Syllabus (Updated: 1/22/2018)

S20.S948: Neurotechnology: from imaging brain function to the study of neuropharmacology

All classes 10am – 4pm in 16-220

Instructors: Haitham Amal (hamal@mit.edu), Aviad Hai (aviadhai@mit.edu), Peter Harvey (pharvey@mit.edu), Katherine Kiwimagi (kiwimagi@mit.edu), Mitul Desai (mituld@gmail.com).

Time: Tues & Thurs 10am-4pm (1/23, 1/25, 1/30, 2/1)

Description: The human brain contains almost 100 billion neurons and 100 trillion connections. Understanding the vast complexity of the brain is paramount to tackling neurological and psychiatric disorders diseases, which are causing an increasing burden on sufferers, carers, and the population as a whole. Neurortechnological advances are required in order to achieve this goal, with new breakthroughs occurring rapidly. In this seminar series we seek to display the cutting edge of research in the field of neurotechnology. We will start with the area of neuropharmacology; from understanding how drugs of abuse affect brain function to discussing how anesthetics and analgesics act. Cutting edge research in breath analysis will be examined, exploring its potential for diagnosis of multiple ailments, from cancer to neurodegenerative diseases. From there, our focus will turn to techniques for understanding how the brain works and monitoring its function. We will cover functional magnetic resonance imaging (fMRI), optogenetics, and devices. Recent findings and current challenges in these fields will be discussed.

By the end of the seminar series, students will be aware of the cutting-edge advances in neurotechnology and understand the techniques required for interpreting research publications in any field. The primary objectives of this course are to;

- Introduce students to the field of neurotechnology and give them an understanding of the current state of play and future challenges in this area.
- Highlight the process of critical review and examine how to interpret research data and publications.
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<th>Lecture</th>
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| 1 (1/23) | A. Hai  
   P. Harvey  
   A. Hai | **Introduction and course overview**<br><br>**MRI basics and how to improve contrast:** Introduction to MRI including contrast agents and how they work (small molecules, nanoparticles, and biological systems)<br><br>**Emerging neuroimaging technologies:** Functional MRI sensors for the direct imaging of neurotransmitters in the brain. Neurobiological sensing of neurochemicals, molecular and microfabricated wireless fMRI sensors.<br><br>**Tour of preclinical MRI facilities** |
| 2 (1/25) | H. Amal  
   M. Desai  
   P. Harvey | **Neuropharmacology of Drugs of Abuse:** This talk considers a broad spectrum of pharmacologic agents implicated in drug abuse and dependence and the brain processes relevant to understanding drug addiction.<br><br>**Towards a Global Evidence of Breath Volatolomics of Cancer and Neurodegenerative Diseases - The Detection of a Disease through Exhaled Breath:** Breath analysis for clinical diagnosis and therapeutic monitoring. Two different techniques will be described: 1) Gas chromatography linked mass spectrometry (GC-MS) in order to understand the nature of the compositions associated with the different states. 2) Sensitive nanomaterials based sensors for the collective sensing of the obtained mixtures with a pattern recognition method for building a breath pattern to identify different diseases.<br><br>**Proteomics to fight Autism and Alzheimer’s:** Use proteomics, systems biology, interactomes analysis to unravel the pathological signaling pathways in Autism and Alzheimer’s.<br><br>**Functional neuroimaging:** Neuroimaging techniques withal particular emphasis cutting edge fMRI based approaches.<br><br>**Mapping dynamic changes in brain neuronal circuits:** Optogenetic, chemogenetic, and electrical microsimulation based techniques and use in fMRI to probe brain networks.<br><br>**The blood-brain barrier:** Challenges in delivery of agents to the brain and strategies to overcome the BBB [If time, otherwise will be moved to 2/1] |
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<td>3 (1/30)</td>
<td>A. Hai, K. Kiwimagi</td>
<td><strong>Devices for the recording of neural signals</strong>: Neuronal electrical signals, extracellular metal probes, glass micropipettes, fundamentals of neuro-electronic interfacing, multisite recordings: arrays of nanoelectrodes, Fabrication techniques: scalable, flexible, bio-friendly devices, cutting edge electrophysiology: Intra-cellular, multi-site devices for neuronal recording. <strong>Synthetic Biology to Control Differentiation</strong>: This talk considers multiple approaches used to construct and implement synthetic biology in iPSC differentiation both into a homogeneous population of neurons as well as a heterogeneous population for the creation of organoids. <strong>Multilayer models for <em>in silico</em> exploration of proposed mechanisms underlying complex biological pattern formation</strong>: This lab like talk will give opportunity for you to create your own computation models of both known and hypothesized mechanisms underlying biological processes. Combing a wide variety of modeling layers from Cellular Potts models to PDEs we will simulate some of the unknown biological processes observed in the differentiation of neuronal systems seen in current research. (No Previous Computational Modeling Experience Required)</td>
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<td>4 (2/1)</td>
<td>K. Kiwimagi, P. Harvey, A. Hai</td>
<td><strong>Multilayer models for <em>in silico</em> exploration of proposed mechanisms underlying complex biological pattern formation</strong>: Overview of simulations from previous seminar and future opportunities. <strong>How to search the primary literature</strong>: Tips and useful resources when searching for research <strong>Recap and course conclusion</strong> <strong>Tour of human MRI facilities [Subject to availability]</strong></td>
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