MSC1088H: Fundamentals of Brain Positron Emission Tomography

COURSE INFO

Course Date/Time: *Sep 9, 2025 – Nov 28, 2025, Tuesday and Fridays, 2 p.m. to 3 p.m.*
Course Location: *In person*
Course Credit: *0.5 FCE*
Prerequisites: Students should have some fundamental background understanding of neuroscience, molecular biology, organic chemistry, and exponential functions.
Exclusions: N/A
Course Drop Deadline:
(Standard deadlines for 0.5 and 1.0 FCE courses can be found on the School of Graduate Studies (SGS) Calendar (link: https://sgs.calendar.utoronto.ca/sessional-dates))

CONTACT INFO

Course Director
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Course Lecturers:
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Individual office hours available upon request.

GENERAL INFO

Target Audience:
Graduate students whose research involves positron emission tomography (PET) imaging or radiochemistry, or graduate students with an interest in nuclear imaging or neurosciences.

Course Description:
PET is an important tool for early disease detection, understanding of molecular aspects of brain function, and evaluating medical treatment. This course reviews the fundamental concepts of PET imaging and explores its applications in brain research and drug development. Taught by a

multidisciplinary team—chemists, physicists, imaging scientists, and clinician scientists—the course provides insights from experts actively engaged in various aspects of PET brain imaging. Their research spans from furthering our understanding of healthy brain function, to studying brain disorders, such as schizophrenia, mood disorders, addictions, neurodegenerative diseases, and movement disorders.

This course will explore specific topics in the context of addressing fundamental research questions. Key areas of focus include: (1) the chemistry of labelling compounds with short-lived positron-emitting radionuclides; (2) the design of PET radiopharmaceuticals and their influence on PET data interpretation, including labelling position, metabolism, the distinction between drugs and radioligands; (3) cyclotron principles; (4) PET physics and instrumentation; (5) PET data analysis and quantification; and (6) the applications of PET in brain research and drug development.

Course Objectives:

After completion of this course, students will be able to:

1. Understand the basics of all scientific aspects involved in PET imaging research
2. Evaluate and discuss relevant literature and emerging research in the field of PET neuroimaging
3. Apply this knowledge to examine molecular mechanisms of both normal neurophysiology and disease progression, from both scientific and clinical perspectives

Requirements:

Students will be required to attend a hands-on workshop at CAMH using software available on computers hosted at the Brain Health Imaging Centre (250 College St).

Location:

All classes will be held at CAMH (250 College St).

<u>From Sep 9 until Oct 7</u> classes will be held in <u>room 853 on Tuesdays</u>, and <u>room 801 on Fridays</u>.

<u>From Oct 14 onwards</u> classes will be held in <u>room 801 on Tuesdays and Fridays</u>.

SYLLABUS

Format:

The 12-week course includes two lectures (1 hour each) per week and will be divided into two parts. In the first part, the Course Coordinators will deliver foundational lectures to establish core concepts. The last weeks will feature guest lectures delivered by experts in the subject matter, each followed by discussions linking the lecture content to previous sessions and the broader discipline. Students will play an active role in these sessions by chairing the guest lectures and leading the discussions.

Class	**Date**	**Topic** Description:	**Instructor**
Week 1, lecture 1	Sep 9, room 853	***Course introduction & PET overview*** Learning objectives: 1. Understand the fundamental principles of PET imaging. Explain the basic physics behind positron emission and annihilation. Explain the process of coincidence detection. 2. Understand PET instrumentation and data acquisition. Identify key components of a PET scanner, including detectors and scintillation materials. Outline the steps involved in data acquisition. 3. Define dynamic and static PET scans and explain their respective advantages and applications.	Prof. Kimberly Desmond
Week 1, lecture 2	Sep 12, room 801	***PET image reconstruction & general applications*** Learning objectives: 1. Explore PET image reconstruction methods. Explain the key image reconstruction techniques in PET (i.e., analytical [FBP] and iterative methods [OSEM, ML-EM]). 2. Describe how reconstruction algorithms affect image quality, resolution, and quantitative accuracy. 3. Discuss the general applications of PET in neuroscience.	Prof. Kimberly Desmond
Week 2, lecture 1	Sep 16, room 853	***Radionuclide production and radiolabelling*** Learning objectives:	Prof. Emily Murrell

		1. Understand the basic working principles of cyclotron operation and radionuclide production. Identify key cyclotron-produced isotopes (e.g., [^{11}C], [^{15}O], [^{18}F]) and their physical properties. Discuss the challenges of producing short-lived positron-emitting radionuclides. 2. Explore the chemistry of radiolabeling. Describe the process of incorporating PET isotopes into biologically relevant molecules. Explain the key considerations in radiolabeling (e.g., half-life, binding specificity, and stability). 3. Compare common labeling strategies for different radionuclides (e.g., nucleophilic vs. electrophilic fluorination for [^{18}F]).	
Week 2, lecture 2	Sep 19, room 801	***PET radiochemistry*** Learning objectives: 1. Recognize quality control and regulatory considerations in PET radiochemistry. Outline the key quality control tests for PET radiopharmaceuticals (e.g., purity, sterility, specific activity). 2. Discuss good manufacturing practices (GMP) and regulatory requirements for clinical PET tracers. 3. Explain the importance of radiochemical yield, molar activity, and tracer validation in PET imaging studies.	Prof. Emily Murrell
Week 3, lecture 1	Sep 23, room 853	***Ligand design for PET brain imaging*** Learning objectives: 1. Recognize the principles of target selection for PET radiotracers. Describe the molecular and physiological considerations for selecting targets (e.g., receptor density, enzyme activity, transport mechanisms). 2. Outline the steps in developing a new PET ligand, including affinity, selectivity, and metabolism studies.	Prof. Chao Zheng

		3. Compare the properties of [^{18}F]- and [^{11}C]-labeled tracers, including advantages and limitations of each isotope	
Week 3, lecture 2	Sep 26, room 801	***Ligand evaluation for PET brain imaging*** Learning objectives: 1. Discuss key preclinical and clinical evaluation methods, including in vitro binding assays, pharmacokinetics, and imaging validation. 2. Discuss common PET targets in neuroscience, such as neurotransmitter receptors, enzymes, and synaptic proteins. ***3.*** Explain how PET imaging contributes to understanding neurodegenerative and psychiatric disorders (e.g., Alzheimer's, Parkinson's, schizophrenia, depression). Describe radiotracers used for imaging synaptic density (e.g., [^{11}C]UCB-J, [^{18}F]SynVesT-1).	Prof. Chao Zheng
Week 4, lecture 1	Sep 30, room 853	***Small animal imaging*** Learning objectives: 1. Describe the principles and challenges of PET imaging in small animals (e.g., rodents, non-human primates). 2. Explain the importance of preclinical PET studies in ligand development and pharmacokinetics. 3. Describe the use of PET in imaging neuroinflammation (e.g., TSPO tracers for microglial activation).	Prof. Amy Boyle
Week 4, lecture 2	Oct 3, room 801	***Clinical translation*** Learning objectives: 1. Outline the key steps in translating a radiotracer from preclinical studies to human use. Explain the role of first-in-human studies. 2. Discuss factors affecting radiotracer performance in humans (e.g., metabolism, blood-brain barrier permeability, and off-target binding).	Prof. Amy Boyle

		3. Discuss the role of PET in oncology, including tumor metabolism (e.g., [^{18}F]FDG PET) and receptor-targeted tracers for cancer diagnosis and treatment monitoring.	
Week 5, lecture 1	Oct 7, room 853	***Advanced PET image processing*** Learning objectives: 1. Understand key PET data processing techniques. Explain the role of normalization, co-registration, and segmentation, in PET image analysis. 2. Describe atlas-based time-activity curves extraction from volumes-of-interest. Describe methods for motion correction (between- and intra-frame) and their impact on data quality. 3. Define partial volume effects (PVEs) and explain their impact on PET quantification, particularly in small brain structures or aging populations. Describe PVE correction methods (e.g., anatomical constraints from MRI and deconvolution approaches).	Prof. Carme Uribe
Week 5, lecture 2	Oct 10, room 801	***Emerging PET radiotracers*** Learning objectives: 1. Explain the principles of PET imaging of neurotransmitter systems (e.g., dopamine, serotonin, glutamate) and receptor binding. 2. Discuss current and emerging radiotracers targeting neurotransmitter receptors and transporters. 3. Explore novel PET targets and their potential applications in studying brain function, neurodegeneration, and psychiatric disorders.	Prof. Carme Uribe
Week 6, lecture 1	Oct 14, room 801	***PET (semi)quantification*** Learning objectives: 1. Recognize key corrections needed for quantification in PET imaging, including decay and attenuation corrections. Explain how these corrections impact image quality and quantification accuracy.	Prof. Lucas Narciso

		2. Discuss simplified semiquantification metrics, such as the variants of standardized uptake value (SUV), SUV ratio, and asymmetry ratio. Understand quantification metrics, such as distribution volumes and binding potentials. 3. Introduce image-derived input function, population-based input function, and simultaneous estimation method as alternatives to arterial sampling. Discuss advantages and limitations of non-invasive approaches for PET quantification.	
Week 6, lecture 2	Oct 17, room 801	***PET quantification and kinetic modeling*** Learning objectives: 1. Define compartmental models and describe their role in quantifying tracer kinetics. 2. Explore the kinetic model used for PET imaging of cerebral blood flow and oxygen metabolism using $[^{15}O]H_2O$ and $[^{15}O]O_2$, respectively. 3. Explore reference tissue models, such as Logan reference plot, simplified reference tissue model (SRTM), and multilinear reference tissue model (MRTM).	Prof. Lucas Narciso
Week 7, lecture 1	Oct 21, room 801	***Workshop on PET quantification***	Prof. Lucas Narciso
Week 7, lecture 2	Oct 24, room 801	***Workshop on voxelwise parametric maps***	Prof. Lucas Narciso
Week 8, lecture 1	Oct 28, room 801	***Journal Club***	
Week 8, lecture 2	Oct 31, room 801	***Journal Club***	
Week 9, lecture 1	Nov 4, room 801	***Journal Club***	
Week 9, lecture 2	Nov 7, room 801	***Journal Club***	
Week 10, lecture 1	Nov 11, room 801	**Guest lecture 1 – PET in Mood Disorders** Chaired by student. Discussions will be based on paper provided by guest lecturer.	

Week 10, lecture 2	Nov 14, room 801	**Guest lecture 2 – PET in Neurodegenerative Disease** Chaired by student. Discussions will be based on paper provided by guest lecturer.	
Week 11, lecture 1	Nov 18, room 801	**Guest lecture 3 – PET in the Brain-Heart Axis** Chaired by student. Discussions will be based on paper provided by guest lecturer.	
Week 11, lecture 2	Nov 21, room 801	**Guest lecture 4 – PET in Addictions** Chaired by student. Discussions will be based on paper provided by guest lecturer.	
Week 12, lecture 1	Nov 25, room 801	**Guest lecture 5 – PET in Neuro-oncology** Chaired by student. Discussions will be based on paper provided by guest lecturer.	
Week 12, lecture 2	Nov 28, room 801	**Guest lecture 6 – PET in Movement Disorders** Chaired by student. Discussions will be based on paper provided by guest lecturer.	

EVALUATION

Grading Option: *Letter Graded*

Assessment	**Deadline** Description	**Grade Weighting**
Journal Club	**Paper approval: Sep 26 (end of week 3)** Presentation of a journal article not related to the student's thesis. Topic must be timely from a major brain PET related topic from a relevant journal. The paper must be approved (by the end of week 3) by course instructors and supervisor(s). The presentation will be followed by a lively discussion on the work described in the publication. Critical thinking is expected.	30%
Participation	Participation will be evaluated based on the quality of questions and engagement in discussion (10%), as well as role as Chair (10%). For the former, students will receive a participation score for each session, and the final grade will be calculated by combining the individual session scores. For the latter, Chairs will be responsible for organizing the session, introducing the speaker, summarizing the paper, and facilitating	20%

	the questions. Prior to the lecture, each student will submit to the Chair and Course Coordinator at least two questions based on a recent publication provided by the speaker.	
Assignment 1: PET Quantification	**Deadline: Nov 7 (end of week 9)** Students will participate in a hands-on workshop on PET quantification, where they will learn to analyze PET datasets using established methods. Following the workshop, each student will be provided with a PET dataset and a specific hypothesis to investigate. They will be required to process the data, perform appropriate statistical analyses, and interpret their findings. The final assignment must be submitted in the format of a conference abstract, adhering to standard scientific guidelines, including a clear background, methods, results, and conclusions. Assignment 1 is due at the end of week 9.	20%
Assignment 2: Research Project Proposal	**Deadline: Nov 21 (end of week 11)** **Research topic approval: Oct 3 (end of week 4)** The essay will be in the form of a 2-page research project proposal aiming at simulating future doctoral/postdoctoral scholarship applications. The research project will be based on topics explored in class and must be outside of the student's thesis research. The research project topics will be selected by students and approved by their supervisor(s) and Course Coordinators (approval is due at the end of week 4.) Assignment is due at the end of week 11.	30%
TOTAL		**100%**