Neuroscience Methods: Cells and Circuits

Department of Psychology – Columbia University

PSYC1950/1951 - Course Syllabus – Spring 2025

Course Location and Time:
Lecture: Thursdays 10:10 – 11:25 AM, location TBD
Lab: Fridays 10:10 AM – 12:00 PM, Education Lab, 1st Floor Zuckerman Institute

Instructor: Dr. Sarah DeMoya
E-mail: sed2182@columbia.edu
Office: Schermerhorn Extension 355D
Office Hours: Friday 10:00 AM – 12:00 PM

Course Description:
Research Methods in Neuroscience: Circuits and Cells offers students a unique opportunity to combine theoretical knowledge with practical skills development. This course pairs a weekly lecture with hands-on laboratory experiences, giving students a chance to see what day to day neuroscience research entails. The first three weeks of the semester will cover introductory topics in neuroscience, the scientific method, and experimental design. Then students will participate in three 3-week long modules covering human cognition, animal behavior, and neurological disease. The last two weeks of the course will be spent preparing students for a successful undergraduate research experience. Throughout the semester students will read scientific review articles to deepen their understanding of the lecture material and to contextualize that week's lab experience.

The three 3-week modules will be run by graduate student researchers at the Zuckerman institute and in the Psychology Department. During these modules, students will be exposed to variety of neuroscience methods. The graduate student instructors will show students the highlights of the techniques that they use in the lab, therein getting around limitations in time and expertise that would otherwise prevent undergrads from experiencing different neuroscience techniques in a classroom setting. In some labs, students will have a class-wide research experience. In other labs, students will rotate through stations in small groups, getting to survey multiple methods in a class. In other labs, students will go in small to various locations in the Zuckerman institute to view animal colonies, testing rooms, and equipment that cannot be brought down to the Education Lab, where the labs will normally be held.

Throughout the semester students will conduct an independent research project investigating how a given research question can be answered using different neuroscience methods and levels of analysis. We will wrap up the semester with students presenting their findings in an in-class, digital poster session.

Course Prerequisites:
Instructor permission is required to take the course. PSYC1001 is a prerequisite for this course. Students must have already taken or must concurrently be enrolled in either PSYC2430/2450/2470.

Course Role in the Department:

PSYC14XX Neuroscience Methods: Cells and Circuits is a lab course designed for undergraduates majoring in Psychology or Neuroscience & Behavior. It fulfills the following degree requirements:

- For the Psychology Major, this course will fulfill the special elective requirement.
- For the Neuroscience and Behavior Major this course will fulfill the P3 Psychology requirement (statistics or research methods)

Enrollment in the Course:

Students interested in taking the course will join the waitlist. The Sunday before the first day of class students will be admitted off the waitlist based on a random lottery system. Students will be notified via email that they have been admitted off the waitlist.

Coursework:

Coursework will consist of weekly readings, weekly responses to questions about the readings, the research project (research methods paper), and completing in-class assignments during the lab portion of the course.

Readings:

The course readings are scientific journal articles to help you better understand the strengths and limitations of various methods in neuroscience and the kinds of questions that the methods are used to answer. The readings will also give context for the hands-on portion that occurs during the Friday lab. The goals of the course readings are to help you gain knowledge of relevant neuroscience history and research techniques, and to help you to develop critical thinking around experimental design and analysis.

Weekly Reading Questions:

The purpose of the weekly reading questions is to help orient you to the major takeaways from the readings. Responses to reading questions are to be submitted Wednesday evening (the day before lecture) each week.

Research Project:

In a series of assignments over the course of the semester, you will compare and contrast how different neuroscience methods can be used to investigate the same research question. You will choose one method from each module and look at the advantages and limitations of using that technique to address your research question, using one original research article per module as supporting evidence. You will synthesize your research into a 10-page research paper that you will submit in the second half of the semester. You will also present your findings to the class at a digital poster session during our final lab period. The goal of the research project is to be help develop science communication skills (both written and oral), critical thinking, research skills, and quantitative reasoning. More detailed instructions for the research paper and the poster presentation can be found in the Research Project Guidelines.

Supplemental Materials:
Various supplemental materials will be provided by the instructor on the course website.

Course Website:
The most up-to-date information, including changes to the syllabus or to the class schedule, announcements, lecture slides and additional materials are contained on the course website on CourseWorks (Canvas). Be sure you are familiar with it, that you are easily able to login to the website, and that you always have the readings with you (whether printed or digital). If you have problems accessing the course website at any point during the semester, please let me know.

Course Objectives:
This course is designed to help you to develop the follow Core Competencies: written communication, creativity and innovation, critical thinking, knowledge, oral communication, quantitative literacy, and research. At the completion of this course students will be equipped to:

- Describe the scientific method, experimental design, and the process of investigating a new research question.
- Describe the levels of analysis in neuroscience research and what kinds of questions can be answered at each level.
- Discuss the role of converging evidence in neuroscience research.
- Compare and contrast research methods in models of human cognition.
- Compare and contrast research methods in models of animal behavior.
- Compare and contrast research methods in models of disease.
- Find, read, interpret, and synthesize information from scientific review articles.
- Communicate science, both in written and oral form, to the general public.
- Engage in discussion about scientific findings.

Course Schedule: Any changes will be announced in class and posted as an announcement on CourseWorks. Students should complete the assigned reading before coming to class.

Weeks 1-3: Introduction to neuroscience, the scientific method, and experimental design
Weeks 4-6: Module 1: Models of Human Cognition
Weeks 7-9: Module 2: Models of Animal Behavior
Weeks 10-12: Module 3: Models of Disease
Weeks 13-14: Wrap Up: Preparing for Undergraduate Research

Tuesday, January 21st, 2025: Week 1 Lecture
Friday, January 24th, 2025: Week 1 Lab
Introduction: Neuroscience: 1.) Identify key neural structures and their functions. 2.) Discuss the historical development of neuroscience through advances in methods. 3.) Understand the different levels of analysis in neuroscience. 3.) Discuss the role of converging evidence in neuroscience research. 4.) Use the Allen Brain Atlas and

Neuormorpho.org to compare anatomical differences in brain regions and neurons between mice and humans.

1. Duncan J. (1998). Converging levels of analysis in the cognitive neuroscience of visual attention. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, *353*(1373), 1307–1317. https://doi-org.ezproxy.cul.columbia.edu/10.1098/rstb.1998.0285

2. Jones, A. R., Overly, C. C., & Sunkin, S. M. (2009). The Allen Brain Atlas: 5 years and beyond. *Nature reviews. Neuroscience*, *10*(11), 821–828. https://doi.org/10.1038/nrn2722

Tuesday, January 28th, 2025: Week 2 Lecture
Friday, January 31st, 2025: Week 2 Lab

Introduction: the Scientific Method: 1.) Identify and describe the steps of the scientific method. 2.) Explain the importance of literature reviews in hypothesis development. 3.) Discuss the importance of replicability and reproducibility in research. 4.) Use PubMed to find articles based on key words and search filters.

1. Neuroscience: Vallet, W., & van Wassenhove, V. (2023). Can cognitive neuroscience solve the lab-dilemma by going wild?. *Neuroscience and biobehavioral reviews*, *155*, 105463. https://doi-org.ezproxy.cul.columbia.edu/10.1016/j.neubiorev.2023.105463

2. Schwab, S., Janiaud, P., Dayan, M., Amrhein, V., Panczak, R., Palagi, P. M., Hemkens, L. G., Ramon, M., Rothen, N., Senn, S., Furrer, E., & Held, L. (2022). Ten simple rules for good research practice. *PLoS computational biology*, *18*(6), e1010139. https://doi-org.ezproxy.cul.columbia.edu/10.1371/journal.pcbi.1010139

Tuesday, February 4th, 2025: Week 3 Lecture
Friday, February 7th, 2025: Week 3 Lab

Introduction: Experimental Design: 1.) Define key terms and concepts related to experimental design and hypothesis testing, including control groups and proxies. 2.) Use a scientific journal article to identify the hypothesis, variables, and controls. 3.) Understand the principles of data analysis, including descriptive and inferential statistics.

1. Alger B. E. (2022). Neuroscience Needs to Test Both Statistical and Scientific Hypotheses. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *42*(45), 8432–8438. https://doi.org/10.1523/JNEUROSCI.1134-22.2022

2. Calin-Jageman R. J. (2022). Better Inference in Neuroscience: Test Less, Estimate More. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *42*(45), 8427–8431. https://doi.org/10.1523/JNEUROSCI.1133-22.2022

Tuesday, February 11th, 2025: Week 4 Lecture
Friday, February 14th, 2025: Week 4 Lab
Module 1: Behavioral Testing with ePrime: 1.) Design a task paradigm in ePrime. 2.) Participate in a behavioral experiment using ePrime. 3.) Explore data collected from ePrime and propose methods of analysis.

1. Crump, M. J., McDonnell, J. V., & Gureckis, T. M. (2013). Evaluating Amazon's Mechanical Turk as a tool for experimental behavioral research. *PloS one*, *8*(3), e57410. https://doi.org/10.1371/journal.pone.0057410

2. Kim, J., Gabriel, U., & Gygax, P. (2019). Testing the effectiveness of the Internet-based instrument PsyToolkit: A comparison between web-based (PsyToolkit) and lab-based (E-Prime 3.0) measurements of response choice and response time in a complex psycholinguistic task. *PloS one*, *14*(9), e0221802. https://doi.org/10.1371/journal.pone.0221802

Tuesday, February 18th, 2025: Week 5 Lecture
Friday, February 21st, 2025: Week 5 Lab
Module 1: Neuroimaging with fMRI: 1.) Observe a fMRI experiment. 2.) Understand the difference between task-based and resting-state scans. 3.) Develop skills in basic processing of fMRI data using Matlab.

1. Heeger, D. J., & Ress, D. (2002). What does fMRI tell us about neuronal activity?. *Nature reviews. Neuroscience*, *3*(2), 142–151. https://doi-org.ezproxy.cul.columbia.edu/10.1038/nrn730

2. Lee, M. H., Smyser, C. D., & Shimony, J. S. (2013). Resting-state fMRI: a review of methods and clinical applications. *AJNR. American journal of neuroradiology*, *34*(10), 1866–1872. https://doi.org/10.3174/ajnr.A3263

Tuesday, February 25th, 2025: Week 6 Lecture
Friday, February 28th, 2025: Week 6 Lab
Module 2: EEG: 1.) Collect EEG data. 2.) Understand the difference between event-related potentials (ERPs) and oscillations. 3.) Practice analyzing EEG data.

1. Cavanagh J. F. (2019). Electrophysiology as a theoretical and methodological hub for the neural sciences. *Psychophysiology*, *56*(2), e13314. https://doi.org/10.1111/psyp.13314

2. Schiller, B., Sperl, M. F. J., Kleinert, T., Nash, K., & Gianotti, L. R. R. (2024). EEG Microstates in Social and Affective Neuroscience. *Brain topography*, *37*(4), 479–495. https://doi.org/10.1007/s10548-023-00987-4

Tuesday, March 4th, 2025: Week 7 Lecture
Friday, March 7th, 2025: Week 7 Lab

Module 2: Songbird Behavior: 1.) Understand principles guiding behavioral testing including shaping, instrumental versus operant conditioning, innage versus learned behaviors. 2.) Understand common behavioral paradigms to assess stress and cognition in animals. 3.) Observe a behavioral paradigm to assess social interactions in songbirds.

1. Burke, J.E. and Schmidt, M.F. (2024). Neural Control of Birdsong. In eLS, John Wiley & Sons, Ltd (Ed.). https://doi.org/10.1002/9780470015902.a0029190

2. Neziri, S., Köseoğlu, A. E., Deniz Köseoğlu, G., Özgültekin, B., & Özgentürk, N. Ö. (2024). Animal models in neuroscience with alternative approaches: Evolutionary, biomedical, and ethical perspectives. *Animal models and experimental medicine*, 10.1002/ame2.12487. Advance online publication. https://doi.org/10.1002/ame2.12487

Tuesday, March 11th, 2025: Week 8 Lecture
Friday, March 14th, 2025: Week 8 Lab
Module 2: Intracellular Slice Recordings: 1.) Understand the difference between single-unit recordings, local field potentials (LFPs), and intracellular recordings. 2.) Understand how pharmacological agents modulate glutamate receptors. 3.) Observe an intracellular slice recording session. 4.) Practice slicing brains on the vibratome.

1. Rubaiy H. N. (2017). A Short Guide to Electrophysiology and Ion Channels. *Journal of pharmacy & pharmaceutical sciences : a publication of the Canadian Society for Pharmaceutical Sciences, Societe canadienne des sciences pharmaceutiques*, *20*, 48–67. https://doi.org/10.18433/J32P6R

2. Widge, A. S., Heilbronner, S. R., & Hayden, B. Y. (2019). Prefrontal cortex and cognitive control: new insights from human electrophysiology. *F1000Research*, *8*, F1000 Faculty Rev-1696. https://doi-org.ezproxy.cul.columbia.edu/10.12688/f1000research.20044.1

SPRING BREAK: March 17th – 21st

Tuesday, March 25th, 2025: Week 9 Lecture
Friday, March 28th, 2025: Week 9 Lab
Module 2: Genetic Manipulations: 1.) Understand the principles behind optogenetics and CRISPR-Cas 9. 2.) Observe a behavioral experiment with and without optogenetic stimulation. 3.) Localize the site of expression using confocal microscope images.

1. Heidenreich, M., & Zhang, F. (2016). Applications of CRISPR-Cas systems in neuroscience. *Nature reviews. Neuroscience*, *17*(1), 36–44. https://doi.org/10.1038/nrn.2015.2

2. Kim, C. K., Adhikari, A., & Deisseroth, K. (2017). Integration of optogenetics with complementary methodologies in systems neuroscience. *Nature reviews. Neuroscience*, *18*(4), 222–235. https://doi.org/10.1038/nrn.2017.15

Tuesday, April 1st, 2025: Week 10 Lecture
Friday, April 4th, 2025: Week 10 Lab
Module 3: Immunofluorescence: 1.) Understand the principles behind immunohistochemistry and immunofluorescence. 2.) Practice immunohistochemistry on brain slices to visualize proteins of interest.

1. Friis, T., Pedersen, K. B., Hougaard, D., & Houen, G. (2015). Immunocytochemical and Immunohistochemical Staining with Peptide Antibodies. *Methods in molecular biology (Clifton, N.J.)*, *1348*, 311–325. https://doi.org/10.1007/978-1-4939-2999-3_27

2. Inavalli, V. V. G. K., Puente Muñoz, V., Draffin, J. E., & Tønnesen, J. (2024). Fluorescence microscopy shadow imaging for neuroscience. *Frontiers in cellular neuroscience*, *18*, 1330100. https://doi.org/10.3389/fncel.2024.1330100

Tuesday, April 8th, 2025: Week 11 Lecture
Friday, April 11th, 2025: Week 11 Lab
Module 3: Microscopy: 1.) Learn how to mount tissue on a slide. 2.) Understand the difference between confocal, widefield, and electron microscopy. 3.) View mounted tissue on the microscope and collect images.

1. Reigoto, A. M., Andrade, S. A., Seixas, M. C. R. R., Costa, M. L., & Mermelstein, C. (2021). A comparative study on the use of microscopy in pharmacology and cell biology research. *PloS one*, *16*(1), e0245795. https://doi.org/10.1371/journal.pone.0245795

2. Zhuang, Y., & Shi, X. (2023). Expansion microscopy: A chemical approach for super-resolution microscopy. *Current opinion in structural biology*, *81*, 102614. https://doi.org/10.1016/j.sbi.2023.102614

Tuesday, April 15th, 2025: Week 12 Lecture
Friday, April 18th, 2025: Week 12 Lab
Module 3: Neuronal Tracings: Neuron Morphology: 1.) Observe cell loading protocol to inject neurons with fluorescent dye. 2.) Use Neurolucida to make tracing of dendritic arbor. 3.) Understand the advantages of cell loading versus Golgi staining. 4.) Practice analyzing dendritic arbor data with a dataset from NeuroMorpho.org.

1. Anderson, K., Yamamoto, E., Kaplan, J., Hannan, M., & Jacobs, B. (2010). Neurolucida Lucivid versus Neurolucida camera: A quantitative and qualitative comparison of three-dimensional neuronal reconstructions. *Journal of neuroscience methods*, *186*(2), 209–214. https://doi.org/10.1016/j.jneumeth.2009.11.024

2. Walker, C. K., Greathouse, K. M., Liu, E., Muhammad, H. M., Boros, B. D., Freeman, C. D., Seo, J. V., & Herskowitz, J. H. (2022). Comparison of Golgi-Cox and Intracellular Loading of Lucifer Yellow for Dendritic Spine Density and Morphology Analysis in

the Mouse Brain. *Neuroscience*, *498*, 1–18. https://doi.org/10.1016/j.neuroscience.2022.06.029

Tuesday, April 22nd, 2025: Week 13 Lecture
Friday, April 25th, 2025: Week 13 Lab
Wrap Up: Connecting with Labs and Research Preparation: 1.) Attend a session with mini presentations from labs across the Zuckerman Institute and Psychology Department who are accepting undergraduate research assistants. 2.) Review requirements and prerequisites for involvement in undergraduate research. 3.) Complete the necessary training and paperwork for research involvement. 4.) Learn the do's and don'ts for undergraduate research success.

1. Bangera, G., & Brownell, S. E. (2014). Course-based undergraduate research experiences can make scientific research more inclusive. *CBE life sciences education*, *13*(4), 602–606. https://doi.org/10.1187/cbe.14-06-0099

2. Haeger, H., Bueno, E. H., & Sedlacek, Q. (2024). Participation in Undergraduate Research Reduces Equity Gaps in STEM Graduation Rates. *CBE life sciences education*, *23*(1), ar11. https://doi.org/10.1187/cbe.22-03-0061

Tuesday, April 29th, 2025: Week 14 Lecture
Friday, May 2nd, 2025: Week 14 Lab
Wrap Up: Transition to Undergraduate Research: 1.) Finalize preparations for involvement in undergraduate research, including applications for research positions. 2.) Reflect on the learning experiences and skills gained throughout the course. 3.) Set short-term and long-term personal goals for future research and academic pursuits.

1. Manzanares, M., Peña, C., Kobak, K. C., & Stratton, M. B. (2023). Ten simple rules for students navigating summer research experiences for undergraduates (REU) programs: From application to program completion. *PLoS computational biology*, *19*(11), e1011573. https://doi.org/10.1371/journal.pcbi.1011573

2. Neuroscience: Past and Future. (2018). *Neuron*, *98*(1), 10–11. https://doi.org/10.1016/j.neuron.2018.03.029

3. Visions for the Future of Neuroscience. (2018). *Neuron*, *98*(3), 464–465. https://doi.org/10.1016/j.neuron.2018.04.024

Grades:
Your overall course grade will be determined by your effort in the following areas:

- **Lecture preparation and participation** **30%**
  - Weekly reading questions (15%)
  - In-class contributions (15%)
- **Lab preparation and participation** **30%**

    - In-lab assignments (20%)
    - In-lab participation (10%)
- **Research project** **40%**
    - Research paper (30%)
    - Poster presentation (10%)

Letter Grade Assignment:

98-100%: A+	87-89.9%: B+	77-79.9%: C+	67-69.9%: D+	<60%: F
93-97.9%: A	83-86.9%: B	73-76.9%: C	63-66.9%: D	
90-92.9%: A-	80-82.9%: B-	70-72.9%: C-	60-62.9%: D-	

Course Policies: please read the following policies carefully!

Disability Services:
Students must register with their school's Disability Services office in order to receive disability-related accommodations and must complete the testing accommodation request form. More information is available at:
Columbia: https://health.columbia.edu/content/disability-services
Barnard: https://barnard.edu/disabilityservices/register-cards

Religious Observance:
If you are going to miss class(es) due to religious observance, you must notify me during the first week of class so that accommodations can be made.

Lecture Participation:
Each class period we will having polling questions to check your understanding of the material. These questions will not be graded for accuracy, but your participation in the poll is required. Your two lowest scores will be dropped. If you have more than two absences you will need a doctor's note or note from your advising dean to get credit for those absences. We will use Poll Everywhere for our polling questions.

Lab Participation:
Attendance and engagement are a critical component of your grade. Attendance will be taken each lab period. Please make every effort to attend as there will not be make up labs available. Active participation is expected from all students during the laboratory potion.

Electronics Policy:
It is strongly encouraged that you take hand-written notes. If you need to use a device, please be respectful of your classmates and your instructor by only accessing the document for class and not using the device to message or access the internet. Coming to class is of no value if you are not paying attention to the lecture. Messaging friends, watching videos online, and browsing social media are not appropriate for the classroom. Remember to silence your phones before class.

Unreadable File Submission:

Any assignments that have unreadable files will automatically receive a 0% score. It is a student's responsibility to make sure that submissions are done in a proper manner and double check that files are readable and accessible to the teaching team. To avoid the penalty for unreadable file submission, try to work on the assignments ahead of time and give yourself enough time to check that the files submitted are accessible/readable.

Late Assignments:

Assignments that are turned in after the submission deadline will receive a deduction in points. An assignment that is turned in within 1 day of the deadline will receive a 25% deduction in points. An assignment that is turned in more than 1 day late will receive a 50% deduction in points. Courseworks will automatically apply this deduction in points. Assignments are not accepted after the last day of the semester (Monday, May 5th at 11:59 PM). If there are extenuating circumstances (death in the family, etc.) please notify me immediately. I cannot make accommodations if I don't know what's going on or if something occurs after the due date. Note: to avoid the penalty for late submissions, do not wait until the last minute to submit an assignment. Courseworks is sometimes slow to upload. Submitting in advance of the deadline is your best bet.

Academic Honesty:

Academic honesty is taken very seriously. Columbia students commit to the Honor Code as follows: "I affirm that I will not plagiarize, use unauthorized materials, or give or receive illegitimate help on assignments, papers, or examinations. I will also uphold equity and honesty in the evaluation of my work and the work of others. I do so to sustain a community built around this Code of Honor." All suspected cases of dishonest behavior will be reported to Student Conduct and Community Standards. All submissions will be run through TurnItIn.

Sexual Respect:

Any form of gender-based misconduct will not be tolerated. "Columbia University is committed to fostering an environment that is free from gender-based discrimination and harassment, including sexual assault and all other forms of gender-based misconduct." Visit this website for more information: http://sexualrespect.columbia.edu/