NGG 572 Electrical Language of Cells

Course directors:

Doug Coulter, Departments of Pediatrics and Neuroscience

Toshi Hoshi, Department of Physiology

Course online delivery link:

https://zoom.us/j/94514817013?pwd=eGpneUw3bVBxLy93UW9BaG1pNVltZz09 (Links to an external site.)

The meeting information may change: please check back again later.

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 role of the calcium ion as an ubiquitous chemical messenger, with applications to neuro-secretion; c) excitatory and inhibitory transmission in the central nervous system; d) 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. Make sure to read the footnotes in the files also.

Lecture schedule:

Typically, we have standard in-person meetings. However, because of the Covid 19 pandemic, our course meetings this year will be online from 9:30 AM to 11:30 AM on Tuesdays and

Thursdays (scroll down to see the lecture schedule). The course meeting logistics, such as which online platform, etc, will be communicated to you later. We expect you to participate actively in every meeting as expanded below.

Each lecturer will use ≤5 minutes at the start of the first lecture to introduce him/herself and the area(s) of expertise.

Neuroscience in practice:

Typically you tour select neuroscience laboratories and see real experiments in action. This year, we will do this virtually and the detail logistics will be communicated to you later.

Core II lunch:

We normally have a lunch event for you to get to know the instructors. Unfortunately, it is not likely that this in-person lunch will take place. Sorry! We are considering an alternative.

Evaluations:

1. Take-home examinations. There will be 3 take-home examinations (60 points, 40 points and 60 points, tentatively). You have ~one week to finish each examination. The questions provided by different instructors may vary in style. The amount of time required to complete an examination may also vary from several hours to >>10 hours; do plan accordingly. In particular, be sure to check when examinations in other classes may take place. The standard examination instructions/rules (some minor modifications may be made in the future) are found here (ExamInstructions.pdf). We assume that you have read the examination instructions/rules carefully.

The examination 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.

You may also wish to browse through the previous examination questions (Files/Previous exams) during the very initial days of the course. Do you have some ideas as to how you may answer the questions? Doing so may give you rough ideas about how much effort is required.

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 (https://mediasite.med.upenn.edu/mediasite/Catalog/catalogs/barchilibrary-department-of-neuroscienceLinks to an external site.).

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 2020 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. 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 to evaluate YOUR (not somebody else's) understanding. 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 needs.

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.

Nerve (at the University of Chicago)

There are several web-based simulators. Some are pretty good. Some are terrible. The biggest problem has been that just about every one required Java, which poses a security headache these days. Here is one without Java! This is a learning/teaching tool, not a research tool. But for this course, this will do. If you want to pick one, do this one!

http://nerve.bsd.uchicago.edu/nervejs/MAP.html

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.

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.

Electrophysiology of the Neuron

This multi-platform program (Windows and MacOS) is based on the work by Huguenard and McCormick (but updated recently through the University of Oklahoma). The relatively simple programs (thus some limitations) have many features that are relevant to the topics discussed in this course. Mac OS Catalina may not be compatible

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.

Course instructors:

Tom Parsons
Department of Clinical Studies, School of Veterinary Medicine
https://www.vet.upenn.edu/people/faculty-clinician-search/thomasparsonsLinks to an external site.
thd@vet.upenn.edu

Toshi Hoshi
Department of Physiology, School of Medicine
https://www.med.upenn.edu/apps/faculty/index.php/g275/p19258Links to an external site.
hoshi@pennmedicine.upenn.edu
hoshi@hoshi.org

Michael "Mikey" Nusbaum
Department of Neuroscience, School of Medicine
https://www.med.upenn.edu/apps/faculty/index.php/g20003260/c2125/p16396Links to an external site.
nusbaum@pennmedicine.upenn.edu

Doug Coulter
CHOP Department of Pediatrics / Department of Neuroscience, School of Medicine
https://www.research.chop.edu/people/douglas-a-coulter (Links to an external site.)

coulterd@email.chop.edu

Marc Fuccillo
Department of Neuroscience, School of Medicine
https://www.med.upenn.edu/apps/faculty/index.php/g20003260/c2125/p8787381Links to an external site.
fuccillo@pennmedicine.upenn.edu

Minghong Ma
Department of Neuroscience, School of Medicine
https://www.med.upenn.edu/apps/faculty/index.php/g20003260/c2125/p42685Links to an external site.
minghong@pennmedicine.upenn.edu

Course Summary:

Date	Details	
Tue Sep 1, 2020	Course Orientation (Coulter) / Reproducibility (Hoshi)	9:30am to 11:30am
Thu Sep 3, 2020	Membrane potential and the Nernst equation (Parsons)	9:30am to 11:30am
Tue Sep 8, 2020	Membrane potential and the Nernst equation, passive properties (Parsons)	9:30am to 11:30am
Thu Sep 10, 2020	Active membrane properties I (Hoshi)	9:30am to 11:30am
	Core II Lunch - get to know your instructors	12pm to 1pm
Tue Sep 15, 2020	Active membrane properties II (Hoshi)	9:30am to 11:30am
Thu Sep 17, 2020	Active membrane properties III (Hoshi)	9:30am to 11:30am
Tue Sep 22, 2020	Active membrane properties IV (Hoshi)	9:30am to 11:30am
Thu Sep 24, 2020	Neurotransmitters and receptors (Nusbaum)	9:30am to 11:30am
Tue Sep 29, 2020	Mono- vs. poly-synaptic transmission I (Nusbaum)	9:30am to 11:30am
Thu Oct 1, 2020	Mono- vs. poly-synaptic transmission II (Nusbaum)	9:30am to 11:30am
Tue Oct 6, 2020	Neuroscience in Practice I	9:30am to 11:30am

Date	Details	
Thu Oct 8, 2020	Neuroscience in Practice II	9:30am to 11:30am
	Exam I questions released	12pm
Tue Oct 13, 2020	Presynaptic mechanisms I (Parsons)	9:30am to 11:30am
Thu Oct 15, 2020	Presynaptic mechanisms II (Parsons)	9:30am to 11:30am
	Assignment Exam I answers due	due by 5pm
Tue Oct 20, 2020	Presynaptic mechanisms III (Parsons)*	9:30am to 11:30am
Thu Oct 22, 2020	CNS synapses I (Coulter)	9:30am to 11:30am
Tue Oct 27, 2020	NO CLASS meeting	9:30am to 11:30am
Thu Oct 29, 2020	CNS synapses II (Coulter)	9:30am to 11:30am
Tue Nov 3, 2020	CNS synapses III (Coulter)	9:30am to 11:30am
Thu Nov 5, 2020	Optogenetics (Coulter)	9:30am to 11:30am
Tue Nov 10, 2020	Synaptic plasticity I (Fuccillo)	9:30am to 11:30am
	Exam II questions released	12pm
Thu Nov 12, 2020	Synaptic plasticity II (Fuccillo)	9:30am to 11:30am
Tue Nov 17, 2020	Synaptic plasticity III (Fuccillo)	9:30am to 11:30am
	Assignment Exam II answers due	due by 5pm
Thu Nov 19, 2020	Sensory transduction I (Ma)	9:30am to 11:30am
Tue Nov 24, 2020	Sensory transduction II (Ma)	9:30am to 11:30am
Tue Dec 1, 2020	Sensory transduction III (Ma)	9:30am to 11:30am
Thu Dec 3, 2020	Neuronal circuit I (Nusbaum)	9:30am to 11:30am
Tue Dec 8, 2020	Neuronal circuit II (Nusbaum)	9:30am to 11:30am
Thu Dec 10, 2020	Neuronal circuit III (Nusbaum)	9:30am to 11:30am
Tue Dec 15, 2020	Neuronal circuit IV (Nusbaum)	9:30am to 11:30am
Thu Dec 17, 2020	Exam III questions released	12pm

Date	Details	
Thu Dec 24, 2020	Assignment Exam III answers due	due by 5pm