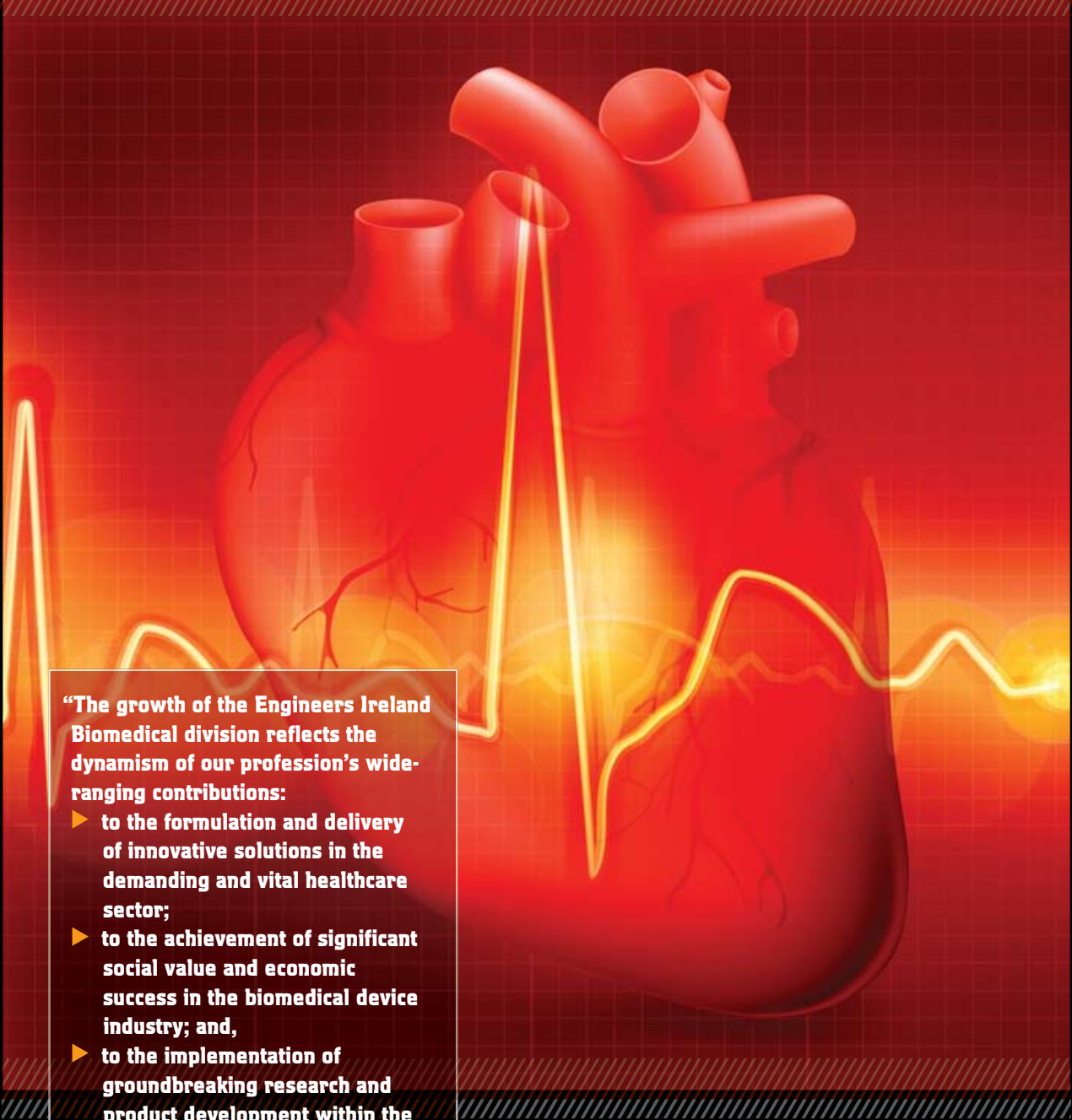




“The growth of the Engineers Ireland Biomedical division reflects the dynamism of our profession’s wide-ranging contributions:

- ▶ **to the formulation and delivery of innovative solutions in the demanding and vital healthcare sector;**
- ▶ **to the achievement of significant social value and economic success in the biomedical device industry; and,**
- ▶ **to the implementation of groundbreaking research and product development within the life sciences.**

This report aims to give recognition to what has been accomplished, as well as indicating some of the directions that biomedical engineering will take in the future.”

**John Power Chartered Engineer,
Director General,
Engineers Ireland.**

Engineers Ireland Biomedical division Special Report

Biomedical engineering set on continued growth path

Bernard Murphy, Chair of the Engineers Ireland Biomedical division, introduces this special report

I have the honour and privilege this year to be chairman of the Engineers Ireland Biomedical division. Many people, too numerous to mention, have put much effort and personal commitment into building up the division and biomedical engineering in this country. This special report in *The Engineers Journal* would not be possible without their efforts and it is an acknowledgement of their work and another step in the development of biomedical engineering in the country. It reflects the growing importance of the discipline and its contribution, not only to the engineering community, but to the economy as a whole. Over the next number of pages you will hopefully gain a better understanding and insight into biomedical engineering as it exists today in Ireland. The amount of information that can be provided in these pages is, of course, limited but we would encourage you to use it as a starting point to further develop your interest in, and knowledge of, this fascinating and expanding field of engineering. It is, without doubt, a growing field and provides a basis for a knowledge economy that has the potential to provide a substantial number of high-end jobs.

What is biomedical engineering?

Biomedical engineering is the application of engineering principles, design concepts and materials technology to the application of practical solutions in medicine and biology. This area of engineering bridges the gap between engineering and medicine. It combines the design and problem-solving skills of engineering with medical and biological sciences for the purpose of improving diagnosis, prevention, monitoring,

and/or treatment of healthcare issues. Compared with many other engineering disciplines biomedical engineering has only recently emerged as its own field. Such a development is not uncommon as a new engineering field transitions from being a mix of already-established engineering disciplines, where traditional boundaries are blurred, to being considered a specialised field in itself.

Many biomedical engineers who graduated in less recent times have engineering qualifications in electrical, computer, mechanical, software, instrumentation, or electronic engineering, to mention just some of the diverse backgrounds.

Biomedical engineers are employed by healthcare providers and support services, medical or device equipment manufacturers, and research departments in third level institutions. Job titles vary depending on the exact nature of the work; they include rehabilitation engineers, clinical engineers and medical informatics engineers.

The work can include researching, designing and developing medical products, such as joint replacements, prosthetic devices, artificial organs, robotic surgical instruments and stents; or medical equipment such as ventilators, anaesthetic machines, infusion devices, diagnostic imaging, and patient monitors; or designing and modifying equipment for clients with special needs in a rehabilitation setting; or managing the use of clinical equipment in hospitals and in the community, working as part of a multidisciplinary healthcare professional team, in the identification, acquisition, and support of medical technology to provide, deliver and advance patient care.

Biomedical division Executive 2011/2012



Chair:

Bernard Murphy Chartered Engineer, graduated with a degree in electronic engineering and spent many years in the electronics industry before a career change to the biomedical sector. He currently works in a clinical engineering capacity in the health sector. After his career change, he continued his education and completed an MSc in Clinical Engineering and a Higher Diploma in HealthCare Management. He joined the Biomedical division in 2007 and has since held the positions of Secretary and Vice-Chair, and serves on the council of Engineers Ireland.



Vice-Chair:

Ger Reilly, MIEI, is head of department in metal fabrication and welding at Dublin Institute of Technology. He has been involved in research and development in bioengineering and biomedical device design for over 15 years. His personal research interest is in bone surgery and detection of micro damage in bone. He previously worked at Institute of Technology, Sligo and was part of the Bioengineering Research group leading a number of large research projects in that area.



Honorary Secretary:

Jonathan Kidd, BSc (Eng.) M Eng, MIEI, is a graduate of the University of Dublin, Trinity College and Dublin Institute of Technology. Jonathan is currently with Enable Ireland SeatTech and previously worked in clinical engineering roles in the acute hospital sector. Previously, Jonathan also worked in several technology sectors, namely robotics/automation, telecommunications software development, and compliance engineering. He joined the Biomedical division in 2009.



Treasurer:

Professor Fergal J. O'Brien

Chartered Engineer, BA, BAI, PhD, MIEI, Department of Anatomy, Royal College of Surgeons in Ireland and Centre for Bioengineering Trinity College Dublin, currently heads one of the largest tissue engineering research groups in Europe (over 30 researchers). He is a graduate in mechanical engineering and his PhD research was in the area of bone mechanobiology (both from Trinity College Dublin).

He subsequently carried out postdoctoral research in orthopaedic tissue engineering at Massachusetts Institute of Technology, in collaboration with Harvard Medical School, before his appointment, in 2003, as a lecturer in anatomy in RCSI.

He was promoted to senior lecturer (2006) and Associate Professor (2007). He currently holds an adjunct professorial appointment in bioengineering in TCD and is a principal investigator (PI) in the Trinity Centre for Bioengineering. He is currently editorial consultant of *Journal of Biomechanics* and subject editor (Tissue Engineering) for the *Journal of the Mechanical Behavior of Biomedical Materials*.

John Mahady is a Chartered Engineer and three of his four sons are also engineers. John has worked in clinical engineering for the past 30 years and his current post is based at Tallaght Hospital. John has presented and published on a wide range of clinical engineering areas, ranging from key performance indicators to WiFi. John has been a member of Engineers Ireland's Membership and Qualification Board, Council, CPD Committee and is a past Secretary and Chair of the Biomedical Engineering division. John is a member of the UK, IPEM, CESIG Group.

John Tiernan Chartered Engineer is senior clinical engineer with SeatTech, Enable Ireland. John's introduction to the field of posture and mobility came as a student engineer working for the OT department in the Royal Hospital Donnybrook in 1998. This experience led John

to undertake a Research MSc, the subject of which was wheelchair design. Since completing his Masters in 2001, John has worked as clinical engineer for Enable Ireland, taking time out in 2005/06 to work in Australia for NovitaTech and the RBWH Brisbane Rehabilitation Engineering Centre.

John Mc Givney MIEI is a clinical engineer working in the National Directorate of Estates, HSE. He has over 20 years' experience in the field of clinical engineering. John has a Masters in Healthcare Informatics from Trinity College Dublin.

He was a founding member of the Biomedical division in 1998 and has served as Chair, Vice-Chair and Secretary in the past. John has also served on both the Council and the Executive Council of Engineers Ireland.

Orla Keane MIEI joined the Irish Medicines Board in 2006 and is product manager for Class I/IIa medical devices in the human products monitoring department. She is a member of the committee of the Biomedical division. Orla is also a member of ETCI TC10 and is the IMB delegate to the European Commission Compliance and Enforcement Working Group (COEN). Prior to joining the IMB, Orla worked in an operations team lead role at an orthopaedic implant manufacturing site.

Orla is a graduate of University College Dublin (BE Electronic Engineering) and subsequently completed the M.Sc. in Bioengineering at Trinity College Dublin.

Dr Ciaran Simms, MIEI, FTCD, is a lecturer in the Department of Mechanical and Manufacturing Engineering, and a PI in the Trinity Centre for Bioengineering.

His research interests are in impact biomechanics with a focus on soft tissue modelling and vulnerable road user safety, and in medical device design. Prior to his appointment at TCD, he worked in industry with Denis Wood Associates in forensic engineering in Dublin and with TNO in automotive safety engineering in the Netherlands and the United States.

Suzanne O'Rourke, BA, BAI., PhD, MIEI, is a graduate of the University of Dublin, Trinity College and University of Limerick. Suzanne is a quality manager in Boston Scientific Clonmel, supporting the tachycardia product business.

Fionn Lahart, MIEI, BEng, MSc is a graduate of DIT and Trinity College Dublin. Fionn is a project manager in AltaScience with extensive experience in design engineering.

Mary Sharp Chartered Engineer, FIEI, is a lecturer in the School of Computer Science and Statistics, Trinity College Dublin. In addition to being a member of the committee of the Biomedical division she is Chair of the Ethics and Disciplinary Board and also a member of the Board of Examiners of Engineers Ireland.

Her research interests include: security, standards, ethics and eLearning.

She is a member of the Advisory Committee for Medical Devices of the Irish Medicines Board. She is a member of CEN TC251 WGIII Safety, Security and Quality, representing the National Standards Authority of Ireland (NSAI). She is the Irish delegate to IMIA (International Medical Informatics Association).

Declan Gibbons, MIEI, B.E., M.Sc.(Med), Dip.P.M., Dip.C.E., MIEI is a graduate of University College, Dublin and post-graduate of the University of Dublin, Trinity College with concurrent training at University of Wisconsin Milwaukee, Marquette University and cooperative research with Dartmouth College, New Hampshire and Richards Orthopaedics. His postgraduate biomedical engineering studies were a comparison of all-polyethylene and metal-backed unicompartmental knee prosthesis.

Dr John Gleeson BA, BAI, PhD, is a Trinity Engineering graduate and currently a PI within the RCSI Tissue Engineering Research Group (TERG). John is lead investigator with the Cartilage Advanced Regenerative Therapies (CART) section of the TERG, whose research focuses on bone and cartilage mechanobiology and degenerative joint disease damage and repair strategies. John is also project and business development manager for the TERG with responsibility for the commercialisation of the suite of common platform technologies developed within the TERG.

Michael Walsh

Dr Michael Walsh, MIEI, is an experienced biomedical engineer and an expert in biofluid mechanics. At the University of Limerick, Dr Walsh is course director of biomedical engineering, a member of the faculty of the Department of Mechanical, Aeronautical and Biomedical Engineering and the Materials and Surface Science Institute and is a founding member of the Centre for Applied Biomedical Engineering Research. He is well published in both the medical and engineering fields having co-authored over 30 peer-reviewed journal papers. He currently supervises 10 PhD students and is a past Chair of the Biomedical Engineering division.

The story so far – growth of the Biomedical Engineering division

In 1998, some members of the Electrical and Electronic division of Engineers Ireland were working in the biomedical engineering field and recognised that this sector required its own voice

Following much discussion and debate the biomedical engineering sector of the Electrical and Electronic division was formed. The first meeting took place on July 1, 1998 in Clyde Road. The first Chair was Meabh Smith, Vice Chair was Alan Rochford and the Secretary was John McGivney. Other members of the committee were Eugene Coyle and Andrea Hanson. The first meeting was also attended by John McEvoy, Secretary of the Electrical and Electronic division.

From these beginnings, through much hard work, foresight and vision, and by building an understanding of the biomedical industry within Engineers Ireland, this sector made a smooth transition to division. In February 2002, the sector officially became the Biomedical Engineering division (BED). Meabh Smith was the first elected chair of the division. The names of the chairs, vice chairs, honorary secretary and treasurer are listed in Table 1. There have been many more personnel from various backgrounds involved over the years. Since those early days, the division has continued to grow implementing a number of initiatives including the Biomedical Engineering division Research Medal.

Research Medal

The Biomedical Engineering division medal was inaugurated in 2003 to acknowledge high-level research in Biomedical Engineering. The medal was launched in October 2002 with the first winner presented with their prize in March 2003. This is an annual award consisting of the medal and an honorarium. It has proved very successful and has helped to increased research awareness among biomedical researchers and to encourage undergraduates to consider postgraduate work in biomedical engineering. This award is given to PhD students who have made a significant contribution to the field of biomedical engineering research, as evidenced by the submission of a research paper and delivery of a presentation to a panel of expert judges.

The award is an annual event in the Biomedical Engineering division calendar. The winner is presented with the Biomedical Engineering division Gold Medal and a €1000 honorarium. There have been a number of sponsors involved since the start. Medtronic AVE sponsored the honorarium for the years 2003 to 2006, Georgia Tech Ireland were the sponsors for the years 2007 to 2010 and Depuy sponsored the 2011 award.

In 2009, the Biomedical Engineering division took the decision to combine this event with the Bioengineering in Ireland Annual

Conference that is run under a section of the Royal Academy of Medicine in Ireland (RAMI). This has proved to be a very successful move, giving more exposure of Engineers Ireland to academia and raising the profile of biomedical engineering within Engineers Ireland.

Today, the Biomedical Engineering division represents biomedical engineers from all over Ireland. The membership is made up of the following main groups:

1. Industry biomedical engineers

Biomedical Engineers design, develop, use and manage devices and instrumentation for patient monitoring, diagnosis, treatment or research. The medical devices industry accounts for approximately eight per cent of GNP. It is estimated that 2,000 biomedical engineers are employed in this sector in Ireland. The sub-sectors of the medical device industry in Ireland are: medical equipment; disposable and support products; interventional products; orthopaedics and implants; and, vision, dental and hearing products.

2. Hospital-based clinical engineers

These are biomedical engineers based in the clinical environment, usually a hospital or rehabilitation unit. They may be responsible for the design, management and quality assurance of patient-connected equipment in hospitals. They provide operational and technical support to users of clinical equipment. In rehabilitation, they provide bio-mechanical assessment, monitoring of patient recovery and the custom manufacture of aids for individual patients.

3. Medical device supplier-based clinical engineers

These provide a service to healthcare providers in the areas of equipment management and quality assurance.

4. Academia-based biomedical and clinical engineers

A large body of biomedical engineers are based in various third level institutions in Ireland, these drive and support the medical device industry.

5. Clinical Engineers working in the field of assistive technologies

Broadly speaking, assistive technologies can be broken into two major categories: (i) mobility and postural management assistive technologies and (ii) electronic assistive technologies. Increasing numbers of engineers are specialising in these areas.

Biomedical Engineering division Research Medal Winners:

2011

Enda Dowling, National University of Ireland, Galway.

Influence of Actin Cytoskeletal Remodelling on the Shear Resistance of Single Chondrocytes: A Computational and Experimental Investigation
(See feature on page 354)

2010

Kevin Moerman, Trinity College Dublin.

Towards the non-invasive determination of the mechanical properties of living human soft tissue

2009

Niamh Plunkett, Trinity Centre for Bioengineering, Trinity College Dublin.

Development and bioreactor culture of collagen-hydroxyapatite scaffolds for bone tissue engineering

2008

David Hoey, MIEI, Trinity College Dublin.

The role of stress concentrations in the fatigue strength of a porous bone cement mantle

2007

Niamh Nowlan, Trinity College Dublin.

Mechanics in embryonic bone development

2006

Nicolle Wilke, Tyndall National Institute.

Micro-Machined Silicon and Polymer Microneedle Arrays For Cancer Therapy and Drug Delivery

2005

Niall MacCarthy, Tyndall Institute, University College Cork.
A Laser Release Method for Producing Prototype Flexible Retinal Implant Devices

2004

Simon P. Kelly, National University of Ireland, Dublin.

EEG-Based Brain Computer Interface Control In An Immersive 3-D Gaming Environment

2003

Adriele Prina-Mello, Trinity College Dublin.

Single Cell Experimental Analysis As A Useful Tool To Investigate Cell Population Behaviour During Leukocyte Inflammatory Response

Table 1. Biomedical Engineering division 1998-2011.

YEAR	CHAIRMAN	VICE CHAIRMAN	HONORARY SECRETARY	TREASURER
1998	Meabh Smith	Alan Rochford	John McGivney	John McGivney
1999	Meabh Smith	Eugene Coyle	John McGivney	John McGivney
2000	Meabh Smith	Eugene Coyle	John McGivney	John McGivney
2001	Meabh Smith	Eugene Coyle	John McGivney	John McGivney
2002	Meabh Smith	Eugene Coyle	John McGivney	Andrea Hanson
2003	John McGivney	Richard Reilly	John Mahady	John Mahady
2004	John McGivney	Richard Reilly	John Mahady	John Mahady
2005	Richard Reilly	Barry Dolan	John Mahady	John Mahady
2006	Barry Dolan	John Mahady	Triona Lally	Richard Reilly
2007	John Mahady	Brendan O'Maolagáin	Bernard Murphy	Richard Reilly
2008	Brendan O'Maolagáin	Michael Walsh	Bernard Murphy	Patrick Pentony
2009	Michael Walsh	John Tiernan	Bernard Murphy	
2010	John Tiernan	Bernard Murphy	Ger Reilly	Fergal O' Brien
2011	Bernard Murphy	Ger Reilly	Jonathan Kidd	Fergal O' Brien

BioInnovate Ireland recruits for fellowship programme

BioInnovate Ireland is now seeking Expressions of Interest for its medical device innovation Fellowship Programme. This programme is modelled on the biodesign programme offered at Stanford University, California.

The recruitment of eight Fellows to work in two elite multidisciplinary teams is now underway. These two teams will focus on a specific clinical area, identifying unmet needs, inventing solutions to meet those needs and implementing the solutions, and mapping a route to commercialisation to enable these solutions to enhance patient care. The Fellowship Programme is full-time, stipend-supported and the next programme will commence on August 1, 2012. There are also two BioInnovate classes open to postgraduate students of the BioInnovate Academic Partners, which include NUI Galway, University of Limerick, Dublin City University, Royal College of Surgeons Ireland and University College Cork.

The BioInnovate class will be mentored by, and work with, the Fellows on the newly identified clinical needs.

Marie Travers, a current Galway BioInnovate Fellow, said: "I feel very privileged to have been able to access experts, patients and clinicians as part of the research. I see great potential for identifying innovations for patient care. "Eligible applicants should have a background in medicine, engineering, technology or business. Applicants with a postgraduate degree or relevant professional experience are particularly welcome. Medical and surgical registrars or specialist registrars with an interest in innovation and improving patient care through technological advancements are also encouraged to apply for the Fellowship. Candidates will be assessed for leadership potential, interest in technology innovation, demonstrated potential for creativity and invention, and ability to work in a team.

For further details, contact Clodagh Barry, BioInnovate programme manager at NUI Galway, on 091 494 212 or clodagh.barry@nuigalway.ie

Response to industry needs transforms biomedical education

Orla Keane, Mary Sharp and Ger Reilly offer a guide to the development of biomedical engineering education at third level and beyond

There is no doubt that among the most important factors shaping biomedical engineering education are the needs of the healthcare and biomedical industry sectors, as well as associated employment trends. The most recent report of the Expert Group on Future Skills Needs (EGFSN) (Condon and McNaboe 2011), indicates that there is an engineering skills shortage in the medical device sector, and that employment in the sector remains strong. Meeting this demand is vital in the short and medium term and the reaction of educational institutions to immediate educational requirements is crucial.

John Lawlor, head of the School of Manufacturing & Design Engineering at DIT recently indicated that he believes the need to respond rapidly to skills shortages and to support government strategies for sector development is crucial to Ireland's future. His school has developed a B.Sc. in Biomedical Device Innovation that is being offered free to applicants on the recent Government-supported Springboard programme to re-educate unemployed professionals.

Convergence of expertise

In the future, biomedical and clinical engineers will work with wide-ranging engineering technology and will need scientific fundamentals across a range of areas, including design, mechanical equipment, biomechanical implants, electronic patient monitoring, cell and implanted medical device interaction.

This impacts directly on the demand for graduates at all levels and the aforementioned EGFSN report indicates that engineering graduates with 'cross-cutting' science skills are much sought after in this sector.

B.Eng. and B.Sc. programmes at Level 8 in biomedical engineering such as those at CIT, DCU, DIT, NUIG, UCD and UL, all include aspects of biology, anatomy, physiology and biomechanics as key components in module content. International research has shown this crossover between science, biology and engineering is highly effective in the education of biomedical engineers (Matsuki, Takeda *et al* 2009; Matsuki, Takeda *et al* 2010).

An emerging feature at third level that affects the instructional content of programmes is the trend to educate biomedical engineers as a distinct engineering profession. This trend has increased in recent years and has meant that there is greater scope for educational institutions to design their courses to impact on the needs of industry and the profession. Ten years ago there would have been relatively few level 7 or level 8 honours degree programmes,

specifically in biomedical engineering, but, in the interim, this sector has grown. Historically, biomedical engineering modules would have been offered as additions or options in later years of degree programmes but now students learn in an integrated fashion right from year one in their study, about the interplay between the body and biology and technology and engineering. This integrated biological component of the curricula is one of the key ways in which the education of biomedical engineers is distinct from that of the traditional engineering professions.

For many years Irish academics have worked hard to develop a strong research base in biomedical engineering. Academic research groups have developed strong links with industry and good research-informed content in teaching aligned to industry requirements is in evidence in undergraduate courses. One example of this is the close connection of the B.Eng. Programme in Biomedical Engineering at CIT with the needs of local medical device companies such as Stryker around clinical engineering and surgical cutting devices. An additional benefit of the research is that students taking programmes in biomedical engineering can look forward to studying with lecturers and working in laboratories that are at the cutting edge of technology and innovation. Professor Tim McLoughlin, director of CABER, and Dr Michael Walsh, manager of CABER and course leader of the B.Eng in Biomedical Engineering at UL, believe that a strong research/teaching linkage is of critical importance in helping undergraduates obtain knowledge and skills that increase their employability and enhance the levels of innovation and productivity in Irish medical device companies.

Undergraduate study programmes

For this article, we conducted some study by web search and telephone on the range and geographical spread of undergraduate and postgraduate courses offered by universities and institutes of technology around the country. The table on page 349 provides a summary of our findings. This is not an exhaustive list, although we did not intentionally omit any course from our enquiries.

It would not be possible to describe in comprehensive detail the complete content of these courses and so readers are referred to the course links in the table for further information on programmes mentioned. Additionally, we have not commented here on the huge number of biomedical research programmes in place in almost every institute of technology and university in Ireland through which one

can gain a postgraduate award by research.

Undergraduate courses fall into a number of categories.

1. Level 7 (B. Eng)

CIT offer a level 7 programme in B. Eng. Biomedical Engineering with a Higher Certificate exit award after two years for students not progressing to year three of the programme. This course provides students with a good grounding in the biological and engineering aspects of biomedical engineering as well as biomaterials, biofluids, and biomechanics. Graduates typically find employment in medical device manufacturing, design, quality control and clean room technology.

2. Level 8 *ab initio* (B. Eng. Honours)

UCD, NUIG, DCU, and UL all offer *ab initio* B. Eng. Honours Degrees in Biomedical Engineering. In general these programmes cover some of the key disciplines of biomedical engineering such as: biomaterials, bioengineering, bioMEMS, bioinformatics, design, biosignalling, biotechnology, clinical

engineering, image processing, instrumentation, biosensing, microtechnology, nanotechnology, robotic surgery, neural systems and rehabilitation. DCU has a six-month INTRA placement programme in year three and places emphasis on rehabilitation, computer vision and modelling in the final year of its degree programme. UCD places importance on biomaterials and nanomaterials, as well as cell and tissue engineering and rehabilitation in year four and has linkages for international study in China and Australia. UL also has a placement programme in year three and focuses on biomaterials, computational analysis and medical device design in the fourth year of its degree. It also arranges hospital and industrial visits for its students. First year applicants to NUIG in 2011/2012 will study in a new state-of-the-art biomedical engineering building reported on in *The Engineers Journal*, Volume 65: Issue 4, July/August, 2011. Its programme focuses on medical device design and manufacture, as well as fluid and finite element analysis.

COURSE TITLE	INSTITUTE/UNIVERSITY	LEVEL	INTERESTING FEATURES AND OBJECTIVES OF COURSE	CONTACT INFORMATION	COURSE WEB LINK
B. Eng. Biomedical Engineering	Cork Institute of Technology	8	Focus on clinical engineering with a work placement	Dr Keith Bryan, keith.bryan@cit.ie	www.cit.ie/course/CR%20520
B. Eng. (Hons) Biomedical Engineering	Cork Institute of Technology	7	Focus on clinical engineering, biomedical devices and equipment	Daithi Fallon, daithi.fallon@cit.ie	www.cit.ie/course/CR%20075
B. Eng. (Hons) Biomedical Engineering	Dublin City University	8	Six-month INTRA placement with optional fifth year to progress to M. Eng	Suzanne Dockery, suzanne.dockery@dcu.ie	www.dcu.ie/prospective/deginfo.php?classname=BMED
B. Eng. (Hons) Biomedical Engineering	National University of Ireland, Galway	8	Module options include medical device design and a new biomedical engineering building has been opened at NUIG	mechbio.eng@nuigalway.ie	www.nuigalway.ie/mechbio/syllabus/syllabus.php? prog=Biomedical
B. Eng. (Hons) Biomedical Engineering	University College Dublin	8	Mechanical and electronic/electrical engineering focus, specialised final year modules available including neural and rehabilitation engineering	eng.arch@ucd.ie	https://myucd.ucd.ie/program.do?programID=97
B. Eng. (Hons) Biomedical Engineering	University of Limerick	8	Eight-month co-op placement, hospital visits in final year, modules in medical device design and biomaterials	Dr Michael Walsh, michael.walsh@ul.ie	www.ul.ie/courses/BiomedicalEngineering.shtml
B. Sc. in Health Informatics	University of Limerick	8	Medical imaging, database management, co-op placement	Annette McElligott, annette.mcelligott@ul.ie	www.ul.ie/courses/HealthInformatics.shtml
B. Sc. (Hons) in Medical Device Innovation	Dublin Institute of Technology	8	Focus on medical device design and manufacture and quality control, team/group project work, course available under Government Springboard initiative	Dr Graham Gavin, graham.gavin@dit.ie	www.dit.ie/study/undergraduate/programmes/medicaldeviceinnovationdt710/
M. Eng. Biomedical Engineering	Dublin City University	9	Biomedical engineering	Suzanne Dockery, suzanne.dockery@dcu.ie	www.dcu.ie/prospective/deginfo.php?classname=BMED
M. Sc. Biomedical Engineering	University of Limerick	9	Develop graduates with a thorough understanding of advanced principles in biomedical engineering, awareness of current and leading-edge topics in biomedical engineering	Professor Tim McLoughlin, tim.mcloughlin@ul.ie	www2.ul.ie/web/WWW/Faculties/Science_&_Engineering/Departments/Mechanical_&_Aeronautical_Engineering/Courses/Bio_Engineering
M. Sc. Biomedical Engineering	University College Dublin	9	Develop graduates with a thorough understanding of advanced principles in biomedical engineering awareness of current and leading-edge topics in biomedical engineering	Professor David FitzPatrick, david.fitzpatrick@ucd.ie	www2.ul.ie/web/WWW/Faculties/Science_&_Engineering/Departments/Mechanical_&_Aeronautical_Engineering/Courses/Bio_Engineering
M.Sc. Biomedical Sciences (Intercalated) for Medical Students	Trinity College Dublin	9	Molecular medicine, neuroscience and bioengineering	longai@tcd.ie	www.medicine.tcd.ie/clinical-medicine/postgraduate/intercalatedMSc/
M. Sc. in Health Informatics	Trinity College Dublin	9	The application of ICT in healthcare	Dr Lucy Hederman, lucy.hederman@scss.tcd.ie	www.scss.tcd.ie/postgraduate/mschi/
M. Sc. in Bioengineering	Trinity College Dublin	9	Provision of engineers and scientists with the education and creative skills needed to practice in the medical devices industry in Ireland	tcbe@tcd.ie	www.tcd.ie/bioengineering/education-outreach/
M. Sc. in Medical Device Design	National College of Art and Design	9	Design and innovation in medical device design with emphasis on product improvement and optimisation. In association with TCD	Paul Fortune, fortune@ncad.ie	www.ncad.ie/postgraduate/taught/postgrad_msc_meddevices.shtml
Structured PhD in Biomedical Engineering and Regenerative Medicine (BMERM)	NUIG with national and international consortium of universities	10	Functional biomaterials; mechanics of biological cells, tissues and systems; bioelectronics and rehabilitation engineering; regenerative orthobiologics and neurotherapeutics; regenerative cardiovascular therapeutics	Professor Peter McHugh, peter.mchugh@nuigalway.ie	
Structured PhD research with taught modules	TCD, UCD, UCC and DIT	10	Graduate Research Education Programme in Engineering (GREP Eng)	Dr Ciaran Simms, ciaran.simms@tcd.ie	www.tcd.ie/Graduate_Studies/PRTL/Bioengineering%20and%20Medical%20Device%20Projects.pdf

These disciplines build on the strengths of the research work of the NCBES at NUIG and the needs of a large number of medical device companies that have set up in the west of Ireland.

3. Level 8 add on (B. Eng. Honours/B.Sc. Honours)

One-year add on level 8 programmes are offered in biomedical engineering (CIT) and biomedical device innovation (DIT). The programme at CIT is integrated with the level 7 degree previously described.

The B.Sc. programme at DIT is designed to meet the needs of graduates from level 7 programmes who may have followed a traditional mechanical, electronic or manufacturing engineering route through the early years of their education. An interesting feature of this course is the group-based project, which is completed in the final semester. This course is currently also offered under the Springboard Programme.

4. Other Related Level 8 Programmes

UL offer a B.Sc. health informatics degree focusing on anatomy, requirements engineering, database design and management, human computer interaction and medical decision support systems with cooperative placement.

Structured postgraduate study programmes

For many years, postgraduate study in Ireland was completed at Masters Degree (level 9) by research or study and examination and

at PhD (level 10) by research only. A new emphasis on research in the medical devices industry has created a need for engineers and scientists who have a deeper knowledge of biomedical engineering. As shown above, there are a range of undergraduate programmes available but many companies have indicated that a postgraduate qualification in biomedical engineering is also very desirable.

1. Level 9, Masters Degree Programmes

UCD, UL, and TCD offer a joint Masters Degree Programme in Biomedical Engineering (UL, UCD) and Bioengineering (TCD). This programme also has some additional input from the Royal College of Surgeons Ireland, and University of Ulster, Jordanstown, and has a number of compulsory modules with each university offering optional modules. It focuses on an industrial sector in which the island of Ireland has developed a global reputation for quality and excellence. TCD Medical School provides medical science inputs for students at TCD. The joint nature of the course brings together the world-class expertise available at the participating institutions in a novel way. The programme has support funding from the HEA and, as such, has slightly lower tuition fees than most Masters Degree courses. DCU and NCAD both offer one-year, add on Masters Degree courses for people interested in developing high-level knowledge and design skills in the areas of biomedical engineering and medical device design. Graduates of their



PIPELINE INDUSTRIES GUILD – IRISH BRANCH

www.pipeguild.com

Technical Paper Prize Competition

Call for Technical Papers from Recently Qualified Engineers

The Irish Branch of the Pipeline Industries Guild is pleased to invite the submission of technical papers related to any aspect of the pipeline industry. This invitation is confined to engineers with less than three years postgraduate experience as of **31st December 2011** and who are current members of Engineers Ireland.

The judging panel will draw up a shortlist of three papers and the authors will be invited to attend the Pipeline Industries Guild (Irish Branch) Annual Dinner on Friday 24th February 2012, where the overall winner will be announced. There will be a prize of €1000 for the winning author. The winner will be required to present the paper at a subsequent technical meeting of the Guild. Papers should not exceed 3000 words and should be illustrated. While there is ample opportunity to choose from a very wide range of topics within the pipeline industry, favourable consideration will be given to papers which would be of interest to a broad spectrum of the industry and the content of which would have practical application.

The closing date for the receipt of papers is **5.00 pm Friday 27th January 2012**.

Papers should be submitted via email to:

**Des Maguire, Secretary, Pipelines Industries Guild, c/o Tech Skills Resources Ltd.,
25 Merrion Square, Dublin 2. Email: des@techskills.ie**

undergraduate degree programmes in biomedical engineering (DCU) and design (NCAD) have the option of progression to these in-house programmes. The role of ICT in healthcare and in management and informing clinician decisions is vital. The School of Computer Science and Statistics at TCD provides an M.Sc covering complex and intellectually demanding interdisciplinary fields such as medicine, computer science, management science, statistics and engineering. This is a two-year, part-time course, currently funded by the HEA Graduate Skills Conversion Programme.

2. Level 10, PhD Degree Programmes

A relatively new initiative in postgraduate study in the field of biomedical engineering is the development of the structured PhD programme at Level 10. In this regard, there is a new four-year programme in biomedical engineering and regenerative medicine (BMERM), which will be delivered by a core partnership of institutions: National University of Ireland, Galway (Administrative Coordinator), University of Limerick and University College Cork. These universities link with a wider consortium of partner institutions nationally and internationally, including: Galway-Mayo Institute of Technology; Institute of Technology, Sligo; University of Ulster; Queen's University, Belfast; Georgia Institute of Technology, USA; University of Pittsburgh, USA; Duke University, USA; Rice University, USA; Mayo Clinic, USA; RWTH Aachen University, Germany; Georgia Tech Ireland; and the Irish Medical Devices Association (IMDA).

BMERM combines a PhD research project with a unique teaching and experiential learning programme, resulting in a new learning experience for the student in terms of world-class research and focused clinical and industrial interaction, the latter facilitated by the direct involvement of IMDA with its membership of over 100 medical technology companies in Ireland.

In conjunction with its Innovation Academy, TCD will offer PhD research opportunities in biomedical engineering with the opportunity to learn additional skills in research creativity and innovative design. It is intended that this structured learning programme will enhance the graduate capacity to exploit research and development opportunities and help in the creation of high-potential, start-up companies in biomedical engineering. This structured PhD programme in the new graduate research education programme in engineering is offered by Trinity College in partnership with University College Dublin, University College Cork and Dublin Institute of Technology.

Significance of professional engineering title

Overall, the profession of biomedical engineering is now being well-supported by third level educational institutions in Ireland. In addition to the range of undergraduate programmes, the emergence of taught and structured postgraduate programmes at Levels 9 and 10 will give the Irish Government strategy for the creation of a knowledge economy a strong impetus in the biomedical and clinical healthcare sectors. From the perspective of Engineers Ireland, and the opportunity for its members to progress to Chartered Engineer, it is very positive to see that a good number of Masters Degree programmes have been developed across the country. Under new requirements, engineers who graduate from 2013 and wish to become Chartered Engineers will need to hold an accredited Master Degree (Level 9), or equivalent. It is important for Engineers Ireland

to work with these universities and institutions to ensure that these courses obtain and retain the accreditation and recognition they merit. Looking to the future for clinical engineers also, there is likely to be a requirement for all engineering people working in the healthcare and biomedical sectors to have a professional engineering title as part of a coherent regulatory practice and the role of education in this regard is essential.

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Orla Keane, MIEI, joined the Irish Medicines Board in 2006 and is product manager for Class I/IIa medical devices in the Human Products Monitoring Department. She is a member of the committee of the Engineers Ireland Biomedical Engineering division. Orla is also a member of ETCI TC10 and is the IMB delegate to the European Commission Compliance and Enforcement Working Group (COEN).

Mary Sharp Chartered Engineer, FIEI, is a lecturer in the School of Computer Science and Statistics, Trinity College Dublin. In addition to being a member of the committee of the Biomedical Engineering division she is Chair of the Ethics and Disciplinary Board and also a member of the Board of Examiners of Engineers Ireland. Among her other roles, she is a member of the Advisory Committee for Medical Devices of the Irish Medicines Board and is the Irish delegate to the IMIA (International Medical Informatics Association).

Ger Reilly is head of department in Metal Fabrication and Welding at Dublin Institute of Technology, and is currently Vice Chair of the Biomedical Engineering division. He has been involved in research and development in bioengineering and biomedical device design for over 15 years and was one of the Irish representatives to the COST Action 532, with special interest in the sub group on orthopaedic implant retrieval.



Biomedical engineering research offers a pathway to economic recovery

Dr John Gleeson provides a 'snapshot' of some of the research groups fueling Innovation Ireland and extending the boundaries of global biomedical engineering

Since the Programme for Research in Third-Level Institutions (PRTL) was set-up, biomedical engineering research has made a real impact on the international stage. Launched in 1998, PRTL has given €1.22bn to strengthen national research capabilities.

That vision was the beginning of over a decade of biomedical research within third level institutions that has been globally recognised, with Ireland now ranking in the top 20 nations for quality of scientific publications. In some areas, such as immunology and nanotechnology, we are now world leaders. This has led to the development of a number of world-class research institutions attracting both national and international funding awards. Based on continued levels of R&D investment in third level institutions, access to start-up capital and a strategic focus on financial allocation to Technology Transfer (TT) activities, these research centres could play a large role in helping the country claw its way out of economic recession.

Tissue Engineering Research Group, RCSI

Extensive research in the field of bioengineering is ongoing in The Royal College of Surgeons in Ireland (RCSI) in the areas of tissue engineering to develop cell, construct and living system technologies to restore the structure and functional mechanical properties of damaged or degenerated tissue. The Tissue Engineering Research Group TERG group carries out research in a wide variety of areas including tissue engineering of bone and cartilage, regenerative medicine, stem cell biology, drug delivery, gene therapy and angiogenesis. They have active collaborations with the Trinity Centre for Bioengineering and REMEDI (NUIG) among other national and international partners. They are also developing translation technologies, which are at different stages of commercialisation. The group is multidisciplinary with physical, material and life scientists, engineers, medics and veterinary surgeons working together. The group has published extensively in some of the top journals in the field (over 80 publications) and has attracted over €8m in funding. The main strands of research within the group are:

- ▶ tissue engineering and regenerative medicine;
- ▶ osteoporosis and bone mechanics; and,
- ▶ cardiovascular disease modification.

Trinity Centre for Bioengineering

The Trinity Centre for Bioengineering (TCBE) in Trinity College combines research with translation to clinical practice. Established in 2002, TCBE plays a key role in both the School of Engineering and the School of Medicine.

TCBE has been successful in attracting research funding, receiving over €18m from national and international agencies. It has 19 principal investigators driving biomedical research, clinical and industry collaborations. The centre has five research themes:

- ▶ cardiovascular;
- ▶ neural;
- ▶ musculoskeletal;
- ▶ biomaterials; and,
- ▶ regenerative medicine.

Recent medical device innovations include a flexi-cutting sheath and a product called Artistent. The former is a unique device, developed by Dr Bruce Murphy, a principal investigator in TCBE, to clear blockages in arteries, for which he received the Enterprise Ireland 'One-to-Watch' award in 2009. Arising from research by Dr Daniel Kelly, Artistent is designed to help overcome issues of stenting peripheral blood vessels. Artistent allows cardiologists to insert several small, unconnected stents through a catheter into a diseased artery in one go. The patented technology has started preclinical trials.

UCD Conway Institute of Biomolecular and Biomedical Research

The UCD Conway Institute of Biomolecular and Biomedical Research is a multidisciplinary centre for research funded by the PRTL. It

brings together over 550 research staff from all over the university and its associated teaching hospitals. Founded in 1999, the Institute was named after the first professor of biochemistry and pharmacology in UCD, Professor Edward J. Conway FRS (1894-1968). It aims to support a community of biomedical researchers exploring cell and systems biology for creative solutions in human disease, and to become a global leader in biomedical research and through partnership will translate this knowledge to benefit patients. At UCD Conway, much of the research centres on systems biology; protein science and bionanointeractions; and the application of these to the following areas of focus:

- ▶ diabetes and vascular biology;
- ▶ infection, immunity and repair; and,
- ▶ neuroscience.

The Institute has a translational focus and has links to a number of commercial ventures e.g. Berand, CelticCatalysts, Enzolve and Ildana Biotech.

University of Limerick

The University of Limerick has a reputation for being Ireland's leading university in industry-led research. This has resulted in significant research commercialisation activities and collaboration between researchers and industry.

The following priority research areas have been identified where the University has internationally recognised strengths:

- ▶ materials and surface science – composite materials, nano-materials, solid-state pharmaceutical materials, catalysis and clean technologies and, bio-mimetic materials; and,
- ▶ bioengineering and biosciences – micro-fluidics and biomedical engineering.

The Centre for Applied Biomedical Engineering Research (CABER) is a University of Limerick designated research centre based in the Materials and Surface Science Institute (MSSI). Established in the Department of Mechanical and Aeronautical Engineering in 2004, it aims to develop a world-leading position in research and development of medical device technology that will enhance patient care and lead to improved patient outcomes. Core activities focus on research in the fields of: cardiovascular systems, medical device design, orthopaedic biomechanics and biomaterials design and characterisation. CABER, under the leadership of Professor Tim McGloughlin Chartered Engineer and Dr Michael Walsh, is comprised of five Post-Doctoral Researchers, 19 PhD students and two mechanical engineering students and has attracted funding of over €5m in the last six years.

NUIG Mechanical and Biomedical Engineering Department

Currently, 28 Ph.D students, eight mechanical engineering research students and eight post-doctoral researchers work in the department. In the period 2003-2005, it published 56 peer-reviewed journal articles and 113 conference papers, and attracted over €3.7m in research funding from state agencies, the EU, industry and other sources. The department is closely linked with the National Centre for Biomedical Engineering Science (NCBES), an interdisciplinary centre on the NUIG campus. The Network of Excellence for Functional Biomaterials, the Energy Research Centre, the Composites Research Unit, the Micromechanics Research Unit and the Aerospace Research Centre are focal points for other major research

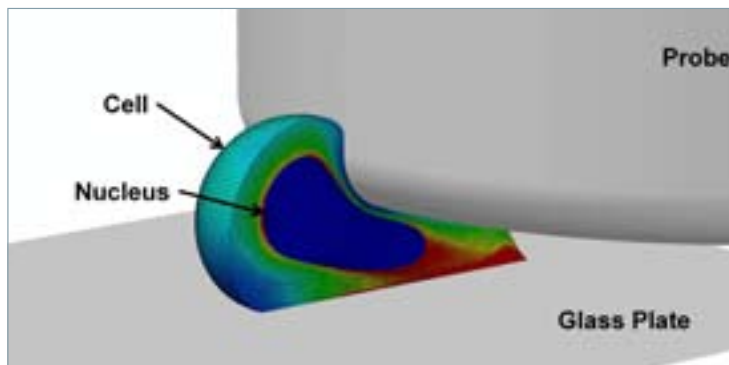
activities. The department conducts research in a number of key research areas;

- ▶ biomechanics and medical device engineering;
- ▶ biomaterials and tissue engineering;
- ▶ computational methods;
- ▶ composite materials; and,
- ▶ micromechanics.

The NCBES brings together scientists, engineers, information technologists and clinicians in a team-based, problem-centered approach to research. Research is focused on therapeutic solutions to medical challenges including cardiovascular disease, orthopaedics, reproductive medicine and cancer. The NCBES currently hosts nearly 400 members. Since its establishment in 1999, with the support of €19.3m under the PRTL, the development, growth and achievements of research clusters at the NCBES has led to the prioritisation of four major research themes: biomedical engineering, cancer, neuroscience and regenerative medicine. The biomedical engineering theme incorporates such disciplines as biomechanics, tissue engineering and biomaterials research into joint collaborative research projects focused on cardiovascular, musculo-skeletal, rehabilitation and neural bioelectronics research. In biomechanics, the principles of engineering mechanics and biology are combined to generate discovery and understanding and to solve problems at the interfaces between engineering, biology and clinical practice. Cardiovascular biomechanics research is focused on the mechanics of endothelial cells and adult mesenchymal stem cells and understanding their response to mechanical loads, involving experimental and modeling methods. Orthopedic biomechanics research develops experimental and computational methods for studying the deformation of skeletal structures and for quantitatively assessing the mechanical performance of structures of bone in both healthy and diseased states. Medical device design research looks at cardiovascular stent analysis and design methods, linking computational models with x-ray data and mechanical performance. In the Network of Excellence for Functional Biomaterials, researchers investigate the use of materials, from metals to alloys to smart polymers, important in biomedicine. Work also focuses on synthesis and characterisation of new polymers and composites that have potential for use in new devices.

The Regenerative Medicine Institute (REMEDI) focuses on gene therapy and stem cell research. Researchers combine the technologies of gene therapy and adult stem cell therapy with the aim of regeneration and repair of tissues. Established in 2003, through a Science Foundation Ireland Centre for Science Engineering and Technology award and industry funding, the institute is located at the NCBES and incorporates the National Cell and Gene Vector Laboratory. REMEDI's focus is the translation of basic research findings from exploratory phases to clinical trial applications, in order to effectively progress from research to human therapy.

Dr John Gleeson, MIEI, BA, BAI, PhD, is a Trinity Engineering graduate and is currently a PI within the RCSI Tissue Engineering Research Group (TERG). John is lead investigator with the Cartilage Advanced Regenerative Therapies section of TERG, whose research focuses on bone and cartilage mechanobiology and degenerative joint disease damage and repair strategies. John is also project and business development manager for the TERG, with responsibility for the commercialisation of the suite of common platform technologies developed.



Finite element simulation of cell shearing experiment.

Living machines that respond to external force

Medal winner enhances understanding of cartilage cells

Enda Dowling, the 2011 Engineers Ireland Biomedical Research Medal winner, and co-authors William Ronan and Dr. Patrick McGarry of NUI Galway, provide an outline of the research recognised by the award of this year's Medal

Recent studies have revealed that biological cells alter their behaviour in response to externally applied mechanical loading. This is particularly true of chondrocytes, the cells that create and maintain the cartilage lining in our joints. Dynamic loading of these cells promotes the production of proteins that are essential for healthy cartilage whereas prolonged static loading inhibits the production of essential proteins. Such mechanically driven alterations in cell behaviour can therefore lead to a degenerative disease of cartilage known as osteoarthritis. However, the precise manner by which these cells actively respond to external forces is not well understood. Our study investigates the mechanisms by which chondrocyte cells responds to an externally applied force. The problem is made particularly complex by the fact that the mechanical properties of cells cannot be described using standard engineering material laws such as elasticity or viscoelasticity. When a force is applied to a cell it responds by actively remodelling its internal structural components. Therefore, if we perform an experiment on a cell whereby we apply a force to a cell and observe the resultant deformation, we must use computer models that predict the active rearrangement of internal structural components in order to predict the stress and strain distributions inside the cell and in the cell nucleus.

Engineering models for living cells

From an engineering viewpoint, the internal structural components of a cell are extremely interesting. This structure consists of truss-like fibrous elements, known as stress fibres. Stress fibres possess the ability to produce an internal tension. Similar to our muscle tissue, stress fibres contain motor proteins that 'burn fuel', converting chemical energy to mechanical work. Hence the stress fibres in cells obey an inverse relationship between the tension that they produce and the velocity at which they shorten, as demonstrated for muscle contraction.

Fibres produce maximum tension if the cell is prevented from shortening. This explains why cells that are attached to very stiff glass surfaces generate a lot of contractile force, whereas cells that are attached to soft gels can shorten at high velocities and produce very little contractile

force. The final piece of the jigsaw concerns the ability of the stress fibre network to actively rearrange itself in response to external forces. If the tensile stresses in a cell body are lowered when the cell deforms, the stress fibres will disassemble. In opposition to this disassembly process, cells have the ability to form new fibres in response to active cellular signalling. This process is captured with a first order kinetic equation. Overall, this description of the active mechanical behavior of the cell is comprised of a set of highly non-linear differential equations. Solution of these equations for complex cell geometries requires a three-dimensional finite element computer program that we have developed with co-workers at the University of Cambridge and the University of California, Santa Barbara.

Micro-scale mechanical test machine

In order to use our computer model to understand and predict how chondrocyte cells respond to mechanical force, we first had to carry out a series of challenging experiments on individual cells. Working with collaborators at Rice University, Texas, we extracted chondrocyte cells from cartilage taken from a cow's fetlock joint, a hinged joint that undergoes similar motion to the human knee. Cells were then attached to a flat glass plate. We then used a microscopic probe to apply a shear deformation to individual cells. Using a microscope, we created movies of the deforming cell as the probe indented its side, essentially resulting in a net shear strain of the cell. Of course, the interaction between the cell and the probe also imparted a slight deflection on the probe, and by measuring this probe deflection we were able to calculate the force applied to the cell using simple beam theory.

The results of our experiments revealed a highly non-linear relationship between the force applied by the probe and the level of cell deformation, with a yield stress being observed following initial contact between the probe and the cell. Interestingly, when we used a chemical agent to remove stress fibres from the cell we obtained a perfectly linear relationship between force and cell deformation.

In order to use our computer model to interpret our experimental results,



Pictured (l-r): Enda Dowling and his PhD supervisor Dr Patrick McGarry outside the new Engineering Building in NUI Galway.

we had to build three-dimensional finite element meshes of the cell and probe geometries and then apply boundary conditions to the model to simulate the interaction between the probe and the cell. Due to the highly non-linear differential equations that we use to describe the cell material, these computer simulations required the use of supercomputer facilities at the Irish Centre for High End Computing (ICHEC). Our model provided a perfect prediction of the forces required to deform the cell. Furthermore, our model predicted that the stress fibre network disassembles in a compressive region at the front edge of the cell. A second series of experiments, where we imaged the stress fibres using fluorescent dyes, verified that this predicted disassembly of the stress fibres does indeed occur. The model presented in this study provides a powerful tool for the prediction of the active response of cells to the physical environment. We are now using this model to identify loading patterns that will lead to chondrocyte malfunction and degeneration of cartilage. Future work will entail the use of the model to devise mechanical loading strategies that could be applied to cells to grow cartilage explants in a laboratory. This would represent a significant breakthrough in the treatment of osteoarthritis.

Enda Dowling, B.Eng is a PhD Research Student at the Dept. of Mechanical and Biomedical Engineering and National Centre for Biomedical Engineering Science, National University of Ireland, Galway. Funding support was provided by the Irish Research Council for Science, Engineering and Technology postgraduate scholarship under the EMBARK initiative, and by the Science Foundation Ireland Research Frontiers Programme and Short Term Travel Fellowship. The authors wish to acknowledge the SFI/HEA/ICHEC for the provision of computational facilities and support.

Trinity appoints engineer as Provost

Patrick Prendergast Chartered Engineer, FIEI, became the 44th Provost of Trinity College Dublin earlier this year. He is the first engineer to be appointed to this post, and he joins two other engineers in similar roles: Professor James Brown Chartered Engineer, FIEI, at NUI Galway and Professor Sir Peter Gregson Chartered Engineer, FIEI, of Queen's University Belfast



Patrick Prendergast outside Trinity College, where he studied as an undergraduate and where he is now the 44th Provost.

Paddy took up office as the 44th Provost of Trinity College Dublin on August 1, having been elected to the 10-year post on April 2 by the academic staff and students. Paddy, from Oulart in County Wexford, first came to Trinity in 1983 graduating with a degree in mechanical engineering and later got a PhD in bioengineering, which he carried out under the supervision of Professor David Taylor Chartered Engineer. The first year of the work, from 1987-1988, was done at Eolas in Glasnevin (now Enterprise Ireland) on finite element analysis of artificial hip joints. He then obtained a Council of Europe scholarship to do

a postdoctoral year in the Rizzoli Orthopaedic Institute in Bologna and, after that, he obtained a Marie Curie Fellowship at the University of Nijmegen in The Netherlands. In these positions, he carried out research on orthopaedic implants. The work in Nijmegen won the Perren Award of the European Society of Biomechanics. Paddy and his then supervisor, Rik Huiskes, developed a method to predict what kind of mechanical stimulation (stretch, fluid flow, etc) promotes the differentiation of stem cells along different lineages.

Most highly referenced mechanical engineer

Paddy returned to Ireland as a lecturer in Trinity in 1995, and was elected a Fellow of the College in 1998. Together with colleagues in engineering, dentistry, medicine and physiology, he established the Trinity Centre for Bioengineering in 2002. He was elected MRIA in 2008 and was awarded an ScD in 2009. He is a Fellow of the Irish Academy of Engineering. Over this period, he wrote more than 150 papers with a current citation of almost 3,000 and a h-index of 34 (Scopus data), making him the most highly referenced mechanical engineer in the country. During this time, he worked on a range of implants: hip, shoulder, middle ear, cardiovascular stents and most recently, extensive work on tissue engineering and regenerative medicine. He was awarded the Parsons Medal by the Royal Irish Academy, The Haughton Medal by the Royal Academy of Medicine in Ireland, and he gave the Wartenweiller Lecture of the International Society of Biomechanics in 2009. He served as the dean of graduate studies between 2004-2007 and was the first appointment to the expanded position of vice-provost as chief academic officer in 2008. His research is in the area of medical device technologies, where he has carried out significant industrial collaboration in implant design and development, including as a board member of Clearstream Technologies Group plc.

No frontiers

from engineer to serial entrepreneur

John O'Dea Chartered Engineer, FIEI and Vice President Engineers Ireland tells *The Engineers Journal* how he made the move from engineer to entrepreneur, the job potential he sees for civil engineers in the biomedical device sector and the importance of breaking down barriers between engineering disciplines



John O'Dea has a consistent track record of initiating innovative businesses from a ventilator R&D facility for Puritan Bennett to novel imaging technology for esophagus and stomach surgery with his own company Crospon. More recently he took the chairman's role with Janisys, which is developing a novel form of drug delivery technology. Does he see himself primarily as an engineer or an entrepreneur? "I

would see myself as an engineer first and foremost and, as such, I enjoy solving problems, identifying unmet needs and meeting them. In that sense, in many ways, I could be seen as an accidental entrepreneur, discovering business opportunities as a by-product of my engineering work.

"I have been fortunate enough to work for world-class multinational companies in the biomedical device industry and was involved in product launches with those companies. That experience helped me develop a deeper understanding of the complex, strictly regulated framework within which the multinational medical device industry operates which has been crucial in growing each of my companies."

Exporting to the US

Inevitably, Crospon can't avoid being affected by the difficult global economic environment: "Our major market is the US health system, which is, of course, hugely challenging at the moment. The medical device sector accounts for six per cent of the cost of healthcare in the US, nonetheless, the process of doing business there continues to be demanding with an evolving framework of codes and regulations and the lengthening of the capital acquisition cycle."

While President Obama's healthcare deal made news all over the world, it has mixed implications for an Irish medical device company exporting into the US: "It can only be good to the extent that it broadens access to healthcare. However, the sales tax it brings will increase the price of products. This combination will make for a market that will be both tighter and broader."

Creating jobs for engineers

Fundamentally, John remains confident about the long-term prospects for Crospon and is recruiting when necessary. "Senior mechanical engineers are hard to find and there are certainly opportunities there for suitable qualified people."

John feels strongly that it is important not to be too rigid in thinking about engineering disciplines and to be open to the potential to adapt. "Conversion courses offer very real opportunities to engi-

neers who would like to move into the biomedical device industry. Civil engineers, I believe, have skills that are transferable. They use a lot of the same tools as biomedical engineers – good CAD skills for instance. Standards are critical aspect of both disciplines. As far as the work goes, much of it involves established processes and structured approaches, you are not exclusively designing *de novo*. The barriers that are perceived to be there are largely artificial."

Crospon is a Galway-based company and a prime beneficiary of the industry/academia partnership that drives the biomedical device cluster in the city. "NUIG is a critical part of the infrastructure and there has been a marked step up in part-time masters degrees in recent years. As an idea factory, hospitals have a vital role, but universities are essential in supplying graduates that can drive the sector. NUIG's research centre, REMEDI is just one example of the future of the industry. One of the key future trends is in bio-active devices, uniting the functionality of device implants with the bioactivity and specificity of therapeutic bio agents."

Ultimately, the biomedical device sector is one which John finds very fulfilling: "It is a sector where, once in, you are very slow to get out of it. It offers a unique opportunity to affect many, many people's lives in a positive way."

'Engineer, first and foremost'

John O'Dea co-founded Caradyme, an Irish respiratory medical device company in 1998, which was selling products in 30 countries, prior to being acquired by Respironics Inc in 2004. In the past 20 years, he has held R&D management positions in Puritan Bennett and engineering positions in Digital Equipment Inc and Dataproducts Inc. Crospon's EndoFLIP imaging system was initially developed to assist in the assessment and surgical treatment of gastroesophageal reflux disease (Gerd). While Crospon continued to research in that area, its EndoFLIP imaging system received FDA approval for bariatric (weight-loss) surgery, one of the fastest growing areas in the US surgical sector. Crospon has spun out another company, Janisys, which is developing a novel, active transdermal drug delivery technology based on IP acquired from Hewlett Packard in 2007. John is a named author on six US patents and is currently a board member of the Irish Medical Device Association, chair of the REMEDI CSET advisory board and a member of the Enterprise Feedback Group and Advisory Science Council Company R&D Task Force. He holds a degree and masters in mechanical engineering and a PhD in electronics engineering, all from University College Dublin.

Science of life

Biomedical sector drives Irish export performance

Ireland has long had a reputation of punching above its weight internationally. With a population of around 4.2m, we have competed on the world stage in many arenas, attracting disproportionate amounts of R&D funding in science and bioengineering as well as large levels of direct foreign investment, most notably in the life sciences industry where we are recognised as a global leader, writes Dr John Gleeson

Ireland has positioned itself as an attractive European manufacturing location for the global life sciences industry and currently employs over 25,000 people in the medical device sector, specifically.

Ireland's medical device sector has evolved into one of the leading clusters for medical device and diagnostic products globally. This sector is comparable in scale to some of the world's leading clusters, such as Massachusetts and Minnesota, with nine out of the top 10 global medical technology companies operating here.

The presence of so many US manufacturers has turned Ireland into one of the world's leading exporters of medical equipment, and we are now the second largest exporter of medical products in Europe, behind Germany, with exports climbing by over 14 per cent since 2009. Approximately 200 companies are currently involved in developing, manufacturing and marketing a diverse range of medical sector products and services. Ireland possesses a number of key advantages that make us extremely attractive to large foreign multinational companies looking to locate manufacturing and development facilities abroad. While the financial incentives for these companies have been the focus of much heated debate with our European peers in recent months, it is our highly skilled workforce that is arguably our greatest strength. As a result, many of the world's top medical technology companies and most large US medical firms have some manufacturing capacity in Ireland.

Innovation-driven

The medical technology industry in Ireland is changing from being primarily manufacturing-based to being driven by innovation and

R&D. It now involves intensive collaboration between a broad range of partners, including research institutions, clinicians, manufacturing companies and government agencies.

We are seeing the emergence of multiple high-potential start-up companies actively attracting local and foreign investment to not only develop innovative ideas, but also to take these ideas all the way through from 'benchtop to bedside'.

Currently, over 90 of the 200 companies in the sector are indigenous and given that over 80 per cent of medical technology companies operating profitably within the EU are SMEs, these research-based, indigenous companies have an exciting future as they are well-positioned to compete at a European and international level.

Innovation nation

Some of the exciting established and up-and-coming technologies and innovators making waves in the contemporary Irish medical device sector.

DePuy Ireland

With a well-established reputation as an innovator in new product development, DePuy's products are primarily used by orthopaedic specialists and spinal neurosurgeons to treat patients with musculoskeletal conditions resulting from degenerative diseases, deformities, trauma and sports-related injuries.

DePuy Ireland established a state-of-the-art manufacturing facility in Ringaskiddy in 1997. The site predominantly manufactures orthopaedic knee and hip replacement joints. Currently, the company employs over 600 people in Cork.

Medtronic

Founded in 1949 in Minneapolis, Minnesota, Medtronic does business in more than 120 countries today and employs 38,000 worldwide. Medtronic has been present in Ireland since 1999, having acquired a cardiovascular business established in Galway in 1982. Their facility in Galway develops and manufactures a number of the company's key medical technologies for the treatment and management of cardiovascular and cardiac rhythm disease.

Medtronic also has a sales and shared service office in Dublin, supporting key businesses including cardiac rhythm disease management, neuromodulation, spinal and biologics, diabetes, cardiovascular, and ear nose and throat (ENT).

Clearstream Technologies Ltd

An Irish-run medical device company situated in Enniscorthy, Co. Wexford, Clearstream Technologies Ltd is expanding worldwide and this expansion has resulted in the rapid growth of the work force, which has tripled to almost 300 in the past three and a half years. Recently, the company has made a significant drive into the peripheral market with a number of the company's best known products such as the Bantam OTW (over the wire) and LitePAC RX (rapid exchange) receiving CE and FDA approval.

Cappella Inc.

A medical device company that is developing novel solutions for the treatment of complex coronary artery disease (CAD) and specifically bifurcation vascular disease, Capella Inc. was established in Galway in May 2005. It now employs more than 30 staff.

Cappella's Sideguard is a next-generation, self-expanding side-branch stent, which offers cardiologists a solution that focuses on treating the sidebranch of diseased coronary arteries first, rather than the main vessel.

Aerogen

A Galway-based specialty pharmaceutical company, developing inhaler and nebuliser products for the home and hospital markets, Aerogen also collaborates with pharmaceutical and biotechnology companies for the treatment of respiratory and other disorders, including diabetes. The company has experienced consistent growth in the last number of years with turnover reported to be an estimated €10m. Aerogen is focused on creating and commercialising novel, superior devices based on its proprietary OnQ Aerosol Generator.

Advant Medical

Formerly known as Contech Medical Ireland, this company, located in Galway, provides outsourced design, manufacturing, assembly and packaging solutions to the global medical devices industry. The company is a leading provider of services in applications such as catheters, guide wire delivery systems, vascular access devices and custom market solutions. In 2011, the company underwent a radical rebranding strategy realigning its product and service offering to include design and development and promoting it under a new name, Advant Medical.

MuteButton

MuteButton, located at NovaUCD, develops technology to alleviate tinnitus, a condition where sufferers hear a constant ringing noise. It was developed using commercialisation funding from Enterprise Ireland.

The initial research was funded by Science Foundation Ireland and the National Digital Research Centre. Pilot human trials have begun, and it is envisaged that a patient could use the MuteButton device for a short period each day.

eBioTech

Specialising in the remote diagnosis and analysis of chronic illnesses, Dublin-based eBioTech has a product portfolio based on a series of core technologies that have been developed to remotely diagnose, analyse and monitor schizophrenia, vocal palsy, asthma and multiple sclerosis using patented acoustic and physiological measurements recorded remotely and analysed at the company's laboratory. eBioTech can differentiate between normal and pathologic voice and achieve real diagnostic and patient tracking information.

Vasorum

Founded in 2005 and based in Citywest, Dublin, where it has set up a custom-built medical device development facility. Vasorum is developing medical devices for the interventional cardiology and radiology markets. It is estimated that 4.3m catheter-based procedures were carried out in the US in 2010 that involved arterial punctures, with a further 4.3m carried out in Europe.

According to Vasorum, it is estimated that the number of these procedures performed will reach over 10m in the US and Europe in 2015. Vasorum has developed Celt ACD, a biocompatible stainless steel implant used to close arterial puncture holes and is set to launch the product in the EU.

The company has exclusive rights to an extensive patent that protects various aspects of the arterial puncture closure implant and its method of use.

AltaScience

This Dublin-based company is developing a female sterilisation device that can be implanted hysteroscopically (routine endoscopic examination) in a gynaecologist's office. It is easy to use, inexpensive to manufacture and provides immediate sterilisation, AltaScience states.

Fallopian tube sterilisation (FTS) involves disrupting the fallopian tube to ensure that sperm cannot get access to the egg, thereby preventing pregnancy. FTS is the most widely used method of contraception worldwide. This is primarily due to its reliability and also the relative absence of chronic side effects associated with other methods. However, its use is limited by the requirement of surgery to close the fallopian tubes. AltaScience is developing a novel implant, AltaSeal, which is placed in the fallopian tubes by a gynaecologist without the need for surgery.