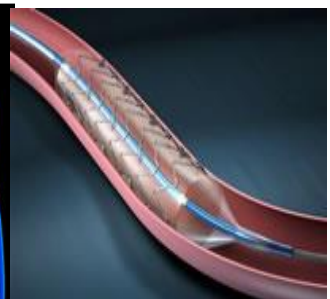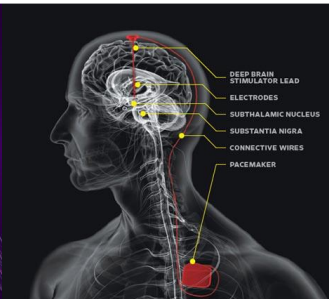# ME Biomedical Engineering

Prof. Madeleine Lowery
UCD School of Electrical and Electronic Engineering

Prof. Eoin O'Cearbhaill
UCD School of Mechanical and Materials Engineering

Biomedical Engineering

- **Biomedical Engineering**

  'The application of engineering principles to understand, modify or control biological systems'

- **Wide variety of application areas**
  - Medical device industry
  - Biosignal and bioimage processing
  - Rehabilitation engineering, orthopaedics…

- **Foundation in Electrical/Electronic or Mechanical Engineering**
  - Complemented with relevant physiology and anatomy
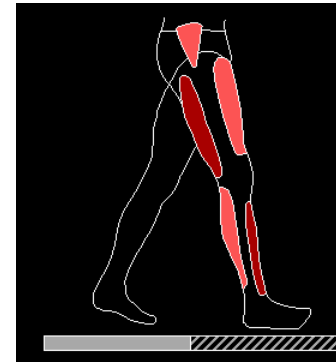 - Brought together in specialised Biomedical Engineering modules
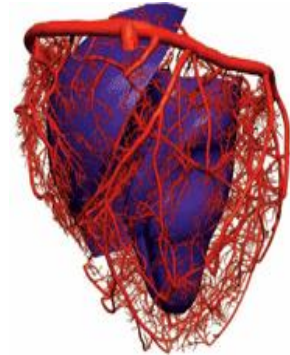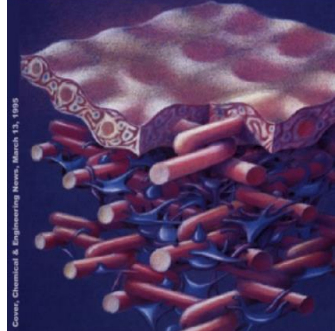
Cochlear implants
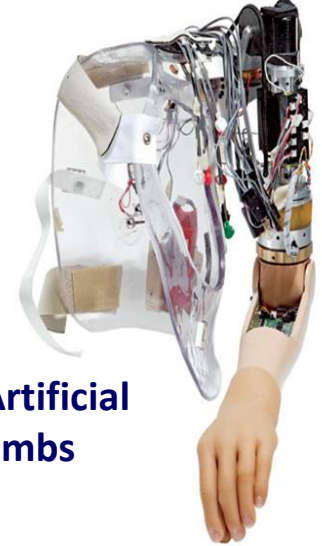
Pacemakers

Deep brain stimulation

Gait analysis

Artificial limbs

Biomedical Engineering

The application of engineering principles to understand, modify or control biological systems

Hip implants

Rehabilitation robotics

Biomedical signal processing
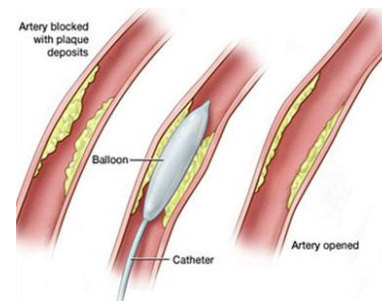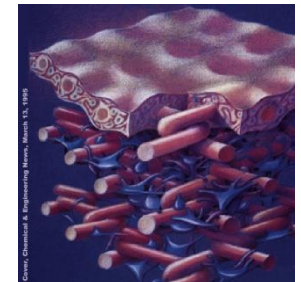
MR imaging
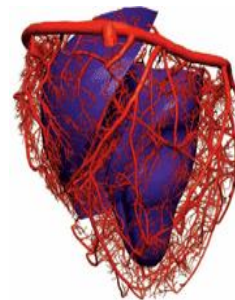
Physiological modelling

Angioplasty

Tissue engineering

UCD Biomedical Engineering Taught Masters Degree

ME Biomedical Engineering
2 Year degree
120 Credit
GPA greater than 2.8 in Biomedical/Electronic/ Electrical or Mechanical Eng.
Accredited by Engineers Ireland
6-8 Month Professional Work Experience and 25 credit project

ME Biomedical Engineering Year 1

Core Modules

ANAT40010	Medical Sciences for Biomedical Engineers (unless already taken)
MEEN40620	Biomechanics
MEEN40630	Biomaterials
EEEN40660	Experimental Design and Statistics for Engineers
MEEN40600	Medical Device Design

1 or 2 Modules From Below or Equivalent

Option Modules

|	
EEEN30160	Biomedical Signal Processing
EEEN40010	Control Theory
PHYS30010	Cardiovascular Physiology
PHYC40940	Bio-inspired technologies
EEEN40580	Optimisation Techniques
MEEN30030	Mech. Eng. Design II
MEEN40020	Mechanics of Fluids II
MEEN40030	Manufacturing Engineering II
PHYC40430	Nanomechanics

ME Biomedical Engineering Year 1
Semester 2 : 30-Credit Professional Work Placement
January – August
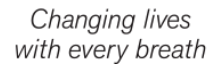
'Also, just a note that we were blown away by the quality of the applications from UCD this year - it was very tough choosing between them at both interview and offer stages. The UCD students really stand out from the other candidates (and we had applicants from all over Ireland and around Europe).'

Shimmer Technologies

'It's rarely I feel the need to go into writing on feedback directly to Universities in relation to student placements we receive here in Boston Scientific, in fact this will be the first time. However, in the case of your Masters students who have just finished placements with us here in the past few weeks…, I feel the need to specifically highlight that these students were of a stand-out nature and not only developed considerably themselves during their placements, but contributed very well to our business – in fact to the extent that they will leave a vacuum behind them now that they have returned to college…As is the case with students of the standard, they are fast learners, very intelligent, constantly ask the right questions and always bring new perspectives. In addition to this, however, what really made these students stand-out for me was their level of enthusiasm, engagement, perseverance, thoroughness, ability to integrate within the team and their strong work ethic.'

Boston Scientific

ME Biomedical Engineering Year 2

| Semester 1		Semester 2	
MEEN40610	Research Project / Thesis	MEEN40610	Research Project / Thesis
MEEN40560	Research Skills and Techniques		
EEEN40730	Biosensors & Actuators		
3 Modules From Below or Equivalent		**3 Modules From Below or Equivalent**	
EEEN40720	Machine Learning for Engineers	**Biomedical Engineering option modules (choose min. of 2)**	
PHYS30010	Cardiovascular Physiology	EEEN 30180	Bioinstrumentation
EEEN40130	Advanced Signal Processing	EEEN40350	Rehabilitation Engineering
COMP47460	Machine Learning	MEEN41160	Musculoskeletal Biomechanics and Mechanobiology
EEEN40300	Engineering Entrepeneurship	EEEN40070	Neural Engineering
EEEN40580	Optimisation Techniques for Engineers		
MEEN30030	Mechanical Engineering Design II	**Option modules**	
MEEN40020	Mechanics of Fluids II	CHEN40470	Cell Culture and Tissue Engineering
MEEN40030	Manufacturing Engineering II	MEEN40040	Materials Science and Engineering III
MEEN40050	Computational Continuum Mechanics I	MEEN30010	Applied Dynamics II
MEEN40060	Fracture Mechanics	COMP40400	Bioinformatics
MEEN40070	Advanced Metals/Materials Processing	PHAR40240	Regulatory Affairs in Science
MEEN40080	Technical Ceramics		
MEEN40160	Kinetics & Thermodynamics of Materials		
MEEN40170	Mechanics of Solids III		
CHEN40790	Bio-material Interactions		

Sample of Recent ME Projects

Sample of Recent ME Projects

Finding the correct model for sensory-motor translations in the brain

Optimising de-binding / sintering processes for manufacturing magnesium (Mg) based biodegradable implants upon Low Temperature 3D-Printing

Crush strength testing of mussel shells considering fish jaw anatomy

Probing the brain mechanisms of multisensory detection

Deep brain stimulation of axons and branching collatorals

Computational modelling of directional electrodes for deep brain stimulation

The Three Dimensional Soldering of an Implantable Heart Sensor for a Closed Loop Circuit

Validation of lab based mechanical properties against clinical outputs of an adhesive patch for an on-body injector device.

Achilles tendon – its age-related changes and potential clinical utility in men

How do the zones of articular cartilage emerge over postnatal development?

One- and few-shot learning with deep neural networks for medical image analysis

Can decision neuroscience help to make our roads safer?

Simulation of unprotected Vs protected head impact events during professional rugby tackles.

A continuous measure of decision processing to monitor changes of mind

Design of a device to measure oropharyngeal force: tongue protrusion.

Does a Mobile bearing Polyethylene spacer really matter in Total Ankle Replacement?

EEG signals of sensorimotor decision formation under varying neuromuscular demands

Identification of novel speech-biomarkers in Huntington's disease

Can sutures share the load?

How do the mechanical properties of the meniscus develop over time?

Longitudinal analysis of sleep and physical activity in Huntington's disease.

Characterisation and simulation of various biomaterials to understand their influence on the design of organ-on-a-chip devices.

Design and development of an organ-on-chip model of pancreatic cancer metastasis

Design of scale up microfluidic chips for the synthesis of polymer nanoparticles

Computational Medical Imaging: Analysis of multimodal brain MRI data sets in type I & II diabetes

Examining EEG signals of sensorimotor decision formation in the learning of complex myoelectric control

Sense of agency for myoelectric control

Does finger pad skin slip inform grip force control?

Assessing new methods for separating sensory, cognitive and motor processes in EEG

Biomechanical Considerations of Menstrual Cups

Biomechanics & pathophysiology of traumatic spinal cord injury

Instrumented pedals for rehabilitation robotics and athletic training

Predictive modelling of lower-limb cycling rehabilitation

Optimisation of the External Cable Assembly for ProVerum Medical Minimally Invasive Expander Imaging and Delivery System in the Treatment of Benign Prostatic Hyperplasia

Design of a novel growth tethering device for treating limb deformities in children

Non-invasive Ultrasound Thrombus Disruption

Motor unit coherence in Type 1 diabetes

Using AI in predictive simulations of gait

Engineering a sense of touch for low-cost hand prostheses

Can Prototypes for Orthopaedic implants be realistic?

Development of stiffness-tuneable hydrogels for pancreatic cancer

Revealing hidden timings in the brain

Design and testing of a robotic system for retraining running gait

Determining material properties of spinal cord tissue from atomic force microscopy experiments using finite element analysis, machine learning and optimization

Design of a device to measure oropharyngeal force: intraoral force.
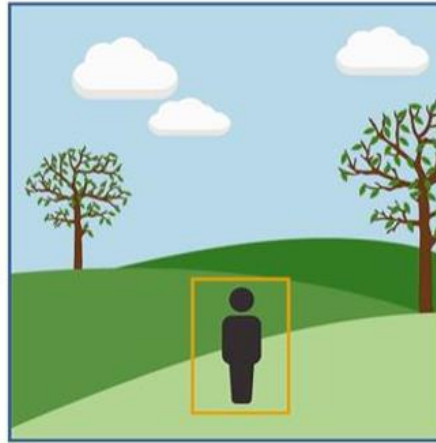
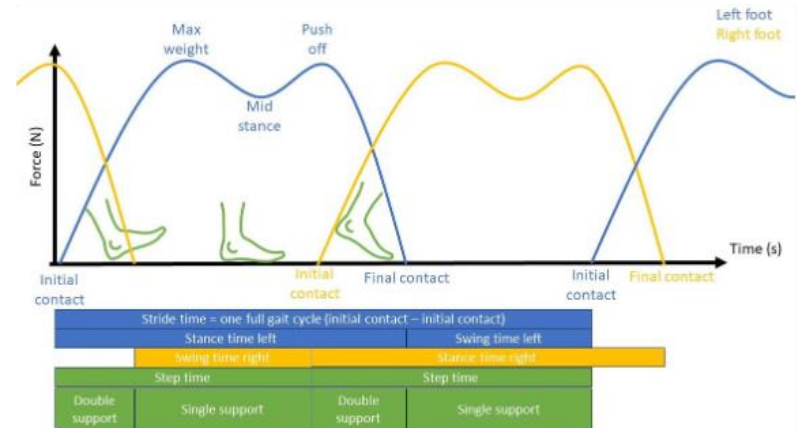EEEN40070 Neural Engineering
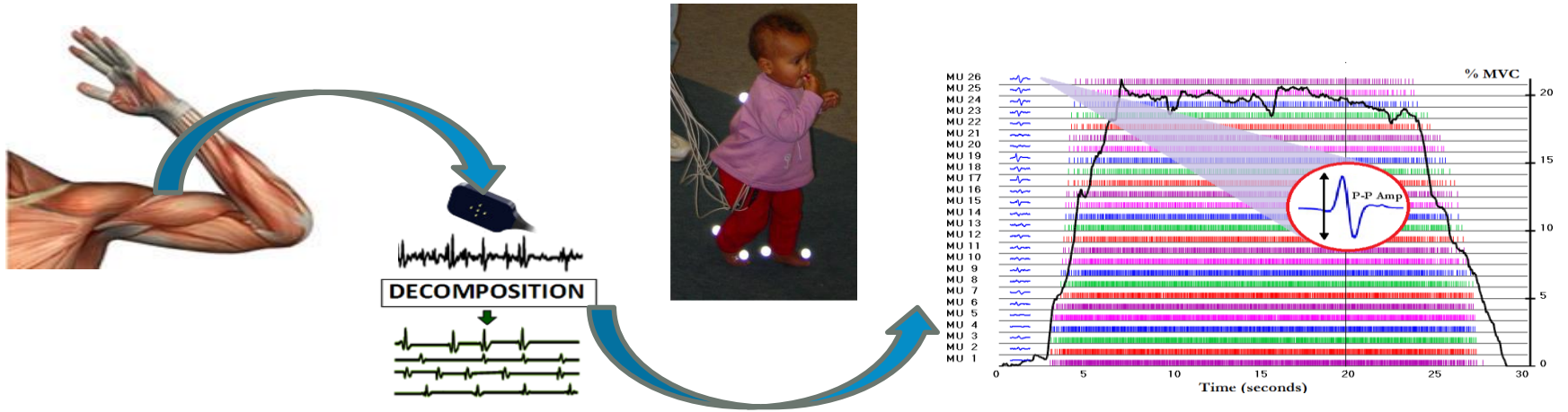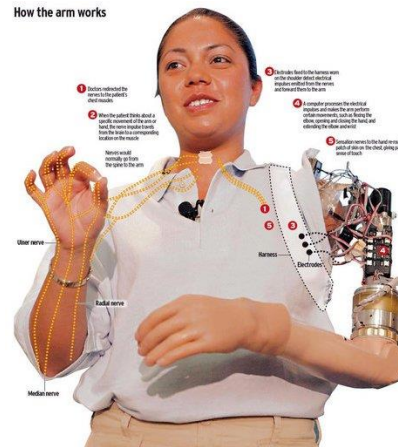
EEEN40350 Rehabilitation Engineering

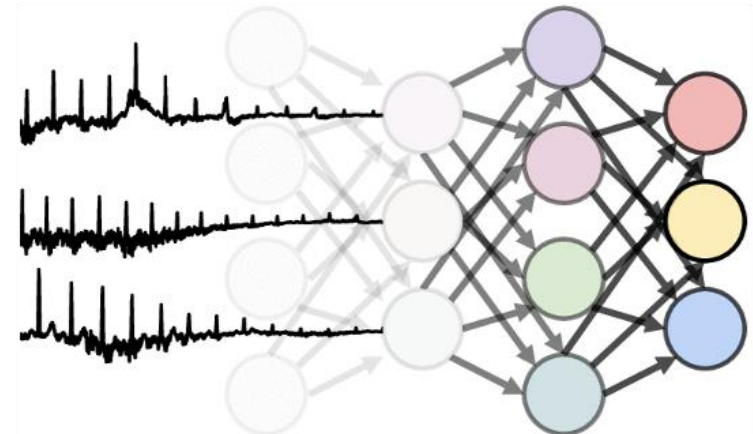# EEEN40720
Machine Learning for Engineers

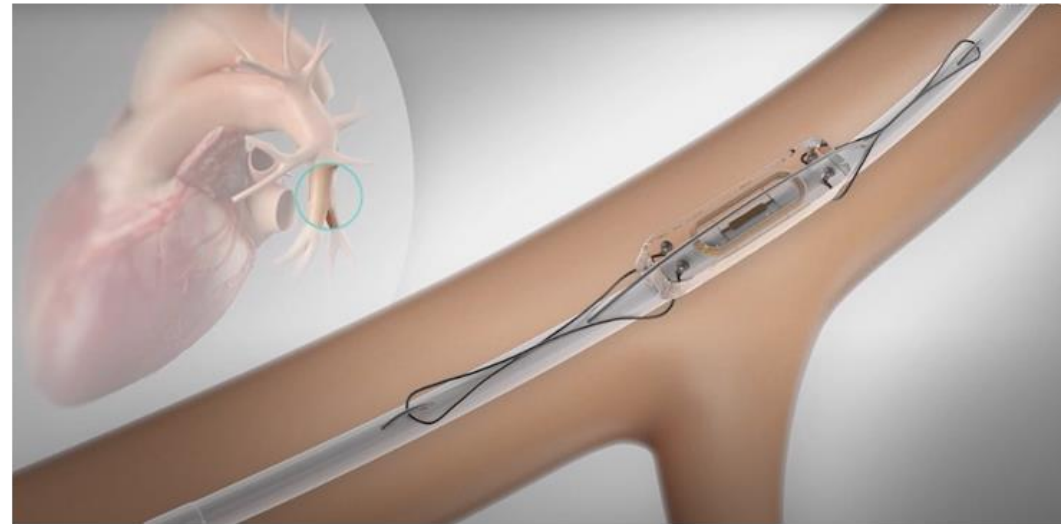Biomedical applications, e.g. Gait, ECG, Sleep

Understand how to apply ML methods to engineering problems.

Deep understanding of a range of machine learning algorithms.

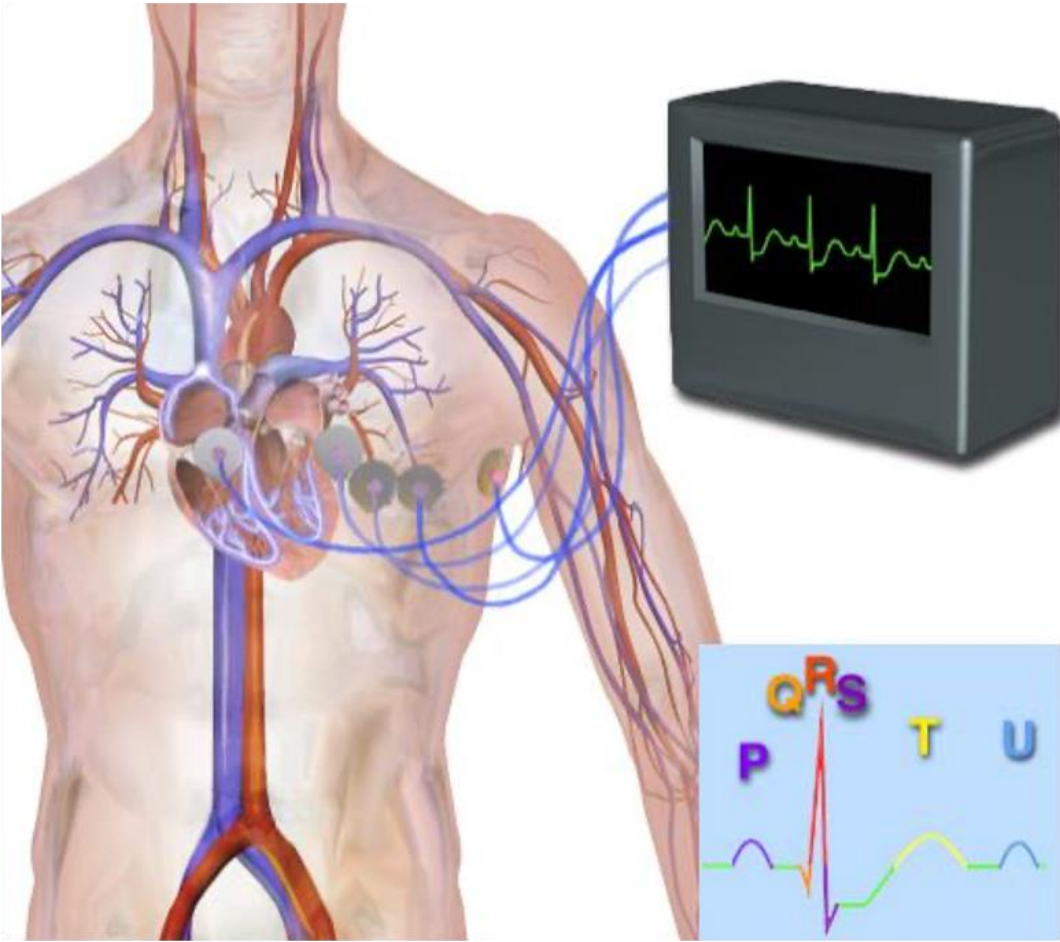**Best practice methods** in training, testing and evaluating ML models.

ActivPAL4 (LT and RT)

Fitbit Charge 4

R   L

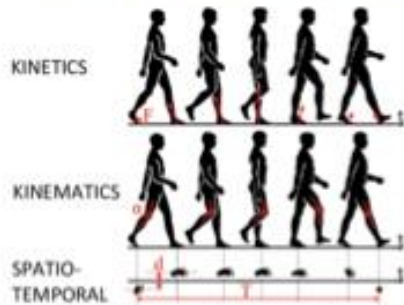ActiGraph GTX9 (LW, LS and RS)

EEEN30180 Bioinstrumentation

Wearable sensors:

EEEN40730 Biosensors & Actuators
EEEN40070 Neural Engineering
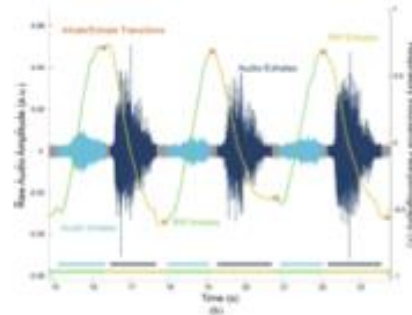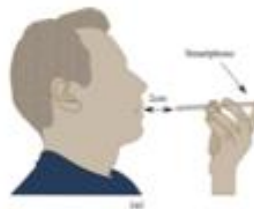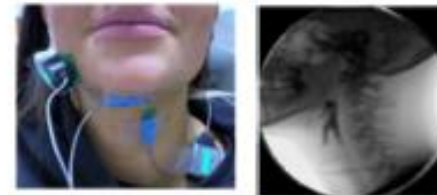**EEEN40720 Machine Learning for Engineers**
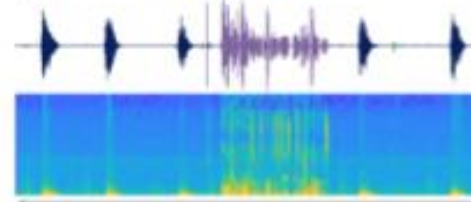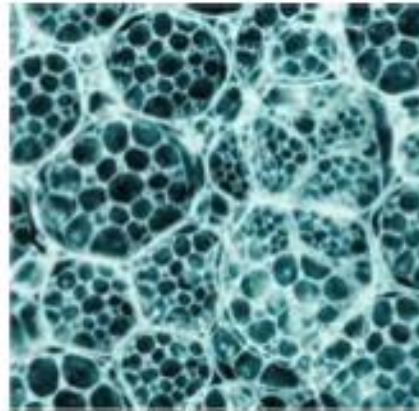
Biomedical Engineering at UCD: Biomechanics

Medical Device Design

Biomaterials

Biofluids

Movement Biomechanics
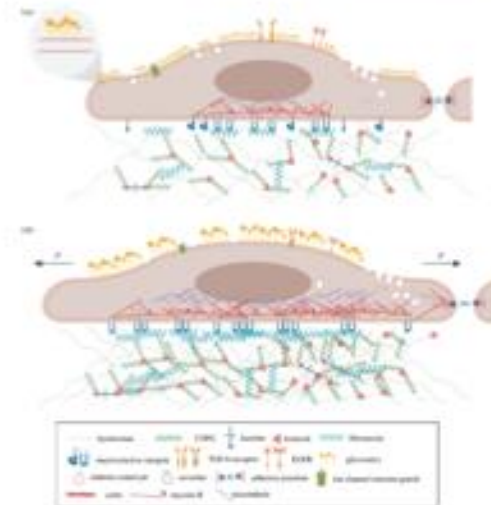
Tissue Biomechanics

MEEN40600 Medical Device Design
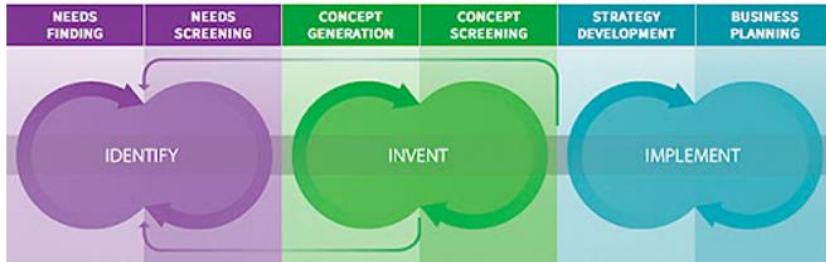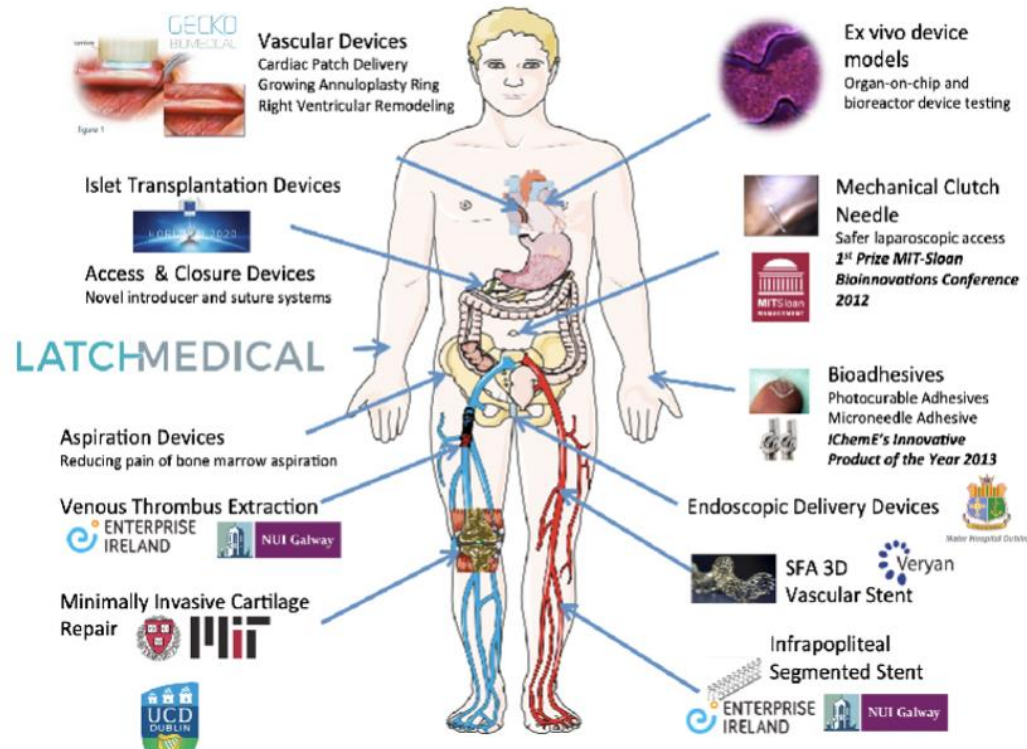
MEEN30160 Biofluids
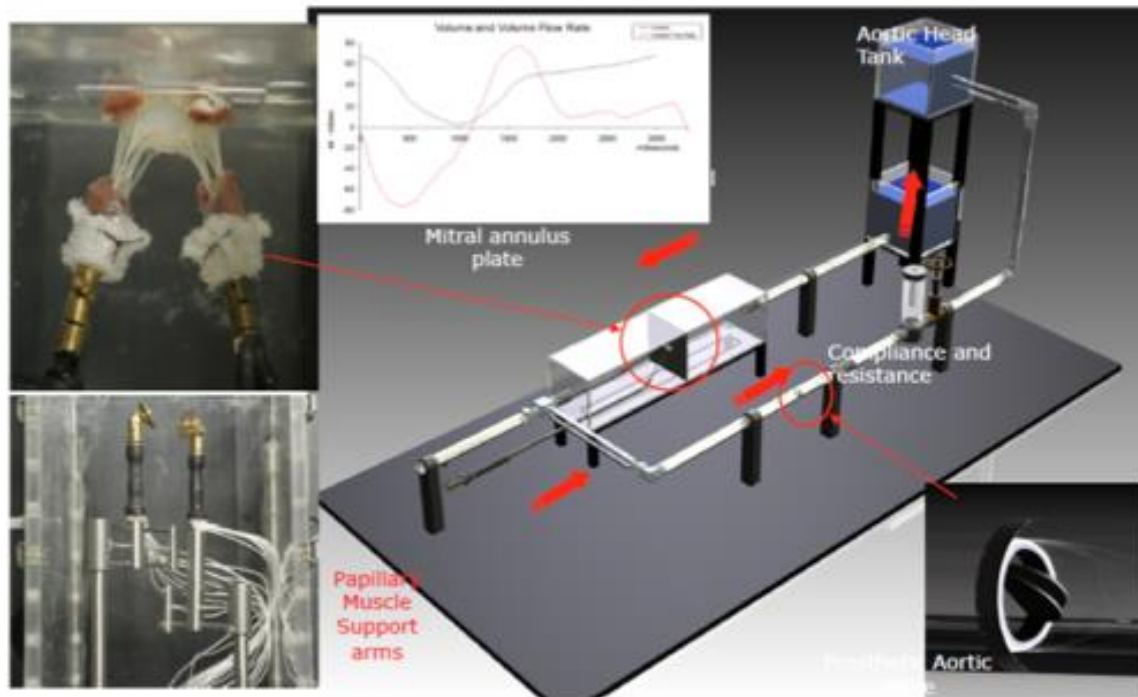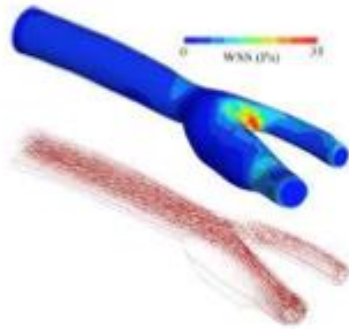
MEEN40620 Biomechanics
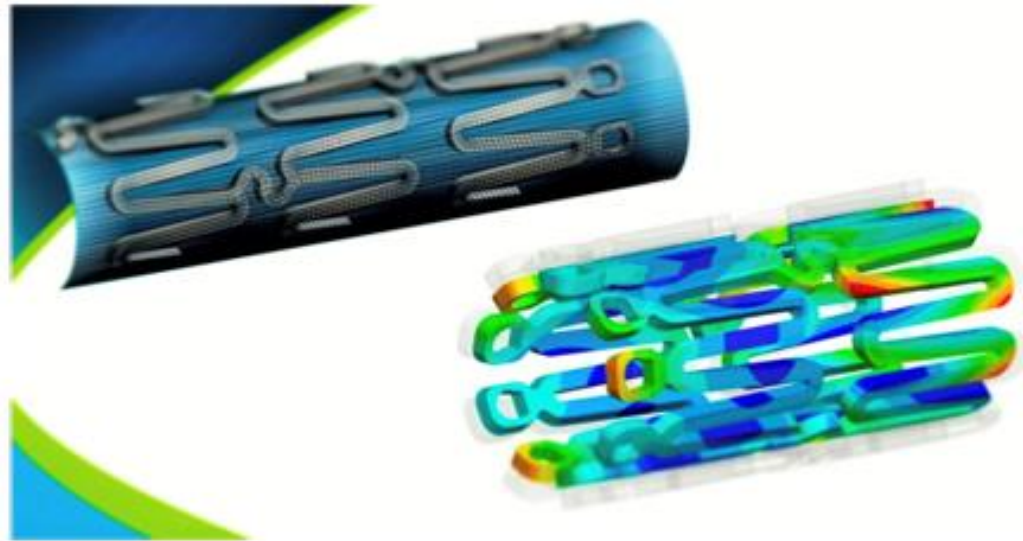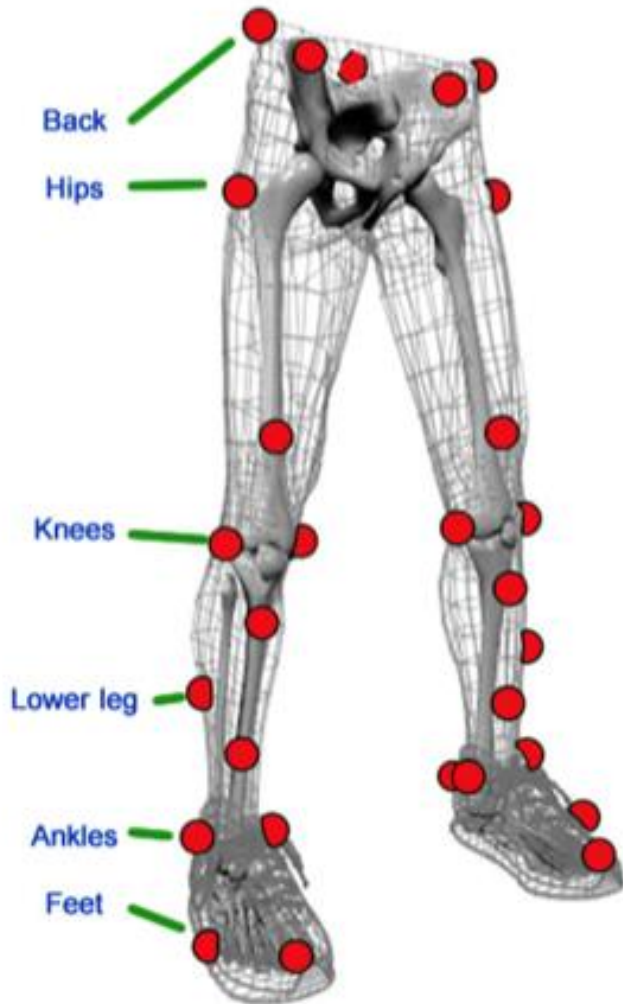
Irish Medtech
Association
Ibec

Ireland a global hub for Medtech
Sector employs over 40,000 people
14 of the world's top 15 medical technology
companies have a base in Ireland.

One of the top 5 global medtech hubs competing with the
likes of Massachusetts, Minnesota and California in the USA

Medtech is a driver of regional growth with major clusters
in Galway, Limerick, Cork, Waterford, Sligo and Dublin

https://www.irishmedtechassoc.ie/

https://www.idaireland.com/explore-your-
sector/business-sectors/medtech

Irish Medical Devices Association

- diagnostic
- hospital and/or homecare products
- Ophthalmic
- orthopaedic
- vascular
- contract research, development,
- connected health
- service

https://www.ibec.ie/connect-and-learn/industries/life-sciences-and-healthcare/medtech-strategy-2025

Defining Ireland's medical technology sector

Medical technology companies are defined as companies that:

- Design and/or manufacture medtech products and/or solutions, including software and hardware for healthtech.
- Manage significant international shared services from Ireland.
- Directly service the medtech sector.

The sector is diverse, and the following seven broad categories have been established to describe and the sector in Ireland:

1. Diagnostic

Devices or software used to identify a disease, condition, or injury.

2. Ophthalmic

Diagnosis and treatment of conditions relating to the eye.

3. Vascular/ Endovascular

Relating to the treatment of vascular disease.

4. Orthopaedic

Relating to the treatment of musculoskeletal system including muscles, bones, joints, ligaments, and tendons.

5. Hospital/ Homecare

Other segments of the market not captured here such as respiratory, surgical devices, minimally invasive devices and so forth.

6. Neurology

Concerning disorders and diseases of the nervous system including the brain and spinal cord, peripheral nerves and muscles.

7. Service

Outsourced function to a third party such as product development, design, manufacturer and generation of intellectual property.

https://www.ibec.ie/connect-and-learn/industries/life-sciences-and-healthcare/medtech-strategy-2025

Defining Ireland's digital healthtech sector

The digital healthtech sector in Ireland is diverse and the following nine broad headings have been established to describe and categorise the sector in Ireland. These categories broadly reflect solution types to offer a consistent view of digital health activity in Ireland.

1. Connected medical devices

Wearable and wireless medical devices; software driven diagnostic products; therapy delivery devices; biometric sensors.

2. Digital therapeutics

Software driven therapeutics.

3. Mobile health (mHealth) and wellness

Wellness, fitness trackers, nutrition and lifestyle apps; virtual health assistants; healthcare coaching.

4. Personalised healthcare

Precision medicine; personalised support, symptom management and interventions; Clinical decision support solutions.

5. Remote patient monitoring & telehealth

Remote patient monitoring solutions; medication adherence tools; telemedicine virtual visits and remote care programmes.

6. Health Information Technology (HIT)

Electronic medical record systems; electronic prescribing and order entry systems; consumer health IT applications

7. Connected care management

Care management platforms, staffing, and financial management solutions.

8. Data, analytics and cyber security

Patient data hosting; encryption and cyber security; AI and predictive analytics; digital biomarkers.
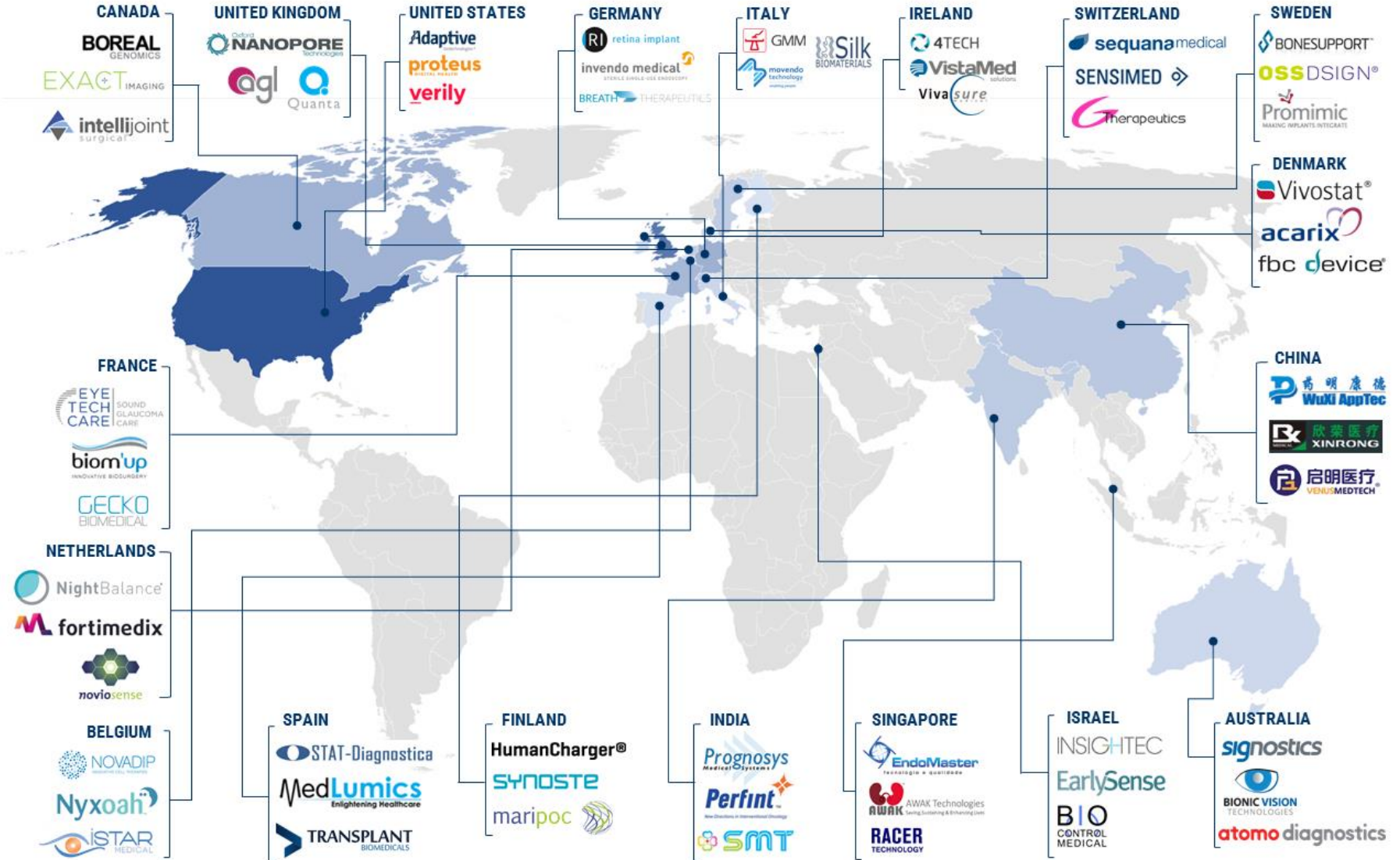
9. Technology solutions and infrastructure

ICT services and infrastructure; IoT solutions.

https://www.ibec.ie/connect-and-learn/industries/life-sciences-and-healthcare/medtech-strategy-2025

MOST WELL-FUNDED MEDICAL DEVICE COMPANIES ACROSS THE GLOBE

As of 5/4/17

CANADA
BOREAL GENOMICS
EXACT IMAGING
intellijoint surgical

UNITED KINGDOM
Oxford NANOPORE Technologies
agl
Quanta

UNITED STATES
Adaptive
proteus DIGITAL HEALTH
verily

GERMANY
RI retina implant
invendo medical STERILE SINGLE-USE ENDOSCOPY
BREATH THERAPEUTICS

ITALY
GMM
movendo technology
Silk BIOMATERIALS

IRELAND
4TECH
VistaMed solutions
Vivasure

SWITZERLAND
sequana medical
SENSIMED
G Therapeutics

SWEDEN
BONESUPPORT
OSSDSIGN
Promimic MAKING IMPLANTS INTEGRATE

DENMARK
Vivostat
acarix
fbc device

FRANCE
EYE TECH CARE SOUND GLAUCOMA CARE
biom'up INNOVATIVE BIOSURGERY
GECKO BIOMEDICAL

CHINA
药明康德 WuXi AppTec
欣荣医疗 XINRONG
启明医疗 VENUSMEDTECH

NETHERLANDS
NightBalance
fortimedix
noviosense

BELGIUM
NOVADIP
Nyxoah
iSTAR MEDICAL

SPAIN
STAT-Diagnostica
MedLumics Enlightening Healthcare
TRANSPLANT BIOMEDICALS

FINLAND
HumanCharger®
SYNOSTE
maripoc

INDIA
Prognosys Medical Systems
Perfint
SMT

SINGAPORE
EndoMaster
AWAK Technologies
RACER TECHNOLOGY

ISRAEL
INSIGHTEC
EarlySense
BIO CONTROL MEDICAL

AUSTRALIA
signostics
BIONIC VISION TECHNOLOGIES
atomo diagnostics

CB INSIGHTS

© DSAT for MSFT, GeoNames, Microsoft, Navteq, Thinkware Extract, Wikipedia

UCD Centre for Biomedical Engineering

UCD Biomedical Engineering

Questions?
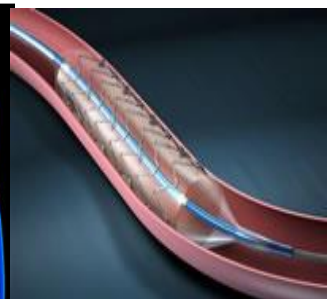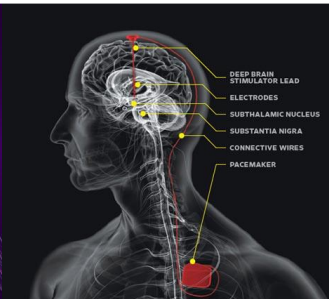
Biomedical Engineering Stream Stage 4

Stage 4					
Semester 1			**Semester 2**		
EEEN30170	BE Biomedical Project		EEEN30170	BE Biomedical Project	
MEEN40600	Medical Device Design		CHEN40470	Cell Culture & Tissue Eng	
MEEN40620	Biomechanics		EEEN40070	Neural Engineering	
EEEN30160	Biomedical Signals and Images		EEEN40350	RehabilitaBon Engineering	
MEEN40630	Biomaterials				
Plus 1 OpBon from :					
EEEN30110	Signals and Systems				
EEEN40010	Control Theory				
EEEN40050	Wireless Systems				
EEEN40300	Entrepreneurship in Engineering				
MEEN30030	Mechanical Engineering Design II				
MEEN30100	Engineering Thermodynamics II				
MEEN30140	Professional Engineering (Finance)				
MEEN40020	Mechanics of Fluids II				

Abdominal Aor@c Aneurysm Dr. Malachy O'Rourke

Predic'on of Thrombus Growth
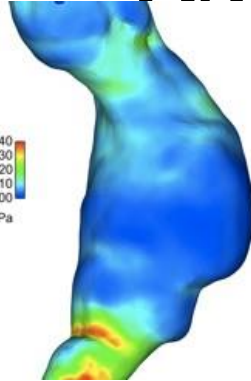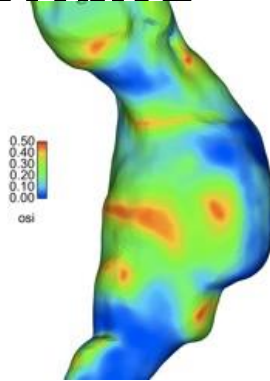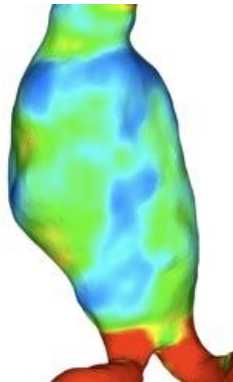
paBent A

paBent C
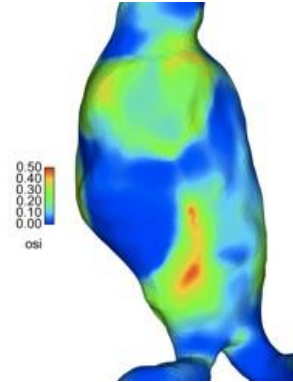
(leU) lumen wall, ini@al scan in blue and follow up scan in red; (middle) @me averaged wall shear stress; (right) oscillatory shear index

O'Rourke, M. J., McCullough, J. P. and Kelly, S.; (2012) 'An invesBgaBon of the relaBonship between hemodynamics and thrombus deposiBon within paBent--specific models of abdominal aorBc aneurysm'. *PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART H--JOURNAL OF ENGINEERING IN MEDICINE*, 226 (7):548--564.

CorrelaBon of cycle averaged wall shear stress (TAWSS) and oscillatory shear index (OSI) with regions of developed thrombus suggest that OSI may correlate with regions of thrombus deposiBon

$$OSI = \frac{1}{2}\left(1 - \frac{\left|\int_{0}^{T} \mathbf{T}_w \, dt\right|}{\int_{0}^{T} |\mathbf{T}_w| \, dt}\right)$$

Wound Healing

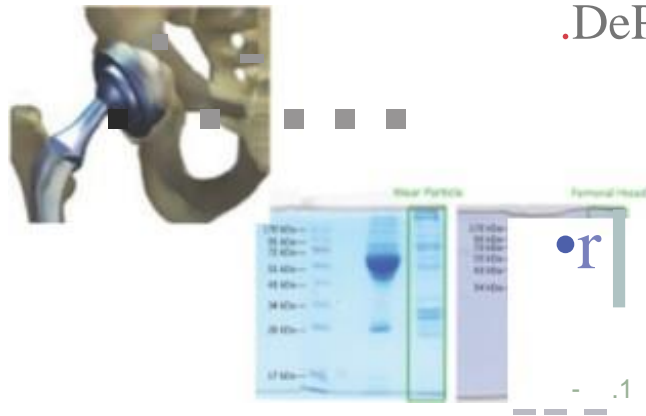**Cancer treatment**

Plasma Medicine
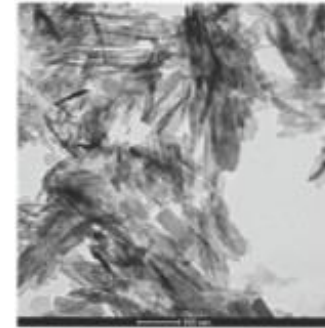
Prof. Denis Dowling

Surface Engineering Research Group

Biomedical Ceramics & Metals (K Stanton}

Orthopaedic and dentistry examples ...

Protein adsorption on wear particles

Nano-toughening for dental cements

.DeP_uy

•BIO

•r

.stryker

QUIN MARY
Q

Apatite-mullite glass-ceramic.s

Coating of Ti dental screws

In-vivo: rat femur

Fibrous capsule layer

Successful Osseointegration
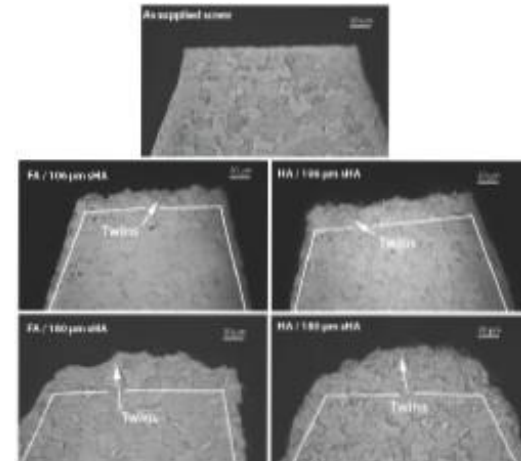
Glass
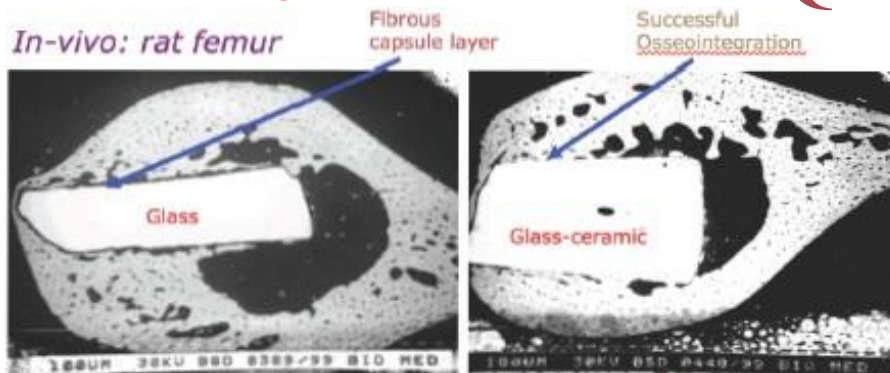
Glass-ceramic

C. O. Freeman, I.M. Brook, A. Johnson, P.V. Hatton, R.G. Hill, K.T. Stanton, " Crystallization modifies osteoconductivity in an apatite-mullite glass-ceramic", J. Mat Sci.: Materials in Medicine 14 (2003) 985-990

Deep Brain Stimulation

Implanted electrode

Subcutaneous wire

Implanted pulse generator (IPG)

© Medtronic, Inc. 2008

UCD Biomedical Engineering

Chemical Eng

Biotechnology for engineers

Cell and Tissue Eng

Neural Eng

Electronic & Electrical Eng

- Signal Processing
- Control theory
- Wireless systems
- CommunicaBon systems
- Computer engineering

Medical Device Design

Biosignal and Image Analysis

Biomechanics I & II

Rehabilitation Engineering

Biomaterials

Medical Sciences for Engineers

Biomedical Imaging

Mechanical Eng

- Dynamics
- Fluid mechanics
- Materials science
- Mechanical Design
- Mechanics of solids

Medical Sciences

- Anatomy
- Physiology
- Neurophysiology
- Cardiovascular Physiology
- Exercise science