization* (2017-2020), FARINA, Dario
- **Commission of the European Communities**: *MSCA H2020 - Decoding neural circuits controlling sleep drive and sedation* (2018-2020), FRANKS, Nicholas P
- **Commission of the European Communities**: *"Living Bionics" - "Living bioelectronics: Bridging the interface between devices and tissues"* (2018-2023), GREEN, Rylie A
- **Consiglio Nazionale delle Ricerche:** *PROCHIP: Chromatin organization PROfiling with high-throughput super-resolution microscopy on a CHIP (H2020-FETOPEN-2016-2017)* (2018-2021), NEIL, Mark A A
- **Department for Business, Energy and Industrial Strategy:** *Rutherford Fund Strategic Partner Grant* (2018-2019), SCHULTZ, Simon R
- **Duchenne Research Fund**: *Combating or treating the Duchenne Muscular Dystrophy* (2017-2019), FAISAL, Aldo A
- **Dunhill Medical Trust**: *The therapeutic effect of PGC1á at late stages of Alzheimer's disease in animal models of amyloid and tau pathology* (2018-2021), SASTRE, Magdalena

- **Engineering & Physical Science Research Council**: *EPSRC Capital Award for Early Career Researchers* (2018-2020), FOUST, Amanda J
- **Engineering & Physical Science Research Council**: *EPSRC IRC - Multimodal targeted delivery strategies for hard-to-treat cancers* (2018-2024), GREEN, Rylie A
- **Engineering & Physical Science Research Council**: *Romy Lorenz - EPSRC Fellowship Tailoring non-invasive brain stimulation* (2017-2018), LEECH, Robert
- **Engineering & Physical Science Research Council**: *EPSRC Impact Acceleration Account* (2017-2020), VAIDYANATHAN, Ravi
- **Engineering & Physical Science Research Council**: *Bionanofabrication Suite (MUBS)* (2018-2023), BOUTELLE, Martyn G, GREEN, Rylie A, STEVENS, Molly M
- **Engineering & Physical Science Research Council**: *Polymer Bioelectronics for High Resolution Implantable Devices* (2018-2023), GREEN, Rylie A, DI GIOVANNI, Simone
- **European Research Council**: *ERC Starting Grant - Vision-in-Flight* (2018-2023), LIN, Huai-Ti
- **Imperial College Healthcare Charity**: *Predicting neurodegeneration after traumatic brain injury: a longitudinal study of axonal injury* (2017-2018), SHARP, David J
- **Imperial College Healthcare NHS Trust- BRC Funding**: *ICIC 2017/18 BRC* (2017-2019), BOUTELLE, Martyn G
- **Imperial College Healthcare NHS Trust- BRC Funding**: *Neurological-Observations Assistant in Healthcare (NOAH)* (2017-2019), FAISAL, Aldo A
- **Imperial College Healthcare NHS Trust- BRC Funding**: *ICIC 2017/18 BRC* (2017-2019), GROSSMAN, Nir
- **Innovate UK**: *GripAble: A mobile-based therapy tool for hand and brain recovery* (2017-2019), BURDET, Etienne
- **Medical Research Council**: *Clinical Research Training Fellowship for Sharon Jewell - Identification of excitability profiles following acquired brain injury: A biomarker of neuronal health* (2017-2020), BOUTELLE, Martyn G
- **Medical Research Council**: *The Role of Neural Activity in Enhancing Axon and Presynaptic Regeneration in the Adult*

Injured Neocortex In Vivo (2017-2020), DE PAOLA, Vincenzo

- **Medical Research Council**: *A novel adaptive sampling technique for mapping brain function* (2018-2020), HAMPSHIRE, Adam
- **Medical Research Council**: *Development of diagnostic batteries for probing individual differences in network function* (2018-2019), HAMPSHIRE, Adam, LEECH, Robert
- **Medical Research Council**: *UK Dementias Platform* (2018-2019), MATTHEWS, Paul M
- **Medical Research Council**: *UK Dementia Research Institute Capital Award* (2017-2020), MATTHEWS, Paul M
- **Medical Research Council**: *Recovery from vestibulopathy following Traumatic Brain Injury: A prospective behavioural and neuro-imaging study* (2017-2020), SEEMUNGAL, Barry M, SHARP, David J
- **Multiple Sclerosis Society**: *The role of neuronal chemokine expression in the pathogenesis of Multiple Sclerosis* (2017-2020), REYNOLDS, Richard
- **National Institute for Health Research**: *BRC Neuroscience Theme - Pilot Study - di Giovanni* (2017-2018), DI GIOVANNI, Simone
- **National Institute for Health Research:** *BRC Neuroscience Theme - Pilot Projects - Hampshire: Ecologically valid assessment of cognitive and motor impairments in Traumatic Brain Injury (TBI) patients using real-world monitoring and machine learning*. (2017-2018), HAMPSHIRE, Adam
- **National Institute for Health Research**: *ICHT NIHR RCF funding* (2018-2019), MATTHEWS, Paul M
- **National Institute for Health Research**: *BRAIN SCIENCES BRC Theme Funding 17-20: Paul Matthews Core Project* (2017-2022), MATTHEWS, Paul M, REICHENBACH, Johann D T
- **National Institute for Health Research:** *BRC Neuroscience Theme Funding 17-22 - Reynolds et al Core Project* (2017-2019), REYNOLDS, Richard
- **National Institute for Health Research**: *BRC Neuroscience Theme 17-22: Seemungal* (2017-2019), SEEMUNGAL, Barry M
- **Nokia Technologies Oy**: *Data-Driven Sleep Neurotechnology for Nokia* (2017-2018), FAISAL, Aldo A
- **Research Council of Norway**: *Developing an integrated open access "organ on a chip" platform for drug discovery* (2017-2022), STEVENS, Molly M
- **Rosetrees Trust**: *PhD Studentship Investigating neuronal activity-dependent pathways to enhance axonal regeneration and recovery after spinal cord injury* (2017-2020), DI GIOVANNI, Simone
- **Rosetrees Trust**: *Combined HDAC3 inhibition and neurorehabilitation for aoxnal regeneration and recovery after SCI* (2018-2021), DI GIOVANNI, Simone
- **Simons Foundation**: *Simons Investigator in MMLS: Inhibition as a gate for learning* (2018-2023), CLOPATH, Claudia
- **The Beckley Foundation**: *Physiobehavioural effects of serotonergic hallucinogens and their interrelationship to cortical haemodynamics* (2017-2018), KNOPFEL, Thomas
- **The Leverhulme Trust**: *Probing synaptic amyloid-beta aggregation by redox reaction enabled super-resolution imaging* (2017-2020), KNOPFEL, Thomas
- **The Royal Society**: *Newton International Fellowships Scheme 2017: Shlomi Haar-Milo - The dynamic of real-world motor skill learning and its neural correlates* (2017-2019), FAISAL, Aldo A
- **The Royal Society**: *Robust and reproducible computational models of the brain* (2017-2018), GOODMAN, Daniel F M
- **The Royal Society**: *The Robot Neuroscientist: Automating Two-Photon Targeted Electrophysiology* (2018-2020), SCHULTZ, Simon R
- **The Weizmann Institute of Science**: *Retrograde Signalling via NOX-dependent oxygen species in neuronal regeneration* (2018-2020), DI GIOVANNI, Simone
- **UK DRI Ltd**: *UK DRI Centre Core Support* (2017-2022), MATTHEWS, Paul M

- **UK DRI Ltd**: *UK DRI Core Programmes - Stage Two* (2017-2022), MATTHEWS, Paul M
- **UK DRI Ltd**: *UK Dementia Research Institute at Imperial College* (2017-2022), MATTHEWS, Paul M, GROSSMAN, Nir, WISDEN, William (Bill)
- **VolkwagenStiftung**: *Coaxial 3D printing of actuating electroactive scaffolds for muscle regeneration* (2017-2020), GREEN, Rylie A
- **Wellcome Trust**: *Multi-scale computational modelling of neurovascular injury after traumatic brain injury* (2018-2020), GHAJARI, Mazdak
- **Wings for Life Spinal Cord Research Foundation**: *Targeting CBP/p300 acetyltransferase with a small-molecule activator to enhance axon regeneration and functional recovery after spinal cord injury* (2017-2019), DI GIOVANNI, Simone

THE BIONIC MAN

CENTRE FOR NEUROTECHNOLOGY

RESEARCHER PROFILES

Since 2014, centre membership has grown to 51 members of academic staff and over 50 student members. Here we introduce some of our newer members and affiliates.

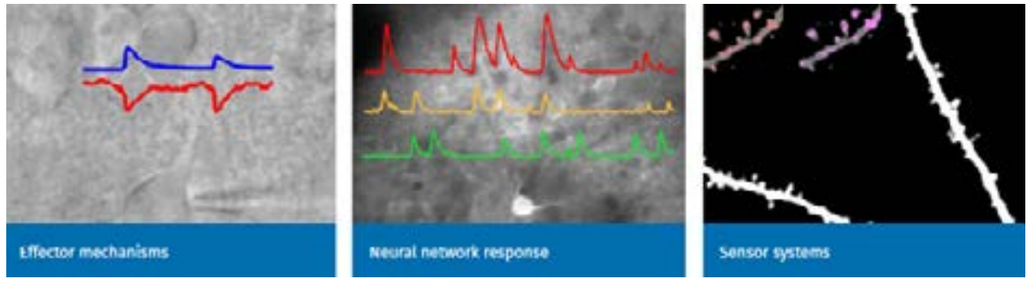
DR SAMUEL BARNES
DEPARTMENT OF MEDICINE

Dr Sam Barnes is a programme leader in the UK Dementia Research Institute and a Lecturer in the Division of Brain Sciences. His group investigates the synaptic, circuit and molecular factors that make the aged brain susceptible to neurodegeneration. His work focuses on the role of key neural-circuit and synaptic plasticity processes thought to be critical for healthy network function. Over the last ten years Sam has used in vivo 2-P calcium and voltage imaging and electrophysiological approaches to understand how neural circuits in the healthy adult brain homeostatically adapt to changes in spontaneous and sensory evoked activity levels. He now applies his understanding of neural plasticity in the healthy brain to preclinical disease models in which plasticity is thought to be dysregulated.

After graduating from Oxford University in 2006 he was awarded an MRC Capacity building PhD studentship at King's College London to investigate synaptic connection loss and neural plasticity in the neocortex. He then completed a post-doc investigating how homeostatic plasticity regulates neural activity in the adult visual cortex at University College London. In October 2015, He won the Edmond J. Safra Early Career Fellowship to investigate multi-modal cortical plasticity in the adult and aged brain. In April 2018 he was awarded a UK Dementia Research Institute Fellowship and became a lecturer in the Division of Brain Sciences at Imperial College London.

The long-term goal of his current work is to identify novel molecular targets, develop and test interventions and facilitate translation of findings that may help in the fight against dementia. His work tackles the earliest stages of neurodegeneration by investigating the emergence of destabilised spontaneous activity using a three-part framework. Firstly, he uses longitudinal in vivo imaging approaches to understand the spatio-temporal propagation of destabilised activity in preclinical rodent models and aged animals. Next, he investigates the synaptic and circuit level plasticity processes that result in dysregulated activity. Finally, he probes the molecular and synaptic sensors that detect and attempt to regulate perturbations in neural network activity.

His recent work includes studies of small neural sub-networks during homeostatic plasticity[1,2], single synapse level structural adaption involving neuron-glia signalling[3,4] and dysregulation of activity in preclinical rodent models[5].

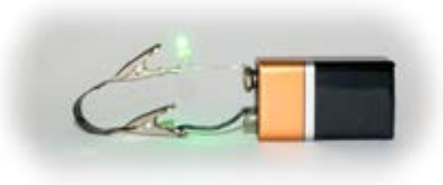


References
1. Barnes, S.J. et al. Neuron 86, 1290–1303 (2015).
2. Sweeney, Y., Barnes, S. & Clopath, C. bioRxiv 312926 (2018).doi:10.1101/312926
3. Barnes, S.J. et al. Neuron 96, 871-882.e5 (2017).
4. Sammons, R.P., Clopath, C. & Barnes, S.J. Cell Rep. 22, 576–584 (2018).
5. Real, R. et al. Science eaau1810 (2018).doi:10.1126/science.aau1810

DR RYLIE GREEN
DEPARTMENT OF BIOENGINEERING

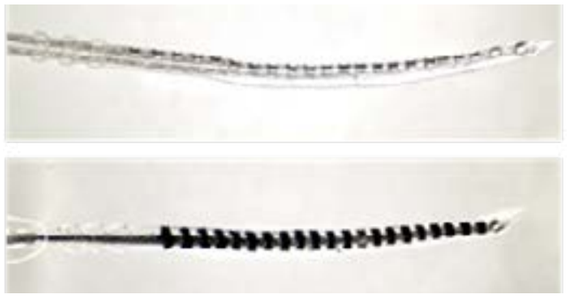
I received my PhD (Biomedical Engineering) from the University of New South Wales, Australia in 2009 and joined the Bioengineering department at Imperial College London in 2016. My research has been broadly focused on developing medical electrodes, with a specific focus on neuroprostheses. Over the past 30 years implantable bionic devices such as cochlear implants and pacemakers, have used a small number of metal electrodes to restore sensory perception or muscle control to patients following disease or injury of excitable tissues. With the miniaturisation of electronic chips, bionic devices are now being developed to treat a wide variety of neural and muscular disorders. Of particular interest is the area of high resolution devices that require smaller, more densely packed electrodes. Due to poor integration with living tissue, conventional metallic electrodes cannot meet these small size requirements and are limited in their ability to safely deliver charge at therapeutic levels. As such my research has focused on bringing together technologies from biomaterials and tissue engineering with neurotechnology and bionics.

I have developed a range of electrode coating materials including conductive hydrogels (CHs), conductive elastomers (CEs) and more recently living electrodes (LEs). These electrode technologies provide synergy between low impedance charge transfer, reduced stiffness and an ability to be provide a biologically active interface. While these approaches have initially been used to modify existing implant electrodes (including cochlear implants and bionics eye arrays), these technologies also offer new opportunities for producing fully organic electrode arrays which are not bound to metallic substrates. My most recent development is tissue engineered "living electrodes", a new concept which will allow neural cells to synaptically interface with bionic devices. Within this program is a technology that uses stem cells within electroactive scaffolds to create a bionic spinal cord bridge.

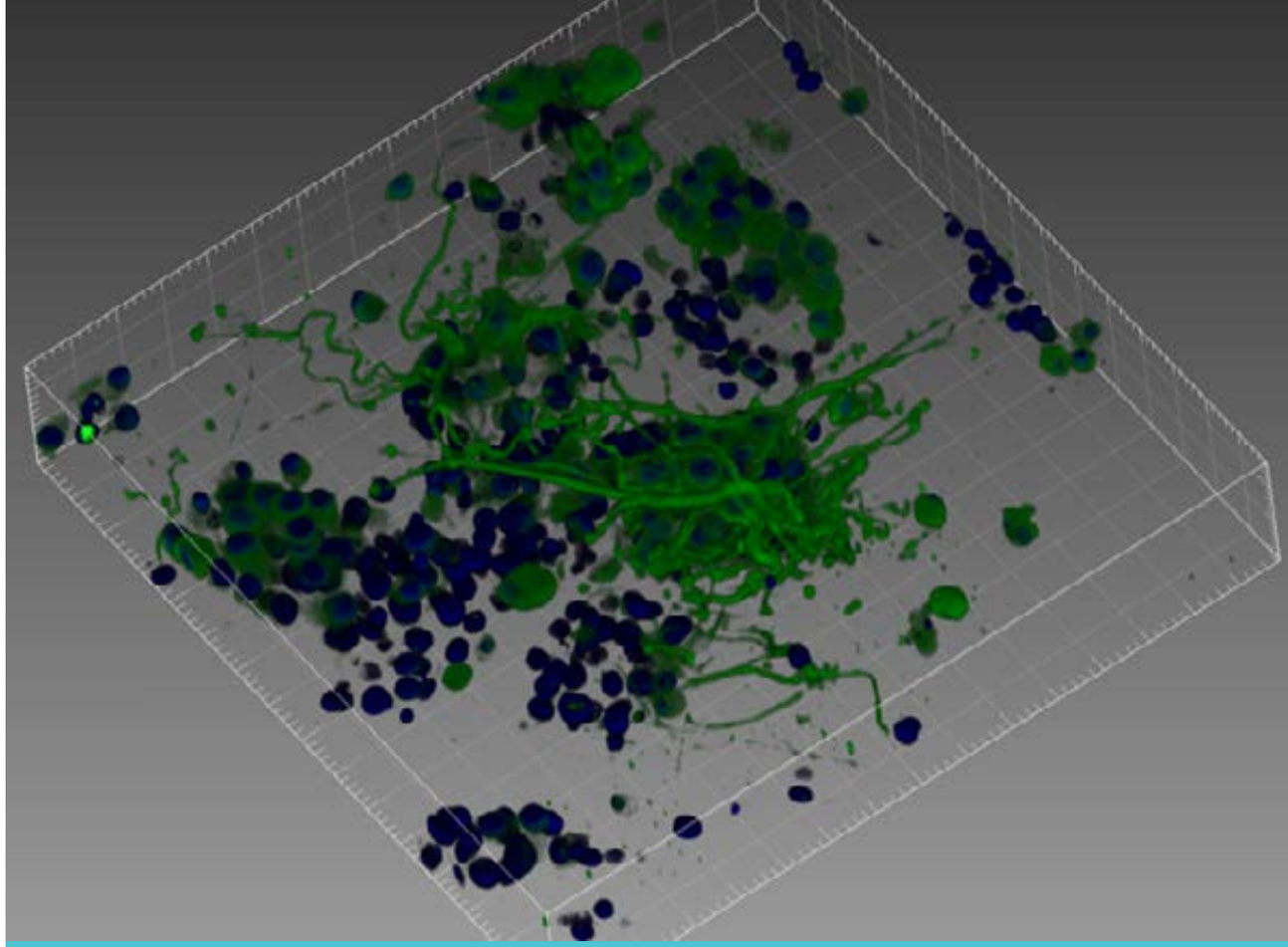


Flexible electronics showing conductive elastomers connecting a battery and LED light

While my research has been focused on developing bioactive conducting polymers to improve performance of stimulating electrodes, I have also developed a range of techniques for characterising the in vitro performance of implantable microelectrodes in biologically relevant environments. Specifically, I have investigated electrode technologies for the developmental bionic eye device (with Bionic Vision Australia), and coatings for commercial implants (with Cochlear Ltd, Galvani Bioelectronics and Boston Scientific). These industry relationships will be critical to developing a program of translation from bench to clinic.



Cochlear implant coated with conductive hydrogel



Living electrodes showing neural networks grown within devices.

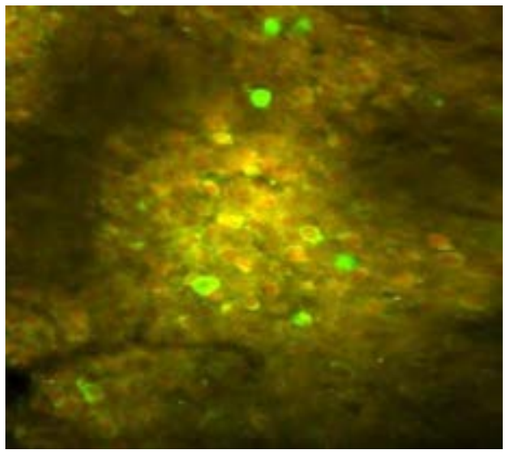
DR MARY ANN GO
DEPARTMENT OF BIOENGINEERING

Mary Ann Go is a postdoc at Prof. Simon Schultz's Neural Coding and Neurodegenerative Disease Lab. Ann leads a project investigating circuit changes in the hippocampus with the progression of Alzheimer's Disease in mice models. She looks at the remapping of place cells, the hippocampal cells that encode spatial information about an animal's environment, using two-photon microscopy to image calcium level changes that report cellular activity and to quantify the volume of amyloid-beta plaques, one of the hallmarks of Alzheimer's Disease. Ann works with the Centre for Doctoral Training (CDT), giving lectures on two-photon microscopy at the CDT Optical Workshop and marking the CDT journal club. She has also actively promoted engagement among postdocs in the Bioengineering Department as a postdoc representative.

Ann comes to Imperial after finishing her PhD in Neuroscience at the Australian National University where she developed a novel two-photon microscope with the flexibility to create spatial and temporal patterns of excitation for photostimulating neurons. She then briefly went to University of Regensburg as a visiting scientist to develop a holographic module, similar to her PhD work, on a commercial two-photon laser scanning microscope for a continuing collaboration.

Ann has won an Alzheimer's Research UK Imperial Network Centre Pump-priming Grant with Simon Schultz and Magdalena Sastre and a Balik (Returning) Scientist Program Grant from the Philippine Council for Industry, Energy and Emerging Technology Research and Development, the latter for her work in training high school research teachers in Tacloban shortly after she finished her PhD.

Ann is familiar with switching fields, having done it during her PhD after earning a BS in Applied Physics and an MS in Physics from the University of the Philippines. Her undergraduate and masters theses were on separating the spectral signatures of aquatic benthos for application in coral reef mapping and assessment. The 'field switch' was motivated by a desire to pursue research with greater impact on human health and well-being, a theme that continues in her current research. She is especially interested in pursuing this theme with a special tool – light.



DR CHRIS ROWLANDS
DEPARTMENT OF BIOENGINEERING

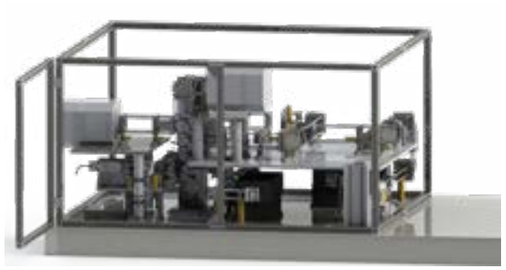
Dr Rowlands works on the development of optical instruments for probing complex biological systems, with a particular focus on neurophotonics. He has a broad background across the physical sciences and engineering, having completed an undergraduate degree at Imperial College before leaving to pursue a PhD in the physics of amorphous materials at the University of Cambridge. During a Wellcome Trust fellowship in MIT, he developed his current interests in optical engineering and neurobiology.

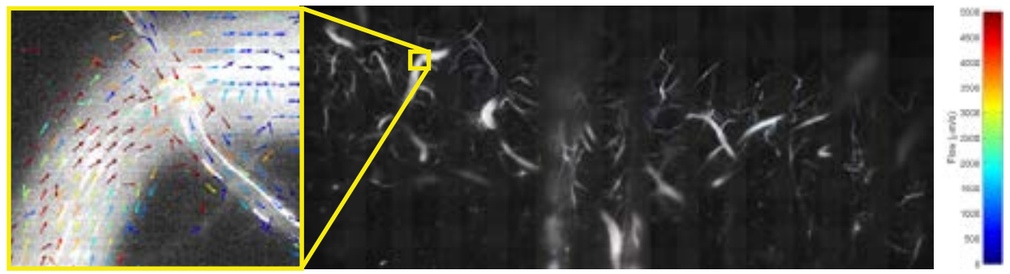
Dr Rowlands' previous work includes a number of cutting-edge instrumentation designs. One project was to develop a high-throughput super-resolution microscope to map the connectivity of the entire mouse brain at synaptic resolution. This ongoing project involved making a one-million-fold improvement in the pixel throughput of conventional point-scanning techniques, while maintaining the quality of the resulting optical fields necessary to achieve good super-resolution. A model of the prototype instrument is shown (right), and work is currently taking place on the second version of the instrument, which will be a factor of 10 cheaper, and with improved resolution.

A second topic under investigation is the development of high-throughput instruments for imaging and controlling neural activity. Previously, Dr Rowlands developed high-speed multiphoton microscopes for mapping blood flow in the mouse brain, as well as for controlling neural activity deep within the brain via three-photon stimulation of optogenetic proteins. An example of the kind of flow data that could be obtained can be seen, demonstrating that flow maps from the scale of arteries right down to the smallest capillaries could be obtained, with applications in the investigation of stroke, as well as the capillary-scale correlation between neural activity and flow.

This previous work forms the basis of new projects, including the development of a 3D volumetric imaging system for mapping neural activity in three dimensions, as well as systems to perform holographic patterning of light over a hundred times faster than current state-of-the-art.

Future projects will be based on these, or similar themes. From finding holographic methods for 'sculpting light' in order to achieve specific targeting of an opsin-expressing neuron, to investigating the effect of various drugs on complete neural circuits within the brain, or even developing methods for whole-brain activity mapping, the need for new instruments with unique capabilities will continue to drive the field of neurobiology, and their development will continue to be a part of the research at Imperial College

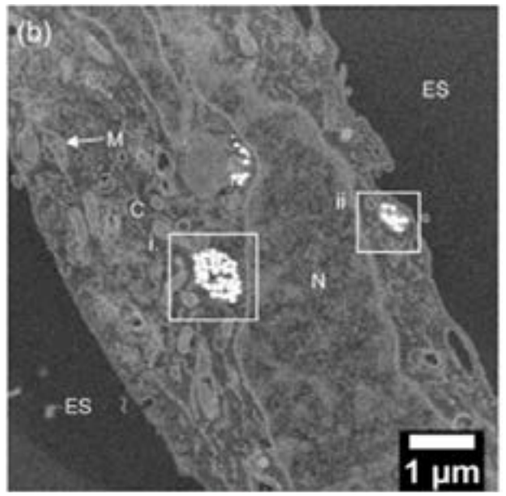




PROF ALEX PORTER
DEPARTMENT OF MATERIALS

Alexandra's group uses correlative electron microscopy techniques to characterise interfaces between biomaterials and cells. Her great interest is in developing a mechanistic understanding of how the chemistry of these materials controls their degradation behaviour, and ultimate bioactivity, to improve their performance and safety.

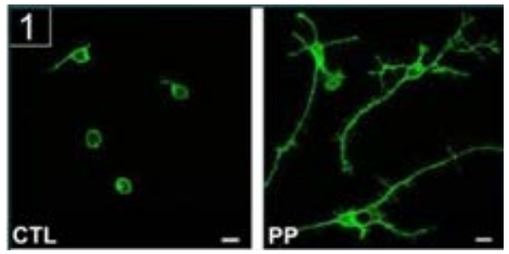
A NEW STAR FOR DELIVERY OF DRUGS INSIDE THE BRAIN?: Clinical treatment strategies for Parkinson's disease (PD) only treat symptoms, without slowing down the disease progression, are short-acting, costly and often cause debilitating side effects. This shortcoming is because most drugs cannot efficiently reach neurons damaged in PD due to the relatively large size of drug molecules and highly impermeable blood-brain-barrier (BBB), which necessitates the use of higher dosages, often leading to severe side-effects. There is an urgent clinical requirement to devise small-size protective agents and strategies to deliver them to neurons. Very small (nano)-materials can target and transport drugs across the BBB in vivo are opening up new treatment approaches, but the efficiency of crossing is currently low. Nanostars are star-shaped nanoparticles, 1-100 nm in diameter. They consist of a spherical core surrounded by multiple spikes of varying length, width and sharpness. Gold nanostars are particularly interesting in biology due to their high surface-to-volume ratio, biocompatibility and chemical stability, their unique optical properties and ability to sensitize tissues to radiotherapy. These interesting properties have prompted our team to investigate gold nanostars for various applications in neuromedicine, including treatment of Parkinson's disease and Glioblastoma Multiforme (in Collaboration with Dr. Nel Syed and Matthew Williams, Division of Surgery & Cancer). Notably, our team (Prof.s Alexandra Porter, Mary Ryan and Rosalia Rodiguez, Dept. Materials) have shown that star-shaped nanomaterials can cross the plasma membrane of brain endothelial cells that line the BBB in very significant amounts (ca. 40% efficiency of BBB transport in vitro (Nanomedicine, 2018). Moreover, in collaboration with Prof. Dexter (Dept. Medicine) we have demonstrated that the nanostars can be functionalised with L-DOPA, which targets the large amino acid (LAT-1) transporter abundantly and selectively expressed in the capillary endothelial cells of the BBB. Importantly, LAT-1 on BBB exhibits ca. 10-fold higher substrate affinity than LAT-1 in peripheral tissues, which results in the preferential accumulation of LAT-binding nanoparticles in the brain. In our experiments, functionalization of nanostars with L-DOPA resulted in almost a double increase of transport efficiency.



Dark field TEM image of clusters of nanostars inside cells that express LAT-1 (ACS applied Materials and Interfaces, 2018).

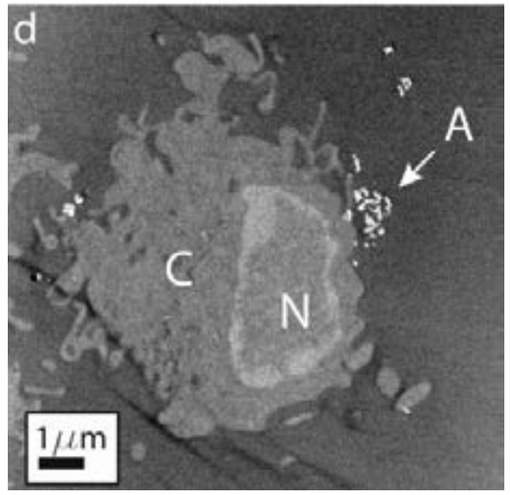
TOWARDS A NEW THERAPY FOR PARKINSON'S DISEASE: In subsequent work led by Dr. Kiryushko, Dept. Materials, we have also discovered small, easily producible synthetic peptides (H3 and H6 – based on S100A proteins that are upregulated in brain disorders) and demonstrated that they mimic the beneficial effects of the parent protein in vivo and in neuronal models of oxidative stress, excitotoxicity, and Parkinson's disease (PD)-related

cytotoxicity, making them promising therapeutic candidates (Theranostics, 2018; Figure 1). Thus these molecules can protect neurons that normally die in PD against toxic insults and stimulate these neurons to grow new branches, potentially offering many long-term advantages over current therapies. However, these protectants cannot cross the BBB. To address this issue, the team has conjugated these H3 and H6 nanocompounds onto the surface of the star-shaped gold nanostars and shown that they have superior neuritogenic and neuroprotective efficiency than their spherical counterparts. We are currently using very high resolution cryo-electron microscopy imaging techniques to study the interface between the nanostars and neurons to understand why they are so effective.



The parent protein (PP) induces neurite outgrowth from hippocampal neurons. CTL, untreated cultures.

IMAGING NEUROTOXIC PROTEINS AT THE NANOSCALE: The aggregation of misfolded proteins is a common feature underlying a wide range of age-related degenerative disorders, including Alzheimer's and Parkinson's diseases. A key aspect of understanding the molecular origins of these conditions is to define the manner in which specific types of protein aggregates influence disease pathogenesis through their interactions with cells. In a separate study published in ACS nano, 2012, we have developed a new chemical mapping technique in the transmission electron microscope (TEM) to image, with a resolution of 5–10 nm, the interaction of human cells with these misfolded protein aggregates whose self-assembly is associated with Alzheimer's disease. Our observations shed new light on the origins of their differential toxicity and the mechanisms of their clearance by neuronal cells. In future we hope to use this imaging technique to understand whether our synthetic peptide-nanostar platform can be used to protect neurons against these toxic proteins.



Dark field TEM image showing Aβ fibrils in the vicinity of the cell membrane of an HMM. The fibrils have been imaged by substituting selenium for sulphur in their molecular structure.

CENTRE FOR NEUROTECHNOLOGY

THE CENTRE FOR DOCTORAL TRAINING

The EPSRC Centre for Doctoral Training in Neurotechnology for Life and Health (the CDT) is training a new generation of multidisciplinary scientists and engineers to develop advanced technology for understanding and interacting with the brain.

THE CDT PROGRAMME, funded primarily by the Engineering and Physical Sciences Research Council, builds on Imperial College's strengths, fusing technology and neuroscience, to produce Neurotechnologists who can cross traditional boundaries between engineering, the physical sciences, and biomedical research. In this way we aim to change the way that neuroscience research is conducted and advance the rate at which neurological treatments are developed, realising positive benefits for industry and society.

CDT TRAINING

In 2018, the CDT welcomed the fifth cohort of students, bringing current student numbers up to 56. Our students come from a range of academic backgrounds including Bioengineering, Mathematics, Computer Science, Physics, Chemistry and Neuroscience.

Students follow a 1+3 programme, comprising a one-year MRes in Neurotechnology, and a three-year PhD project. The MRes year provides students with a grounding in neuroscience and engineering subjects and prepares them for their full-time research PhD. In conjunction with their academic training, CDT students benefit from additional training elements throughout the programme including professional skills training workshops, neurotechnology seminars and symposia, public engagement and outreach training and activities, careers training, attendance at national and international conferences and an internship or academic exchange.

RESEARCH PROJECTS AND SUPERVISION

The CDT has facilitated an unprecedented level of cross-Faculty collaboration in new areas. Co-supervision by at least two supervisors with complementary expertise is fundamental to this success and is an essential part of the CDT student experience. Supervision teams commonly span departmental boundaries, maximizing the range of perspectives and research infrastructure support available for each project. Over 70 PhD supervisors from 14 Departments are involved from the three Faculties of Engineering, Medicine and Natural Sciences at Imperial College, plus external supervisors from satellite groups and industry.

Research projects cover several technology and health themes and tackle a variety of diseases/conditions, reflecting the breadth and interdisciplinarity of the CDT and varied expertise of research supervisors. Dementia is a strong focus within the CDT research with a quarter of projects addressing this theme. Other projects address diseases and disorders including neurotrauma, CNS, stroke and Parkinson's Disease.

PROJECTS

24% ADDRESS DEMENTIA

14% INVOLVE INDUSTRY

57% HAVE MEDICAL OR CLINICAL COLLABORATION

SUPERVISION

70 RESEARCH SUPERVISORS

14 DEPARTMENTS

3 FACULTIES

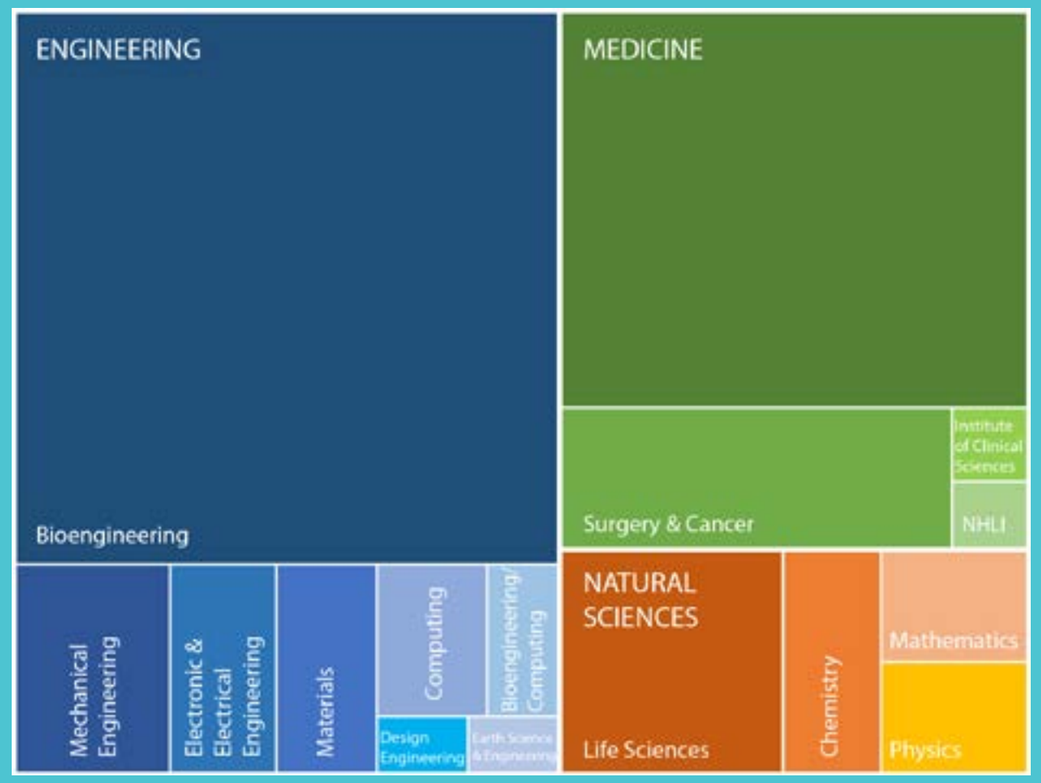
STUDENTS

30% ARE WOMEN

35% OF 2017 & 2018 STARTERS HAVE A BAME BACKGROUND

>15 ACADEMIC DISCIPLINES RECRUITED FROM

The CDT involves over 70 research supervisors from 14 different departments, across the three Faculties of Engineering, Medicine & Natural Sciences



STUDENT PROJECTS

COHORT 1 (2014)

Cher Bass (Bioengineering)
High-throughput Visualization and Computational Consequences of Increased Synaptic Plasticity and Axon Regeneration in the Living Aged Brain
Supervisors: Vincenzo De Paola, Claudia Clopath, Anil Bharath

Tamara Boltersdorf (Chemistry)
Designing novel imaging probes for targeting inflammatory lesions in brain disorders
Supervisors: Nicholas Long, Felicity Gavins

Rajinder Lotay (Bioengineering)
Virtual physiotherapy for assessment and training of arm function
Supervisors: Etienne Burdet, Paul Bentley

Diana Lucaci (Life Sciences)
High-resolution mapping of age-related functional changes in cortical connectivity
Supervisors: Stephen Brickley, Paul Chadderton, Bill Wisden

Peter Quicke (Bioengineering)
Optical Measurement of Neuronal Connectivity using a Genetically Encoded Voltage Indicator
Supervisors: Simon Schultz, Mark Neil, Thomas Knöpfel

Hugo Weissbart (Bioengineering)
EEG assessment of spoken language processing in aphasia
Supervisors: Tobias Reichenbach, Robert Leech, Etienne Burdet, Richard Wise

THE CDT

Aidan Wickham (Bioengineering)
Wearable wireless sensor arrays to detect the progression of amyotrophic lateral sclerosis (ALS)
Supervisors: Martyn Boutelle, Manos Drakakis

Georgios Zafeiropoulos (Bioengineering)
Automated Neonatal EEG Early Warning System based on novel signal analysis tools in the field and/or novel features
Supervisors: Manos Drakakis, David Edwards

COHORT 2 (20154)

Tiffany Chan (Chemistry)
Ultrasound technology to deliver novel theranostic agents to malignant brain tumours
Supervisors: Ramon Vilar, James Choi, Amin Hajitou, Matt Williams

Patricia Gallego (Medicine)
Axo-glial pathology in Multiple Sclerosis and its effects on neurotransmission: development of a computational model
Supervisors: Richard Reynolds, Aldo Faisal, Kambiz Alavian

James Clarke (Mechanical Engineering)
Integrated Sensor Suite to Investigate Neurological Dysfunction in Balance
Industry partner: McLaren Applied Technologies
Supervisors: Ravi Vaidyanathan, Alison McGregor

Carl Lubba (Bioengineering)
Peripheral nerve decoding algorithms for bioelectronic medicines
Industry partner: Galvani Bioelectronics
Supervisors: Simon Schultz, Nick Jones

Darije Custovic (Medicine)
Neural network mechanisms of inhibitory and attentional control
Supervisors: Adam Hampshire, Claudia Clopath

Gerald Moore (Life Sciences)
Developing technology to enable macroscopic imaging of neuronal connectivity to quantify changes during health and disease
Supervisors: Stephen Brickley, Simon Schultz

Sofia Dall'Orso (Bioengineering)
Robot-assisted fMRI investigation of learning in newborn infants
Supervisors: Etienne Burdet, Daniel Rueckert, David Edwards, Tomoki Arichi

Konstantinos Petkos (Bioengineering)
ReBooT: Restoring Brain Operation with Technology; Microelectronics to enable an open source instrument for exploring closed loop neural systems Industry partner: Medtronic
Supervisors: Manos Drakakis, Peter Brown (University of Oxford), Tim Denison (Medtronic)

Lewis Formstone (Mechanical Engineering)
Lesion-symptom mapping using motion-tracking: How neural trauma impacts motor function
Supervisors: Ravi Vaidyanathan, Paul Bentley, Etienne Burdet, Alison McGregor

Tom Robins (Bioengineering)
Towards whole brain functional imaging in freely moving subjects
Supervisors: Mengxing Tang, Paul Chadderton

COHORT 3 (2016)

Tunvez Boulic (Bioengineering)
Biologically inspired computation for real-time motor learning
Supervisors: Paul Chadderton, Claudia Clopath

Matthew Copping (Bioengineering)
Development of a noninvasive and localised blood-brain barrier opening system for the treatment of Alzheimer's Disease
Supervisors: James Choi, Magdalena Sastre

Giuseppe Gava (Bioengineering)
Information theoretic analysis tools for studying the cellular assembly of memory
Supervisors: Simon Schultz, David Dupret (University of Oxford), Bill Wisden

Bryan Hsieh (Life Sciences)
Microdevices to investigate sleep and temperature regulation in mice
Supervisors: Nick Franks, Tim Constandinou, Bill Wisden

Sihao Lu (Bioengineering)
Characterising receptive fields of astrocytes in auditory cortex
Supervisors: Andrei Kozlov, Simon Schultz, Claudia Clopath

Sebastian Mancero (Mechanical Engineering)
Wearable Force-Feedback Interface supporting in vivo Brain-Robot Interface
Supervisors: Ravi Vaidyanathan, Etienne Burdet Peter Brown (University of Oxford)

Thomas Martineau (Mechanical Engineering)
Neural implants for brain-robot interface
Supervisors: Ravi Vaidyanathan
Peter Brown (Oxford University)

Sebastian Popescu (Medicine)
Measuring brain and body biological age to predict health outcomes and disease risk during ageing
Supervisors: David Sharp, Ben Glocker, Paul Matthews, James Cole

Martin Priessner (Chemistry)
Role of copper ions in the toxicity of α-synuclein in Parkinson's disease
Supervisors: Ramon Vilar, Liming Ying, Alfonso De Simone, Magdalena Sastre

Kaja Ritzau-Reid (Materials)
Conductive polymer platforms for the integrated in vitro investigation of neural networks
Supervisors: Molly Stevens, Ramon Vilar

Jeevan Soor (Bioengineering)
Engineering fast, flexible, precise, and parallel light sculpting for neural circuit elucidation
Supervisors: Amanda Foust, Simon Schultz, Mark Neil

Lotte Weerts (Electrical & Electronic Engineering)
Learning to hear with plasticity across multiple timescales
Supervisors: Daniel Goodman, Claudia Clopath

COHORT 4 (2017)

Claire Baker (Design Engineering)
AutoTRIAGE: a clinical, computational and biomechanical investigation of the feasibility of using vehicular event data recorders for assessing head trauma severity in collisions Industry partner: Transport Research Laboratory (TRL)
Supervisors: Mazdak Ghajari, David Sharp, Philip Martin (TRL), Mark Wilson

Mario Bracklein (Bioengineering)
Spinal motor neurons control of redundant robotic system
Supervisors: Dario Farina, Etienne Burdet

Richard Daws (Medicine)
Development of a diagnostic battery for probing individual differences in network function
Supervisors: Adam Hampshire, Pete Hellyer (KCL), Rob Leech (KCL)

Hristo Dimitrov (Bioengineering)
A multi-sensor, hybrid model- and signal-based control system for powered lower limb prostheses
Industry partner: OttoBock
Supervisors: Dario Farina, Anthony Bull, Bernhard Graimann (OttoBock)

Mikolaj Kegler (Bioengineering)
Developing a novel type of neurostimulation to foster speech processing and rehabilitation from aphasia
Supervisors: Tobias Reichenbach, Mauricio Barahona, Rob Leech (KCL)

Gillican Koehl (Bioengineering)
The bionic spinal cord bridge: Combined therapies for neural regeneration
Supervisors: Rylie Green, Simone Di Giovanni

Alessandra Lo Fiego (Materials)
Neuronal Interfacing System for Human Pluripotent Stem Cell Interrogations using Materials-based Nanotechnologies
Supervisors: Molly Stevens, Simone Di Giovanni

Amadeus Maes (Bioengineering)
Mathematical and computational analyses of plastic spiking recurrent networks
Supervisors: Claudia Clopath, Mauricio Barahona

De-Shaine Murray (Bioengineering)
One-probe - a new device for non-penetrative monitoring of the injured brain
Supervisors: Martyn Boutelle, Mark Wilson

Sam Podmore (Medicine)
Large scale population functional connectomic parcellation and individual variation
Supervisors: Paul Matthews, Yi-ke Guo

Seigfred Prado (Bioengineering)
A two photon imaging platform for characterising memory circuit dynamics and response to therapeutic strategies in neurodegenerative disease Industry partner: Eli Lilly & Co Ltd
Supervisors: Simon Schultz, Bill Wisden, Keith Wafford (Eli Lilly)

Nathan Steadman (Mechanical Engineering)
A Robotic Instrument for Adaptive Neurostimulation
Supervisors: Ravi Vaidyanathan, Peter Brown (Oxford University), Dipankar Nandi, Huling Tan (Oxford University)

Jonny Taylor (Materials)
High resolution imaging of multimodal nanoparticles for treatment of brain cancers
Supervisors: Alexandra Porter, Matthew Williams, Mary Ryan

Dan Terracina-Barcas (Surgery & Cancer)
Monitoring muscle fatigue using novel wireless sensors
Supervisors: Paul Strutton, Pantelis Georgiou

James Tyrrell (Physics)
Large-Area Flexible Plastic Electronic Sensor for 2D Neural Recording
Supervisors: Alasdair Campbell, Martyn Boutelle

COHORT 5 (2018)

Grace Ang (Bioengineering)
Development of long-range connections in auditory cortex
Supervisors: Claudia Clopath, Andrei Kozlov

Oscar Bates (Bioengineering)
3D ultrasound computed tomography of the brain
Supervisors: Mengxing Tang, Mike Warner, Matthew Williams

Chiara Cicatiello (Bioengineering)
Neurochemical CMOS array – bedside assay of ionic and inflammatory marker from the human brain
Supervisors: Martyn Boutelle, Pantelis Georgiou, Mark Wilson

Alex Clarke (Bioengineering)
A clinically-viable brain-computer interface for inducing neuroplasticity for stroke rehabilitation
Supervisors: Dario Farina, Paul Bentley

Patrycja Dzialecka (Medicine)
Development of non-invasive deep brain stimulation technology
Supervisors: Nir Grossman, Bill Wisden, Paul Matthews

Pierre Guilleminot (Bioengineering)
Engineering tactile signals to aid hearing in noisy background
Supervisors: Tobias Reichenbach, Etienne Burdet

Irene Mendez-Guerra (Bioengineering)
Surface Electromyography for Brain-Machine Interface Applications
Industry partner: CTRL-Labs
Supervisors: Dario Farina, Etienne Burdet, Manos Drakakis, Patrick Kaifosh (CTRL-Labs)

Filip Paskiewicz (Mechanical Engineering)
Sensory Motor Interface for Lower Extremity Robots (SMILER) Industry partner: Ossur
Supervisors: Ravi Vaidyanathan, Alison McGregor, Hildur Einarsdóttir (Ossur), Ásgeir Alexandersson (Ossur)

Will Trender (Medicine)
Whole-brain dynamics and higher cognitive processing in disorders of consciousness
Supervisors: Adam Hampshire, Aldo Faisal, Rob Leech (KCL), Gregory Scott

Matteo Vinao-Carl (Medicine)
Closed-loop, personalized brain stimulation intervention for impairment of cognitive control
Supervisors: David Sharp, Nir Grossman, Adam Hampshire, Peter Hellyer (KCL)

Isabell Whiteley (Bioengineering)
3D-resolved optogenetic excitation using time-averaged speckle patterns
Supervisors: Chris Rowlands, Paul Chadderton

ALIGNED STUDENTS

Chris Caulcrick, PhD Mechanical Engineering
Quasi-Passive Human-Exoskeleton System Modelling (EPSRC ICASE studentship)
Industry partner: McLaren Applied Technologies
Supervisors: Ravi Vaidyanathan, Alison McGregor, Caleb Sawade (McLaren)

Farnaz Fahimi-Hanzaee, MRes Neurotechnology 2018
Modular Reconfigurable Low-Power Stimulators
Supervisors: Manos Drakakis, Dario Farina

Rufus Mitchell-Heggs, MRes Neurotechnology 2018
Analysis of calcium signals recorded endoscopically from the rodent brain
Supervisors: Simon Schultz, Mauricio Barahona

Paul Mu, MRes Neurotechnology 2018
Ensemble coding models in the LGN: an asymmetry between ON and OFF?
Supervisors: Simon Schultz, Amanda Foust

Thomas Tiennot, MRes Neurotechnology 2018
Ultrasound technologies for brain imaging and therapy
Supervisors: Mengxing Tang, Mike Warner

Sam Wilson, PhD Mechanical Engineering
Research area: *The Natural User Interface*
Supervisors: Ravi Vaidyanathan, Alison McGregor, R Harkins (US Naval Postgraduate School)

ALUMNI

Paolo Angeles, PhD Mechanical Engineering, Brain Science & Engineering Fellow, 2013-2018
Quantifying symptoms of Parkinson's Disease
Supervisors: Ravi Vaidyanthan

Solomia Boretksa, MRes Neurotechnology , 2017
A data analysis pipeline for two photon calcium imaging in mouse models of dementia
Supervisors: Simon Schultz, Paul Chadderton

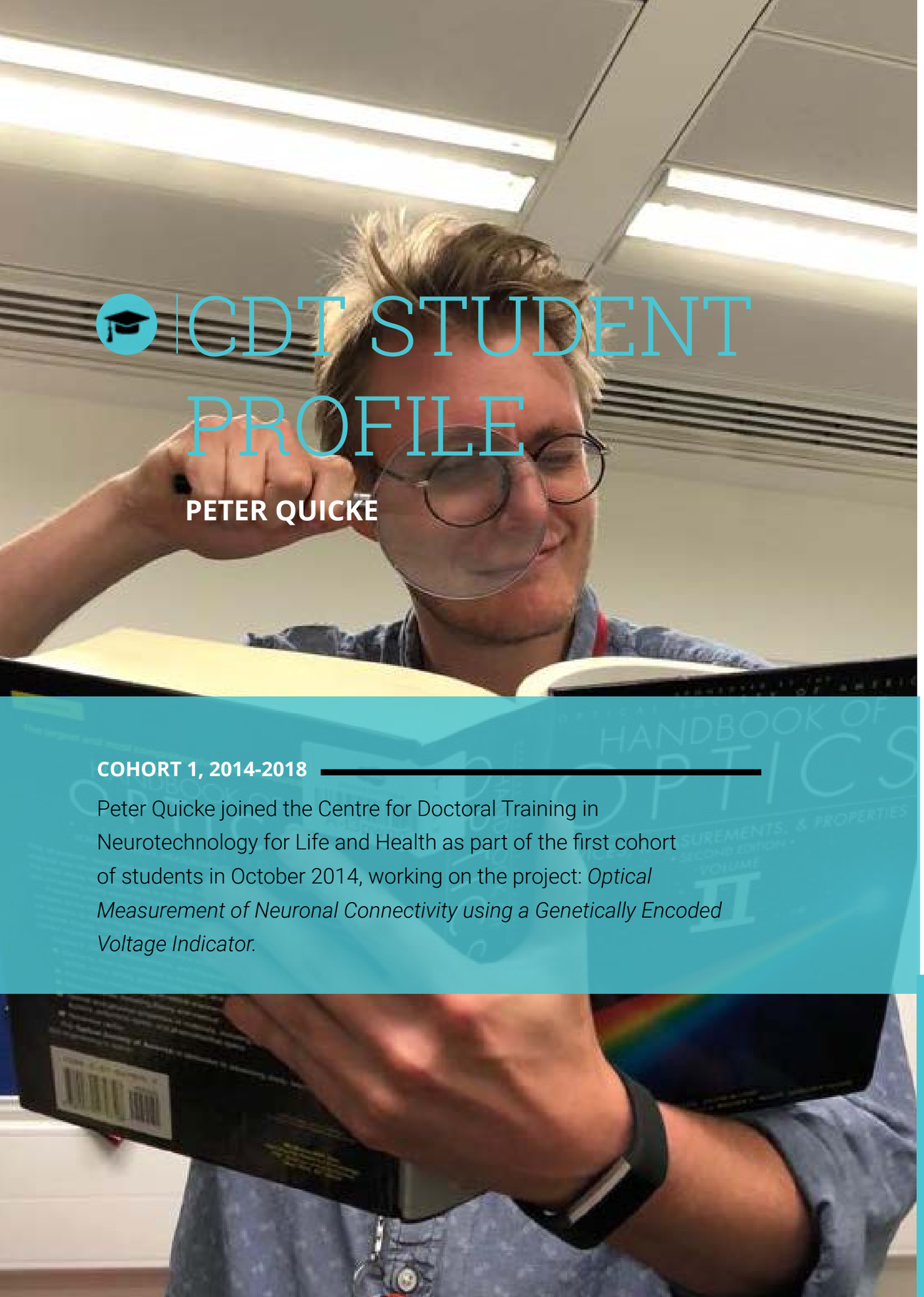
Muhammad Ihsan, MRes Neurotechnology, 2016
Brain functional imaging with ultrasound
Supervisors: Mengxing Tang, Paul Chadderton

Jiewon Kang, MRes Neurotechnology, 2017
Development of machine learning decoders of brain functional connectivity states
Supervisors: Adam Hampshire, Rob Leech

Romy Lorenz, PhD Medicine, Brain Science & Engineering Fellow, 2013-2017
Neuroadaptive Bayesian Optimization - Implications for the Cognitive Sciences
Supervisors: Rob Leech

Jean-Charles Mariani, MRes Neurotechnology, 2017
Structural changes in brain circuitry in healthy ageing
Supervisors: Paul Chadderton , Stephen Brickley

Martyna Stachaczyk, MRes Neurotechnology, 2016
Interactive tasks for the assessment of sensorimotor control
Supervisors: Etienne Burdet, Paul Bentley



CDT STUDENT PROFILE

PETER QUICKE

COHORT 1, 2014-2018

Peter Quicke joined the Centre for Doctoral Training in Neurotechnology for Life and Health as part of the first cohort of students in October 2014, working on the project: *Optical Measurement of Neuronal Connectivity using a Genetically Encoded Voltage Indicator.*

THE CDT

I really enjoyed my time as part of the academic community at Imperial, and as part of the CDT in particular. The structure of the CDT was particularly helpful as a nervous new starter in an unfamiliar field for mixing with a diverse research community and for setting up support and collaboration networks.

During my PhD I worked on a variety of different projects, all related to developing and using new optical techniques for basic neuroscientific research. Coming from a physics undergraduate, I knew I wanted to work on tools for biological and biomedical research, but my knowledge biology and medicine was sorely lacking! The CDT gave us all a crash course in neuroscience and then dropped us into the thick of it, enabling us to find out what interested us and define our long-term projects.

My MRes project involved trying to use voltage reporting fluorescent proteins to measure electrical signals in peripheral nerves. Although I didn't manage to see anything, the techniques (in particular the troubleshooting and noise elimination skills!) really helped throughout my later work. During my PhD years I kept the interest in voltage imaging but moved to imaging cells in the central nervous system, in the cerebral cortex. My main achievements during my PhD were developing a control and data processing algorithm improving multifocal two-photon microscopy's performance in optically scattering tissue like the brain, and also demonstrating that light field microscopy could be used to image single-cell voltage signals from fluorescent protein voltage sensors in 3D.

I found working out what I most wanted to do when I finished quite difficult - during my final PhD year I did a 3 month internship at an engineering consultancy and, despite enjoying it, I decided that I wanted to see what life as a postdoctoral researcher was like!

As I progressed throughout my PhD, and particularly towards the end, I identified the common thread that ran through all of my projects and particularly interested me was computational microscopy - using computing power to enable new and improved methods of imaging biological samples. I also wanted to experience working in a more applied biomedical area and I managed to identify a postdoctoral opening which combined these two interests. I am now working using lens free holographic imaging, microfluidics and acoustics for medical sample imaging and diagnosis at Glasgow University, which combines these interests.

Overall, I am really glad of the diverse opportunities and training that the Neurotechnology CDT has afforded me. It is great to see how the centre has grown the neuroscience community at Imperial from the first cohort, when I joined, to now!

> **"HAVING A COHORT OF STUDENTS STARTING TOGETHER GIVES YOU A GROUP OF PEERS WHO ARE ABLE TO OFFER ADVICE AND SUPPORT INDEPENDENTLY OF YOUR LAB GROUP OR EVEN DEPARTMENT WHO ARE IN AN EXACTLY SIMILAR SITUATION REGARDING DEADLINES AND FUNDING ETC WHICH IS USEFUL."**
>
> Peter Quicke, CDT Neurotechnology Cohort 1












SATELLITE GROUPS

We interact with satellite groups at the Oxford MRC Brain Network Dynamic Group, Francis Crick Institute and Sainsbury-Wellcome Centre for Neural Circuits and Behaviour at UCL, through joint supervision of students, involvement in the Centre Research Board and reciprocal organisation of events, such as symposia and seminars.

EXTERNAL PARTNERS

The Centre and CDT continue to benefit from links with industry partners through studentship funding and joint supervision of Centre and CDTN projects (McLaren Applied Technologies, Medtronic, Galvani Bioelectronics), as well as through Advisory Board membership (Stryker, Eli Lilly). New partnerships with OttoBock, Transport Research Laboratories, CTRL-Labs and Ossur were established through joint supervision and funding of CDT Neurotechnology student projects starting in 2017 and 2018.

Our industry partners augment the activities of the Centre and CDT through access to technology platforms, technical expertise and use of facilities, discussion of commercialisation of technology and direct supervision of students.

HEALTH SECTOR

The Centre and CDTN work closely with the health sector, with NHS staff involved in numerous projects, including work on monitoring of brain injury and rehabilitation after stroke.

STUDENT INTERNSHIPS AND EXCHANGES

Students in the CDTN are encouraged to undertake an internship or academic exchange as an integral part of their programme, to broaden the student's skillset and experience. These placements may be directly relevant to the student's research or on a complementary theme, or may be unrelated to the research topic but allow the students to gain experience in another field, such as patent law or policy. Industry and academic partners for placements in 2017 and 2018 included GripAble, The Technology Partnership, Morgan Stanley, Toshiba Medical Systems Corp, NeuroCreate and Columbia University.

COLLABORATION

The Centre has a large network of national and international collaborators from industry, academia and the health sector which is constantly evolving.

CENTRE FOR NEUROTECHNOLOGY

OUTPUTS AND ACTIVITIES

PUBLICATIONS AND PATENTS

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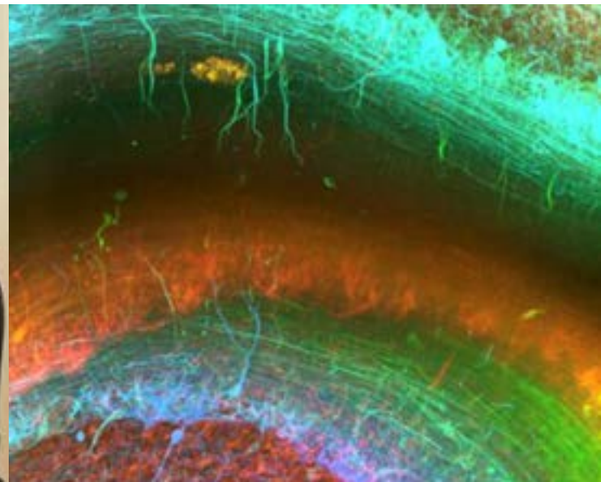

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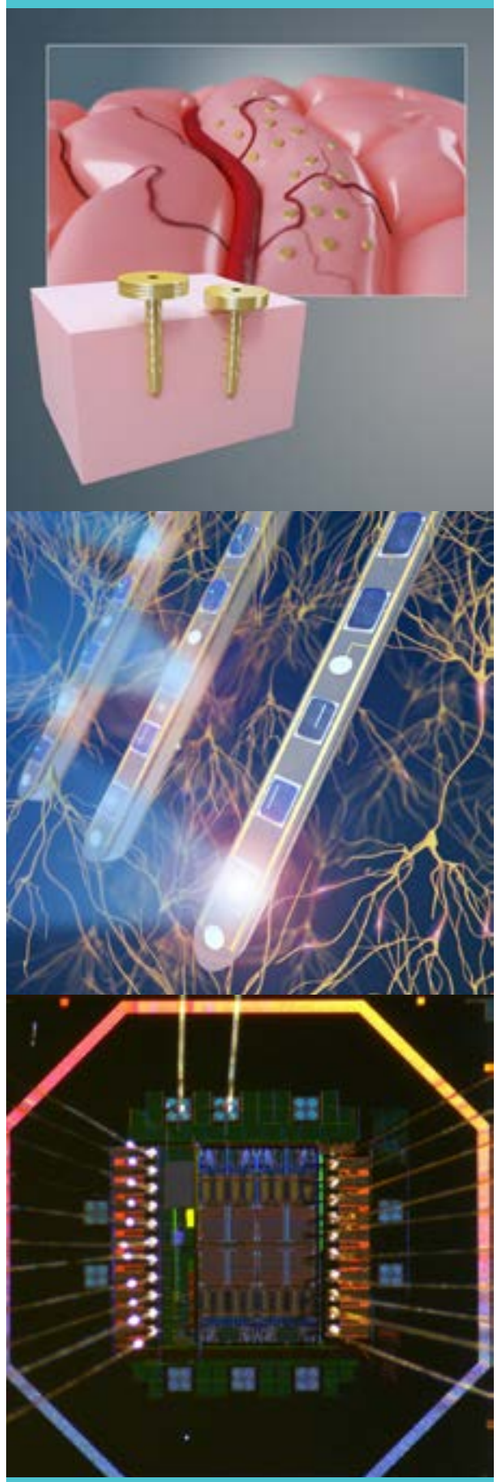

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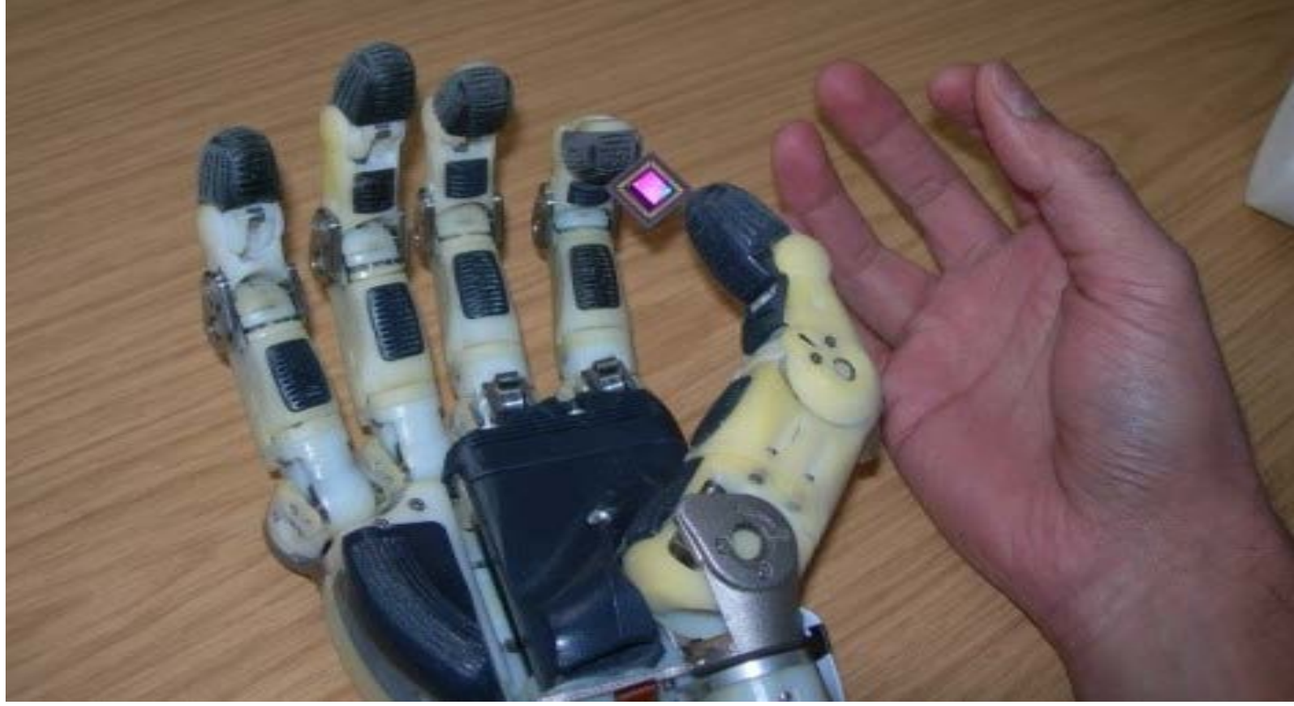

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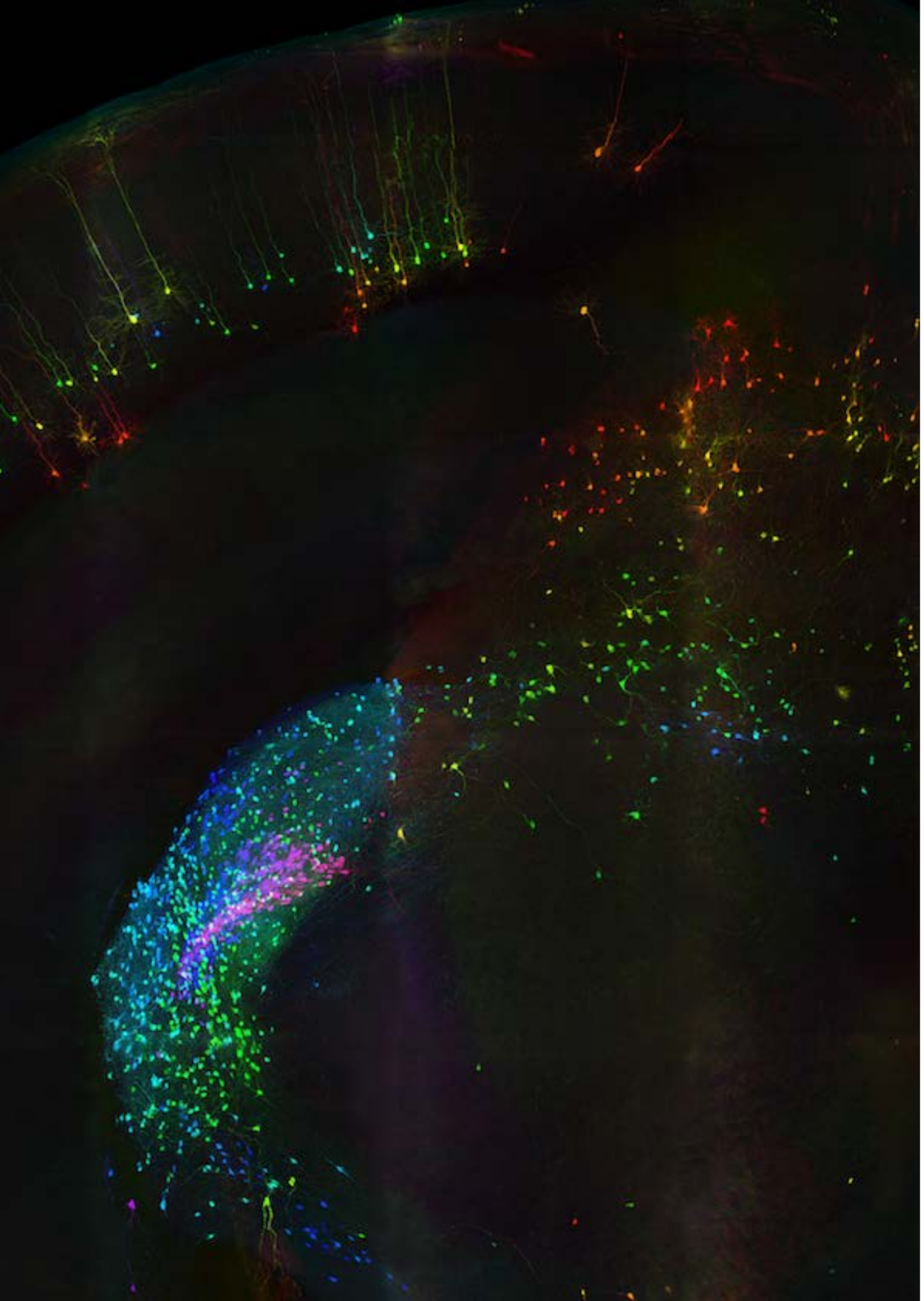

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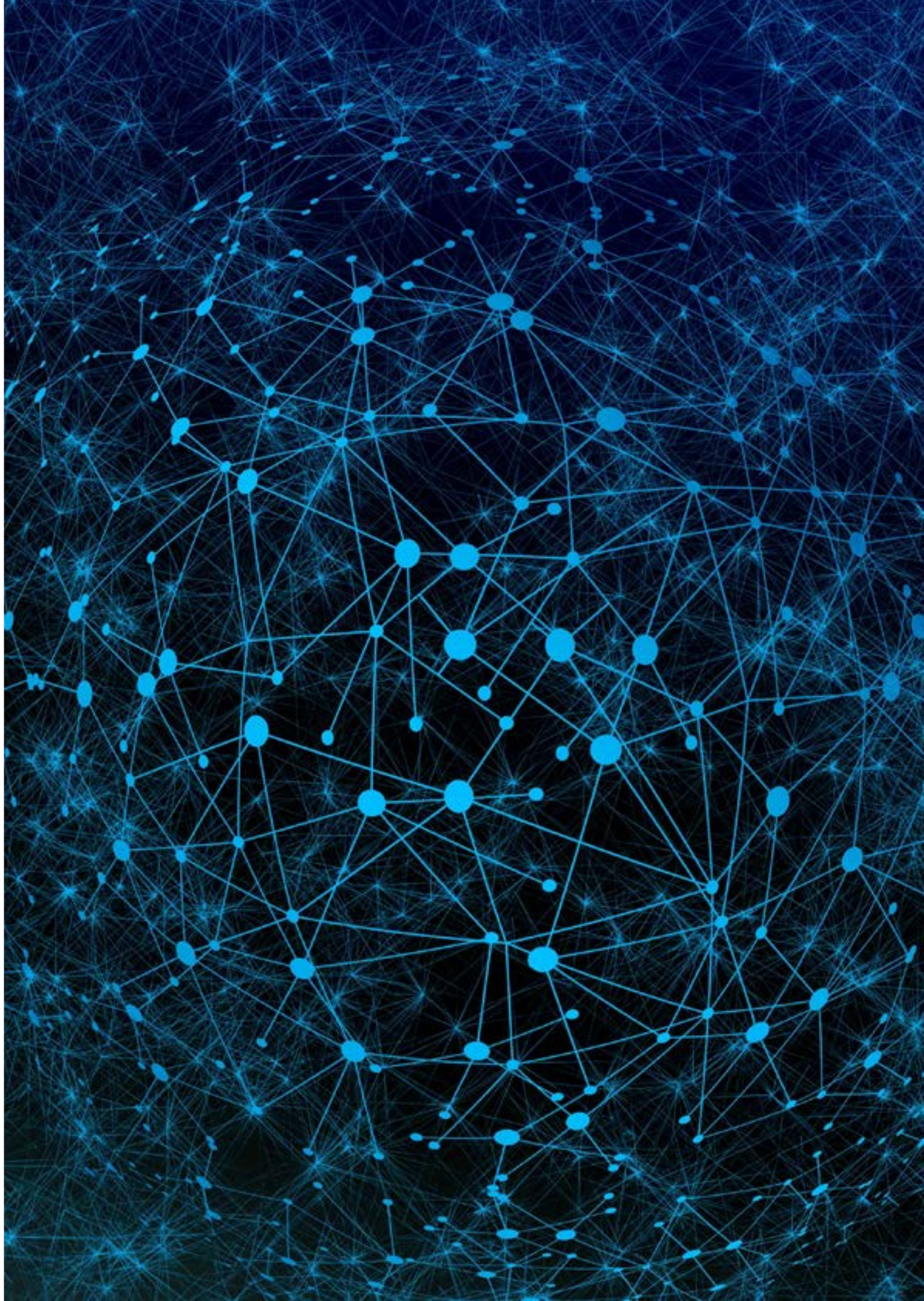

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EVENTS AND ACTIVITIES

INVITED TALKS

- Nov 2018: Inaugural Lecture, Imperial College London (Schultz)
- Oct 2018: Royal College of General Practitioners annual conference, Glasgow (Burdet)
- May 2018: Unmanned Maritime Systems Conference, London (Kovac)
- May 2018: World Congress on Neurology and mental disorders, Rome (Sastre)
- Apr 2018: IEEE RAS Conference on Soft Robotics, Livorno, Italy (Kovac)
- Mar 2018: TEDxNTUA, Athens (Lorenz)
- Mar 2018: ERF 2018 - European Robotics Forum (Kovac)
- Mar 2018: Gatsby Computational Neuroscience Unit – UCL (Lorenz)
- Feb 2018: University of Bradford (Sastre)
- Feb 2018: Technical University Berlin, Neuroergonomics Group (Lorenz)
- Jan 2018: Birkbeck University, Centre for Brain and Cognitive Development (Lorenz)
- Dec 2017: 2017 Children Christmas Lecture at Surrey University (Kovac)
- Dec 2017: NIPS Workshop "Bayesian Optimization for Science & Engineering", LA, US (Lorenz)
- Nov 2017: WIRED Live, London (Lorenz)
- Oct 2017: National University of Singapore, Clinical Imaging Centre (Lorenz)
- Aug 2017: Cardiff University, School of Psychology (Lorenz)
- Apr 2017: King's College London, Department of Neuroimaging (Lorenz)
- May 2017: University of Malaga (Sastre)
- Feb 2017: Achucarro Institute of Neuroscience, Bilbao (Sastre)

SEMINAR SERIES

The Centre hosts a regular neurotechnology seminar series attracting national and international speakers. Seminars hosted by the Centre in 2017 and 2018 included:

DEC 2018 | Fabien Wagner
Center for Neuroprosthetics and Brain Mind Institute, EPFL
Targeted neurotechnologies for restoring walking after spinal cord injury

NOV 2018 | Sam Barnes
Imperial College London
Functional signatures of homeostatic plasticity in health and disease

OCT 2018 | Konstantinos Meletis
Karolinksa Instituet
Mapping brain circuits

SEPT 2018 | Anthony Burkitt
University of Melbourne
The quest to restore vision: Optimizing neural activation in retinal implants

MAY 2018 | Alvaro Fernandez
SharpBrains
Why the Future of Brain Enhancement is Digital and Pervasive

APR 2018 | Mehrdad Jazayeri
Department of Brain & Cognitive Sciences, McGovern Inst for Brain Research, MIT
Flexible mental computations through regulation of cortical dynamics

APR 2018 | Oliver Thorn-Seshold
Department of Pharmacy, Centre for Drug Research, Ludwig-Maximilians-University
Chemical tools for high-precision control of cytoskeletal functions

APR 2018 | Esra Neufeld
Computational Life Sciences Group at the IT'IS Foundation, ETH
Neuro-functionalized computable anatomical models

JAN 2018 | Mina Teicher
Bar-Ilan University
Synchronization in brain activity and applications to Medicine

JAN 2018 | Anna Wexler
University of Pennsylvania
Outside the Ivory Tower: the Use of Noninvasive Brain Stimulation in Do-it-Yourself (DIY) Contexts and "Brain Wellness" Centers

NOV 2017 | Jonas Obleser
University of Lübeck
Neural filters for the listening challenge in time and space

NOV 2017 | Christoph Herrmann
University of Oldenbug
Transcranial alternating current stimulation: Models, EEG/MEG, and cognition

AUG 2017 | Karim Oweiss
University of Florida
Targeted Neuroplasticity: Natural and Artificial Shaping of Neural Correlations for Cognitive Neural Interfaces

JUL 2017 | Vincent Hayward
University of London
Neurotechnology of Touch: Early haptic processing and tactual curiosities

JUN 2017 | Sliman Bensmaia
University of Chicago
Biological and Bionic hands: Natural neural coding and artificial perception

JUN 2017 | Shlomi Haar
Ben-Gurion University of the Negev, Israel
Encoding of Movement and the Learning of Movement in the Human Brain

MAY 2017 | Andrew Schwartz
University of Pittsburgh
A new view of motor cortical function

APR 2017 | Lawrence Moon
Kings College London
In-cage automation of a test for reaching and grasping in rodents

APR 2017 | Gregoire Courtine
EPFL
Spinal Cord Injury

JAN 2017 | Angus Silver
UCL
New technologies for predicting and measuring circuit function

JAN 2017 | Adam Kampff
UCL
Distributed, whole-brain, single-unit electrical recordings

JAN 2017 | Lee Miller
Northwestern University
Reverse Engineering Proprioception
(Joint seminar with Bioengineering Dept)

CENTRE FOR NEUROTECHNOLOGY RESEACH SYMPOSIUM

The Centre for Neurotechnology annual research symposium brings together researchers from Imperial College and other national and international academic intuitions, industry colleagues and members of the public for a day of presentations on the subject of neurotechnology. External speakers for the symposia in 2017 and 2018 included Bernhard Graimann (OttoBock Healthcare GmBH), Tamar Makin (UCL), Thomas Nowotny (University of Sussex), Cian O'Donnell (University of Bristol), Tobias Rose (Max Planck Institute of Neurobiology) and Caleb Sawade (McLaren Applied Technologies). Students from the CDTN cohorts 3 and 4 presented posters showcasing their varied projects.

PUBLIC ENGAGEMENT AND OTHER ACTIVITIES

"BRAIN 2.0" PUBLIC PANEL DISCUSSION

In January 2018, the Centre hosted a public discussion which examined neural enhancement and its potential consequences for society. An expert panel and facilitator were sourced, including Professors of Neuroscience and Mathematics, a Reader in Neuroprosthetics and specialists in Neuro-ethics. The event was attended by over 100 participants, from the College and wider public, and involved audience questions and lively debate, followed by further informal discussion and networking. A follow-up colloquium on neural enhancement, involving two of the panellists, was hosted the following day.

IMPERIAL FESTIVAL

The annual Imperial Festival is a showcase of the best in science and arts at Imperial College. The event features interactive activities, performances and workshops and regularly attracts more than 15,000 public and alumni visitors. Centre members were involved in a number of exhibits at the festival, and students from the CDT Neurotechnology presented interactive exhibits at the festival in 2017 and 2018. CDTN exhibits comprised hands-on demonstrations and interactive games. The 2017 exhibit, "Sensible Brains" described a journey through the brain from three perspectives Motor, Auditory, Visual, whilst the 2018 exhibits invited visitors to control a video game using signals from their peripheral nervous system, use EEG signals to bend a spoon or control the pitch and tempo of sounds and listen to the "sounds of their brain". The stands were extremely popular, receiving hundreds of visitors over the festival weekends.

CDT FESTIVAL OF SCIENCE AND ENGINEERING

Researchers from the CDTN participated in the annual CDT Festival of Science and Engineering in 2017 and 2018. The student-led event is organised by representatives of the 14 CDTs at Imperial. Themes for the festival in 2017 and 2018 were "Science and Art" and "Science and Ethics".

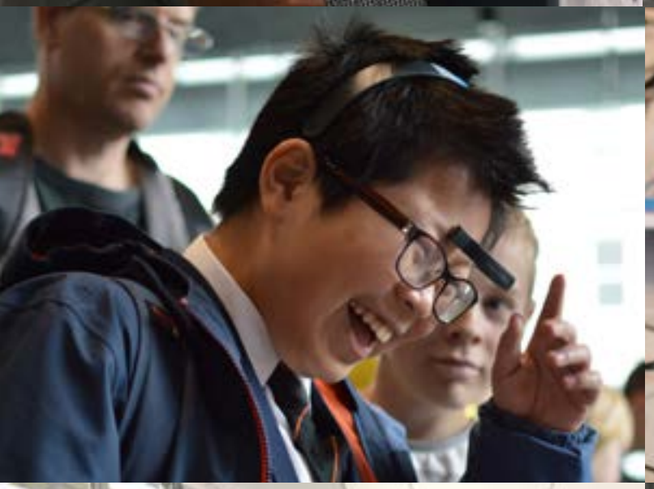
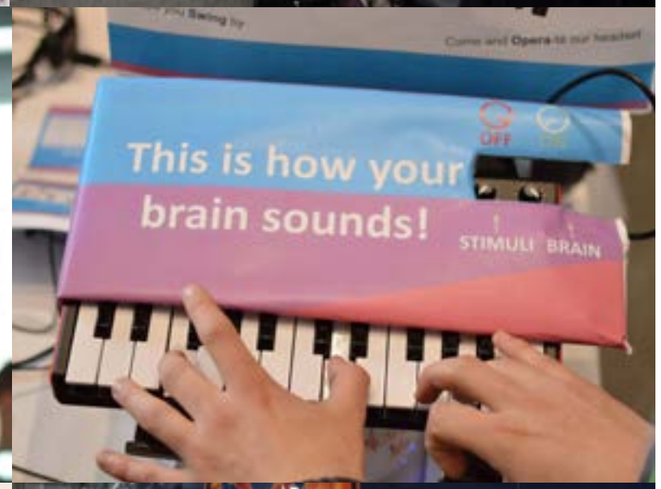
IMPERIAL FRINGE: INTELLIGENCE REDESIGNED

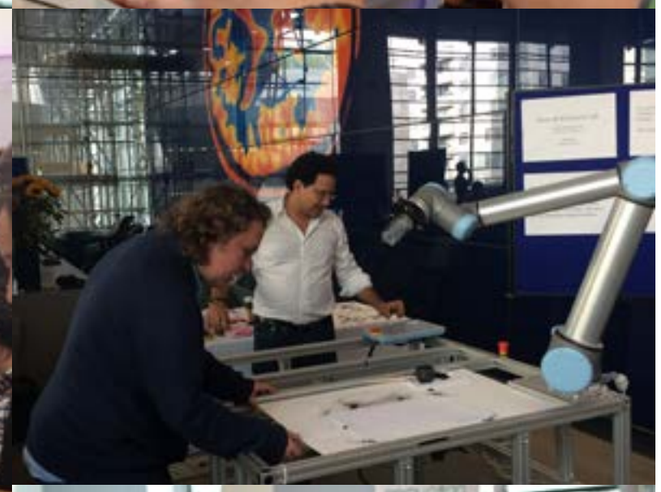
Centre researchers from the participated in the Imperial College Fringe festival on artificial intelligence, in January 2017, presenting "Cognitron", the first AI designed to test human intelligence. Members of the public were invited to test their mental skills through a series of brain teasers posed by Cognitron, and the data gathered was used to create more sophisticated intelligence tests. (Hampshire, Leech, Lorenz)

ROYAL SOCIETY SUMMER SCIENCE EXHIBITION

Members of the Centre for Neurotechnology presented some of their research in bioinspired technology and






OUTPUTS

biomimetics as part of the “Nurturing nature’s innovations” exhibit at the Royal Society Summer Science Exhibition in 2018. (Krapp, Lin)

MEDIA MENTIONS

- BBC News online (Sept 2017): article featuring biomechatronics research of Centre and CDTN members https://www.facebook.com/bbcnews/videos/10155125665807217/ (Vaidyanathan, Wilson, Caulcrick)
- Wired Magazine (Sept 2017): Feature on “Automatic Neuroscientist” research (Lorenz, Hampshire, Leech)
- FT.com (Mar 2018): research featured in article about prosthetics (Constandinou)

AWARDS

- Sept 2018: Mobility Unlimited Challenge Discovery Award, Toyota Mobility Foundation & Nesta (Faisal)
- Sept 2018: Best student poster, Basic Auditory Science conference 2018 (Kegler)
- Aug 2018: Science & PINS Prize for Neuromodulation (Grossman)
- Jul 2018: EPSRC Doctoral Prize Fellowship award (Lorenz)
- Jun 2018: CogX Outstanding PhD Thesis award (Lorenz)
- May 2018: IEEE ICRA best paper award finalist (Kovac)
- Feb 2018: Award for scientific achievement, Onda cero Mallorca (Sastre)
- Jan 2018: Rosalind Franklin Medal and Prize, Institute of Physics (Stevens)
- Jan 2018: Medema Lecture Award, Polymer Technology Netherlands (Stevens)
- Jan 2018: Marshall R. Urist Award, Orthopaedics Research Socitey (Stevens)
- Nov 2017: EPSRC Healthcare Technologies Challenge Award, EPSRC (Green)
- Jul 2017: Dementia Symposium Prize, Imperial College Alzheimer’s Research Network (Ghajari)
- Oct 2017: Scientist of the year award, Mujeres en iguadad (Women in equality) (Sastre)
- Oct 2017: IEEE Biomedical Circuits and Systems (BioCAS) Conference Best Paper Award (3rd Place) (Constandinou)
- Sept 2017: Codex 50 innovators of industry of the futures award (Kovac)
- Jun 2017: Emerging Technologies Competition: Materials and Enabling Technologies, Royal Society for Chemistry (Green)
- Apr 2017: EPSRC Impact Accerleration Award (Vaidyanathan, Angeles)
- Apr 2017: British Pharmacological Society Schachter Award (Boltersdorf)
- Mar 2017: Suffrage Science Award, Suffrage, UK (Green)
- Mar 2017: MBZ International Robotics Competition finalist (Kovac)
- Feb 2017: Drones for Good award finalist (Kovac)
- Feb 2017: AAAI Best Robot Video Award (Kovac)
- Jan 2017: Harrison Medal, Royal Pharmaceutical Society (Stevens)

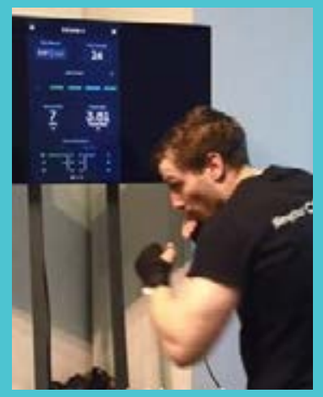
SPIN OUT COMPANIES

ATHLETEC

Drawing from neurotechnology research in motion tracking for stroke and Parkinson's disease, Athletec was formed to enhance the effectiveness and direct the focus of training in Combat sport in a manner akin to neural rehabilitation. In 2018, Athletec released the wearable product 'Corner'. Corner is a complete 'Internet of Things' solution that uses wrist-worn sensors to calculate statistics from every punch thrown by a boxer and deliver performance feedback through a smartphone app. This process is fully automated to allow the athlete to focus on their training. A small device clips onto the boxer's hand wraps and fits under the boxing gloves. An onboard microprocessor analyzes the data to detect punches and extract key features from each punch's waveform. The device then sends this data via Bluetooth to a smart device for display and storage to build a picture of the boxer's performance in each round, session, week, and month of training. Data collected in the app is stored on a cloud server and made available to coaches through an online web application, allowing them to analyse data for every user within their gym. CDT Neurotechnology student and semi-professional mixed martial arts (MMA) fighter Nathan Steadman has been working with the data and will draw paradigms from its analysis into his research using robotics to assess the severity of movement dysfunction associated with Parkinson's Disease. Insights into sports training provides a unique basis to understand neural learning for analysis of neurological movement disorders. Furthermore, the 'big data' database of boxers using the system enables the development and testing of algorithms that will analyse large scale trends in movement tied to exercise, which will further support neurotechnology research addressing rehabilitation from conditions such as stroke.

Corner was named Gadget of the Month in *Wearable Technologies* (March 2016). The company was also a Finalist for the *UK Big Chip Digital Industry Award* (June 2016) and was featured on the TV show *Dragon's Den* in 2018.

Corner tracking system with smart phone app



Corner founder and Imperial College student Charles Burr demonstrating the system

Centre member Ravi Vaidyanathan demonstrating the system at a Keynote Lecture during the London FitTech summit

CDT Neurotechnology students Sebastian Mancero and Filip Paszkiewicz with Serg co-founders Samuel Wilson (CDTN aligned student) and Alex Lewis

Centre member and CDT Neurotechnology supervisor Ravi Vaidyanathan working with Alex Lewis on artificial limbs

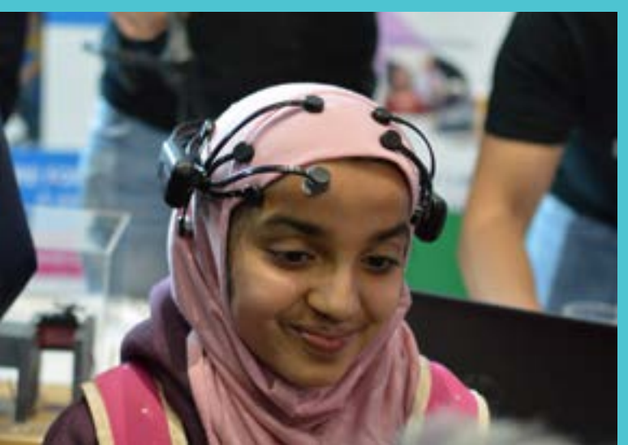
SERG TECHNOLOGIES

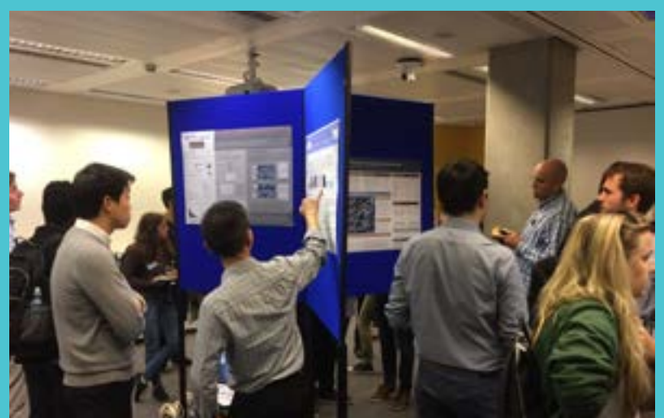
Gesture-control Human-Machine Interface (HMI) is poised to surpass all machine interface technologies (mouse, touch screen, etc) within the next decade; it will be the interface of the Internet of Things (IoT). However HMI devices today remain non-intuitive and unnatural. They rely on physical manipulation or some kind of electrical connection to the skin or require externals such as a camera. A user rarely feels a natural thought-based connection with technology. In robotic limbs, for example, one in three prosthetics (typically costing £40,000+) are discarded because of control. Major digital innovators such as Microsoft, Google, Apple and Samsung are already looking into gesture-control interface. In parallel, app and game developers are incorporating gesture-control, with the goal of enabling touch-less control over digital media. Despite this need, said systems still require hand held controllers, unnatural gestures, or disruptive voice commands. Furthermore there is a broader need for new HMI for clinical support of neurological assessment and rehabilitation for conditions such as stroke and Parkinson's Disease.

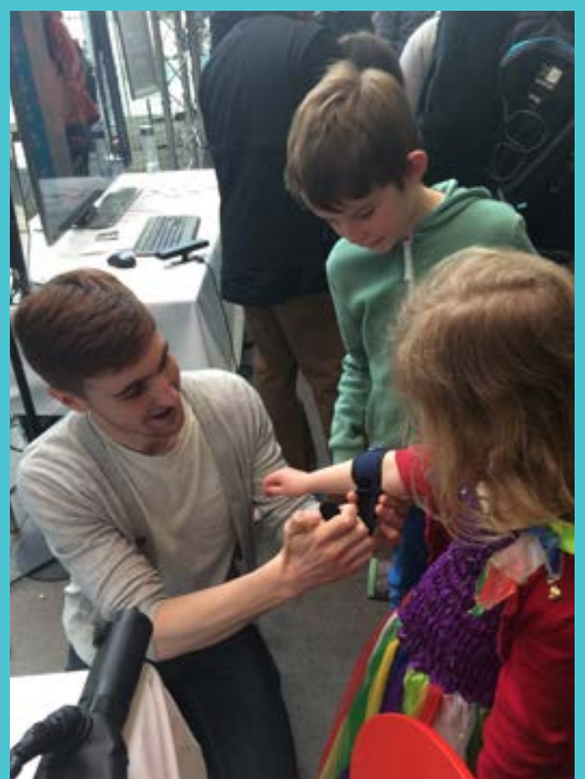
Serg Technologies was founded in February 2019 to address this gap through a neurological sensing package, dubbed the Natural User Interface (NUI). The NUI is an array of novel physiological sensors which do not rely on bioelectrical signals, whose feasibility for use in neuroprosthetics and Parkinson's Disease was established in the research of CDT Neurotechnology aligned students Samuel Wilson and Paolo Angeles. It has already controlled robotic limbs, computers, televisions, and drones, won innovation awards from the UK NHS and IET, has been featured for innovation by BBC and ITV, and been invited for presentation at 10 Downing Street. A patent for the system has been granted with commercial and clinical translation underway. The company's first product will be a new system for amputees to control prosthetic limbs, with subsequent growth as a mass market device to control computers, TVs, or any smart piece of technology. It should be stressed that machine interface is only the first release of this platform technology. The system has also been tested for monitoring of patients with stroke for rehabilitation as well as a system for testing the efficacy of treatments of Parkinson's Disease, both of which are the subject of complementary clinical and commercial research. Products in these and other arenas are envisioned as a revenue stream once the human-machine interface is established.

Testing of the NUI interface for artificial hands


Empathy





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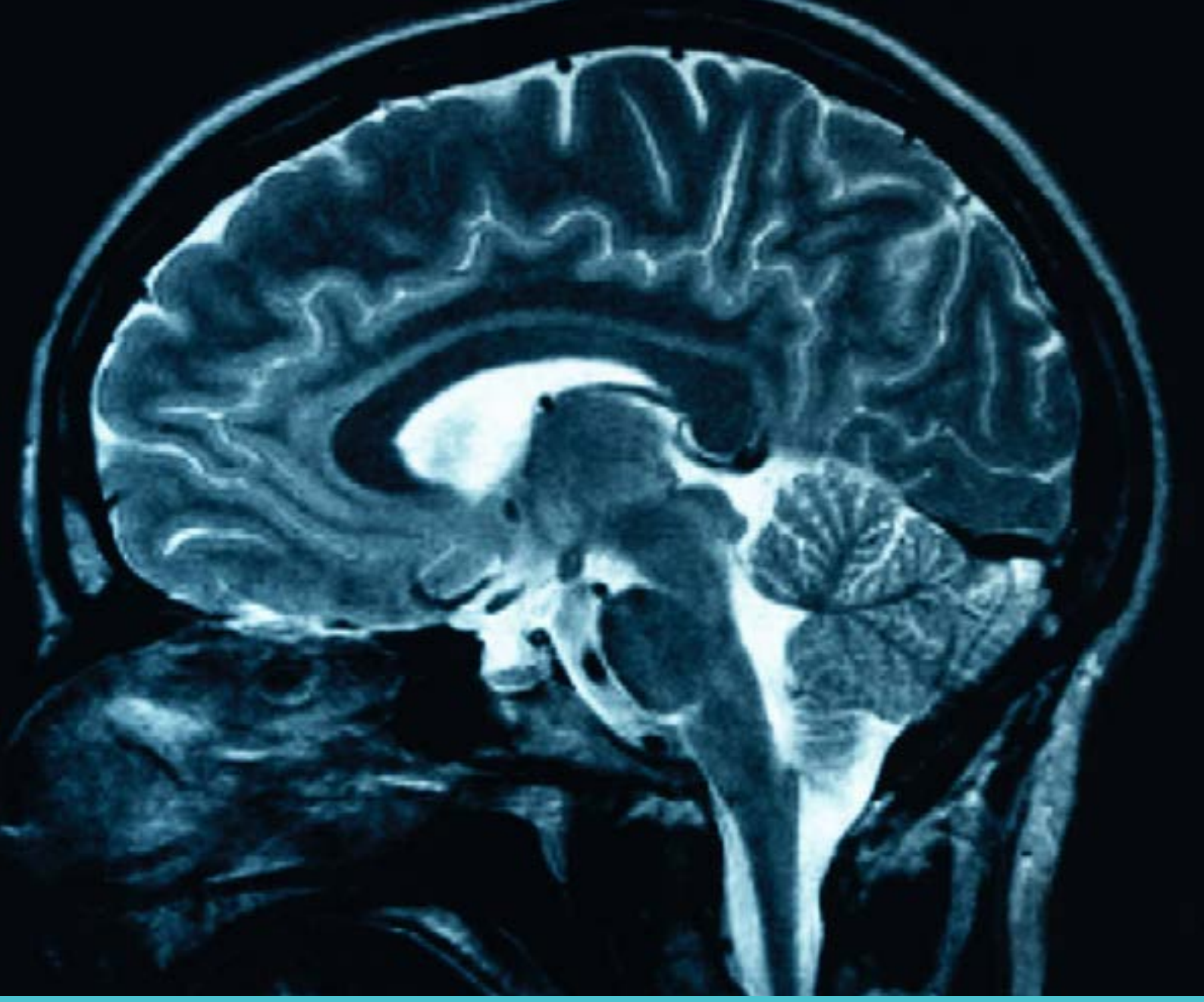

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