

PSYC 4745/PHYS 4745/PSYC 8890 Syllabus

Physics of Cognition (3 CR)

Fall 2026

Instructor Information

Instructor
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Please use Canvas for course communications.

General Information

Description

Unlike an artificial neural network, neural systems exhibit a high degree of variation at all scales, from molecules to neurons to networks to individuals, in space and in time. Yet, the brain is capable of cognitive feats that artificial neural networks perform badly or not at all, with training sets and energy consumption that are orders of magnitude less than those used by modern machine learning and artificial intelligence. Understanding how this is possible motivates deeper study of the "physics" of biological neural networks.

This course surveys a selection of fundamental insights into perception, memory, and learning motivated by physical principles. In the first part of this course, we trace the interaction between physics and psychology, from Helmholtz to Hopfield, examining at a mechanistic level the physical basis of cognition. In the second part of the course, we turn to modern neural recording methods, and what we can learn from these data using tools developed for studying complex systems in physics. Students will explore these concepts through direct engagement with classic and modern literature, culminating in a project in which they model a neural system or analyze a dataset of their choice.

Pre- &/or Co-Requisites

There are no pre-requisites for this course, but having some experience with coding will be helpful. We will draw broadly from many disciplines, including core mathematics (linear algebra, differential equations, probability, and statistics), neuroscience, and theoretical biological physics. It is recognized that students in an interdisciplinary course will have varied backgrounds, and assignments have been designed with this in mind.

Course Goals and Learning Outcomes

The key goal of this course is to introduce students to a way of approaching problems in cognitive neurosciences that is shaped strongly by principles of (bio)physics. We work toward this content goal by developing a set of skills through reading primary literature and hands-on computer-based exercises. Upon successful completion of this course, you should be able to

- Identify key principles of theoretical biological physics and give examples of how they have been or could be applied to problems in cognitive neuroscience.
- Critically read, evaluate, and summarize primary literature, in written or oral presentation.
- Translate conceptual models into code for numerical experimentation.

Course Requirements & Grading

Assignment	Due Date	Weight (Percentage)
HWS 1-10	Weekly, Friday	5% each
Final project paper		15%
Journal Club Presentation	TBD	15%
Final presentation	December 1, 3, 8, 2026	5%
Paper Quizzes	Each Thursday	10% (+ up to 3% EC)
Reflections/Questions	Each Tuesday	10% (+ up to 3% EC)

Description of Graded Components

Based on the principle that learning requires practice, making mistakes, and opportunities for feedback, grades in this course will be determined by classroom participation, weekly assignments, journal club presentations, and a final project. There is no midterm or final exam. The lowest grade on the assignment may be dropped.

Grade components:

Participation Grade: 20% (1% per class, up to 26% possible)

Written Assignments: 40% (5% each, 10 total)

Journal Club Presentation: 15%

Final project: 25% (5% for abstract, 20% final paper)

Participation grade: 20%, up to 26% possible

Mondays are typically didactic lectures and in-class exercises. Index cards will be distributed each Monday for students to submit a question or comment on that class. One point toward the final grade is earned by turning in the index card. **Names must be written on cards for credit to be given.**

Journal Clubs take place on Wednesdays. At the beginning of each Wednesday meeting, a brief quiz (1 question) will be given to check that the paper was read. One point toward the final grade is earned by getting the quiz question correct.

Written Assignments: 40%, up to 50% possible

Upload as PDFs to the Canvas site before class (by 2:00 PM) on the due date. All assignments can be found in the shared class Overleaf repository: <https://www.overleaf.com/read/phnxdkvffdrm#d2c70a>.

Homework assignments will have additional problems for students enrolled in 8890.

You are welcome to use whatever program you wish to write up assignments, but you are encouraged to take advantage of Overleaf for its ease of equation editing and reference management. **All completed assignments must be uploaded as a pdf to the Canvas website. Please remember to put your name on your assignment.**

Journal Club Presentations: 15%:

Every Wednesday the class will be a journal club. One to two students will be assigned a paper to present each week. All students are expected to participate in the discussion. Presentations do not need to have polished slides but may have slides to guide the discussion if needed.

On the Monday prior to the journal club presentation, two candidate quiz questions will be submitted to Prof. Sederberg. These may be used for the understanding-check quiz given on Wednesday prior to the journal club discussion.

Students enrolled in 8890 will be solo presenters (75-minute class). Students enrolled in 4803 will present in pairs.

Grading for presentations is as follows:

	Full credit (5 pts)	Partial (3 pts)	No credit (0 pt)
Engagement of the class	Lively discussion that is on point. Presentation includes questions for the class, either questions the presenter is still unclear on or questions to stimulate discussion.	Discussion limited to the group of presenters. No attempt to engage the class in discussion.	Crickets
Clarity of presentation	The main results of the paper are conveyed clearly and accurately in context	The general concept is explained well, but minor points confused and/or insufficient context provided.	Presentation is confusing or misleading.
Preparation	The presenter has prepared sufficiently to answer all basic content questions about the paper. Two candidate quiz questions were submitted by Monday preceding the presentation.	The presenter can answer some basic content questions. Discussion questions are superficial. Quiz questions were not submitted.	No apparent preparation, not clear that anyone read more than the abstract.

Final project: 25%

In lieu of a final exam, students will complete a final project and presentation. The final project is worth 25% of the grade. The project will be comprised of original data analysis using public datasets (option 1) or a review paper on a topic approved by the instructor (option 2). Grade is based on three components: the abstract/proposal (5%, due 3/14/25), the written report (15%, due at the end of the final exam period for this class, 4/25/25 at 5:30 PM) and a 10-minute presentation on the project (5%, final weeks of class).

Grading Scale

Your final grade will be assigned as a letter grade according to the following scale:

A	85-100%
B	75-84%
C	65-74%
D	50-64%
F	0-49%

Note that the lower end of the A range is 85%.

Extra Credit Opportunities

Full credit is achieved by submitting 8 of 10 assignments and attending 20 of 26 classes. Extra credit may be earned by submitting all assignments and attending all classes.

Course Materials

Course Text

There is no required textbook for this course: all material will be presented in-class. Reading primary literature is a key part of the course. All papers will be accessible from the Canvas website.

A subset of the lectures will follow selections of *Biophysics: Searching for Principles* (Bialek) and this text may be consulted for additional depth.

Course Website and Other Classroom Management Tools

All material will be posted to the Canvas site. All communication regarding the class will occur on Canvas. Questions for Prof. Sederberg or the TA should be submitted via Canvas.

Course Expectations & Guidelines

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit <http://www.catalog.gatech.edu/policies/honor-code/> or <http://www.catalog.gatech.edu/rules/18/>.

Any student suspected of cheating or plagiarizing on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible to set up a time to discuss your learning needs.

Attendance and/or Participation

Attendance is expected and participation counts toward the grade.

Mondays are typically didactic lectures and in-class exercises. Index cards will be distributed each Monday for students to submit a question or comment on that class. One point toward the final grade is earned by turning in the index card.

Journal Clubs take place on Wednesdays. At the beginning of each Wednesday meeting, a brief quiz (1 question) will be given to check that the paper was read. One point toward the final grade is earned by getting the quiz question correct.

Collaboration & Group Work

You may work with classmates on homework assignments and as needed to coordinate journal club presentations. Submitted assignments are expected to reflect your own effort. In the words of Count Rugen, this is for posterity, so... be honest.

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

Late work policy: Assignments submitted after the due date (typically, Wednesdays before class starts) are automatically flagged as late and marked down by 20% (maximum points achieved is 4, not 5). Assignments will remain 'open' until the Sunday following the regular due date, and late assignments can be submitted until then. *Note that only 8 of 10 assignments are required, and you may choose not to submit any two of the ten.* This is intended to give flexibility, particularly for non-emergency extension needs.

I recognize that emergencies arise and sometimes it is not possible to turn in an assignment on time. Extensions will be granted for unforeseeable events, such as the death of a loved one, illness, or serious injury, as well as for approved Institute activities and religious observations, per <http://www.catalog.gatech.edu/rules/4/>. In these events, notify Prof. Sederberg on Canvas as soon as possible with the extension request.

Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See <http://www.catalog.gatech.edu/rules/22/> for an articulation of some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Student Use of Mobile Devices in the Classroom

Please refrain from cell phone use during class.

Additional Course Policies

Use of generative artificial intelligence:

The following are acceptable uses of AI in this course:

- 1) Grammar checking and proofreading services such as Grammarly
- 2) Literature search/review through services such as Connected Papers
- 3) Code writing assistance through MATLAB Chat or via Chat GPT. Note that you must still verify that AI-assisted code runs as you expect it to.

Please refrain from using ChatGPT to generate or revise text.

Course Schedule

The draft course schedule is below. The most up-to-date information can be found on the Canvas website.

Week #	Module	Class 1	Class 2
1	The edge of what is possible	Course overview / why physics of cognition? Mini-lecture: Signal and noise I: Photon counting in vision	How to do a journal club / Journal Club 0 (Sederberg): Hecht, Shlaer and Pirenne, 1942 Journal Club Sign-Ups
2	The edge of what is possible	Lecture: Signal and noise II: from photons to psychometrics <i>Coding tutorial: Simulating random processes</i>	Journal Club 1: Barlow 1956 Sakitt 1972 (link) Mini-Lecture: Bayes' Rule HW 1 Due
3	The edge of what is possible	NO CLASS - Martin Luther King Day	Journal club 2: Optimal predictions I Griffiths and Tenenbaum 2006 HW 2 Due
4	The edge of what is possible	Lecture: Information and predictions in neural populations <i>Coding tutorial: probability distributions</i>	Journal Club 3: Optimal predictions II Palmer et al. 2015 HW 3 Due
5		Lecture: Hopfield networks / modern Hopfield networks (30 min.) <i>Coding tutorial: Hopfield networks</i>	Journal Club 4: Hopfield 1982 HW 4 Due
6	Fine tuning and robustness	Lecture: Maximum entropy models <i>In-class exercises/board</i>	Journal Club 5: Schneidman et al. 2006 HW 5 Due
7	Fine tuning and robustness	Lecture: Criticality I <i>Coding tutorial: log-log plots</i>	Journal Club 6: Zipf's Law Aichison, Corradi, and Latham, 2016 HW 6 Due

8	Fine tuning and robustness	Lecture: Avalanche Criticality <i>Coding tutorial: plotting distributions</i>	Journal Club 7: Avalanche criticality: Beggs and Plenz, 2003; Fontenele et al. 2019 (PRL) HW 7 Due
9	Fine tuning and robustness	Lecture: Phenomenological renormalization group <i>Coding tutorial: Covariance matrices and eigenvalues</i>	Journal Club 8: Renormalization group in neural data and models Meshulam et al. 2019 Morrell et al. 2021 HW 8 Due
10	Fine tuning and robustness	Lecture: Analysis of large neural populations + Sources of publicly available data	Journal club 9: Model parameters Blue Brain Project (TBD) and Golowasch et al. 2001 Abstracts Due
11	NO CLASS - SPRING BREAK		
11	Variability is not (always) noise	Lecture: Model networks (Random network dynamics and reservoir computers)	Journal club 10: Laje and Buonomano, 2013 HW 9 Due
12	Variability is not (always) noise	Lecture: Topological approaches to neural data analysis <i>Coding tutorial: Using TDA</i>	Journal club 11: Hyperbolic spaces Zhou and Sharpee 2018 Giusti et al. (Itskov) 2015 HW 10 Due
13	Variability is not (always) noise	Lecture: Order and disorder in sensory systems	Journal club 12: Counting is hard Bushdid et al. (Keller) 2014 Meister 2015 Gerkin and Castro 2015
14		Presentations	Presentations
15		Presentations	NO CLASS - END OF SEMESTER