MEDICAL IMAGING SCIENCES AND APPLICATIONS
HST.565; Tue, Thu 4:30pm-6:00pm; Lecture Zoom Link: **Course Zoom Link**
Course Directors: Georges El Fakhri, PhD ; Moses Q. Wilks, PhD (MWilks@mgh.harvard.edu)

Week	Date	Suggested Literature	Description
1	Thur 9/8/2022	SC12 Chp. 1, 15	Introduction to molecular imaging (**Georges El Fakhri**)

Covers types of imaging modalities used in medicine (MRI, US, PET, SPECT, CT) providing an overview of the applications in medical imaging and how they complement each other (i.e. what does MRI do that CT does not and v.v., what does PET do and SPECT cannot and v.v.; these are covered at an application level, where advantages/disadvantages are mentioned from a pathology detection perspective).

Week	Date	Suggested Literature	Description
2	Tues 9/13/2022	SC12 Chp. 3, 4, 6	Radioactive Decay, Particle Interactions, Dose and Exposure (**Moses Wilks**)

Covers the basics of nuclear physics, and implications from exposure to radiation.

Week	Date	Suggested Literature	Description
2	Thur 9/15/2022	SC12 Chp. 13, 14	Radiation detectors, Counting Statistics I (**Hamid Sabet**)

Covers the physics of radiation detection and different types of detectors (gas, semiconductors and scintillators), as well as the basics of counting statistics.

Week	Date	Suggested Literature	Description
3	Tues 9/20/2022	SC12 Chp. 13, 14	Radiation detectors, Counting Statistics II (**Hamid Sabet**)

Covers types of radiation detector systems (PMT, monolithic crystals, solid state, pixelated crystals) and their applications to imaging systems, event positioning algorithms (advantages and disadvantages, and possibility for improvement), how the physical properties and (mechanical) design of crystals provides potential for the improvement of image quality.

Week	Date	Suggested Literature	Description
3	Thur 9/22/2022	SC12 Chp. 16	Introduction to Tomographic Imaging (**Moses Wilks**)

Covers topics in transmission tomography imaging, such as the mathematics of computed tomography (parallel, fan-beam, and cone-beam integral transforms), analytic reconstruction algorithms (FPB, FBP, etc.).

Week	Date	Suggested Literature	Description
4	Tues 9/27/2022	SC12 Chp. 17, MW04 Chp.7 & 2,	Single Photon Emission Computed Tomography (**Hamid Sabet**)

Covers topics in SPECT acquisition such as artifacts during acquisition (e.g. center-of-rotation artifacts), and principles of collimation (compatibility with radiotracer, collimator-detector response compensation including intrinsic response, geometric response, and septal penetration/scatter response), flood-field uniformity correction, attenuation &, scatter correction, and partial voluming.

Week	Date	Suggested Literature	Description
4	Thur 9/29/2022		Problem Set I (**Staff**)

Review of problem set 1.

| 5 | Tues 10/4/2022 | SC12 Chp. 18 | Positron Emission Tomography I (**Nicolas Guehl**) |

Topics on the fundamentals of Positron Emission Tomography.

| 5 | Thur 10/6/2022 | SC12 Chp. 18 | Positron Emission Tomography II (**Georges El Fakhri**) |

Expanded topics on PET Imaging Acquisition and Corrections

| 6 | Tues 10/11/2022 No Class | | Indigenous Peoples Day |

| 6 | Thurs 10/13/2022 | SC12 Chp. 21 | CT: Analog, Digital, Dual Energy, and Proton (**Bill Worstell**) |

Covers physical principles of X-ray computed tomography (Hounsfield units, types of acquisitions, detectors, etc.), artifacts arising from the physics of CT (beam hardening, low-dose), and artifact correction methods

| 7 | Tues 10/18/2022 | | Problem Set II (**Staff**) |

Review of problem set 2

| 7 | Thur 10/20/2022 | Handouts | Iterative Tomographic Reconstruction (**Kuang Gong**) |

Covers the Bayesian framework under which iterative tomographic reconstruction is interpreted (this includes a detailed explanation of Expectation Maximization), followed by a presentation of the MLEM algorithm, and continued by an introduction to maximum a posteriori (MAP) methods of image reconstruction (modeling of the prior distribution, anatomical priors, bias on the solution, penalty/regularization term in optimization).

| 8 | Tues 10/25/2022 | Handouts | Radiochemistry for Molecular Imaging I (**Pedro Brugarolas**) |

Covers fundamentals of radiochemistry, and a survey of radiochemistry techniques with regards to specific radiotracers and their clinical/experimental applications

| 8 | Thurs 10/27/2022 | Handouts | Radiochemistry for Molecular Imaging I (**Pedro Brugarolas**) |

Continued from 10/25

| 9 | Tues 11/1/2022 | | Midterm Exam (**Staff**) |

Covers topics from lectures up to 10/20/2022

| 9 | Thur 11/3/2022 | Handouts | Kinetic Modeling of Physiologic Data I (**Nicolas Guehl**) |

Covers compartmental modeling kinetics, applications to PET and SPECT imaging

| 10 | Tues 11/8/2022 | Handouts | Kinetic Modeling of Physiologic Data II (**Marc Normandin**) |

Covers compartmental modeling kinetics, applications to PET and SPECT imaging

| 10 | Thurs 11/10/2022 | | Clinical PET (**Thomas Ng**) |

Covers common uses of PET in clinical practice, including common tracers, diseases, and complications of clinical interest.

| 11 | Tues 11/15/2022 | Handouts | Magnetic Resonance Imaging I (**Jonghye Woo**) |

Covers topics in MR physics (magnetization, relaxation, Bloch equations), signal detection concepts, basics of multi-dimensional MR Imaging (slice selection, phase and frequency encoding).

| 11 | Thur 11/17/2022 | ZPL99 JP10 DWM07 | Magnetic Resonance Imaging II (**Chao Ma**) |

Covers topics on interpretation of k-space, signal in k-space, sampling and aliasing, signal/contrast/noise, and basics of acquisition (spin echo, gradient echo).).

| 12 | Tues 11/22/2022 | | Problem Set III |

Review of Problem Set 3

| 12 | Thur 11/24/2022 | | Thanksgiving |

No Class

| 13 | Tues 11/29/2022 | Handouts | Ultrasound Imaging (**Viksit Kumar**) |

Topics in ultrasound elastography will be discussed, the physical basis and clinical context in which this technology is applied, through the framework of precision medicine for diffuse liver disease.

| 13 | Thurs 12/1/2022 | Handouts | Optical Imaging and Immunotherapy (**Satoshi Kashiwagi**) |

Covers topics in optical fluorescence imaging and immunotherapy using near-infrared fluorescence imaging devices and targeted contrast agents.

| 14 | Tues 12/6/2022 | Handouts | Nanomedicine: Small Molecules to Nanoparticles (**Kai Bao & Homan Kang**) |

Covers topics in design and applications of targeted contrast agents ranging from small molecules to nanoparticles for nanomedicine and image-guided surgery.

14	Thurs 12/8/2022	Image Guided Brain Therapies (**Emiliano Santarnecchi**)

Covers methods and techniques for noninvasive brain stimulation (NIBS) including transcranial electrical and magnetic stimulation. The integration of NIBS with neuroimaging data (e.g., PET, MRI, fMRI, DTI) for image-guided therapeutics, and with electrophysiology (e.g. EEG, MEG) for closed-loop neuromodulation, are discussed in the context of both cognitive enhancement and clinical applications in the fields of neurology, psychiatry and neuro-oncology..

15	Tues 12/13/2022	Problem Set IV & Multimodality Imaging (**Moses Wilks**)

Review of Problem Set IV & Covers topics in multi-modality imaging such as challenges in simultaneous acquisition (providing an overview of state of the art image registration methods that may be used to fuse the modalities), and hybrid imaging for PET/MR and PET/CT comparing advances in each modality

16	Tues 12/20/2022	Final Exam (**Staff**)

Covers material from all lectures – Held in lecture hall from 4:30-6

Bibliography

SC12: Simon Cherry, Physics in Nuclear Medicine, 2012
MW04: Miles Wernick, Emission Tomography: The Fundamentals of PET and SPECT, 2004
ZPL99: Zhi-Pei Liang, Paul C. Lauterbur, Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, 1999
JP10: Jerry Prince, Jonathan Links, Medical Imaging Signals and Systems, 2010
DWM07: DW McRobbie, EA Moore, MJ Graves, MR Prince, MRI from Picture to Proton, 2007