Course Syllabus

July 27, 2016

Electrical Language of Cells

Course directors

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Course goals:

This course introduces students to the high-speed electro-chemical signaling mechanisms that occur in nerve and other excitable cells during normal activity. Topics considered in substantial detail include: a) a fundamental description of the passive and active membrane electrical properties; b) the molecular architecture and functional role of ion channels in cell signaling; c) the role of the calcium ion as an ubiquitous chemical messenger, with applications to neuro-secretion; d) excitatory and inhibitory transmission in the central nervous system; e) sensory transduction, as illustrated by the visual, olfactory and auditory pathways. The course assumes a standard background in cell biology, as well as basic concepts from college physics and college calculus.

Expectations and assumptions:

1. You are taking this course because you want to know and learn about electrical properties of cells.

2. Some materials may be difficult (for some) but they are not impossible to master.

3. **Active** participation is very important for your learning (this is expanded below).

4. The course directors and instructors will assist your learning and training; *however, the ultimate responsibility rests with you. You must take an active role in learning. This is graduate school after all.* Numerous resources are available for you.

Before the course starts:

Some lectures and reading materials are already available. It is very strongly recommended that you read the files in the "Files/•Essential Background Reading Materials" directory/folder before the course starts.

Lecture schedule:

The lectures are from 9:30 AM to 11:30 AM on Tuesdays and Thursdays. The lecturers will use ≤5 minutes at the start of their 1st lecture to introduce themselves and their area(s) of expertise. It is assumed that you will participate in each class meeting.

Evaluations:

1. Take-home examinations. There will be 3 take-home examinations. The questions provided by different instructors may vary in style. The course meetings are in 140 John Morgan, Barchi Library.

There will be three examinations and the dates are posted in the course calendar.

2. In-class participation/effort. The course directors and instructors will monitor your in-class participation and perceived effort level. This will count only when the exam scores are at a borderline level between two categories (e.g., "A" vs. "B").

While obtaining a good grade is an important goal, the most important objective is that you learn the material.

Reading assignments and lecture materials:

Please make every effort to read all assigned readings and the lecture material (PowerPoint file or "handout") before each lecture. Doing so will enable you to learn way more from of each lecture. This point cannot be over-emphasized.

We will provide no handouts in class. All lecture materials and readings (PDF files) will be posted on the course website ("Files") in advance of each lecture. Feel free to bring a mobile device of your choice to class with the relevant file(s) on it and/or print out the lecture material and bring it along for making notes.

Class participation:

We expect everyone to participate actively in class, including (*a*) asking questions when you do not understand something being presented or are curious about some aspect of it, and (*b*) being prepared to answer questions posed by the lecturers. Whether you do or do not participate consistently in class will have an impact on final grade and, **much more importantly, your learning.**

Lecture styles:

Core II includes lecture presentations from several instructors, as do most graduate school courses. Not surprisingly, each lecturer has his/her own style. There is no single "best" lecture style, and what is most important is for each lecturer to engage your interest and enable you to understand the material being presented. Therefore, be prepared for and open to an assortment of lecture presentation styles. Do remember that ultimately **YOU** will have to learn.

Do not hesitate to ask questions during the lectures; the lecturers want to get questions from the students.

Lecture videos:

All Core II lectures are recorded (video, voice and presentation images) and archived on the NGG website (link: http://www.med.upenn.edu/ngg/resources.shtml or http://tinyurl.com/ktzog25).

Click on the mediasite hot link and then enter your Penn Key username and password to gain access. Once you are in the media site, you should click on the link for the Fall 2016 on the left side of the screen, and then on the Core II link. You will see that last year's Core II lectures are also available (in the "Past Barchi Presentations" section). This material is made available to you as a study aid, not as a replacement for attending classes. We want to emphasize that it is not acceptable to miss class simply because it is easier/more convenient to watch the videos. Missing class for this reason prevents one from "learning interactively", thereby resulting in learning less than optimal. Becoming comfortable and capable of being involved in interactive discussions in large groups is also an important aspect of your professional training. Lastly, it is rather selfish to stay away and replace attendance with the videos because the student who does so is taking advantage of the efforts of their classmates to ask questions and ensure understanding during the lectures. Hence, we will note consistent absences from class and communicate with anyone who does so.

Take home exams:

All Core II Exams are take-home exams. You will have ~7 days to complete each one. All exam questions will be largely essay-style questions that aim to push your understanding by integrating your newly learned information into novel settings. Hence, the answers to the exam questions will not be available in any resource. During each exam period, you are welcome to utilize any "print" resource including your notes, textbooks, review articles, original papers, websites, and the like, as well as the lecture videos. However, you are not permitted to discuss any exam questions or answers with any person, either verbally or via written/typed media until after each exam period has ended. Additional instructions will appear on the first page of each exam. **Please do follow the instructions carefully.** The previous year's exam questions and exemplar answers are posted on the course website. Please note, however, the instructors may change the examination question styles.

Post-lecture questions:

All Core II lecturers are accessible to you before/after their lectures. If you have additional questions pertaining to any/all lectures (or simply explore the topic further on your own), you should start by communicating with the relevant lecturers.

General reading materials and "text books"

The course does not utilize a single textbook. One textbook may be suitable for some but not for others. The list below contains some of the books that you may wish to explore. The course directors and instructors are available to make suggestions to suit your own specific need.

Principles of neural science, fifth Edition, edited by Kandel et al.

This book broadly covers many aspects of neuroscience. For this course and others, this may be a nice book to have around. For those of you with a limited exposure to cellular electrical signaling, some of the chapters in this book represent a good *starting* point.

Foundations of cellular neurophysiology, Johnston and Wu

This book is appropriate for those with a solid foundation in cellular excitation already. It covers cellular electrical properties in a quantitative and rigorous manner.

Molecular and cellular biophysics, Jackson

This book is not a neuroscience textbook but the information contained here about cellular excitability, ion channels, transporters, and pumps is quite relevant and useful for this course and well presented. If you have a solid background in biophysics and if you want to utilize quantitative measurements, this book is very highly recommended.

Ion channels of excitable membranes, Hille

The latest edition (third) is getting dated (2001) but the first 9 chapters of this book (PART I) will serve you very well. These chapters are readable and are at the appropriate level for the course.

The physiology of excitable cells, Aidley

This is a dated book; the last update in 1998. However, if you want to learn about those *classic* electrophysiology experiments, **this is a superb book**! Because of its age, it is weak in molecular and atomic aspects of cellular excitation.

Nerve, muscle, and synapse, Katz

Originally published in 1966 and this short monograph presents a very good account of nerve excitation and synaptic transmission. Some parts of the book may not be that relevant now (e.g., cathode ray oscilloscope) but many others remain very useful. Probably one of those "must-read" books if you want to study synaptic transmission. You cannot call yourself a synaptic physiologist if you have not read this book.

Exercise problem sets:

Some instructors provide you with select exercise problems (with answers) and they may be found in the "Files" folder at the course website. The books listed above also contain exercise problems that you can work through. Additionally, the previous examination questions (and answers) are available for you to study.

Simulation programs:

There is no question that **"playing with a neuronal simulation program" is a great way to learn about neuronal excitability**. Numerous programs (including those available on the web) exist to simulate electrical changes in a neuron/a group of neurons. Some are too simplistic and not very accurate. Others are accurate (and can be used for research projects) but come with a very steep learning curve.

Neurons in action, Moore and Stuart

This program relies partly on Java and runs on both Windows and Mac platforms. Some aspects of the tutorial are helpful (and others may be not be so helpful). This may not be the slickest program you encounter.

SynAps, Clay Armstrong

Prof. Armstrong here at Penn wrote this program intended originally for medical students sometime ago. It does not have a modern interface but some of you may find the program useful. This runs only on Windows (not tested on Windows 8). Another program "Osmoxa" simulates changes ion ion concentrations and cell volume and this is also available for download.

LabAxon, Bers et al.

This is a straight forward program to simulate electrical properties of the squid axon and contains many useful self-guided exercises. Worth doing. One short coming is that the program runs only on Windows and Mac users need to run a Windows virtual machine (e.g, Parallel, FusionVM). If you want to explore a more complicated system, try *LabHeart* by Bers et al., which contains many more channels, transporters, and pumps.

CalDyx, Stephen Baylor

CalDyx (on Windows) is a simulation program that illustrates changes in intracellular calcium concentration during excitation-contraction (EC) coupling in skeletal muscle cells. While the program is about skeletal muscle cells, calcium ions are important in neurons (and other cells) and this program nicely illustrates the complex regulation of intracellular calcium concentration.

Here is the description provided by the author (Prof. Baylor)

CalDyx (short for "Calcium Dynamics") is a self-study interactive teaching program about excitation-contraction (EC) coupling in skeletal muscle cells. The program simulates the myoplasmic calcium responses of three types of muscle cells (slow-twitch, fast-twitch, and superfast-twitch) in response to stimulation by action potentials (APs). The simulations are closely tied to experimental measurements of myoplasmic calcium transients carried out with calcium indicator dyes in these fiber types. Ten exercises are included that guide the student through the major calcium signaling events of EC coupling. The program is quantitatively-based and is expected to increase the student's understanding of kinetic processes within cells.

Other files posted at the course website:

A few interesting articles that you may find useful are posted at the course website ("•Fun Stuff"). For example,

Bernard Katz.pdf

This is a short autobiography of Sir Bernard Katz.

Alan L. Hodgkin.pdf

This is a short autobiography of Sir Alan Hodgkin.

Feuillet et al.pdf

This an interesting clinical case history paper that shows that we don't need much of the brain at all?

In addition, you can find an old British TV show clip about squid giant axons. This TV documentary features many prominent neurobiologists, whose work you will learn about.

Assignments Summary:

Date	Details	
Tue Aug 30, 2016	📅 Course Orientation (Coulter) (https://canvas.upenn.edu/calendar?event_id=2005312&include_contexts=course_1314031)	9:30am to 11:30am
Thu Sep 1, 2016	📅 Membrane potential and the Nernst equation (Parsons) (https://canvas.upenn.edu/calendar?event_id=2005318&include_contexts=course_1314031)	9:30am to 11:30am
Tue Sep 6, 2016	📅 Membrane potential and the Nernst equation, passive properties (Parsons) (https://canvas.upenn.edu/calendar?event_id=2005317&include_contexts=course_1314031)	9:30am to 11:30am
Thu Sep 8, 2016	📅 Active membrane properties I (Hoshi) (https://canvas.upenn.edu/calendar?event_id=2005311&include_contexts=course_1314031)	9:30am to 11:30am
Tue Sep 13, 2016	📅 Active membrane properties II (Hoshi) (https://canvas.upenn.edu/calendar?event_id=2005316&include_contexts=course_1314031)	9:30am to 11:30am

Thu Sep 15, 2016	📅 **Active membrane properties III (Hoshi)** (https://canvas.upenn.edu/calendar?event_id=2005315&include_contexts=course_1314031)	9:30am to 11:30am
Tue Sep 20, 2016	📅 **Neurotransmitters and receptors I (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005310&include_contexts=course_1314031)	9:30am to 11:30am
Thu Sep 22, 2016	📅 **Mono- vs. poly-synaptic transmission I (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005313&include_contexts=course_1314031)	9:30am to 11:30am
Tue Sep 27, 2016	📅 **Mono- vs. poly-synaptic transmission II (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005334&include_contexts=course_1314031)	9:30am to 11:30am
Thu Sep 29, 2016	📅 **Presynaptic mechanisms I (Parsons)** (https://canvas.upenn.edu/calendar?event_id=2005333&include_contexts=course_1314031)	9:30am to 11:30am
Tue Oct 4, 2016	📅 **Presynaptic mechanisms II (Parsons)** (https://canvas.upenn.edu/calendar?event_id=2005332&include_contexts=course_1314031)	9:30am to 11:30am
Thu Oct 6, 2016	📅 **Neuroscience in Practice I** (https://canvas.upenn.edu/calendar?event_id=2005331&include_contexts=course_1314031)	9:30am to 11:30am
	📄 **Exam I** (https://canvas.upenn.edu/courses/1314031/assignments/5218258)	due by 5pm
Tue Oct 11, 2016	📅 **Neuroscience in Practice II** (https://canvas.upenn.edu/calendar?event_id=2005330&include_contexts=course_1314031)	9:30am to 11:30am
Thu Oct 13, 2016	📅 **Optogenetics (Coulter)** (https://canvas.upenn.edu/calendar?event_id=2005329&include_contexts=course_1314031)	9:30am to 11:30am
Tue Oct 18, 2016	📅 **Presynaptic Mechanisms III (Parsons)** (https://canvas.upenn.edu/calendar?event_id=2005328&include_contexts=course_1314031)	9:30am to 11:30am
Thu Oct 20, 2016	📅 **CNS synapses I (Coulter)** (https://canvas.upenn.edu/calendar?event_id=2005327&include_contexts=course_1314031)	9:30am to 11:30am
Tue Oct 25, 2016	📅 **CNS synapses II (Coulter)** (https://canvas.upenn.edu/calendar?event_id=2005326&include_contexts=course_1314031)	9:30am to 11:30am
Thu Oct 27, 2016	📅 **CNS synapses III (Coulter)** (https://canvas.upenn.edu/calendar?event_id=2005325&include_contexts=course_1314031)	9:30am to 11:30am
Tue Nov 1, 2016	📅 **Synaptic plasticity I (Fuccilo)** (https://canvas.upenn.edu/calendar?event_id=2005324&include_contexts=course_1314031)	9:30am to 11:30am

Thu Nov 3, 2016	📅 **Synaptic plasticity II (Fuccilo)** (https://canvas.upenn.edu/calendar?event_id=2005336&include_contexts=course_1314031)	9:30am to 11:30am
Tue Nov 8, 2016	📅 **Synaptic plasticity III (Fuccilo)** (https://canvas.upenn.edu/calendar?event_id=2023349&include_contexts=course_1314031)	9:30am to 11:30am
	📄 **Exam II** (https://canvas.upenn.edu/courses/1314031/assignments/5218259)	due by 5pm
Thu Nov 10, 2016	📅 **Sensory transduction I (Ma)** (https://canvas.upenn.edu/calendar?event_id=2005323&include_contexts=course_1314031)	9:30am to 11:30am
Tue Nov 15, 2016	📅 **NO CLASS Meeting SfN** (https://canvas.upenn.edu/calendar?event_id=2005335&include_contexts=course_1314031)	9:30am to 11:30am
Thu Nov 17, 2016	📅 **Sensory transduction II (Ma)** (https://canvas.upenn.edu/calendar?event_id=2005322&include_contexts=course_1314031)	9:30am to 11:30am
Tue Nov 22, 2016	📅 **Sensory transduction III (Ma)** (https://canvas.upenn.edu/calendar?event_id=2005337&include_contexts=course_1314031)	9:30am to 11:30am
Thu Nov 24, 2016	📅 **NO CLASS Meeting Thanksgiving** (https://canvas.upenn.edu/calendar?event_id=2005320&include_contexts=course_1314031)	9:30am to 11:30am
Tue Nov 29, 2016	📅 **Neuronal circuit I (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005321&include_contexts=course_1314031)	9:30am to 11:30am
Thu Dec 1, 2016	📅 **Neuronal circuit II (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005338&include_contexts=course_1314031)	9:30am to 11:30am
Tue Dec 6, 2016	📅 **Neuronal circuit III (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005319&include_contexts=course_1314031)	9:30am to 11:30am
Thu Dec 8, 2016	📅 **Neuronal circuit IV (Nusbaum)** (https://canvas.upenn.edu/calendar?event_id=2005309&include_contexts=course_1314031)	9:30am to 11:30am
Tue Dec 20, 2016	📄 **Exam III** (https://canvas.upenn.edu/courses/1314031/assignments/5218260)	due by 5pm
	📅 **Exam #3** (https://canvas.upenn.edu/calendar?event_id=2005314&include_contexts=course_1314031)	
	📅 **Exam #3** (https://canvas.upenn.edu/calendar?event_id=2005339&include_contexts=course_1314031)	