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# Research Centre for Biomedical Engineering

## Designing biomedical technologies, from fundamental science to the patient

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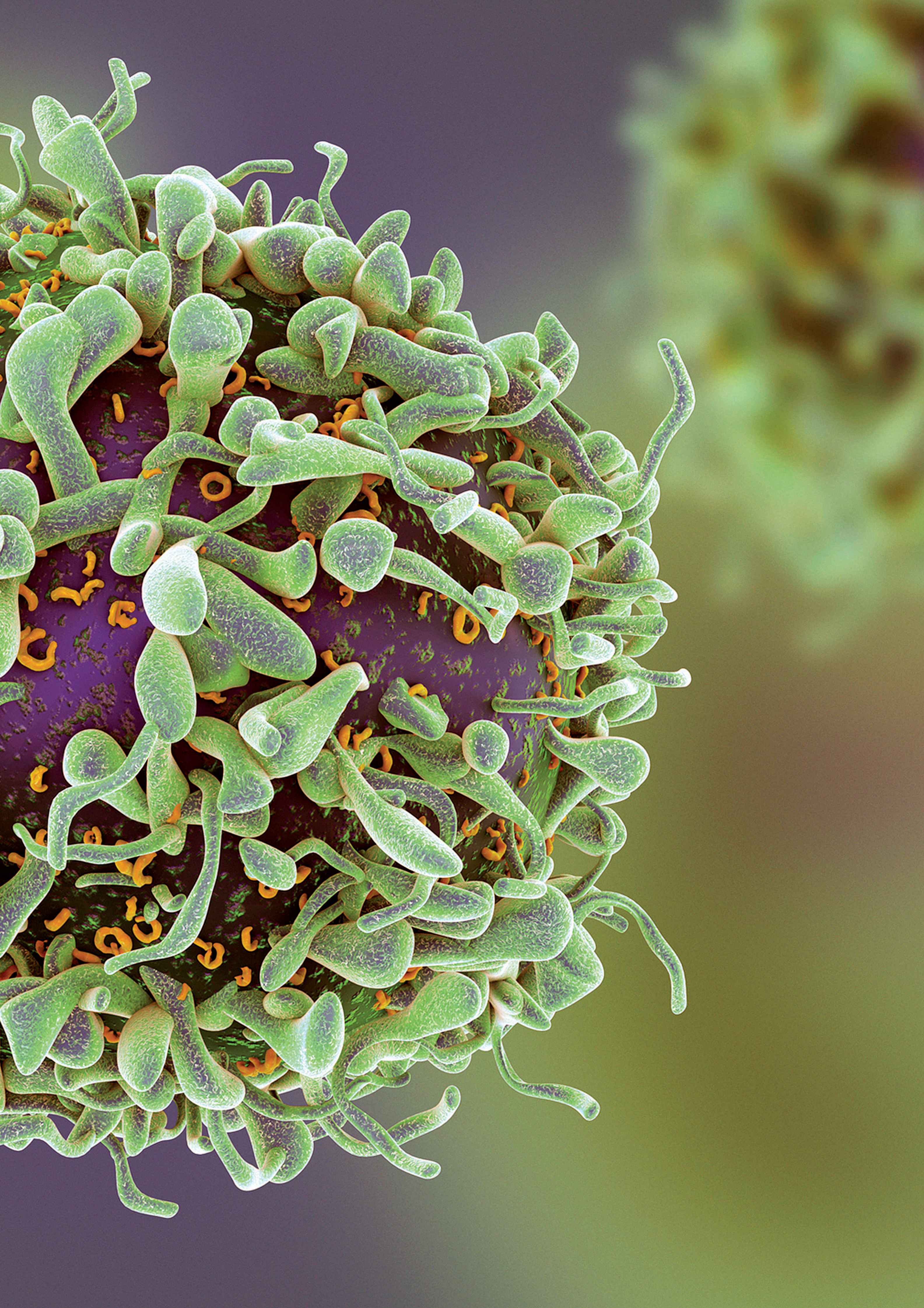


# Welcome to the RCBE

## We offer world-class research in state-of-the-art laboratories, where engineers, scientists and healthcare experts work together to resolve some of the most challenging problems in healthcare.

The Research Centre for Biomedical Engineering (RCBE) at City, University of London was founded in the mid-1990s with the aim of pursuing research in the emerging field of biomedical engineering, a discipline that applies the principles of physics and engineering to the complex medical devices used in the diagnosis and treatment of the sick and injured.

The RCBE has since built a global reputation, offering first-rate facilities and expertise to researchers and collaborators including scientists, engineers and clinicians from around the world. Working in close partnership with leading hospitals and healthcare technology companies, our researchers develop medical devices, biosensors and signal and image processing techniques for applications across a wide range of medical specialities. Together, we address both patients' needs and broader societal issues, making breakthroughs in the diagnosis, monitoring, treatment and prevention of disease.

### Our vision

Our shared vision is to develop novel medical technologies to address major challenges in global healthcare, including:

- The early non-invasive screening of cardiovascular diseases;
- Non-invasive blood and tissue biochemistry;
- Diagnostic and monitoring technologies in mental health;
- Technologies for improved clinical monitoring and management of neurodegenerative conditions.

"It has truly become a critical global resource with the capability of transforming worldwide medical care."

**Professor Kirk Shelley**
Professor of Anesthesiology
Yale University, USA

"The brand new and spacious laboratory facilities, together with state-of-the-art and high-quality equipment, allow me to perform my research without compromise."

**Dr Loukas Constantinou**
Post-Doctoral Researcher
RCBE

"The novel optical sensors developed by the RCBE could have a significant impact on the management of neonates and children with numerous different diseases."

**Professor Andy Petros**
Consultant Intensivist
Great Ormond Street Hospital for Children, UK

Please visit our website for further information about the RCBE **www.city.ac.uk/biomedical-engineering-research-centre**

# A challenging environment

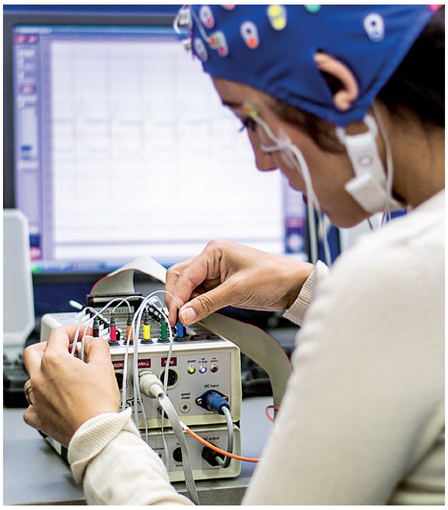
Our members are passionately engaged in the development of innovative technological solutions to a wide range of global healthcare challenges.

> "There is something magical about watching one's ideas become reality through the minds and efforts of young, dedicated researchers."

Biomedical engineering contributions to healthcare through research and development in the University and in the medical devices industries have brought about a change in how healthcare is delivered. As new technologies for diagnosis, monitoring, treatment and the development of hospital laboratory facilities grow, the hospital has become the focal point of the delivery of healthcare, with an associated development of allied health specialities. Research in this most fascinating area is literally the act of creating knowledge from where there once was none. The synthesis of a novel hypothesis, and ability to test it, is best accomplished in environs wherein creativity is valued.

I have found that the ability to take chances with ones' more risky ideas with PhD and Post-Doctoral researchers at the helm fosters innovation and, in the process, provides a unique educational component to a researchers' career. If even a glimmer of success emerges from such projects, it may lead to greater things, such as scientific papers, patents, grant funding and, most importantly, a piece of new knowledge or technology which can direct impact in the improvement of the quality of life of people. There is something magical about watching one's ideas become reality through the minds and efforts of young, dedicated researchers.

**Professor P Kyriacou**
Research Centre Director

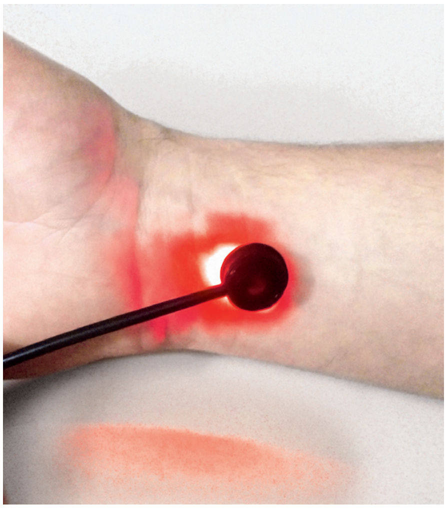


*Advancing patient-centric healthcare and ubiquitous monitoring:*
## Wearable sensors

The implementation of non-invasive sensing technologies with wide applications, in both the clinical and home settings, is one of the RCBE's main activities. Such sensing technologies could be used for diagnostic screening, monitoring and therapeutic purposes. The development of such technologies is in line with the strategic plan of the NHS and other similar health organisations, which is to shift lower-level delivery of healthcare out of hospitals and into the community. The recording of physiological and psychological variables in real-life conditions could be especially useful in the management of chronic disorders or other health problems, including high blood pressure, diabetes, chronic pain, stress and depression.

*Reducing dependence on blood sampling:*
## 'Bloodless' blood tests

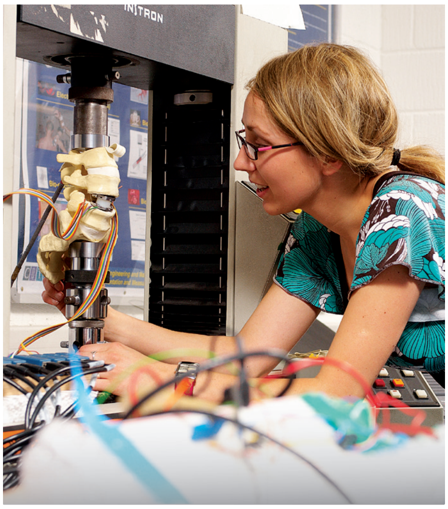
The provision of non-invasive, rapid or continuous measurements of biological variables, currently only measurable via blood samples or invasive techniques, will revolutionise medicine. Such variables within biological tissues and blood include concentrations of chromophores, gases, hormones, ionic salts, enzymes, lipids, and other biomarkers relating to various pathophysiological phenomena. The Centre is addressing this challenge by applying optical and electrical impedance spectroscopic techniques to the non-invasive measurements of blood analytes.

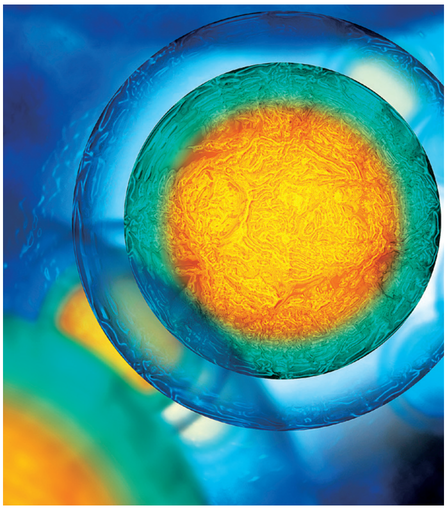


RCBE pioneers techniques for identifying biomarkers such as specific molecules found in blood or other body fluid that can provide a sign of abnormal conditions or diseases (such as inflammation, heart disease or cancer).

*Screening for cardiovascular disease:*
## Non-invasive solutions

Cardiovascular disease remains the leading cause of mortality worldwide, yet diagnosis before the disease reaches an acute stage requires costly methods such as echocardiography, angiography or other imaging modalities. The non-invasive and continuous mapping of physiological and haemodynamic parameters could provide early identification of those at risk of cardiovascular complications or diagnosis at the early stages of the disease. We are developing multi-parameter sensors in combination with advanced signal processing techniques to enable the continuous monitoring of regional and global tissue perfusion and the screening of pathologies such as peripheral vascular (artery/vein) disease, lower limb claudication, atherosclerosis, carotid artery disease, hypertension and stroke. Targeted parameters include arterial stiffness, pulse wave velocity (PWV), local blood flow, blood volume fraction, arterial and venous oxygen saturation and blood pressure.



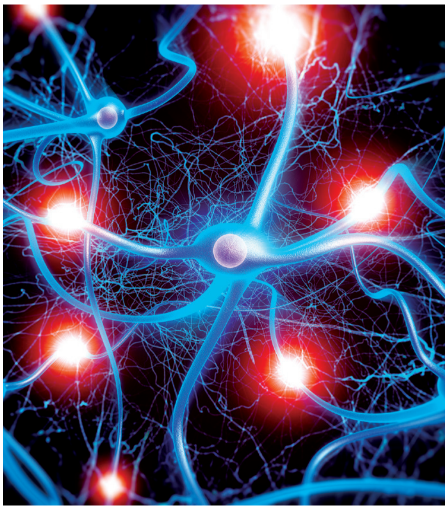


*Managing mental health:*
## Point-of-care diagnostic & monitoring technologies

Despite the impact of mental illness across a broad range of functional, economic and social outcomes, the challenges of mental health have not been effectively met by developments in biomedical engineering technology. Point-of-care devices for monitoring pharmaceutical blood levels – ensuring that patients are not at danger of toxicity-related complications – or stress biomarkers, which correlate with possible depressive relapses in mood disorder patients, would allow for timely intervention and improved health outcomes. An inter-disciplinary team with expertise in microelectromechanical systems (MEMS), biomedical sensors, biochemistry and psychopharmacology is addressing this area through the development of new, sensitive and accurate point-of-care diagnostic and monitoring devices for use by mood disorder patients at home.

*Reducing the side effects of therapeutic technology:*
## Selective neural interfacing

Often the adverse side effects of a therapeutic intervention outweigh its benefits. This problem is being addressed by developing peripheral nervous system implants that will utilise sensory neural pathways as probes into the brain and the spinal cord, while minimising the effects on the periphery. Examples include Vagus nerve stimulators that can be used for a range of diseases including epilepsy, Alzheimer's, depression and Parkinson's disease. The methods developed at the Centre will have a range of benefits: from the neuroscience perspective, gaining invaluable insights into the neural pathways that provide access to deep brain structures, to clinical practices, where signals from the brain are used as triggers for preventive stimulation providing fully automated symptom suppression.



*Accelerating the healing process:*
## Optical and electrical stimulation

The rapid healing of wounds, including those that relate to surgery or injury, as well as those that occur due to a disease (e.g., diabetic ulcers), would have enormous benefits for both patients and the health system by reducing mortality, infection, the time of hospitalisation and the enormous use of resources necessary for conventional treatment. We are addressing this challenge using application-specific optical spectroscopy and electrical stimulation in combination with 'smart' dressings that will feature embedded miniaturised multi-modal sensors for real-time monitoring of the condition of the wound.

# A broad spectrum of research

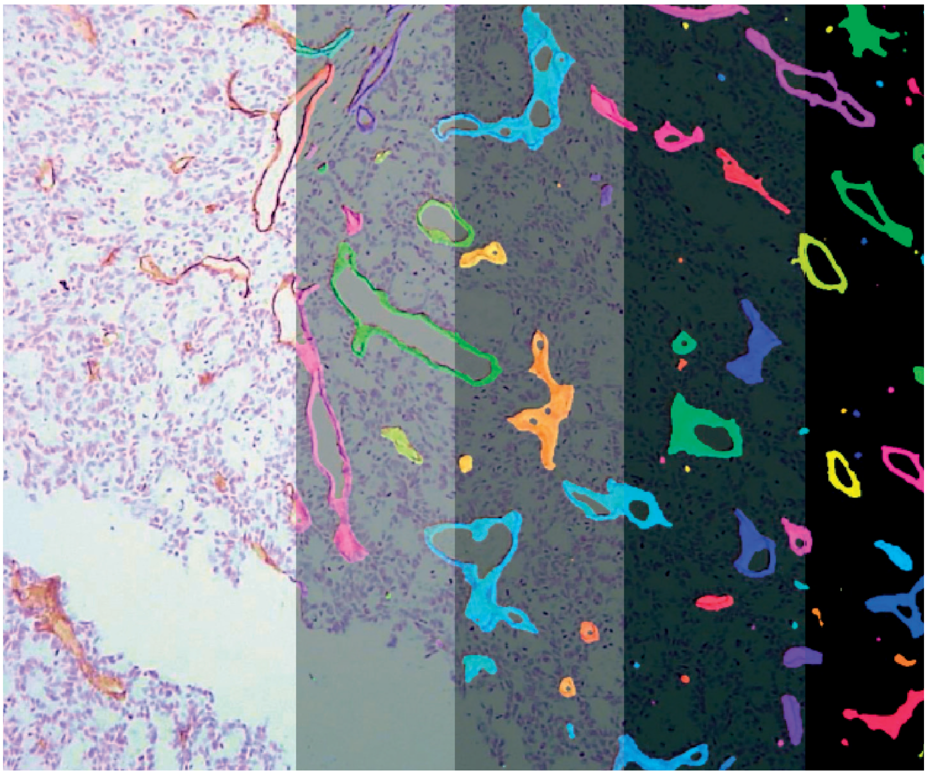
Our work embraces many areas of medicine and healthcare, harnessing a wide range of technologies and forging innovative solutions through dedicated research as well as through collaboration and shared insight.

“I have sent my medical students and faculty to work within their laboratory to learn their unique methods and approach.”

As far as I am concerned, the RCBE offers the finest bio-optics – and especially photoplethysmography – laboratory in the world. The Biomedical Engineering Research Group's study of light-tissue interaction, its physiologic implications and the development of clinical monitors have led to extraordinary breakthroughs in the field.

Their unique position in the world led me to use sabbatical time in order to do three separate extended visiting professorships (2007, 2011, & 2014) within their facilities. In addition, I have sent my medical students and faculty to work within their laboratory to learn their unique methods and approach. Over the years, I have seen the RCBE grow from a small single room to an expansive laboratory complex with a wide range of analytical, manufacturing and testing capabilities. It has truly become a critical global resource with the capability of transforming worldwide medical care.

**Professor Kirk Shelley**
Professor of Anesthesiology
Yale University, USA



## Biomedical optical sensing

The Centre's Biomedical Optical Sensing Group has over two decades of knowledge in the areas of tissue optics, haemodynamics, vascular mechanics, multi-wavelength photoplethysmography, static and dynamic spectrophotometry, *in vitro* modelling and chemometrics. This knowledge is applied to the design and development of novel optical sensors and medical instrumentation for use in a wide range of applications including pulse oximetry, tissue and organ perfusion, cerebral/muscle near infrared spectroscopy, tissue gas measurement and non-invasive monitoring of blood analytes and disease biomarkers.

The underpinning focus of the group's activity is to elicit broad understanding of the physics of the light-tissue interaction applicable to optical path determination, spatial intensity distribution and propagation dynamics through biological tissue structures. These models are validated by rigorous *in vitro* and *in vivo* experimental work using cardiovascular circuits and tissue phantoms to evaluate sensor designs. Specific areas of experimentation include evaluation and parametric characterisation of light sources, detectors, free optics and fibreoptic sensor systems, conventional spectroscopy studies on biomaterials, volumetric and directional photometry, and spectrometry in scattering media.

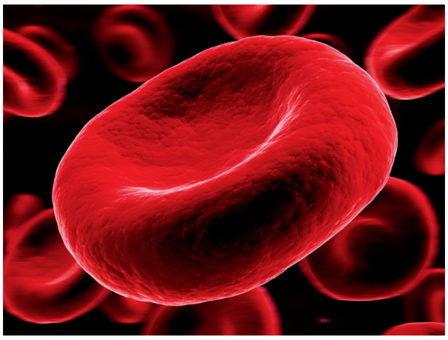
The design of novel sensors for use in a wide range of applications is based on the data generated by these models. Experimentation with novel optoelectronic materials enables technological advancements such as miniaturisation, reduced power consumption and improved biocompatibility of implantable sensors. These advancements open new avenues of research and clinical application of non-invasive diagnostic technologies.

## Optical and impendance spectroscopy

Our Optical Spectroscopy Group is devoted to understanding the optical properties of biological media and tissue, with the aim of developing the next generation of multi-wavelength optical sensors for biomedical applications. The laboratory houses various spectroscopic instruments and techniques to conduct such work. This includes sophisticated UV-Vis-NIR and FTIR, fluorescence and flame photometry instrumentation, while expert techniques include fibre optic handling and dip-coating, and micro-volume sampling.

The work carried out involves *in vivo, in vitro* and *ex vivo* testing of concentration, and identifies the spectroscopic 'signatures' of various gases and analytes of interest. This serves as the basis of biosensor design and development for physiological monitoring or disease diagnosis. Instrument and sensor evaluations are often carried out on human volunteers and through clinical trials.

The Impedance Spectroscopy Group carries out blood analysis research, mainly towards increasing sensitivity to small variations of analytes, such as lithium, which is used extensively by bipolar patients. Impedance instrumentation research includes the use of FEM simulations (COMSOL) for the design and assessment of electrode topologies and fluidic channel designs, as well as the design of circuits for improved sensitivity, impedance range and frequency range in application-specific solutions. Some of the instrumentation includes analogue electronic circuit design for waveform generation and differential output AC current sources, as well as mixed-signal design for multi-electrode adjustable topologies. Combining both optical and impedance spectroscopy allows spectra to be 'cross referenced' to detect specific low-concentration analytes with unprecedented sensitivity.



"Our Optical Spectroscopy Group is devoted to understanding the optical properties of biological media and tissue, with the aim of developing the next generation of multi-wavelength optical sensors for biomedical applications."

“We are hoping that these novel research technologies will be translated into commercial medical devices that can be routinely used in clinical settings both nationally and internationally.”

Great Ormond Street Hospital treats more than 90,000 patients each year – children who are suffering from the most complex and often life-threatening conditions. The availability of new and novel clinical information delivered through the research and development of new healthcare technologies is of paramount importance to help diagnose, manage and treat these children.

The novel optical sensors developed by the RCBE could have a significant impact on the management of neonates and children with numerous different diseases – in particular, children with meningococcal septicaemia or severe burn injuries. These sensors could also be invaluable to any child or neonate with compromised peripheral perfusion. We are hoping that these novel research technologies will be translated into commercial medical devices that can be routinely used in clinical settings both nationally and internationally.

**Professor Andy Petros**
Consultant Intensivist
Great Ormond Street Hospital for Children, UK

## Neural interfacing and neuroprosthetics

The Centre’s Neural Interfacing and Neuroprosthetics Group exploits the electrical and other physical (e.g., thermal) properties of excitable and non-excitable tissues with the aim of developing ultra-miniaturised implantable devices for targeted rehabilitation with minimal side-effects. The goal is to develop a peripheral nerve stimulation method that will activate either exclusively sensory or exclusively motor neural pathways, using combined electrical and optical stimuli.

With this new method aimed to replace present stimulation techniques, which activate simultaneously sensory and motor nerve signals, the Group seeks to eliminate related side-effects, eventually allowing for its wider use in mainstream clinical practice for disease-specific and event-triggered therapeutic intervention in both chronic and intraoperative conditions.

The Group also employs intelligent adaptable multi-electrode topologies and dedicated adjustable-parameter AC current injection electronics. The therapeutic effects of electrical stimulation in wound healing are also being researched using the knowledge and instrumentation developed for neural interfaces.

RCBE’s research in selective neural stimulation will revolutionise therapy of previously incurable conditions, by providing targeted treatment with minimal side-effects.

## Biomedical signal and image processing

Our Biomedical Signal and Image Processing Group works on developing novel and sophisticated computational and mathematical tools to extract useful information from challenging biomedical data sets, such as multi-dimensional data sets,as well as to integrate information from multiple biomedical modalities at different scales, i.e., from macroscopic levels to microscopic levels like histopathology and biometrics.

The Group also utilises advanced linear and non-linear signal processing techniques including Time-Frequency Distribution (TFD) and Empirical Mode Decomposition (EMD) to extract features from biosignals, such as Electrocardiograph (ECG), Photoplethysmograph (PPG), and Near-infrared Spectroscopy (NIRS), that will provide useful physiological information related to the haemodynamic and cardiovascular state of a person.

Some of the activities of the Group have led to open-source software packages like PhagoSight (www.phagosight.org) and online repositories of cancer image analysis (www.caiman.org.uk) which are routinely used by researchers of all levels of computational abilities. These have been cited in several publications as useful computational tools. The data sets that are analysed have addressed difficult tasks such as: segmentation and tracking of immune cells, measurement of microvascular permeability, tissue texture segmentation and classification, feature selection for multidimensional data sets, automated segmentation of vasculature and stenosis grading, and multi-scale reconstruction of electrical impedance tomography images.

The Group also promotes soft field imaging modalities as an alternative to the use of ionising radiation through the development of a unified theoretical framework for the forward and inverse problems.

## Biomedical instrumentation

The design of biomedical instrumentation is at the heart of our research activities. Medical devices must meet exceptionally high standards of reliability and precision under demanding conditions. They must also be ergonomic, intuitive and must adhere to rigorous standards of patient safety, accuracy and quality control. Devices such as patient monitoring systems are sometimes custom-made for specific projects, or flexible multi-channel monitoring platforms may be adapted to a specific application. Our medical instruments are designed using a ‘top-down’ approach, where the medical application and needs of the patient are considered from the earliest stages of the design process. Discrete and integrated circuits, power supplies, interfaces and housings may be designed and fabricated in-house. Novel sensor technologies are designed in the Centre and where necessary are mass-produced by our industrial collaborators.

# Innovation in action

Our research projects focus on the practical application of new technologies designed to transform medical practice and to revolutionise the experience of patients and healthcare professionals alike.

"The RCBE is excellent at collaborating with both the clinical and engineering sectors around the world."

After graduating from City, University of London with a 1st Class Master's degree in Biomedical Engineering (MEng Hons) in 2015, I was awarded a Doctoral Scholarship by the School of Mathematics, Computer Science & Engineering to carry out research in the area of biomedical instrumentation. Since joining the RCBE, I have engaged in a research project that involves the development and assessment of a novel intra-luminal sensor for monitoring intestinal viability in colorectal cancer surgery.

Colorectal cancer patients undergo a surgical procedure named 'bowel resection', which involves cutting the cancerous section of the intestine and joining two healthy ends of the bowel. Hence, determination of the bowel viability is essential, as inadequate blood supply is a major factor causing the disruption to the healing process. Although I am in the early stages of my research, I have been able to collaborate with the renowned National Centre for Bowel Disease & Surgical Innovation (NCBRSI) at Barts and the London School of Medicine and Dentistry. This was only possible because the RCBE is excellent at collaborating with both the clinical and engineering sectors around the world.

**Zaibaa Patel**
PhD Researcher, RCBE

## Personal lithium blood level analyser for patients with bipolar mood disorder

**Principal Investigator:** Prof P A Kyriacou

**Co-Investigators:** Dr I Triantis, Dr M Hickey (City, University of London); Dr E Palazidou (Barts and The London School of Medicine and Dentistry, QMUL)

**Researchers:** Dr M Qassem, Dr L Constantinou

**Funding:** National Institute for Health Research (NIHR)

Bipolar disorder is a serious life-long condition, characterised by recurrent episodes of depressed and manic mood states that cause major impairment in the lives of those affected. Around 1-2% of the general population in the UK is diagnosed with bipolar disorder, which often develops between the ages of 18 and 24. Lithium is the most widely used medication for treating bipolar disorder, as it is highly effective at controlling mood swings, preventing further episodes and reducing suicidal risk.

This situation prompted the development of a low-cost, personal healthcare technology to monitor blood lithium levels at home. The device employs smart medical optical and electrical sensors to monitor changes in blood lithium levels, increasing patients' sense of involvement in the management of their illness, improving adherence with effective monitoring, and facilitating early detection of shifting of lithium concentrations outside the therapeutic range.

## Multi-parameter oesophageal sensor for the early detection of multiple organ dysfunction syndrome (MODS)

**Principal Investigator:** Prof P A Kyriacou

**Co-Investigators:** Dr J Phillips, Dr M Hickey (City, University of London); Prof R Langford (Barts Health NHS Trust)

**Researcher:** Dr J Davenport

**Funding:** National Institute for Health Research (NIHR)

Patients in the intensive care unit (ICU) are extremely vulnerable to complications related to sepsis, an infection of the blood stream. Once sepsis takes hold, it can develop into more serious conditions such as septic shock and multiple organ dysfunction syndrome (MODS), both of which are associated with very high mortality rates.

"Approximately 19% of patients admitted to intensive care develop MODS, which is estimated to cause from 47% to 80% of deaths in the ICU."

Currently, there is no bedside monitor suitable of providing an early indication of inadequate oxygen supply in abdominal organ tissues.

This project uses a disposable optics-based probe to continuously monitor the oxygen and carbon dioxide levels in the wall of the lower gullet. This provides valuable information regarding the adequacy of the blood supply to the gut and vital organs. Following evaluation in surgery and Intensive Care Unit (ICU) patients, the ultimate aim is to develop a new type of sensor to reduce death from sepsis and MODS, leading to significant reductions in mortality and shorter stays in intensive care.

## Improved healing by combining optical and electrical stimulation of nerves (HOpES)

**Principal Investigator:** Dr I. Triantis

**Researcher:** Dr E. Rahman

**Funding:** EPSRC

This project is developing a peripheral nerve stimulation method that will activate either exclusively sensory or exclusively motor neural pathways, using combined electrical and optical stimuli. The goal is to replace present stimulation techniques – which activate sensory and motor nerve signals simultaneously – with the proposed method, in order to eliminate related side-effects and eventually allowing for its wider use in mainstream clinical practice. The project combines *in vitro* experimental measurements with Matlab and COMSOL simulation models.

## Non-invasive optical sensor for the monitoring of blood glucose in diabetes

**Principal Investigator:** Prof P A Kyriacou

**Co-Investigators:** Professor A Petros (Great Ormond Street Hospital for Children)

**Researcher:** Dr V Rybynok

**Funding:** Emerald Fund, City, University of London, Great Ormond Street Hospital for Children

Currently, blood glucose can only be monitored through the use of invasive techniques that involve drawing blood through a small pinprick. The market is very large, as all diabetics in the world are potential users of the sensor and the number of diabetics in the UK has increased since 1996 from 1.4 to 1.8 million people. Worldwide it is expected to grow from 150 million in 2004 to 220 million by 2010 and 300 million by 2025.

Through this project, we are developing an easy-to-use, non-invasive and calibration-free finger optical sensor for the accurate and continuous measurement of blood glucose. This will be accomplished by using a novel patented technology named Dynamic Pulsatile Spectroscopy (DPS).

“The Centre has achieved an international reputation built upon the design, development and clinical evaluation of novel biomedical devices and sensors.”

My knowledge of the Research Centre for Biomedical Engineering stems from a longstanding collaboration with its Director, Professor Panicos Kyriacou and his team.

The Centre has achieved an international reputation built upon the design, development and clinical evaluation of novel biomedical devices and sensors for patient monitoring, analytical imaging and mathematical modeling techniques. This success has realised academic grants and innovation funding to build the outstanding team and research laboratories. Most unusually, the team has the skills to take its innovative medical technology ideas to patent application and beyond to commercial prototype and clinical evaluation.

**Professor Richard Langford**
Honorary Consultant in Anaesthesia
and Pain Medicine
St Bartholomew's Hospital, UK

## Non-invasive optical intracranial pressure monitoring system

**Principal Investigator:** Dr J P Phillips

**Funding:** NIHR/Royal Academy of Engineering/ Leverhulme Trust

The medical treatment received immediately after traumatic head injury is critical to the survival and recovery of the patient, and intracranial pressure (ICP) is routinely monitored in patients suffering from traumatic brain injury. Raised ICP can result in compression of the brain tissue causing a reduction in the supply of oxygenated blood to the brain leading to irreversible disability or death.

“The standard ICP monitoring method requires insertion of a pressure-sensing catheter into a cranial bolt screwed into the skull, which carries a significant risk of infection as well as causing delay in establishing emergency monitoring.”

This project aims to develop a completely non-invasive system based on a probe placed on the forehead, for continuous external monitoring of ICP. A prototype system is currently under development, which includes a probe containing infrared light sources that can illuminate the brain tissue beneath the forehead. The reported ICP will provide screening of newly admitted head-injured patients to indicate the need for rapid intervention and to guide long-term treatment. Ultimately, this could lead to significant improvements in mortality, length of hospital stays and reduced post-trauma disability. The technology could also benefit patients suffering from meningitis, hydrocephalus (‘water on the brain’) and migraine.

## Image analysis for neutrophils and other cells: behaviour modelling and tracking

**Principal Investigator:** Dr C Reyes-Aldasoro

**Co-Investigators:** Prof. Stephen Renshaw (University of Sheffield), Dr Brian Stramer (King's College London), and Prof Donald Wlodkovic (Monash University Australia).

**Researcher:** Mr J Solis-Lemus

**Funding:** City, University of London

The analysis of immune cell response is important for understanding their role in the processes of inflammation and infection. However, observing these cells in humans is complicated, with scientists using alternatives such as cells in petri dishes.

A recent development is the use of ‘model’ organisms: other animals with immune systems similar to those of humans. Of these, one of the most promising is the zebrafish, which allows the observation of cells due to its transparency. This project observes the movement of immune cells in situations of inflammation and infection, and will contribute to the understanding of the conditions behind numerous human illnesses such as like asthma, atherosclerosis or rheumatoid arthritis.

## Non-invasive optical sensors for the monitoring of cerebral oxygenation and detection of Hypoxic Ischaemic Encephalopathy (HIE) in neonates

**Principal Investigator:** Prof P A Kyriacou

**Co-Investigators:** Professor A Petros (Great Ormond Street Hospital for Children)

**Researcher:** Dr J May

**Funding:** EPSRC DTA

There is a need for a more reliable, non-invasive and alternative measurement site for the monitoring of arterial blood oxygen saturation in critically ill neonates when there is the risk of cerebral hypoxia (lack of oxygen reaching the brain). When babies suffer from Hypoxic Ischaemic Encephalopathy (HIE), a condition in which the brain does not receive enough oxygen, there is no readily available technology to detect such deficiency of oxygen in the brain. HIE can be fatal; within as little as five minutes of oxygen deprivation, brain cells can begin dying.

To overcome this challenge, the anterior fontanelle (AF) is proposed as a potential measurement site, on the hypothesis that blood circulation may well be better preserved at this central site. New novel optical non-invasive sensors have been custom-made for this anatomical part and are currently being investigated in clinical trials.

# State-of-the-art facilities

The new biomedical engineering research laboratories form a highly-specialised research facility for the development of cutting-edge biosensing, diagnostic and rehabilitation devices.

"The friendly atmosphere between all members of the Centre enhances team spirit and promotes research excellence."

After I finished my PhD at University College London (UCL) I joined the RCBE in July 2014 as a research associate. My work here at City involves the design and development of portable instrumentation for the detection of lithium concentration in blood using Electrical Impedance Spectroscopy (EIS). Maintaining therapeutic levels of lithium is vital for patients with bipolar mood disorder. Here at the Centre, I was given the opportunity to apply the principles and knowledge gained throughout my research degree, and tackle such a sensitive mental health issue.

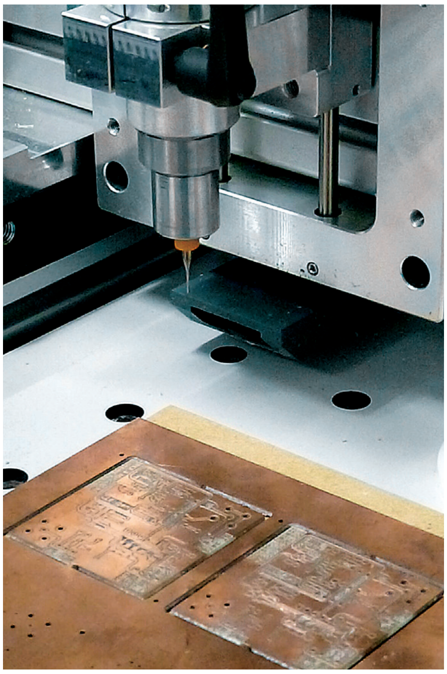
This work is funded by the National Institute for Health Research (NIHR), and represents an important milestone in the vision of the Centre to provide solutions that will improve the lifestyle of mental health patients. The brand new and spacious laboratory facilities, together with state-of-the-art and high-quality equipment, allow me to perform my research without compromise. The friendly atmosphere between all members of the Centre enhances team spirit and promotes research excellence. Research in the field of biomedical engineering can be quite challenging, and generating new knowledge is the highest priority. Strong clinical collaborations and funding opportunities provided by the Centre can facilitate the generation of new knowledge and further promote research excellence in the field.

**Dr Loukas Constantinou**
Post-doctoral Researcher

## Sensor and instrumentation fabrication laboratory

This laboratory houses state-of-the-art facilities for the design and fabrication of optical, fibreoptic and electrochemical sensors, including a clean bench, an anti-vibration shielded bench, advanced 3D printing and CNC manufacturing. Engineering design tools are also available, including Cadence, and prototyping devices, such as solder ovens and pick-and-place equipment for small-scale mass production of analogue and digital circuits.

The lab also provides the latest analogue and digital test equipment used for the technical evaluation of newly developed sensors and instrumentation. This includes high end mixed-signal oscilloscopes; fully programmable waveform generators; network and signal analysers for the analysis of MHz bio-signals; an isolation amplifier for electrical stimulation experiments; a logic analyser; and a precision impedance analyser. A cutting-edge environmental chamber is also available for testing the sensors under different environmental conditions (temperature and humidity).



## Optical spectroscopy and wet laboratory

The optical spectroscopy and wet laboratory houses a range of analytical instrumentation for conducting *in vitro* spectroscopic research, *in vitro* rheological research and vascular mechanics studies. Our spectrometers (UV-VIS, FIR, NIR, and flame photometer) are amongst the best in the community and cover a broad range of wavelengths that extend from UV to far IR at high resolutions.

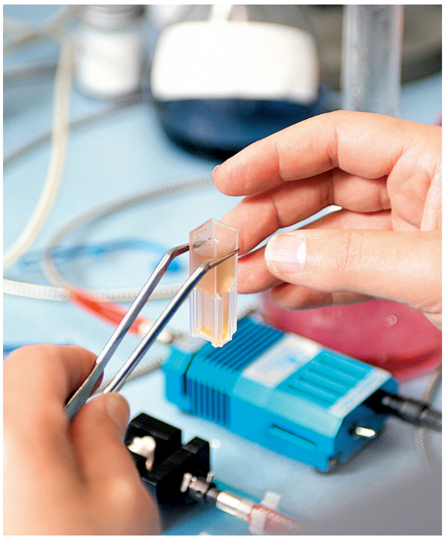
"Our spectrometers are amongst the best in the community and cover a broad range of wavelengths that extend from UV to far IR at high resolutions."

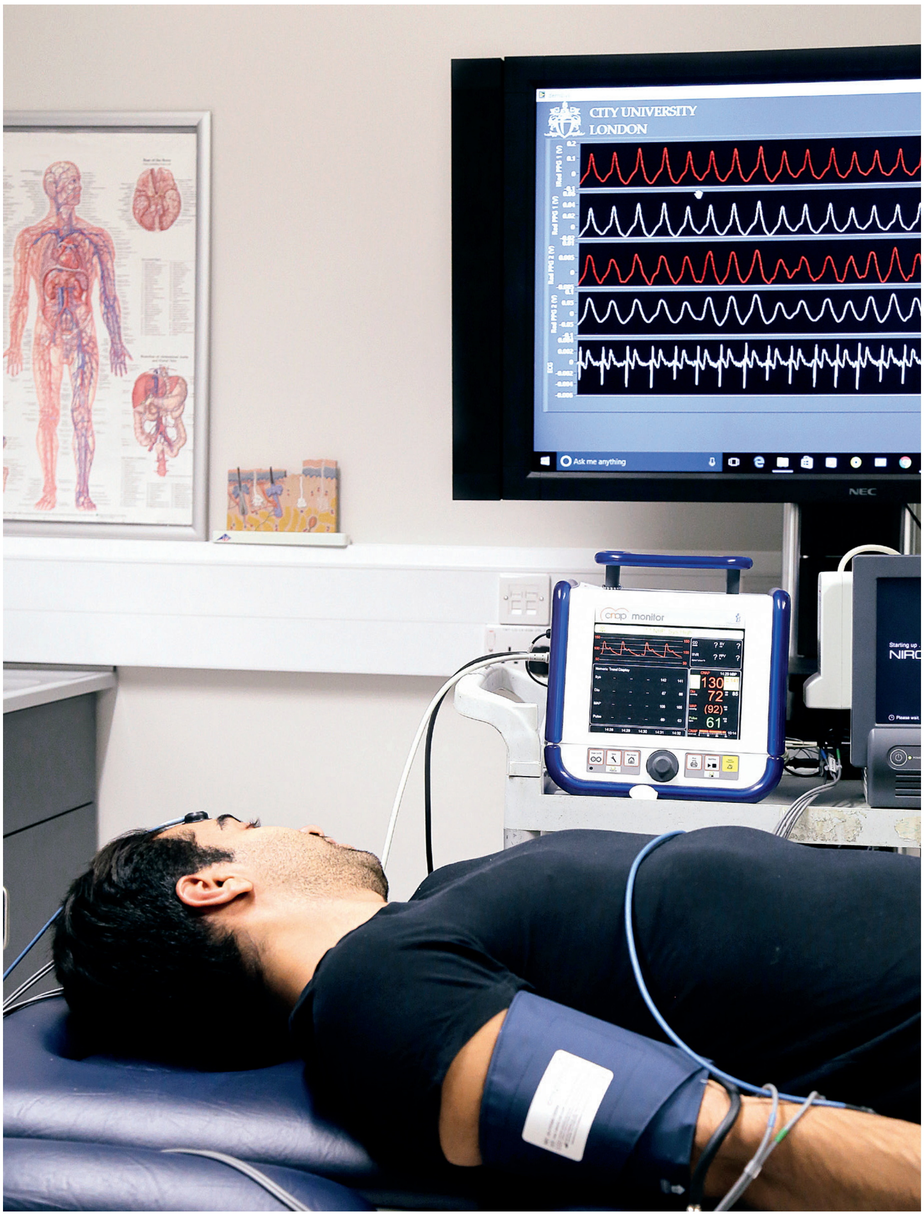
The chemical section of the laboratory includes equipment for the preparation of chemical solutions and for dealing with biological samples, and is also equipped with a centrifuge, a controlled stress rheometer and conductivity/pH meters. This area also hosts a hub for experimental fluid dynamics and mechanics. A pulsatile pump setup with a model of an arterial network is designed to mimic human circulation for controlled cardiovascular and haemodynamic investigations.

## Physiological measurement laboratory

This is a temperature-controlled clinical area for conducting physiological studies in volunteer subjects. It is equipped with state-of-the-art commercial patient monitoring equipment such as devices for electrophysiological monitoring, continuous blood pressure, pulse oximetry, and near infrared spectroscopy (NIRS), as well as experimental devices and sensors developed in the Centre. There are multi-channel data acquisition systems and facilities for blood sampling, sample handling and analysis equipment, namely blood gas analysis and haemoximetry.

The laboratory also contains an adjustable bed for prone and Trelendenberg (head up/down) positions. The physiological measurement laboratory provides an ideal quiet and discreet environment for the detailed study of physiological phenomena and the validation of experimental sensors and instrumentation under different environmental conditions and physiological challenges. We plan to extend the range and utility of this laboratory to include exercise and hypoxia challenge conditions.






“The physiological measurement laboratory provides an ideal quiet and discreet environment for the detailed study of physiological phenomena and the validation of experimental sensors and instrumentation under different environmental conditions and physiological challenges.”

"The lab provides a wonderful environment for new ideas to take shape."

The RCBE comprises facilities for development and evaluation of novel and innovative medical devices and sensors for a wide range of medical applications. Our collaboration has resulted in many successful projects, some of which are being developed into products that could profoundly change how medicine is delivered in the future.

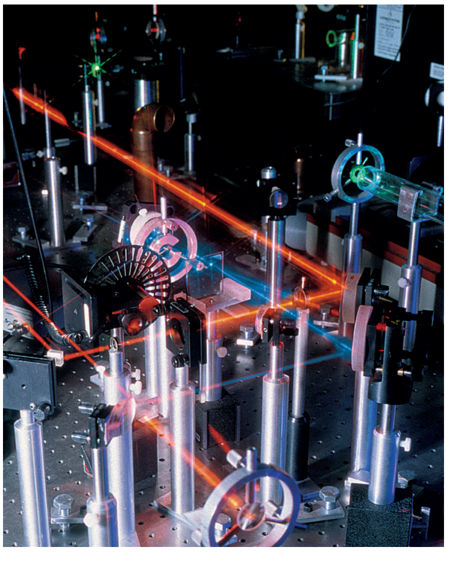
The lab provides a wonderful environment for new ideas to take shape. The staff have abundant knowledge of physics, engineering and physiology and skills in electronics, design and manufacture which enable them to produce prototype devices for volunteer and patient studies. There is a well-equipped wet lab which is divided into an area for vascular mechanical modelling and a spectroscopy area, containing state of the art UV-VIS-NIR spectrophotometers, NIR tissue spectroscopy and FTIR instruments. The wet labs and darkroom areas provide valuable spectroscopic data to support development of stand-alone non-invasive monitoring devices. There are also substantial electronics fabrication and 3D-printing/CNC equipment for rapid prototyping. Computational facilities support optical and physiological modelling. Finally, the lab includes a physiological measurement suite in which volunteer studies are conducted, which are invaluable for producing proof-of concept data prior to clinical trials, or to support large grant applications.

**Dr Saowarat Snidvongs**
Consultant Anaesthetist
Royal London Hospital (Barts Health NHS Trust)

## Dark room

The dark room hosts experimental work involving free optics and lasers, used for the development and evaluation of optical and fibreoptic sensors. It offers optical benches, lasers and all associated optical accessories and components, including optical tooling.

The dark room features a full suite of optical fibre processing facilities, including tools for cleaving, polishing and mounting as well as advanced fusion splicing capabilities. Pioneering optical sensor development takes place in this area, such as fluorescence gas sensors, miniaturised fibreoptic pulse oximeters and spectroscopic blood component sensors. The facilities are used in the design, development, and testing of such novel sensors. *In vitro* studies in the field of tissue optics are also conducted in this laboratory.



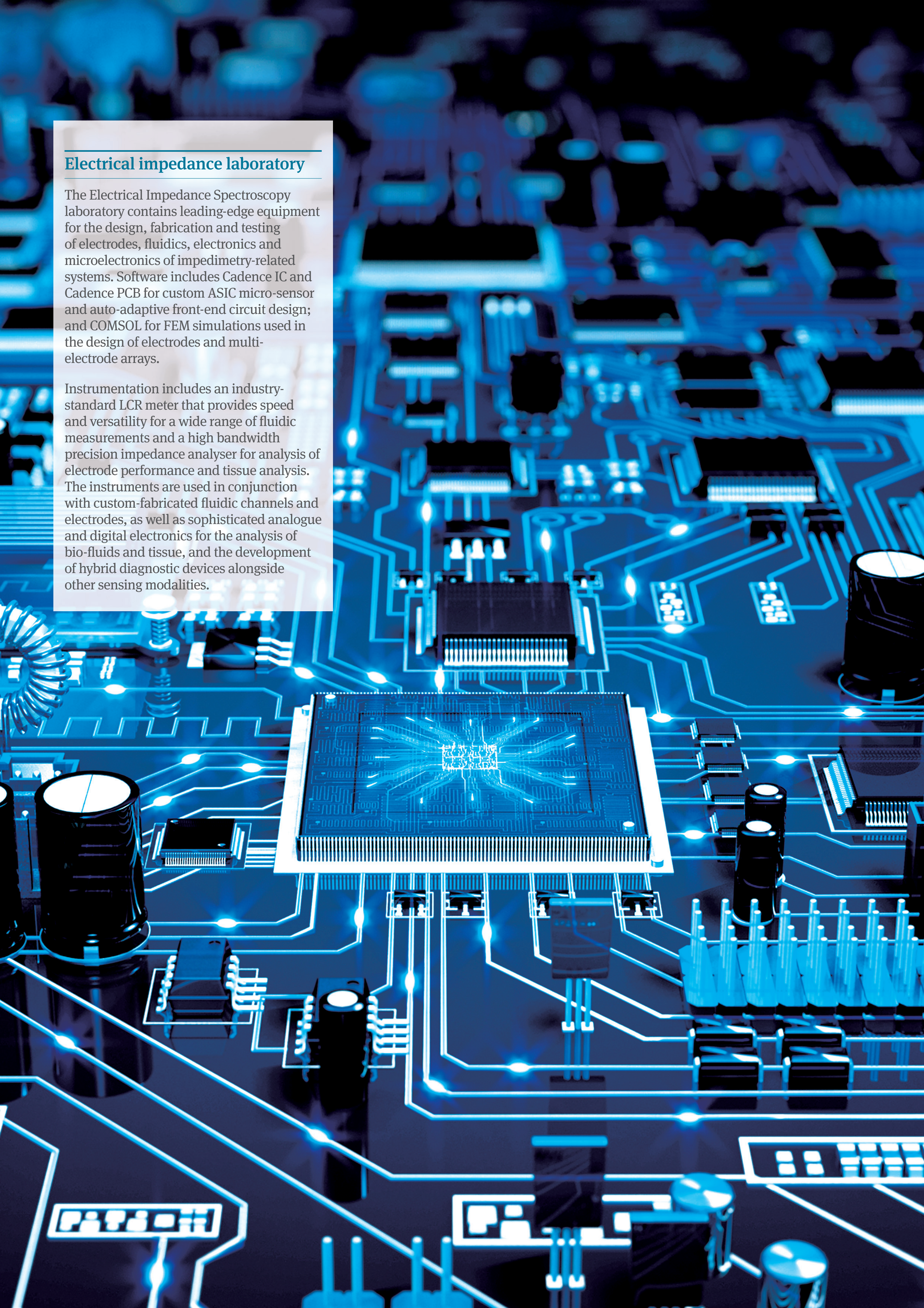
## Signal and image processing laboratory

The computation laboratory contains powerful computational facilities and workstations for advanced signal analysis, signal processing and image processing. This facilitates the analysis of data sets (signals, images, videos, three-dimensional volumes and three-dimensional volumes in time) off-line by developing bespoke algorithms tailored to the data using software platforms, mainly in Matlab and LabVIEW. Software licences are available to researchers covering many areas of biomedical research, from Magnetic Resonance Images in the analysis of cartilage thickness to pre-clinical experiments of cancer, inflammation and radiation.

## Electrical impedance laboratory

The Electrical Impedance Spectroscopy laboratory contains leading-edge equipment for the design, fabrication and testing of electrodes, fluidics, electronics and microelectronics of impedimetry-related systems. Software includes Cadence IC and Cadence PCB for custom ASIC micro-sensor and auto-adaptive front-end circuit design; and COMSOL for FEM simulations used in the design of electrodes and multi-electrode arrays.

Instrumentation includes an industry-standard LCR meter that provides speed and versatility for a wide range of fluidic measurements and a high bandwidth precision impedance analyser for analysis of electrode performance and tissue analysis. The instruments are used in conjunction with custom-fabricated fluidic channels and electrodes, as well as sophisticated analogue and digital electronics for the analysis of bio-fluids and tissue, and the development of hybrid diagnostic devices alongside other sensing modalities.



# More about us

Research Centre for Biomedical Engineering
Northampton Square
London, EC1V 0HB

Our talented and highly experienced team work together to develop innovative solutions to a broad spectrum of global healthcare challenges.

## RCBE membership

### Professor P Kyriacou *Director*

**Tissue optics, chemometrics, blood and tissue perfusion, biomedical sensors and instrumentation, physiological/clinical measurement, wearable devices**

After a decade at City as a Lecturer and latterly Professor of Biomedical Engineering, in 2014 Professor Kyriacou was appointed Associate Dean for Research and Enterprise at the School of Mathematics, Computer Science & Engineering and Director of the Biomedical Engineering Research Centre.

### Dr J Phillips

**Biomedical optical sensors, optical/ physiological modelling, physiological measurement, patient monitoring**

With over fifteen years' experience of clinical research in the field of surgery, intensive care and anaesthesia, Dr Phillips is an Honorary Research Fellow at St Bartholomew's Hospital and has authored many scientific papers and conference proceedings.

### Dr I Triantis

**Neuroprostheses, electrical stimulation, electrical impedance spectroscopy and tomography, microelectronics**

A Senior Lecturer in instrumentation and sensors at City, Dr Triantis has designed a number of chips for biomedical applications and has explored multi-modal bio-sensing and bio-actuation techniques, including combining electrical with chemical and optical methods for neural interfacing.

### Dr C Reyes-Aldasoro

**Biomedical signal and image processing, pattern recognition, feature selection, texture analysis**

A Senior Lecturer at the School of Mathematics, Computer Science & Engineering, Dr Reyes-Aldasoro's area of expertise is in biomedical image analysis, with a particular interest in cancer, immunology and microcirculation. He collaborates closely with life scientists in several institutions.

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**Find out more, visit**
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## Postdoctoral fellows

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Dr K Budidha

Dr L Constantinou

Dr J Davenport

Dr J May

Dr M Qaseem

Dr E Rahman

Dr K Shafqat

## PhD students

Mr A Al-Aishan

Mr M Bejarano

Ms S Chatterjee

Mr B Escobar

Mr Z Hashim

Mr P Ioakim

Mr N Kumar

Mr S Leandrou

Mr G Menikou

Mr R Meysam

Ms H Njoum

Miss M Nomoni

Mr N Papadopoulos

Ms Z Patel

Mr JA Solis-Lemus

Mr S Villa

## Academic and clinical collaborators

**Mr K Aquilina**
Great Ormond Street Hospital for Children

**Dr B Cunniffe**
English Institute of Sport

**Professor S Greenwald**
Barts and the London School of Medicine

**Mr P Harris**
The Royal Marsden NHS Foundation Trust

**Professor RM Langford**
St. Bartholomew's Hospital

**Professor P Liatsis**
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**Dr K Nikolic**
Imperial College London

**Professor S O'Connor**
EBR Systems, Inc., USA

**Professor SK Pal**
St Andrew's Centre for Plastic Surgery & Burns

**Dr E Palazidou**
Bart's and The London School of Medicine

**Ms H Patel**
The Royal London Hospital

**Professor AJ Petros**
Great Ormond Street Hospital for Children

**Professor K Shelley**
Yale University

**Mr M Thaha**
The Royal London Hospital

**Professor G Tozer**
The University of Sheffield

## Industrial collaborators

AVOptics

Draeger Medical

GE Healthcare

GMD

Intelligent Fabric Technologies Plc

Medtronic

Philips

Schurter Electronics

Siemens Medical

## Publications

Members of the RCBE have authored and co-authored over 500 publications in high-impact engineering, scientific and clinical journals; prestigious international conferences; invited chapters in books; books; and monographs. Conferences to which the Centre makes a significant contribution include: IEEE EMBC, IEEE Sensors, IEEE International Symposium in Biomedical Imaging, IEEE International Conference in Image Processing, IEEE Biomedical Circuits and Systems, Annual International Conference on Cardiology & Cardiovascular Medicine Research, World Congress of Biomechanics, SPIE Photonics West and IAMPOV. Members of the Centre also currently hold several patents with inventions in the area of biomedical instrumentation and optical biomedical sensors. Dr Reyes-Aldasoro recently published a book on Biomedical Image Analysis Recipes in MATLAB with the editorial Wiley.