NGG 572-001 202330 Neuroscience Core II: Electrical Language Of Cells

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Electrical Language of Cells

Course directors

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Course goals:

This course introduces students to the high-speed electro-chemical signaling mechanisms in nerve and other excitable cells during normal activity. Topics considered in substantial detail include:

1. Passive and active membrane electrical properties.

2. The role of the calcium ion as an ubiquitous chemical messenger, highlighting its application to neurosecretion.

3. Excitatory and inhibitory synaptic transmission in the central nervous system.

4. 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. The course prioritizes **depth** over breadth, focusing on select fundamental concepts and is **not** intended as a broad-spectrum survey course.

Expectations and assumptions, etc :

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). Accordingly, instructors **will call on you** during the lectures.

4. The course directors and instructors will assist your learning and training - do not hesitate to ask for any help or assistance. Numerous resources are available for you. ***However, the ultimate responsibility rests with you. You must take an active role in learning. This is graduate school after all.***

5. While obtaining a good grade is a good goal, ***the most important objective is that you LEARN the material.***

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.

We very strongly recommend that you **browse through the past examination questions** to gauge your starting level of understanding . Please do this immediately. This will allow you to engage in additional preparatory work if needed - contact the course directors.

Lecture schedule:

The course meetings will be in the **Class of 1962 Auditorium** in John Morgan. It is assumed that you will participate in every class meeting.

8:30 AM to 9:30 AM : unstructured time on your own.

9:30 AM - 10:30 AM : class meeting/lecture

10:30 AM - 10:45 AM : a break

10:45 AM - 11:45 AM : class meeting/lecture

11:45 AM - 12: 15 PM : unstructured time on your own.

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:

You will tour select neuroscience laboratories and see real experiments in action!

Core II lunch:

Come and learn the dark secrets of your instructors. This event will take on place on September 5, 2023 (12 to 1 PM). You will pick up your box lunch in Barchi Library (140 John Morgan) and then head to the Biopond area/Kaskey Park near Levin Bldg and Lynch Lab. Your Core 2 instructors should be there. In case of inclement weather, we will stay in Barchi.

Evaluations:

1. Take-home examinations. There will be **3 take-home examinations** (60 points, 40 points, and 60 points). 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 depending on your level of understanding; do **plan** accordingly. In particular, be sure to check when examinations in other classes 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 and that you strictly **adhere to the rules and guidelines**. The take home examination format is explained more later (see below).

Please remember that these examinations aim to assess **your own** personal understanding of the course material, not that of another individual or an artificial intelligence service.

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 come into play (in either direction) only when the exam scores are at a borderline level between two categories (e.g., "A" vs. "B").

As noted earlier, while obtaining a good grade is a good goal, **the most important objective is that you learn the material.**

Do browse through the previous examination questions (Files/Previous exams). 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 - this is important because you will have other tasks during the semester. If you need any help/assistance, contact the instructors and course directors.

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 get 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 a unique 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 questions from you**. In part to facilitate interactive learning, some may instructors **will call on you to pose questions**, etc. Be prepared.

Lecture videos:

All Core II lectures are recorded (video, voice and presentation images) and archived on the NGG website (Core II media 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 2023 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 Examinations are take-home examinations to evaluate **YOUR** (**not somebody else's**) understanding. You will have ~7 days to complete each one. All examination questions will be largely essay/problem-solving-style questions that aim to push your understanding by integrating your newly learned information into novel settings. Hence, the answers to the questions will not be readily available in any single 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. Please note that discussing exam questions or answers with any individuals, either verbally or through written or typed communication, is expressly prohibited until the end of each examination period. 'Artificial intelligence' resources do not qualify as 'individuals'; however, they are unlikely to provide useful assistance for our examinations. It's crucial to understand that while some AI-generated responses may appear correct, others could be amusingly inaccurate. As a result, you may find that discerning the validity of AI-generated answers could require more time than effectively studying the material initially. 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.

You are expected to resolve any examination grading issues within one week.

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.

Core II recitation group:

There will be a recitation/review group lead by NGG students to along with the course, which meets about once a week. The details will be communicated to you separately.

FAQs:

• *"I am not familiar with the topics covered in this course at all and I may need extra help..."*

Please contact the course directors immediately. We can formulate an individualized plan to facilitate your learning. This plan can include a (peer) tutor for you. The sooner you do this, the better it is.

• *"I know the topics well already. I need more in-depth coverage opportunities..."*

We can suggest extra reading items, etc. Please contact the course directors and/or instructors.

• *"Can I use an artificial intelligence (AI) service for my take-home examinations?"*

The examination questions are designed for you and us to evaluate YOUR level of understanding. The questions are not designed to test how good various AI services are (e.g., ChatGPT). That said, nothing is preventing you from using the AI services. However, we find that the AI-generated responses are often (**amusingly**) incorrect/wrong!!! The AI-generated answers would have gotten really really bad scores. Garbage in , Garbage out. Please keep in mind that these examinations are to test your actual understanding of the relevant topics, not your ability to run AI tools.

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. However, this book weights a lot!

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.

The annotated Hodgkin & Huxley. A reader's guide, Raman and Ferster

This book, published in 2021, is all about the five classic papers by Hodgkin and Huxley in 1953. Once you open this book, you see an original Hodgkin and Huxley page on your left and the authors' annotations on your right.

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.

One newer strategy may be to let an AI service (e.g., chatGPT) generate a custom simulation program for you. You must have a way to validate the program/results, however. The constant/variable values (as well as some of the assumptions) may be totally wrong. Some procedures/scripts do not run at all.

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 and later 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:

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Course Summary:

Date	Details	Due
Tue Aug 29, 2023	Course Orientation (Coulter) / Reproducibility (Hoshi)	9:30am to 11:45am
Thu Aug 31, 2023	Passive properties of neurons and the equivalent circuit model I (Parsons)	9:30am to 11:45am
Tue Sep 5, 2023	Passive properties of neurons and the equivalent circuit model II (Parsons)	9:30am to 11:45am
	Core II Lunch - get to know your instructors	12pm to 1pm
Thu Sep 7, 2023	Active membrane properties I (Hoshi)	9:30am to 11:45am
Tue Sep 12, 2023	Active membrane properties II (Hoshi)	9:30am to 11:45am
Thu Sep 14, 2023	Active membrane properties III (Hoshi)	9:30am to 11:45am
Tue Sep 19, 2023	Active membrane properties IV (Hoshi)	9:30am to 11:45am
Thu Sep 21, 2023	Neurotransmitters and receptors (Nusbaum)	9:30am to 11:45am
Tue Sep 26, 2023	Mono- vs. poly-synaptic transmission I (Nusbaum)	9:30am to 11:45am
Thu Sep 28, 2023	Mono- vs. poly-synaptic transmission II (Nusbaum)	9:30am to 11:45am
	Review/Discussion by Nusbaum	11:45am to 1:15pm
Tue Oct 3, 2023	Neuroscience in Practice I (Coulter, Fuccillo, Ma, Scholl)	9:30am to 11:45am
	Exam I questions released	12pm
Thu Oct 5, 2023	Neuroscience in Practice II (Coulter, Fuccillo, Ma, Scholl)	9:30am to 11:45am
Tue Oct 10, 2023	Presynaptic mechanisms I (Parsons)	9:30am to 11:45am
	Exam I answers due	due by 5pm
Thu Oct 12, 2023	Presynaptic mechanisms II (Parsons)	9:30am to 11:45am
Tue Oct 17, 2023	Presynaptic Mechanisms III (Parsons)	9:35am to 11:55pm
Thu Oct 19, 2023	CNS synapses I (Coulter)	9:30am to 11:45am
Tue Oct 24, 2023	CNS synapses II (Coulter)	9:30am to 11:45am
Thu Oct 26, 2023	CNS synapses III (Coulter)	9:30am to 11:45am
Tue Oct 31, 2023	Optogenetics (Coulter)	9:30am to 11:45am
Thu Nov 2, 2023	Synaptic plasticity I (Fuccillo)	9:30am to 11:45am
	Exam II questions released	12pm
Tue Nov 7, 2023	Synaptic plasticity II (Fuccillo)	9:30am to 11:45am
Thu Nov 9, 2023	Synaptic plasticity III (Fuccillo)	9:30am to 11:45am
	Exam II answers due	due by 5pm
Tue Nov 14, 2023	NO CLASS meeting (SfN)	9:30am to 11:45am
Thu Nov 16, 2023	Sensory transduction I (Ma)	9:30am to 11:45am
Tue Nov 21, 2023	Sensory transduction II (Ma)	9:30am to 11:45am
Thu Nov 23, 2023	NO CLASS meeting (Thanksgiving)	12am
Tue Nov 28, 2023	Sensory transduction III (Ma)	9:30am to 11:45am
Thu Nov 30, 2023	Neuronal circuit I (Nusbaum)	9:30am to 11:45am
Tue Dec 5, 2023	Neuronal circuit II (Nusbaum)	9:30am to 11:45am
Thu Dec 7, 2023	Neuronal circuit III (Nusbaum)	9:30am to 11:45am
Tue Dec 12, 2023	Neuronal circuit IV (Nusbaum)	9:30am to 11:45am
	Review/discussion by M. Nusbaum	11:45am to 1:15pm
Thu Dec 14, 2023	Exam III questions released	12pm
Thu Dec 21, 2023	Exam III answers due	due by 5pm
	Exam #3	
	Exam #3	
	Final Letter Grade	

Course assignments are not weighted.