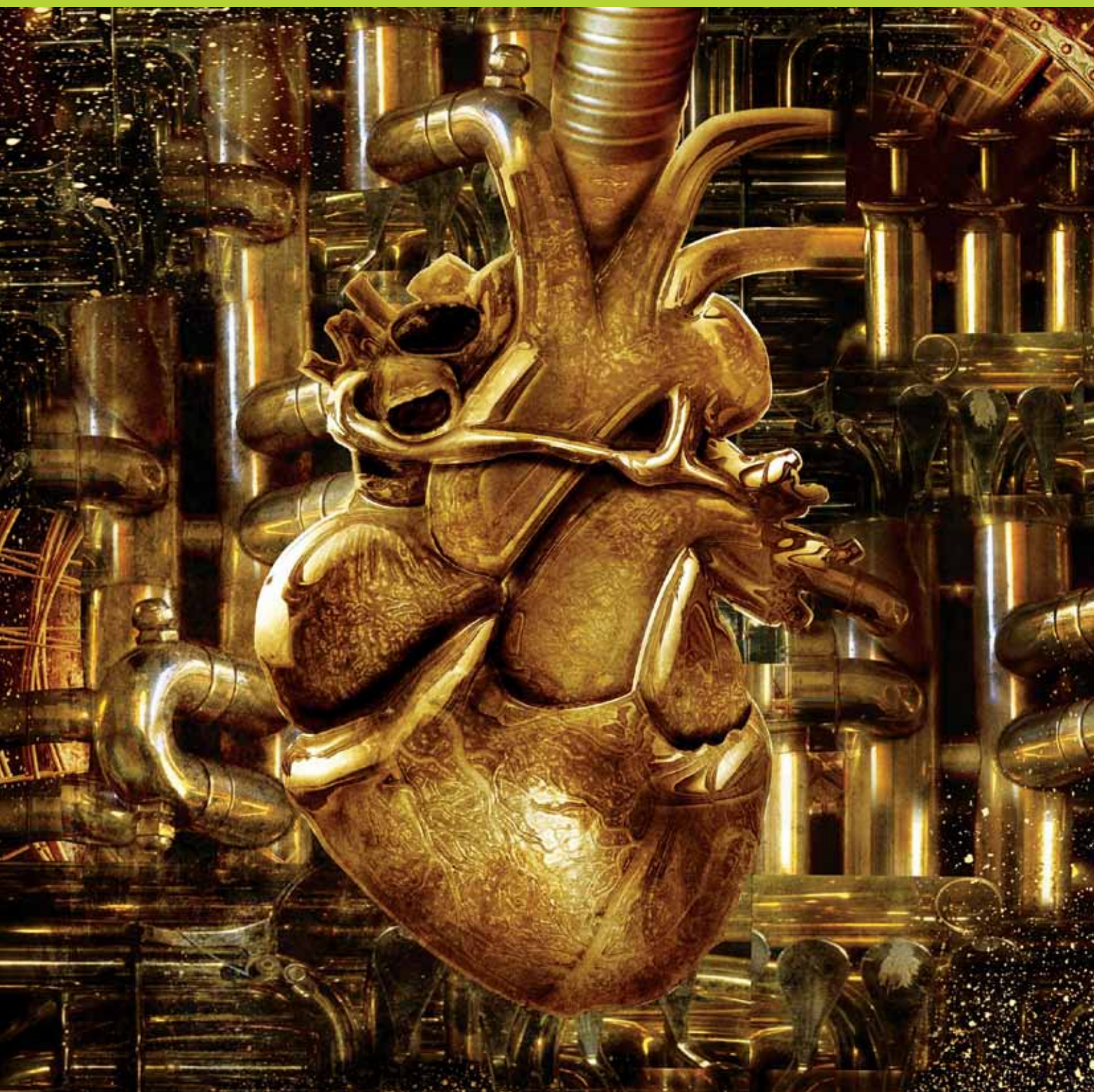



MEDICAL ENGINEERING INITIATIVE

wellcometrust EPSRC





Introduction Engineers have been at the forefront of medical innovation throughout the history of medicine. Millions of people have benefited from their inventions, which include tools such as implants and prosthetic limbs, devices to monitor patients and instruments to maintain the body's functions, such as the implantable pacemaker. Both medicine and engineering continue to advance at great pace, so it is crucial that the links between these disciplines are maintained and that opportunities for engineers and medical scientists to collaborate are not missed – especially with the potential for groundbreaking advances in fields such as imaging and genetics.

In June 2009, the Wellcome Trust and the Engineering and Physical Sciences Research Council (EPSRC) announced that they would, in partnership, fund four new Centres of Excellence in Medical Engineering in the UK. The intent is that each centre will provide an environment for mathematics, physical science, engineering and medical research to come together, to encourage exploratory research and the translation of that research into products that can improve healthcare.

Four interdisciplinary research teams – at Imperial College London, King's College London, the University of Leeds and the University of Oxford – will receive a combined total of £41 million over the next five years. Through the Medical Engineering scheme, the Trust and EPSRC hope to engage engineers, scientists and medics in groundbreaking research, and stimulate collaborations that will continue beyond the five-year lifetime of the funding. The aim is to ensure cutting-edge technology continues to enter the clinic in an effective and evidence-based manner, to improve the lives of patients in the National Health Service and around the world.



Biology and medicine are powerful disciplines in their own right, but they do not stand alone. Each interacts with, and depends upon, a variety of other disciplines, and we should always look to enhance these links – for they can stimulate new ideas, approaches and innovations.

The discipline that has had and will continue to have a huge impact on healthcare is that of engineering. There is a long history of collaboration between doctors and engineers, bringing us health-transforming developments such as hip and knee replacements, pacemakers, dialysis machines and video laryngoscopes, and today it is the fastest-growing area of engineering.

It is this spirit of innovation that underpins our newly awarded funding to four Centres of Excellence in Medical Engineering. At these centres, engineers and medical scientists are using the latest technologies to tackle major unmet needs in medicine. The Wellcome Trust is delighted to be collaborating with the Engineering and Physical Sciences Research Council in providing major funding to drive forward this important area of research

Sir Mark Walport,
Director of the Wellcome Trust

The four interdisciplinary research centres funded through this Medical Engineering initiative have provided an opportunity for some of the UK's leading clinicians, physical and biomedical scientists, and engineers to pool their expertise and work together to solve some of the key challenges facing healthcare. The scale of the combined investment between the Wellcome Trust and EPSRC should help to keep the UK at the forefront in this area.

From a long-term perspective, there are many exciting possibilities for the excellent research arising from the synergy of these communities working together to make a real impact on the lives of UK citizens, not only now but in future generations. Improving the uptake and exploitation of the research from UK universities is important to EPSRC and its vision for the UK to be as renowned for knowledge transfer as it is for research discovery.

EPSRC is proud to partner with the Wellcome Trust in this exciting initiative and the possibilities it provides for medicine, science and engineering to work together in pushing the boundaries of medical innovation and providing a path for the translation of cutting-edge research into application.

Professor David Delpy,
Chief Executive of EPSRC



Medical imaging King's College London Medical Engineering Centre



KING'S
College
LONDON

Centre focus

The King's College London Medical Engineering Centre aims to break down the barriers between biology, medicine, and the fields of engineering, physics, mathematics, computer science and chemistry. Our work on medical imaging brings together basic scientists and medical researchers in a hospital setting, and we focus on the clinical translation of the underpinning science and technology. As well as moving towards clinical studies that show patient benefit, we aim to facilitate a closer partnership between the university and industry.

The programmes

Our six scientific programmes bring together strong basic science with clinical translation in the setting of an academic health science centre.

Guiding keyhole robotic surgery on the heart: We are developing new ways to improve the treatment of heart rhythm problems by keyhole robotic surgery. This includes the use of magnetic resonance imaging (MRI) to visualise the heart and the lesions made during treatment – which has the added benefit of avoiding X-ray radiation – as well as improving the automated guidance of the robots.

Computer simulations of coronary artery

disease: With new computer simulations, we can increase the accuracy of diagnosis of suspected coronary artery disease, and improve the selection of patients for interventional treatment.

Atherosclerosis: We are building a specialist combined MRI and positron emission tomography (PET) scanner that, with special imaging agents, can characterise atherosclerosis accurately. This will allow us to improve predictions of patients at risk of heart attack and stroke.

Cancer: Using novel imaging agents to improve the diagnosis and treatment of cancer.

Cancer surgery: Using tissue engineering to rebuild faces after cancer surgery.

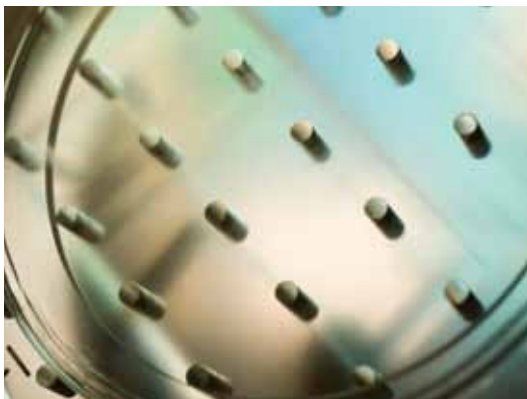


Principal investigator

Professor Reza Razavi is the Centre Director and Head of Division of Imaging Sciences at King's. He is a paediatric cardiologist with a research focus on imaging and image-guided intervention of the heart and vessels. His research group at King's College London was the first to perform MRI-guided cardiac catheterisation in patients.

The team

Phil Blower
Rene Botnar
Fauzia Farooq
Eike Nagel
Tobias Schaeffter
Lakmal Seneviratne
Nic Smith
Slavik Tabakov
Tim Watson



Psychiatric illness: By developing new imaging and computational tools, we aim to improve the diagnosis of psychiatric illness as well as predictions of treatment effects.

We also have several general initiatives:

- a multidisciplinary MSc and MRes programme to get the brightest undergraduates from mathematics and science to move into biomedical research
- pump-priming of joint academic-industrial research initiatives that can be built upon to develop the Centre's future programmes and allow its long-term sustainability
- collaborations with international research groups that will bring leading scientists to visit the Centre, and allow our scientists to work at these sites for short periods to learn new techniques and set up new collaborations.



**'50 active years after 50':
engineering solutions for an ageing
population with musculoskeletal and
cardiovascular disease** WELMEC
Centre of Excellence in Medical
Engineering, University of Leeds



UNIVERSITY OF LEEDS

Centre focus

As we age, our musculoskeletal and cardiovascular systems degenerate, impairing our mobility, ability to work and quality of life. Yet our expectations for health, activity and wellbeing in the second 50 years of life are increasing. At the WELMEC Centre, we aim to develop new ways to extend human joint and cardiovascular health, and so improve quality of life, for '50 active years after 50'. We research, develop and deliver to patients new types of intervention for the musculoskeletal and cardiovascular systems, which will provide biological and biomechanical functionality by harnessing the regenerative potential of patients' own stem cells.

The programme

Advances in engineering and bioscience have created opportunities for new devices and therapies that can use innovative biomaterials or biological scaffolds to guide a patient's own stem cells to repair degenerative tissues. Meanwhile, progress in imaging and diagnostic techniques enables early diagnosis, so we can intervene earlier in the degenerative process, preserve healthy tissue and provide a patient-specific continuum of care.

We will advance the diagnosis, treatment and evaluation of degenerative disease in two major clinical areas:

- treatments for age-related injury and degeneration of joints, the spine and teeth
- surgical and bioengineering solutions for age-related cardiovascular dysfunction.



Specifically, WELMEC will deliver:

Longer-lasting joint replacements for the hip, knee and spine: Approximately 15 per cent of the population is affected by osteoarthritis. We are seeking to transform therapy for these patients by developing early-stage treatments that delay the need for total joint replacement, and by finding ways to improve joint replacements so that they can last for 50 years. Patients with chronic back pain could also benefit from our research: by addressing the degeneration, pain and function in ageing spinal joints and discs, we aim to develop alternatives to current treatments (which can limit motion in the spine).

Novel regenerative biological scaffolds for degenerative joint tissues and cardiovascular surgery: Our approach provides scaffolds that have the same biomechanical and biological functions as living tissue. This approach offers enormous opportunities in orthopaedic and cardiovascular applications.



Advances in cell therapies using a patient's stem cells: The potential use of therapies based on stem cells offers exciting promise for the treatment of challenging clinical problems in musculoskeletal and cardiovascular repair and regeneration. We are addressing some of the significant scientific challenges in this area to enhance the potential of translating these therapies into patient benefit.

Advanced medical imaging to facilitate earlier diagnosis and intervention: It is essential to be able to understand the complex biotribology (the interaction of biological surfaces in motion) in joints affected by osteoarthritis, and to measure and non-invasively assess cartilage damage before treatment and during and after repair. We are advancing magnetic resonance imaging and digital pathology techniques to enable non-invasive assessment of function and morphology in the clinic.

Novel protein biosensors for disease diagnosis and improved patient targeting: To monitor all the biological molecules that are associated with a disease – the diagnostic biomarkers – we need to be able to measure the presence of, and variation in, hundreds of proteins at the same time. The ability to do this will enable us to, for example, monitor a patient's response to implants and biological and biomimetic scaffolds.

To achieve these goals, we are bringing together more than 200 engineering, physical science, life science and medical researchers with clinicians and industrialists to develop and deliver innovative therapies and patient services.



Principal investigator

Professor John Fisher, Director of the Institute of Medical and Biological Engineering at Leeds, is one of the world's leading researchers in the tribology of artificial joints. A Fellow of the Royal Academy of Engineering, John leads collaborative projects worth over £50 million, developing medical engineering solutions to improve the quality of life of an ageing population.

The team

Giles Davies
Josephine Dixon-Hardy
Paul Emery
Richard Hall
Shervanthi Homer-Vanniasinkam
Eileen Ingham
Zhongmin Jin
Jennifer Kirkham
Dennis McGonagle
Stephen Smye
Ruth Wilcox

Centre focus

Much of the 20th century was devoted to developing treatments that are broadly effective in most people. However, the management of chronic disease or the treatment of cancer, for example, can be made much more effective if the patient's response is quantified and used to optimise therapy. We are developing ways to measure precisely an individual's response to their condition or treatment, so that healthcare can be tuned to their own characteristics. The use of personalised monitoring and treatment, from birth to old age, will lessen the effects of growth restriction in the womb, enable people with chronic diseases to live healthier lives, and improve survival rates for liver cancer.



UNIVERSITY OF
OXFORD

Medical engineering for personalised healthcare

Centre of Excellence in Personalised Healthcare, Institute of Biomedical Engineering, Department of Engineering Science, University of Oxford



The programme

Personalised fetal and neonatal monitoring using functional imaging:

Why do some small babies thrive when they are born and others do not? To find out, we are studying intrauterine growth-restricted babies in the womb and then during the first year of life. We use ultrasound imaging and MRI to assess the function of the brain and liver, so that we can correlate organ growth in the womb with their function after birth. This should provide the evidence base for the development of personalised, neonatal feeding strategies, which are optimised for each baby according to their rate of development in the womb.

Personalised vital-sign monitoring in the

home: A key objective of 21st-century medicine is to deliver healthcare closer to the patient's home. This can be achieved by improved self-management and self-care for people with chronic diseases, and by discharging patients from hospital early. For patients who have had cancer surgery, we are developing personalised models of their vital signs while they are in hospital; we can then monitor their vital signs when they are at home using wireless sensors.

Targeting drug delivery for cancer: For most patients with liver cancer, chemotherapy is the preferred treatment option. But as well as causing significant side-effects, the treatment is generally not tailored to the patient and response is thus typically poor. We are designing an ultrasound-based system that will allow us simultaneously to activate drugs at particular sites within the body, monitor the patient-specific tumour response

to the drug and vary the dosage 'on demand'. The ability to map, in real time, where the drug has been successfully activated will also remove uncertainties associated with patient-to-patient variations in tumour vasculature and uptake. This will ensure that the drug is delivered to the right location at the right dosage for each patient.

Treatment of cerebrovascular disease: Treating ischaemic stroke patients can cause brain haemorrhages, so we are constructing patient-specific models of stroke to predict the extent of the damage both with and without treatment. Similarly, a new generation of deployable stents is being designed to match the characteristics of an individual's aneurysm. We are using a combination of 3D imaging and numerical analysis to model the interaction between stent, blood flow and the thrombogenic potential of a stent implanted at a specific vascular segment.



Principal investigator

Professor Lionel Tarassenko holds the Chair in Electrical Engineering at Oxford and is Director of the Oxford Institute of Biomedical Engineering. His work on healthcare has been recognised by awards such as an E-health Innovation Award in 2005 and the 2006 Silver Medal of the Royal Academy of Engineering. He is the founder-director of three University spin-out companies. He is also a member of the Department of Health's Management Committee for Invention for Innovation (i4i) and of the Wellcome Trust's Technology Transfer Strategy Panel.

The team

Tipu Aziz
James Byrne
Constantin Coussios
Alexandra Czapiewska
Peter Dobson
Andrew Farmer
Vicente Grau
Tom Leslie
Alison Noble
Aris Papageorghiou
Stephen Payne
Penny Probert Smith
Heiko Schiffter
Julia Schnabel
Len Seymour
Peter Sullivan
Yiannis Ventikos
Zhong You

Imperial College London

Centre focus

Our Centre aims to use emerging technologies to revolutionise the management of osteoarthritis. The focus is on the disease, its early detection and monitoring, as well as on interventions for prevention and treatment, and the rehabilitation of patients after intervention. Research at the Centre is interdisciplinary and operates from the molecular to the whole-body level, and includes *in vitro*, *in vivo* and *in silico* approaches. We have a strong emphasis on producing techniques and products that will be developed by industry, and made available to improve the lives of patients.

The programme

Osteoarthritis affects millions of people and is the most common cause of chronic pain in the UK today, with huge social and economic costs. This problem will grow as the population ages. Ultimately, through our work, we want to increase the quality of life of individuals with the disease and so reduce the burden on society. We do this by bringing together engineers, surgeons, rehabilitation therapists and scientists of various disciplines to make advances in three theme areas:

Early detection and monitoring of

osteoarthritis: Sensor systems and lab-on-a-chip technologies based on nucleic acids will enable early detection of mechanical joint dysfunction and of molecular markers of joint damage. This will lead to earlier diagnosis and exciting opportunities to slow or halt the progression of this debilitating disease. We also plan to develop devices for high-throughput mechanical stimulation of cells and preconditioning of novel biomaterials such as bone–cartilage constructs, and rapid-throughput screening of changes in cartilage morphology in animal models of osteoarthritis.

**Medical engineering
solutions in osteoarthritis**
Medical Engineering Solutions
in Osteoarthritis Centre of
Excellence, Imperial College
London



Intervention: Novel materials, designs and *in situ* sensing, together with less invasive and more accurate surgery, will reduce costs and improve clinical outcomes, and will enable next-generation monitoring of joint function. A better understanding of joint biomechanics and quality control using robotic devices to help deliver a high level of surgical precision will reduce the intraoperative risks and the theatre inventory costs. One objective is to develop a flexible, microvision-equipped robotic instrument to deliver probes for sensing, imaging, surgery and therapy, while another is to engineer implantable, nanostructured material scaffolds and cells, which are minimally invasive, for the regeneration of damaged tissue.

Rehabilitation and prevention: Improved rehabilitation strategies, driven in part by technological advances (such as detailed assessment and remote measurement of function using wireless sensing), will delay joint deterioration and speed post-operative recovery.



Principal investigator

Ross Ethier is Head of the Department of Bioengineering at Imperial College London. Previously he was Director of the Institute of Biomaterials and Biomedical Engineering at the University of Toronto. He received his PhD from the Massachusetts Institute of Technology in 1986 and his research looks at the biomechanics of cells and whole organs.

The team

Andrew Amis
Anthony Bull
Tony Cass
Justin Cobb
Rob Fenton
Steven Heggie
Alison McGregor
Jeremy Saklatvala
Molly Stevens
Chris Toumazou
Guang-Zhong Yang



The Wellcome Trust promotes interdisciplinary research and has recently funded a number of programmes bringing together engineers, physicists and clinicians to drive forward training, research and product development in medical engineering, including:

Strategic Translation Award (£2.1m, 2007)

Professor Guang-Zhong Yang and Professor Ara Darzi (Imperial College London)

To develop an Imaging-Sensing Navigated And Kinematically Enhanced (i-Snake) surgical robot for minimally invasive surgery. It is equipped with multiple sensing-enabled flexible joints that permit full forward control and tactile feedback to the operator for following curved anatomical pathways, which is essential for performing complex procedures. The robot will enable the performance of a range of procedures that are not possible with current technology and ensure the greater success of future clinical robotic systems used for keyhole surgery.

in a human clinical trial. Meniscal cartilage fails to heal naturally in around 95 per cent of cases, and standard clinical practice has been simply to remove the damaged part of the tissue. To protect the knee and preserve its long-term functionality, an absorbable implant is required to take over the function of the damaged tissue in the short term while allowing the meniscal cartilage to heal properly in the long term.

Additionally, the Wellcome Trust supports training and development for researchers in interdisciplinary fields:

Wellcome Trust-MIT Postdoctoral Fellowships

For recently qualified postdoctoral researchers to gain experience in research at the interface of biology/medicine and mathematics, engineering, or computer, physical or chemical sciences. Fellows will tackle important biomedical research questions using an interdisciplinary approach in the best laboratories.



Translation Award (€800 000, 2007)

Dr Liam Marnane, Dr Geraldine Boylan and Dr Gordon Lightbody (University College Cork) and Dr Janet Rennie (University College London Hospitals)

To develop a signal processing system, based on EEG and ECG, that will help medical staff to identify all seizures in newborn babies without the need for complicated equipment or an expert to interpret the results. Failure to detect seizures and the resulting lack of treatment can result in brain damage and, in severe cases, death. The work will assess how well the system works in clinical practice, and adjust the design to make it baby-friendly, easy to use and acceptable to parents.

Translation Award (£1.6m, 2009)

Dr Nick Skaer (Orthox)

To design, develop and evaluate a new material based on silk protein, Spidrex®, as a meniscal cartilage implant and demonstrate its efficacy

International Genetically Engineered Machine (iGEM) competition student stipends

To support the participation of UK teams in the iGEM competition. The aim of the stipends is to provide promising undergraduates with hands-on experience of synthetic biology during their summer vacation and to encourage them to consider a career in interdisciplinary research.

EPSRC

EPSRC supports a strong research portfolio in medical engineering from tissue engineering, through drug formulation and delivery and medical instrumentation, to biomechanics and rehabilitation. It also supports healthcare-related research across its other programmes, including Digital Economy, Towards Next Generation Healthcare and ICT; this is often interdisciplinary and collaborative in nature. Researchers often work alongside clinicians, who may be users of the devices being developed, and with industry, who can provide a route for exploitation. Some examples of recent activities are shown below.

Centre for Innovative Manufacturing in Regenerative Medicine (£5.3m, 2010)

Principal Investigator: Professor D J Williams, Loughborough University

The regenerative medicine centre (therapies to enable damaged, diseased or defective tissues to work normally again) at Loughborough

with the business skills needed to turn pioneering ideas into products and services, thereby boosting their impact on the UK's economy. The centre at the University of Oxford will develop the next generation of biomedical engineering researchers, whose research will span a range of technical areas, from hardware devices to software systems, artificial organs, biomaterials and drug delivery.

Healthcare Partnerships (£5.5m, 2010)

EPSRC piloted a new Healthcare Partnerships initiative in 2009 to establish a joint funding stream for high-quality engineering and physical science research within academe that provides a potential route for exploitation within the UK healthcare arena. Seven collaborative research proposals, all of which included a non-academic partner (small charity or an SME), were announced in March 2010, addressing a range of important healthcare issues.



University is one of three new state-of-the-art manufacturing research centres funded under a £70 million government investment in 2009, bringing researchers and industry together to create technology products of the future, attracting investment and underpinning manufacturing growth. Funded over five years, this centre includes 28 industrial and government partners who will contribute a further £3 million. The partner universities are Nottingham and Keele.

Centre for Doctoral Training in Healthcare Innovation (£7.1m, 2008)

Director: Professor Alison Noble, University of Oxford

A total of 17 new Doctoral Training Centres were announced in 2008, providing a bold new approach by EPSRC to training PhD students by creating communities of researchers working on current and future challenges. These industrial training centres are intended to equip students

KT-EQUAL (£1.9m, 2009)

Principal Investigator: Professor Gail Mountain, University of Sheffield

The KT-EQUAL consortium aims to actively draw the attention of industry and others to the needs of an ageing population and to build on the outcomes from earlier programmes (EQUAL and SPARC) by offering significant potential benefits for society and investment opportunities for industry. This will be achieved in part through events to raise awareness and promote a high profile in the media. Working with stakeholders (manufacturers, technologists, designers and those responsible for delivering public services), the consortium will encourage researchers to publicise their work in ways that will be understood by a wide audience. Co-Investigators are based in the Universities of Bath, Cambridge, Loughborough, Reading and Salford, and Edinburgh College of Art.





The Wellcome Trust

We are a global charity dedicated to achieving extraordinary improvements in human and animal health.

We support the brightest minds in biomedical research and the medical humanities. Our breadth of support includes public engagement, education and the application of research to improve health.

We are independent of both political and commercial interests.

www.wellcome.ac.uk/medicalengineering

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Technology Transfer
Wellcome Trust
Gibbs Building
215 Euston Road
London NW1 2BE, UK

T +44 (0)20 7611 8202
F +44 (0)20 7611 8857
E techtransfer@wellcome.ac.uk

EPSRC

The Engineering and Physical Sciences Research Council (EPSRC) is the UK's main agency for funding research in engineering and the physical sciences. The EPSRC invests more than £800 million a year in research and postgraduate training to help the nation handle the next generation of technological change.

www.epsrc.ac.uk

The Engineering and Physical
Sciences Research Council
Polaris House
North Star Avenue
Swindon SN2 1ET

T 01793 444100
F 01793 444005
E infoline@epsrc.ac.uk



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“In my mind it seems to make sense that if the entire human body were created mechanically, it would be an elaborate series of pipes, valves and pistons.”

Bill McConkey, creator of the mechanical heart artwork.

