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Techniques and Physics

Semester 1 / Autumn **20 Credits**

Each Course is composed of Modules & Activities.

Modules:

Imaging Basics	NI4R	IMSc	AMIA	PETMR
CT Basics	NI4R	IMSc	AMIA	PETMR
MR Basics	NI4R	IMSc	AMIA	PETMR
Contrast Agents in Imaging	NI4R	IMSc	AMIA	PETMR
Ultrasound Basics		IMSc		PETMR
MR Spectroscopy Basics & advanced	NI4R		AMIA	PETMR
MR Diffusion Imaging	NI4R		AMIA	PETMR
Functional Imaging Basics	NI4R		AMIA	PETMR
SPECT & PET	NI4R	IMSc	AMIA	PETMR
Light Microscopy Basics		IMSc	AMIA	PETMR
Images – Fundamentals	NI4R	IMSc	AMIA	PETMR
MR dynamic techniques	NI4R	IMSc	AMIA	PETMR

- MR perfusion imaging
- MR permeability imaging

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:

- NI4R - Neuroimaging for Research programme
- IMSc - Imaging programme
- AMIA - Applied medical image analysis
- PET-MR - PET-MR principles & applications

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Techniques and Physics - Modules include:

Imaging Basics:

- History: past to present
- Terminology and orientation
- Anatomy basics
- Orientation to body imaging

CT Basics:

- CT Basics
- Grey scale perception – Technical
- Grey Scale Perception – Applications
- CT advanced techniques 1
- CT advanced techniques 2

MR Basics

MR Basics

- Physics
- T1 & T2
- Localisation
- k-Space

Contrast agents in Imaging

Contrast Agents in Imaging:

- CT Contrast Agents
- MR Contrast Agents
- Ultrasonic contrast agents

Ultrasound Basics:

- Introduction to Ultrasound Imaging
- Ultrasound Waves
- Basic beam formation
- Transducer basics
- Array transducers and beam forming 1
- Array transducers and beam forming 2

MR Spectroscopy Basics:

- Introduction
- Techniques

MR Spectroscopy Advanced:

- Advanced 1
- Advanced 2

MR Diffusion Imaging:

- MR Diffusion Imaging

MR Dynamic Techniques

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MR Permeability Imaging:
- MR Permeability Imaging

Perfusion Imaging:
- Basics
- Advanced

Functional Imaging Basics:
- Neurophysiology techniques
- Neurovascular techniques
- Applications: Linking Sensation to Spiking

SPECT & PET
- Physics
- Scanning

Light Microscopy Basics:
- Introduction into Light Microscopy

Images – Fundamentals:
- Imaging Systems
- Images
- Image Processing Basics
- Image Perception

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Further details of modules that may be within your Techniques and Physics course.

Imaging Basics

Lecture 1
Title: History: past to present
Description: Historical perspective through to modern imaging departments
Author(s): Dr. Andrew Farrall
Learning Objectives
- Outline the historical development of imaging
- List the techniques used in modern imaging departments
- Identify which techniques do or do not use ionizing radiation
- Distinguish between techniques which use ionizing radiation

Lecture 2
Title: Terminology and orientation
Description: Becoming familiar with how radiology looks at the body
Author(s): Dr. Andrew Farrall
Learning Objectives
- Use and interpret radiological orientations, directions and convention

Lecture 3
Title: Anatomy basics
Description: A look at common anatomical landmarks and features
Author(s): Dr. Andrew Farrall
Learning Objectives
- Identify common anatomical landmarks and features including:
- Anatomical landmarks of the head surface anatomy
- Skull features
- Lobes, fissures and sulci
- Grey and white matter
- Arterial supplies to the brain

Lecture 4
Title: Orientation to body imaging
Description: A look at common body imaging descriptors and features
Author(s): Dr. Michael Jackson, Dr. Andrew Farrall
Learning Objectives
- Recognise the three conventional anatomical planes: axial, coronal and sagittal as they relate to the body
- Appreciate the direct relevance of these planes to cross-sectional imaging
- Be aware of the concept of the anatomical position
- Understand the terms proximal and distal in different settings
- Be familiar with the meaning of the anatomical terms dorsal, ventral and cranio-caudal

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CT Basics

Lecture 1
Title: Computed Tomography Basics
Description: History, principles and practice
Author(s): Dr. Andrew Farrall
Learning Objectives
- Outline the historical development of scanners
- State the difference between generations of scanners
- Define "pitch" and collimation
- Describe attenuation in CT
- Outline back projection reconstruction
- Outline beam hardening artefact
- Discuss applications of modern CT techniques

Lecture 2
Title: Grey scale perception - Technical
Description: Physics and other relevant concepts behind the grey scale in radiology
Author(s): Dr. Andrew Farrall
Learning Objectives
- Describe the pathway of perception
- Explain radiological imaging and how it uses the grey scale to represent images

Lecture 3
Title: Grey Scale Perception - Applications
Description: How perceiving the grey scale has important clinical ramifications
Author(s): Dr. Andrew Farrall
Learning Objectives
- Describe how the human eye perceives contrast and brightness off grey scale images
- Explain factors which alter human perception of grey scale images
- Discuss the limitations of grey scale imaging

Lecture 4
Title: CT advanced techniques 1
Description: Maximum and minimum intensity projections
Author(s): Dr. Michael Jackson, Dr. Andrew J. Farrall
Learning Objectives
- Describe production of maximum (and minimum) intensity projection images
- Describe the effect of varying slice thickness on MIPs and MinIPs
- Explain the difference between intensity projection and windowing
- Demonstrate clinical uses for intensity projection images
- Describe the limitations of intensity projection images

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Lecture 5
Title: CT advanced techniques 2
Description: Multi-planar and 3D reconstructions
Author(s): Dr. Michael Jackson, Dr. Andrew J. Farrall
Learning Objectives

- Understand the role of multi-planar reformatting
- Discuss the advantages and limitations of 3D CT reconstructions
- Be aware of 3D editing techniques
- Name endoluminal visualisation techniques
- Understand differences between orthographic rendering and immersive perspective rendering
- Explain when 3D techniques are complementary to conventional imaging

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MR Basics

Lecture 1
Title: Physics
Description: Basic principles behind MR
Author(s): Dr. Paul Armitage, Dr. Andrew Farrall
Learning Objectives
- Describe "spin" and its relevance to Magnetic Resonance
- Explain the relevance of protons in MR
- Know the Larmor frequency equation
- Describe “relaxation”
- Define the “Free Induction Decay”
- Distinguish between T1 & T2

Lecture 2
Title: T1 & T2
Description: Using relaxation parameters in imaging
Author(s): Dr. Paul Armitage, Dr. Andrew Farrall
Learning Objectives
- Recognise different tissues have different T1 & T2 values
- Understand how the differences are exploited to generate image contrast
- Differentiate between T1 weighted & Proton Density weighted imaging
- Understand what T1 imaging is useful for clinically
- Understand T2 weighted imaging
- Understand what T2 imaging is useful for clinically
- Discuss how FLAIR & STIR imaging relate to each other
- Know why FLAIR & STIR imaging are used

Lecture 3
Title: Localisation
Description: Overview of how MR signal is associated with the point from which it originates
Author(s): Dr. Paul Armitage, Dr. Andrew Farrall
Learning Objectives
- Explain MR slice selection
- Describe how localization is performed in the MR image plane
- Recognise the difference between frequency and phase encoding
- State the difference between pixel and voxel

Lecture 4
Title: k-Space
Description: Relating raw MR data to the image we see
Author(s): Dr. Andrew Farrall, imaging provided by Dr. Trevor Carpenter
Learning Objectives
- Explain what information lies in k-space
- Describe how k-space relates to MR images
- State the role of the Fourier Transform
- List some common artefacts in MR images which result from errors and problems in k-space

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Contrast Agents in Imaging

Lecture 1
Title: CT contrast agents
Description: Contrast agent use, administration and phases
Author(s): Dr. Michael Jackson
Learning Objectives
- Outline the technical aspects of contrast use in CT
- Identify generic molecular structure of intravascular CT contrast agents
- Evaluate different methods by which IV contrast can be administered
- Demonstrate the importance of timing the image acquisition in relation to the contrast phase
- Recognise the variety of mechanisms by which contrast aids image interpretation

Lecture 2
Title: MR Contrast Agents
Description: Means and ways of altering tissue visibility in MR
Author(s): Dr. Andrew Farrall
Learning Objectives
- Define what permeability is
- Explain why permeability is interesting to measure in the brain
- Describe how contrast agent concentration can be estimated from the signal change measured following contrast agent administration
- Describe how blood-brain barrier permeability can be estimated from temporal measurements of contrast agent concentration
- Discuss the clinical application of MR permeability imaging to tumour investigation and other disorders

Lecture 3
Title: Ultrasonic contrast agents
Description: Definition, imaging and research
Author(s): Dr. Carmel Moran
Learning Objectives
- Define ultrasonic contrast agents composition and size
- Interpret the interaction of contrast agents in the ultrasound beam
- Evaluate contrast-specific imaging modalities
- Assess research in ultrasonic contrast agents

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Ultrasound Basics

Lecture 1
Title: Introduction to Ultrasound Imaging
Description: Introduction to ultrasound principles
Author(s): Prof. Peter Hoskins
Learning Objectives

- Identify main components of an ultrasound system
- Compare ultrasound to other imaging techniques
- Describe ultrasound imaging modes
- State what the main operation principle is of modern ultrasound systems

Lecture 2
Title: Ultrasound waves
Description: Ultrasound frequency, velocity, wavelength and wave phenomena
Author(s): Prof. Peter Hoskins
Learning Objectives

- Describe ultrasound characteristics such as frequency, velocity, and wavelength
- Discuss wave phenomena relevant to clinical use
- Explain phenomena of propagation of ultrasound through tissues

Lecture 3
Title: Basic beam formation
Description: Understanding ultrasound beam formation
Author(s): Prof. Peter Hoskins
Learning Objectives

- Outline the Huygens principle
- Describe ultrasound beam shapes
- Describe mechanical focussing
- Discuss non-linear propagation

Lecture 4
Title: Transducer basics
Description: Piezoelectric principle and components of a transducer
Author(s): Prof. Peter Hoskins
Learning Objectives

- Explain the piezoelectric principle
- Describe the components of a transducer

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Lecture 5
Title: Array transducers and beam forming 1
Description: Formation, focussing and steering of the beam using multi-element arrays
Author(s): Prof. Peter Hoskins
Learning Objectives
- Describe beam formation, focussing & steering
- Explain side lobes
- Outline focussing mechanisms
- Define apodisation

Lecture 6
Title: Array transducers and beam forming 2
Description: Formation, focussing and steering of the beam using multi-element arrays
Author(s): Prof. Peter Hoskins
Learning Objectives
- Describe phased array transducers
- Explain grating lobes
- Demonstrate high frame rate beam formation
- Discuss transducers for 3D imaging

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MR Spectroscopy Basics

Lecture 1
Title: Introduction
Description: MR review, & comparison of MR Spectroscopy with MR Imaging
Author(s): Dr. Katherine Lymer
Learning Objectives

- Review MR slice selection and understand its relevance to MR spectroscopy (MRS)
- Explain why good signal-to-noise (SNR) in MRS is critical
- Outline how SNR is optimised in MRS
- Define shimming
- Describe water suppression
- Explain why water suppression is important

Lecture 2
Title: Techniques
Description: Generating spectra; identifying metabolites; clinical applications
Author(s): Dr. Katherine Lymer
Learning Objectives

- Know available nuclei for MRS
- Name common localisation sequences
- Describe Chemical Shift Imaging (CSI)
- Name major metabolites of interest in MRS
- Identify major components of an MR spectrum
- Know applications of MRS in stroke

MR Spectroscopy – Advanced

Lecture 1
Title: Advanced 1
Description: Chemical Shift Imaging & 2D Spectroscopy
Author(s): Dr. Kristin Haga
Learning Objectives

- Understand the limitations of traditional 1D, 1H MRS
- Describe “Chemical Shift Imaging” and list a couple of its applications
- Discuss some of the other (non 1H) nuclei that can be used in MRS studies
- Explain what is meant by “J-coupling” in 2D MRS
- Consider some of the advantages and limitations of advanced MRS methods

Lecture 2
Title: Advanced 2
Description: Multi-nuclear spectroscopy & applications of spectroscopy
Author(s): Dr. Kristin Haga
Learning Objectives

- Discuss some of the other (non 1H) nuclei that can be used in MRS studies
- Understand applications of spectroscopic techniques in clinical situations

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MR Diffusion Imaging

Lecture 1
Title: MR Diffusion Imaging
Description: Principles, techniques & applications
Author(s): Dr. Mark Bastin
Learning Objectives
- Define diffusion
- Describe how MR is sensitised to diffusion
- Describe what affects diffusion in vivo
- Explain why fast imaging is needed
- Describe diffusion anisotropy
- List some clinical applications of diffusion MR imaging

MR Permeability Imaging

Lecture 1
Title: MR Permeability Imaging
Description: Imaging endothelial permeability
Author(s): Dr. Paul Armitage
Learning Objectives
- Define what permeability is
- Explain why permeability is interesting to measure in the brain
- Describe how contrast agent concentration can be estimated from the signal change measured following contrast agent administration
- Describe how blood-brain barrier permeability can be estimated from temporal measurements of contrast agent concentration
- Discuss the clinical application of MR permeability imaging to tumour investigation and other disorders

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Perfusion Imaging

Lecture 1
Title: Basics
Description: Basic principles of MR perfusion imaging
Author(s): Dr. Trevor Carpenter
Learning Objectives

- Define the Central Volume Principle (CVP)
- Describe Contrast Bolus tracking
- Outline the principles of how MR signal is converted to concentration
- List the relative perfusion measures and how they are obtained
- Distinguish between:
    - Cerebral Blood Volume (CBV) and relative CBV
    - Mean Transit Time (MMT) and relative MTT
    - Cerebral Blood Flow (CBF) and relative CBF
- Name some applications of perfusion imaging and outline its role in studying disease

Lecture 2
Title: Advanced
Description: Advanced principles of MR perfusion imaging
Author(s): Dr. Trevor Carpenter
Learning Objectives

- Understand the how the CVP is related to the residue function
- State the process the residue function describes
- Describe the difference between quantitative and relative measures
- Explain a basic approach to quantification
- State the assumptions this approach makes

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Functional Imaging Basics

Lecture 1
Title: Neurophysiology techniques
Description: Magnetoencephalography (MEG) & Electroencephalography (EEG)
Author(s): Dr. David McGonigle
Learning Objectives
- Discuss the relative strengths and weaknesses of MEG and EEG

Lecture 2
Title: Neurovascular techniques
Description: Principles of Positron Emission Tomography and functional Magnetic Resonance Imaging in assessing function
Author(s): Dr. David McGonigle
Learning Objectives
- Discuss the relative strengths and weaknesses of neurovascular techniques as tools for functional neuroimaging

Lecture 3
Title: Applications: Linking Sensation to Spiking
Description: Applying functional imaging techniques to detection of sensory processing
Author(s): Dr. David McGonigle
Learning Objectives
- Describe how physical stimuli are coded by the brain
- Outline the use of functional imaging to detection of sensory processing

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SPECT & PET

Lecture 1
Title: Physics
Description: Basic principles behind SPECT
Author(s): Prof. Jonathan Best
Learning Objectives

- Define what a radionuclide is
- Compare and contrast SPECT and PET
- Identify the differences between radionuclide effective halflife, physical half-life and biological half-life
- Name three radionuclides commonly used in SPECT
- Describe the basic components of a gamma camera
- Discuss why collimation is important in SPECT
- Name at least three methods of image reconstruction
- Discuss how SPECT compares to other imaging modalities in terms of spatial resolution, sensitivity and observational time

Lecture 2
Title: Scanning
Description: Applications of SPECT imaging
Author(s): Prof. Jonathan Best
Learning Objectives

- Outline why Cerebral Blood Flow is used as a proxy marker for brain metabolism
- Describe what is meant by biodistribution and understand how it affects to radiation dose
- Describe how Statistical Parametric Mapping is used in SPECT
- Identify what the major differences are between dementias when investigated by SPECT

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Light Microscopy Basics

Lecture 1
Title: Introduction into Light Microscopy
Description: Basics of optics and essentials of basic and advanced light microscopy
Author(s): Dr. Rolly Wiegand
Learning Objectives

- Discuss the power of light microscopy techniques
- Describe the historical evolution of light microscopes
- State the basics of optics
- Differentiate between essentials of light microscopy and advanced optical technologies

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Images – Fundamentals

Lecture 1
Title: Imaging systems
Description: The imaging process, PSF, deconvolution, artefacts & noise
Author(s): Prof. Peter Hoskins
Learning Objectives
- State the imaging process
- Define ‘imaged quantity’ & point spread function
- Describe the imaging process
- Discuss deconvolution and artefacts
- Compare random noise & structured noise (speckle)
- Demonstrate the detection of lesions
- Illustrate effects of contrast, noise, spatial resolution

Lecture 2
Title: Images
Description: Digital image formation, key features; spatial/intensity resolution, resizing and brightness/contrast control
Author(s): Dr. Tom MacGillivray
Learning Objectives
- Describe how a digital image is formed
- Identify the key features of digital images
- Explain spatial and intensity resolution
- Outline how a digital image is resized
- Define brightness and contrast

Lecture 3
Title: Image processing basics
Description: Purpose, key operations, 3D visualisation of medical data and image registration
Author(s): Dr. Tom MacGillivray
Learning Objectives
- Outline the purpose of digital image processing
- Identify key image processing operations
- Differentiate between global & neighbourhood operations
- Describe 3D visualisation of medical image data
- State how image registration is implemented

Lecture 4

Title: Image perception
Description: Anatomy of the eye and vision performance
Author(s): Prof. Peter Hoskins
Learning Objectives
- Define the relevant anatomy of the eye

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- Compare night and day vision
- Demonstrate log response in brightness discrimination
- State the adaptation range and Weber ratio
- Specify grey level discrimination
- Describe mach bands edge enhancement
- Describe the point spread function of the eye
- Evaluate a model of image perception