BMEn 5910: Neuromodulation

Spring 2011 (3 credits)

Course Information

Course Instructor: Professor Matt Johnson
E-mail: john5101@umn.edu (please include "BMEn 5910" in the subject)
Office: 6-134 NHH
Office Hours: TBD

Course Meetings: T/Th 8: 15-9:30 am

Course Website: Moodle

Course Description: Fundamentals of bioengineering approaches to modulate the nervous system including bioelectricity, biomagnetism, and optogenetics. Topics include design of computational models of neuromodulation, fabrication of neural interface devices, and development of technologies to evaluate the physiological effects of neuromodulation. Clinical exposure to managing neurological diseases and disorders with neuromodulation technology will be emphasized.

Course Text: *Neuroanatomy through Clinical Cases* by Hal Blumenfeld**;** Reading supplements will be provided to you in class.

Course Prerequisites: BMEn 5411, or permission from the instructor.

Course Format: This is a lecture-based course consisting of two 75-minute lecture sessions per week. We will have periodic in-class demonstrations to reinforce concepts and homework sets that use real data from humans and animal models. Students will have opportunities through this course to shadow clinicians in the implantation and programming of neuromodulation devices.

Grading Policy: Course assessment will be based on weekly homework assignments (30%), a midterm (30%), a final exam (30%), and classroom participation / final report (10%). Grading will be based on 100-90%=A, 89-80%=B, 79-70%=C. The threshold for grades may be lowered depending on overall class performance.

> **Homework (30%) --** Weekly problem sets will focus on your ability to integrate concepts across several engineering, physiology, and clinical disciplines. Assignments will be due one week after they are distributed in class. We will use MATLAB in the homework, so familiarity with this software package will be useful.
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> **Midterm (30%) --** The midterm will allow you to demonstrate your understanding of neural implants and the fundamentals bioelectricity, biomagnetism, and optogenetic stimulation.
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> **Final Exam (30%) –** The final exam will provide you with a chance to apply the principles you have learned through the semester and extend those concepts to other neurological disorders.

Classroom Participation / Final Project (10%) – Undergraduate students will be evaluated on participation in class whereas graduate students will write a critical review paper comparing the effectiveness and future potential of two different neuromodulation techniques for a specific neurological disorder.

E-mail Policy: I will try to respond to your e-mails as quickly as possible. For questions on the homework, please use the discussion forum on the website so that everyone in the course can benefit.

Class Policies: Students may work in groups for the homework, but the expectation is for each student to hand in his or her own work and abide by the *Student Conduct Code*. Re-grades on homework and the midterm need to be submitted to me within one week of when I hand them back to you. Should you need to reschedule the midterm, please give me at least two week's notice. Any other questions or concerns – by all means, feel free to stop by during office hours or e-mail me at john5101@umn.edu.

I look forward to a great semester!

Schedule of Lectures and Assignments (*tentative*)

Date	Lect	Theme	Topic	Reading	Homework Distributed
18-Jan	1	Introduction	**Course Introduction** • Course syllabus • Macroscopic overview of the nervous system • Technology to modulate the nervous system		
20-Jan	2	Introduction	**Clinical Neuroanatomy** • Clinical cases: peripheral nervous system • Clinical cases: central nervous system	Blumenfeld Ch 2	HW 1
25-Jan	3	Introduction	**Clinical Neuroradiology** • Clinical cases: computerized tomography (CT) • Clinical cases: magnetic resonance imaging (MRI) • Clinical cases: angiography	Blumenfeld Ch 4	
27-Jan	4	Introduction	**The Neurologic Exam** • Guest lecture – Dr. Jerrold Vitek (Neurology) • In class demonstration	Blumenfeld Ch 3	HW 2
1-Feb	5	Meninges and Vasculature Management	**Cranium, Vertebrate, and Meninges** • Clinical cases: intracranial implants, herniation • Design of intracranial pressure technologies • Design of cranial and dural repair technologies	Blumenfeld Ch 5	
3-Feb	6	Meninges and Vasculature Management	**Subdural Malformations** • Clinical cases: tumors • Design of ablation technologies: gamma-knife, cooling, radiofrequency, electrolytic lesioning		HW 3
8-Feb	7	Meninges and Vasculature Management	**Blood-Brain Barrier** • Clinical cases: tumors, edema • Design of intracranial drug-delivery technologies • Design of technologies to bypass the BBB		
10-Feb	8	Meninges and Vasculature Management	**Cerebral Vasculature** • Clinical cases: stroke and aneurysms • Design of diagnostic tools • Design of intravascular delivery approaches	Blumenfeld Ch 10	HW 4
15-Feb	9	Neuromodulation Approaches	**Treatment for Stroke** • Guest lecture – Dr. Kenneth Baker (Neurology) • Design of epidural and subdural stimulation systems • Design of stimulation to induce neural plasticity		
17-Feb	10	Neuromodulation Approaches	**Non-Invasive Neuromodulation I** • Principles of transcranial magnetic stimulation (TMS) • Modeling electromagnetic fields in neural tissue • Effects of TMS frequency on neurophysiology	Liepert 2000	HW 5
22-Feb	11	Neuromodulation Approaches	**Non-Invasive Neuromodulation II** • Principles of transcranial direct current stimulation • Modeling electric fields in the neural tissue • Effects of constant current versus pulse trains	Hummel 2005	
24-Feb	12	Neuromodulation Approaches	**Modeling Electrical Fields in Neural Tissue I** • Homogeneous finite element models • Current versus voltage-controlled stimulation • Design of multi-polar stimulation systems		HW 6
1-Mar	13	Neuromodulation Approaches	**Modeling Electrical Fields in Neural Tissue II** • Heterogeneous finite element models • Diffusion tensor imaging and impedance tomography • Tissue response to intracranial implants		

3-Mar	14	Neuromodulation Approaches	**Optogenetic Neuromodulation I** • Principles of light-activated ion channels • Strategies for delivering microbial opsin genes • Optimizing expression and function	Gradinaru 2010	prepare for midterm
8-Mar	15	Neuromodulation Approaches	**Optogenetic Neuromodulation II** • Design of intracranial infusion systems • Neural responses to optical stimulation • Optical control of behavior	Zhang 2010	
10-Mar	16		**Midterm**		
15-Mar	--		Spring Break		
17-Mar	--				
22-Mar	17	Neuromodulation Approaches	**Design of Electrodes I** • Designing multi-channel electrode geometries and configurations specifically for the anatomical target • Insulation and biocompatibility issues		
24-Mar	18	Neuromodulation Approaches	**Design of Electrodes II** • Microfabrication processes: photolithography, chemical vapor deposition, metal deposition, etching • Polymer versus silicon substrates		HW 7
29-Mar	19	Neuromodulation Approaches	**Design of Electrodes III** • Integration of drug delivery channels • Integration of optrode design • Optimization for biocompatibility	Zhang 2009	
31-Mar	20	Evaluating Neuromodulation Therapies	**Measuring Effects of Neuromodulation I** • Non-invasive functional imaging (fMRI, EEG, MEG) • Designing therapies for clinical subtypes • MR / device compatibility issues		HW 8
29-Mar	21	Evaluating Neuromodulation Therapies	**Measuring Effects of Neuromodulation II** • Intracranial microelectrode recordings • Stimulus artifact suppression techniques • Signal processing algorithms for spikes and LFPs		
31-Mar	22	Evaluating Neuromodulation Therapies	**Measuring Effects of Neuromodulation III** • Intracranial neurotransmitter recordings • Voltammetry and amperometry • Microdialysis techniques		HW 9
5-Apr	23	Evaluating Neuromodulation Therapies	**Physiological Mechanisms of Neuromodulation** • Excitation or inhibition? • Release of neurotransmitters • Effects on synchronicity		
7-Apr	24	Neuromodulation Applications	**Neuromodulation for Pain** • Pathophysiology and clinical cases • Spinal cord and thalamic stimulation • Multi-channel programming	Blumenfeld Ch 7-9	HW 10
12-Apr	25	Neuromodulation Applications	**Neuromodulation for Essential Tremor** • Pathophysiology and clinical cases • Sculpting stimulation according to brain somatotopy • Designing settings to avoid paresthesia side-effects	Blumenfeld Ch 16	
14-Apr	26	Neuromodulation Applications	**Neuromodulation for Parkinson's disease** • Pathophysiology and clinical cases • Mechanisms underlying multiple stimulation targets • Possible neuroprotective effects of stimulation		HW 11
19-Apr	27	Neuromodulation Applications	**Neuromodulation for Dystonia** • Pathophysiology and clinical cases • Stimulation-induced neural plasticity • Temporal effects of therapeutic onset/cessation		

21-Apr	28	Neuromodulation Applications	**Neuromodulation for Epilepsy** • Pathophysiology and clinical cases, Dr. Abosch • Identification of pathological brain regions • Automated closed-loop stimulation	Blumenfeld Ch 18	HW 12
26-Apr	29	Neuromodulation Applications	**Neuromodulation for Depression and OCD** • Pathophysiology and clinical cases • Fiber tractography and neuromodulation • Issues of power consumption and battery life		
28-Apr	30	Neuromodulation Applications	**Neuromodulation – Emerging Areas** • Alzheimer's disease, obesity, Tourette's syndrome, • Designing stimulation systems to the target anatomy • Ethical issues with neuromodulation	Blumenfeld Ch 17	grad project abstract due
3-May	31	Translational Neuroengineering	**Intellectual Property and Seed Funding** • Provisional patents and patents through UMN • NIH SBIR/STTR grants and venture capital		
5-May	32	Translational Neuroengineering	**FDA Process** • Phases of clinical trials • Process for bringing a device to market		grad project report due
??-May Finals			**Final Exam**		