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Course: Biomechanics

Semester 1 / Autumn **10 Credits**

Each Course is composed of Modules & Activities.

Modules:

Biomechanics basics	IMSc
Ultrasound – advanced	IMSc
Cardiovascular	IMSc

Each Module is composed of Lectures, Reading Lists, MCQ self-assessments, & Discussion Boards.

These Modules are taught on the following Programmes, or are incorporated into blended Courses which teach students enrolled outwith the Edinburgh Imaging Academy:

- IMSc - Imaging programme

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Course: Biomechanics

Modules include:

Biomechanics basics:
- Biomechanics introduction
- Biofluid dynamics

Ultrasound – advanced:
- Doppler Measurements
- 3D Ultrasound

Cardiovascular:
- Pressure and flow 1
- Pressure and flow 2
- Arterial stiffness
- Flow states and blood velocity
- Wall shear stress
- Biomechanics of cells, tissues and organs – mechanisms of ageing and disease
- Blood constituents and viscous behaviour
- Blood as a suspension of particles
- Endothelial mechanics and mechanotransduction
- Motivation
- Imaging-only methods
- Processing chain and simulation
- Patient specific modelling – part 1

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Biomechanics basics

Lecture 1
Title: Biomechanics introduction
Description: Cell, tissue & organ biomechanics
Author(s): Professor Peter Hoskins
Learning Objectives
- Define biomechanics
- Describe molecular biomechanics
- Describe cellular biomechanics
- Give an overview of constitutive equations
- Describe patient specific modelling
- Describe multi-scale modelling

Lecture 2
Title: Biofluid dynamics
Description: Definition, example and flow
Author(s): Definition, example and flow
Learning Objectives
- Define a fluid
- Describe static fluid: hydrostatic pressure
- Discuss moving fluid and shear force
- Define viscosity
- Explain tube flow
- Define the Reynolds number
- Explain different flow states

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Ultrasound – advanced

Lecture 1
Title: Doppler Measurements
Description: Measurement of blood velocity and waveform shape; waveforms in disease
Author(s): Professor Peter Hoskins
Learning Objectives

- Explain blood velocity measurement
- Explain the waveform shape
- Describe waveforms in disease
- Local disease (atherosclerosis)
- Downstream disease (placental disease)

Lecture 2
Title: 3D Ultrasound
Description: Acquisition of 3D data, STIC, visualisation of the data
Author(s): Professor Peter Hoskins
Learning Objectives

- List methods for 3D data acquisition
- Describe spatio-temporal image correlation (STIC)
- Discuss methods for visualisation of the data

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Cardiovascular

Lecture 1
Title: Pressure and flow 1
Description: Pressure and flow wave propagation; simple model of pressure, flow & resistance
Author(s): Prof Peter Hoskins
Learning Objectives
- Explain the Windkessel model
- Describe pressure and flow wave propagation
- Illustrate pulse wave velocity (PWV)
- Explain the Moens Korteweg equation

Lecture 2
Title: Pressure and flow 2
Description: Pressure and flow rate interpretation
Author(s): Professor Peter Hoskins
Learning Objectives
- Describe pressure and flow rate including:
    - Reflected waves
    - Effect of increase in stiffness on pressure waveform
    - Simple model of pressure, flow and resistance

Lecture 3
Title: Arterial stiffness
Description: Mechanics of the normal circulation
Author(s): Professor Peter Hoskins
Learning Objectives
- Explain arterial elasticity
- Examine arterial construction
- Describe stress-strain behaviour
- Describe the role & mechanical behaviour of elastin & collagen
- Define stiffness indices, material stiffness & structural stiffness
- Explain in vivo measurements of stiffness & pulse wave velocity

Lecture 4
Title: Flow states and blood velocity
Description: Flow states, blood velocity, velocity profiles, spiral flow
Author(s): Prof Peter Hoskins
Learning Objectives
- Explain flow states and blood velocity
- Describe laminar flow, turbulence, disturbed flow
- Analyse velocity profiles
- Interpret fully developed flow, inlet length
- Describe spiral flow

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Lecture 5
Title: Wall shear stress
Description: Mechanics of the normal circulation
Author(s): Prof Peter Hoskins
Learning Objectives
- Give an overview of wall shear stress
- Describe the control of wall shear stress
- Explain Murray's law
- Interpret in-vivo measurement of wall shear stress from wall shear rate
- Perform flow based methods
- Evaluate velocity based methods using ultrasound and MRI

Lecture 6
Title: Biomechanics of cells, tissues and organs – mechanisms of ageing and disease
Description: Stiffening of the arteries, athero-sclerosis and aneurisms
Author(s): Prof Peter Hoskins
Learning Objectives
- Describe the stiffening of the arteries
    - Ageing
    - Remodelling of arteries
- Explain atherosclerosis
    - Flow / velocity +/- stenosis and simple modelling
    - Initiation and progression
    - Plaque rupture
    - Role of wall shear stress (WSS) and of tissue stress
- Interpret aneurysmal disease
    - Observations on biology and mechanics

Lecture 7
Title: Blood constituents and viscous behaviour
Description: Blood constituents, red cell aggregation and deformation, viscous behaviour
Author(s): Prof Peter Hoskins
Learning Objectives
- Define blood constituents
- Explain viscosity as a function of shear rate
- Relate red cell characteristics and environment to aggregation and deformation
- Explain viscous behaviour in-vivo in major arteries
- Describe non-Newtonian flow

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Lecture 8
Title: Blood as a suspension of particles
Description: Blood as an inhomogeneous suspension of particles...
Author(s): Professor Peter Hoskins
Learning Objectives
- Define blood as an inhomogeneous suspension of particles
- Explain the Segre-Silberberg Fahraes Lindquist effect: i.e. red cell inhomogeneity in-vivo
- Explain particle-wall interactions
- List particles relevant to atherosclerosis
- Predict monocyte impaction using CFD
- Discuss current practice in modelling studies

Lecture 9
Title: Endothelial mechanics and mechanotransduction
Description: Vascular mechanotransduction
Author(s): Professor Peter Hoskins
Learning Objectives
- Define endothelial mechanotransduction
- Examine forces on endothelium
- Provide evidence for mechanotransduction
- Define a decentralised model of mechanotransduction
- Explore the physical deformation of the surface
- Explain intracellular transmission of forces
- Describe conversion of mechanical force to chemical force
- Show downstream biochemical signalling and feedback
- Demonstrate Smooth muscle cell mechanotransduction
- Examine arterioles - myogenic effect
- Explain arteries - hypertension

Lecture 10
Title: Motivation
Description: Motivation and imaging-only methods
Author(s): Professor Peter Hoskins
Learning Objectives
- Define motivation: the selection of patients for surgery
- Explain the role of biomechanical forces in normal physiology and disease progression
- Describe imaging-only measurement of mechanical quantities in arteries
- Discuss simple methods and applications in health and disease

Lecture 11
Title: Imaging-only methods
Description: Structural and molecular imaging techniques
Author(s): Professor Peter Hoskins
Learning Objectives
- Describe imaging-only methods used in simulation and image guided modelling

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Lecture 12
Title: Processing chain and simulation
Description: Processing chain, simulation, examples
Author(s): Professor Peter Hoskins
Learning Objectives
- Describe the processing chain
- Explain simulation
- Provide examples of use

Lecture 13
Title: Patient specific modelling - part 1
Description: Patient specific modelling; steps in the processing chain; imaging techniques
Author(s): Professor Peter Hoskins
Learning Objectives
- Define patient specific modelling
- Explain the steps in the processing chain
- Give an overview of imaging techniques