Neuroscience PhD Program Course Curriculum and Course List

Updated November 2017

COURSE REQUIREMENTS

1. Foundational courses. Students must take 3 foundational courses distributed among three broad areas: (A) Cellular, Molecular & Developmental Neuroscience; (B) Circuits, Systems and Computational Neuroscience; and (C) Cognition, Brain and Behavior. Students can either take one graduate level course from each category, or three graduate level courses chosen from two areas, plus a selected advanced undergraduate course from the third area. Foundation courses are listed below, and must be 3 or more units. They are taken in Years 1-2.

2. Additional elective courses. In addition, students must take one additional elective course. This can be either a graduate-level seminar or a graduate-level lecture course and can be 1 unit or more. This is typically taken in Years 3 and 4. The elective can be chosen from any relevant graduate-level class in any department. Commonly chosen electives are listed below.

3. Training in statistics and quantitative methods. Beginning with the entering class of 2014, all students must complete a one semester course on statistical analysis or quantitative methods. This course is chosen from a large number of appropriate classes at Berkeley and can be completed at any time prior to the semester of graduation. Students with prior appropriate coursework or whose thesis research uses substantial quantitative methods can use that prior experience to fulfill this requirement, subject to approval by the Head Graduate Adviser.

In addition to these scientific subject classes, students must take the required rotation, rotation presentation, and 4th year research presentation classes (NEUROSC 290, 291, and 294). Please see the "Progress through Degree" document for specifics.

Neuroscience-Related Course List

Warning! This course list is accurate as of November 2017. While we try to keep it up to date, courses are often added, dropped, or changed by departments without notifying us. So, please check for complete course listings for the upcoming semester at the Berkeley Online Schedule of Classes, http://schedule.berkeley.edu/

Courses that Satisfy Foundation Requirements

(R) = Recommended intensive survey courses. These are not required, but are suitable for a comprehensive survey of a field within Neuroscience.

(U) = Undergraduate class, will only satisfy distribution requirement if students takes 3 graduate classes in the other 2 areas.

Category A. Cellular, Molecular & Developmental Neuroscience

(R) MCB C261/NEUROSCI C261. Advanced cellular neurobiology. Advanced survey of cellular and molecular neuroscience, with focus on modern research questions. Topics include membrane physiology, ion channel and neurotransmitter receptor physiology, synaptic physiology and plasticity, sensory transduction. Every Fall. Feller, Isacoff, Kramer, others.

MCB C263/NEUROSCI C263. Advanced developmental neurobiology. Current research problems in embryonic and post-embryonic development of invertebrate and vertebrate nervous systems. Currently Spring, odd-numbered years, but may be sporadic. Feller, Ngai.

MCB 231: Advanced Stem Cell and Developmental Biology. Principles of animal development in vertebrates and invertebrates. Induction, localization, patterning mutants, axis formation, regional gene expression, and cell interactions. 3 hrs lecture plus 1 hr weekly reading/discussion section. Every Spring. Weisblat, Harland, Roelink.

MCB 240. Advanced Genetic Analysis. Genetic analysis as applied to eukaryotic organisms, including yeast, nematodes, Drosophila, mice and humans. Isolation and analysis of mutations, gene mapping, suppressor analysis, chromosome structure, control of gene expression, and developmental genetics. Every Spring.

MCB 236. Advanced Mammalian Physiology Principles of mammalian (primarily human) physiology emphasizing physical, chemical, molecular, and cellular bases of functional biology. Covers general cellular physiology and elementary neurophysiology; cell and endocrine regulation; autonomic nervous system regulation; skeletal, smooth, and cardiac muscle; cardiovascular physiology; respiration; renal physiology; gastrointestinal physiology. Three hours of lecture and two hours of discussion per week. Every Fall. Staff.

Category B. Systems and Computational Neuroscience Courses

(R) MCB C262/NEUROSC C262: Advanced Topics in Systems Neuroscience. Survey of current research problems in circuit- and systems-level neuroscience. Sensory and motor systems, circuit-level computation, memory systems. Three hours per week, mixed lecture and seminar format. Every Spring. Y. Dan, Feldman.

Psychology 210B. Biological Bases of Behavior. Kriegsfeld. Spring of odd-numbered years (but may vary!!) Meets 3 hours per week, mixed lecture and seminar format.

Vision Science 260C: Introduction to Visual Neuroscience. This course will provide an overview of the neuroscience of vision, spanning the entire neural pathway from retinal neurobiology to cortical processing of visual signals. The class will comprise a combination of lectures and active learning by the students in the form of a project, to be presented at the end of the semester. Silver, Olshausen, and Taylor. 3 units.

(R) Vision Science 265: Neural Computation. Introduction to the theory of neural computation, including the major theoretical frameworks and models used in neuroscience and psychology. Provides hands-on experience in using these models. Fall of even-numbered years. Olshausen.

CATEGORY C. COGNITION, BRAIN AND BEHAVIOR COURSES

(U) Psychology 117: Human Neuropsychology. Advanced undergraduate course. Psychological approaches to neuropsychiatric disease and disability, including mental disorders, behavior changes following human brain injury and disease, and mental subnormality. Nervous system models and basic research are considered. Every Spring. D'Esposito, Knight, others.

(U) Psychology C127: Cognitive Neuroscience. Advanced undergraduate course. The neurological basis of cognition, including perception, attention, memory, language, motor control, executive control, and emotion. Findings from brain-injured patients, neurophysiological research in animals, and normal cognitive processes in humans studied with functional Magnetic Resonance Imaging (fMRI), electroencephalography (EEG), and transcranial magnetic stimulation (TMS). Every Fall. Gallant.

(R) Psychology 210A: Cognitive Neuroscience. Proseminar surveying cognitive neuroscience. Instructors include Gallant, Wilbrecht, Kriegsfeld. Fall of odd-numbered years (but may vary!!). Neuro and Psych graduate students are given equal priority for enrolling in this class.

Psychology 210D: Learning and Memory. Proseminar. Shimamura, with Theunissen, Jacobs, Knight, Griffiths, Kihlstrom. Fall of odd-numbered years (but may vary!!)

Psychology 214: Functional MRI Methods. Overview of functional MRI methodology. Includes basic physics of fMRI, the nature of BOLD fMRI signal, the spatial and temporal resolution of fMRI, experimental design, and statistical techniques. Includes hands-on experience performing an fMRI experiment and analyzing the data. D'Esposito and others. Every Fall. <u>Because of its specific focus on methodology, this course is only appropriate for cognitive neuro students who will use fMRI in their thesis research; it is not appropriate for other students looking to fill the cognitive neuroscience requirement.</u>

Psychology 240: Proseminar on Biological, Cognitive, and Language Development. Development of the nervous system and behavior. Biological focus includes neurogenesis, synaptogenesis, cell death and synapse elimination, and genetic and experiential determinants of neural development. Cognitive focus includes development of knowledge from infancy through childhood and across multiple domains including physics, biology, math, and psychology. Includes language acquisition and review of phonology, syntax, and morphology. Fall of even-numbered years. Bunge, Gopnik, Xu, Theunissen.

Public Health C217D: Biological and Public Health Aspects of Alzheimer's Disease. Survey of Alzheimer's disease (AD) from a biological and public health perspective. Includes clinical and neuropathological features, genetics and molecular biology, epidemiology, diagnosis, treatment and ethics of AD. Students read original research papers in medicine, neuroscience, and epidemiology. 3 hours per week. Seminar format. Every Spring. Jagust.

Vision Science 262. Visual Cognitive Neuroscience. An overview of visual cognitive neuroscience, drawing from neuroanatomy, neurophysiology in humans and animal models, psychophysics, neuroimaging, neuropharmacology, neuropsychology, and computational models of vision and cognition. Topics include basic anatomy and physiology of the mammalian visual system, motion perception and processing, depth perception and representation of visual space, brightness and color, object and face recognition, visual attention, developmental and adult plasticity, perceptual learning, multisensory integration, and visual awareness. Fall, every 2-3 years. Silver. 3 units.

Summary schedule for foundation courses

Semester	Fall 2017	Spring 2018	Fall 2018	Spring 2019
Molec/Cell/Devel	**MCB 261** MCB 236	MCB 263 MCB 231 MCB 240	**MCB 261** MCB 236	MCB 231 MCB 240
Systems/Computational	**VS 265**	**MCB 262** PSYCH 210B^ VS260C	**VS 265**	**MCB 262** VS260C
Cognition/Behavior	PSYCH 127 (U) **PSYCH 210A** PSYCH 214 PSYCH 240	PSYCH 117 (U) PH C217D	PSYCH 127 (U) **PSYCH 210A^** PSYCH 210D^ PSYCH 214 VS262	PSYCH 117 (U) PH C217D

Bold are recommended survey courses. ^ **Warning**: These classes are often moved to different semesters. Please check with the online Schedule of Classes, or with the Psych department, to see when they are offered next!

Courses that are Commonly Chosen as Electives

Electives can be chosen from any relevant graduate-level class in any department, including both seminars and lectures courses. Commonly chosen electives are listed below. Many of these electives will satisfy the statistics/quantitative analysis course requirement. You can also take any course in the Foundation Classes section as an elective. Consult your thesis adviser and thesis committee to select the most appropriate classes for you.

NEURO-RELATED SEMINAR COURSES

Seminar courses are small, highly interactive 1- and 2-unit courses that focus on specific current research topics, led by a faculty member who is a leading researcher in the field. Topics change each semester, so check the online catalog and the "Neuroscience-Related Seminar Course" list (updated just prior to each semester).

Neurosci 299. Graduate Seminar. Selected research topics in neuroscience. Past topics have included sensorimotor control and learning.

MCB 290. Graduate Seminar. Selected research topics in molecular and cell biology. Past topics have included: molecular and cellular mechanisms of touch and pain; neural correlates of behavior; neurobiology of sleep; gene transfer to the nervous system; motor control; from synaptic pharmacology to consciousness; topics in synaptic pharmacology; cerebral cortex; topics in systems neuroscience.

Psychology 290's: Graduate Seminar. Selected research topics in cognition, brain and behavior. Past topics have included: Neuronal mechanisms of learning and memory, data pre-processing for fMRI, neural bases of circadian rhythms; sleep; advanced topics in vision research, critical periods and plasticity, computational models of cognition.

Vision Science 298: Graduate Seminar. Past topics have included: advanced topics in color vision; statistics and data modeling; advanced topics in neural computation.

EECS 290: Advanced Topics in Electrical Engineering. Current topics of research interest in electrical engineering.

Linguistics 290: Special topics in Linguistics. This series of seminars covers advanced topics in syntax, semantics, pragmatics, phonology, psycholinguistics, and more.

NEUROSCIENCE

(R) NEUROSC 299: Applied statistics for neuroscience. A cooperative course covering statistical methods commonly used in neuroscience. Topics include a wide variety of parametric statistics, non-parametic statistics, and modeling. Students will learn implementations in R and Matlab. Instructor of record: Feldman. But primary instruction is cooperative among the students, facilitated by a GSI. 1-3 units. Every Spring.

STATISTICS

(U) Psychology 102. Advanced statistics for psychological sciences. Covers research design, statistical reasoning and methods for psychological research. Meets four times per week: 3 lectures plus a computer lab/discussion section. Descriptive statistics, normal distribution, hypothesis testing, Z-test, Effect size and power, t-test, ANOVA, regression, correlation, chi-square, Monte Carlo and GLM. Theunissen. 3 units. Every Spring.

Psychology 205A-B. Data analysis. A general data analytic course that emphasizes design issues and problems, from pure experimental research through field studies. Techniques of ANOVA and multiple regression/correlation will be presented as analytical models for both lab and field research. Three hours of lecture and two hours of discussion/laboratory per week. Every Fall and Spring.

(U) Stat 150. Stochastic Processes. Random walks, discrete time Markov chains, Poisson processes. Further topics such as: continuous time Markov chains, queueing theory, point processes, branching processes, renewal theory, stationary processes, Gaussian processes. Typically taught in Spring. Priority goes to Stats majors, and class fills up early.

(U) Stat 151A-151B. Linear Modeling: Theory and Applications. A coordinated treatment of linear and generalized linear models and their application. Linear regression, analysis of variance and covariance, random effects, design and analysis of experiments, quality improvement, log-linear models for discrete multivariate data, model selection, robustness, graphical techniques, productive use of computers, in-depth case studies. 151A every Fall, 151B every Spring, B can be taken without A. Priority goes to Stats majors, and class fills up early.

(U) Stat 153. Introduction to Time Series. An introduction to time series analysis in the time domain and spectral domain.Topics will include: estimation of trends and seasonal effects, autoregressive moving average models, forecasting, indicators, harmonic analysis, spectra. Every Fall and Spring. Priority goes to Stats majors, and class fills up early.

(U) Stat 158. The Design and Analysis of Experiments. This course covers planning, conducting, and analyzing statistically designed experiments with an emphasis on hands-on experience. Standard designs studied include factorial designs, block designs, latin square designs, and repeated measures designs. Other topics covered include the principles of design, randomization, ANOVA, response surface methodoloy, and computer experiments. Purdom. Spring.

Stat 204. Probability for Applications. A treatment of ideas and techniques most commonly found in the applications of probability: Gaussian and Poisson processes, limit theorems, large deviation principles, information, Markov chains and Markov chain Monte Carlo, martingales, Brownian motion and diffusion. Every Fall.

Stat C241A. Statistical Learning Theory. Classification regression, clustering, dimensionality, reduction, and density estimation. Mixture models, hierarchical models, factorial models, hidden Markov,and state space models, Markov properties, and recursive algorithms for generalprobabilistic inference nonparametric methods including decision trees, kernal methods, neural networks, and wavelets. Ensemble methods. Also listed as Computer Science

C281A. Every Fall. Fills quickly, register as early as possible.

Stat C241B. Advanced Topics in Learning and Decision Making. Graphical models and approximate inference algorithms. Markov chain Monte Carlo, mean field and probability propagation methods. Model selection and stochasticrealization. Bayesian information theoretic and structural risk minimization approaches. Markov decision processes and partially observable Markov decision processes. Reinforcement learning. Also listed as Computer Science C281B. Offered most Spring semesters (but not all).

Stat 248. Analysis of Time Series. requency-based techniques of time series analysis, spectral theory, linear filters, estimation of spectra, estimation of transfer functions, design, system identification, vector-valued stationary processes, model building. Spring.

MATHEMATICS

(U) Math 118. Wavelets and Signal Processing. Introduction to signal processing including Fourier analysis and wavelets. Theory, algorithms, and applications to one-dimensional signals and multidimensional images. Generally offered once a year, but semester varies.

Math 220. Methods of Applied Mathematics. Variational principles; optimization; control; dynamical systems; stochastic ordinary differential equations; estimation; data analysis. Schedule is unclear.

COMPUTER SCIENCE AND PROGRAMMING

CS C280. Computer Vision. Paradigms for computational vision. Relation to human visual perception. Mathematical techniques for representing and reasoning, with curves, surfaces and volumes. Illumination and reflectance models. Color perception. Image segmentation and aggregation. Methods for bottom-up three-dimensional shape recovery: line drawing analysis, stereo, shading, motion, texture. Use of object models for prediction and recognition. Also listed as Vision Science C280. Offered most Fall semesters.

AY 250. Python Computing for Science. An undergraduate/graduate seminar course in Python, “the de facto superglue language for modern scientific computing”. To be eligible, you must complete the Python Boot Camp – 3 full days in late August. Josh Bloom. The class assumes familiarity with basic programming concepts like loops and recursion. One 3-hr meeting per week. Weekly coding assignments and a final project in your own area.

ELECTRICAL ENGINEERING

(U) EE 120. Signals and Systems. Continuous and discrete-time transform analysis techniques with illustrative applications. Linear and time-invariant systems, transfer functions. Fourier series, Fourier transform, Laplace and Z-transforms. Sampling and reconstruction. Solution of differential and difference equations using transforms. Frequency response, Bode plots, stability analysis. Illustrated by analysis of communication systems and feedback control systems. Every Fall and Spring.

(U) EE 123. Digital Signal Processing. Discrete time signals and systems: Fourier and Z transforms, DFT, 2-dimensional versions. Digital signal processing topics: flow graphs, realizations, FFT, chirp-Z algorithms, Hilbert transform relations, quantization effects, linear prediction. Digital filter design methods: windowing, frequency sampling, S-to-Z methods, frequency-transformation methods, optimization methods, 2-dimensional filter design. Every Fall.

(U) EE 126. Probability and Random Processes. This course covers the fundamentals of probability and random processes useful in fields such as networks, communication, signal processing, and control. Sample space, events, probability law. Conditional probability. Independence. Random variables. Distribution, density functions. Random vectors. Law of large numbers. Central limit theorem. Estimation and detection. Markov chains. Every Fall and Spring.

EECS 221A: Linear System Theory. Concepts and properties of linear systems. Includes statespace and input-output representation, controllability, observability, minimality, state and outputfeedback, stability, observers, characteristic polynomial, Nyquist test. Fall, Spring.

EE 225A. Digital Signal Processing. Advanced techniques in signal processing. Stochastic signal processing, parametric statistical signal models, and adaptive filtering. Application to spectral estimation, speech and audio coding, adaptive equalization, noise cancellation, echo cancellation, and linear prediction. Offered once per year, but semester varies.

EE 225B. Digital Image Processing. 2-D sequences and systems, separable systems, projection slice thm, reconstruction from projections and partial Fourier information, Z transform, different equations, recursive computability, 2D DFT and FFT, 2D FIR filter design; human eye, perception, psychophysical vision properties, photometry and colorimetry, optics and image systems; image enhancement, image restoration, geometrical image modification, morphological image processing, half-toning, edge detection, image compression: scalar quantization, lossless coding, Huffman coding, arithmetic coding dictionary techniques, waveform and transform coding DCT, KLT, Hadammard transform, multi-resolution coding pyramid, sub-band coding, Fractal coding, vector quantization, motion estimation and compensation, standards: JPEG, MPEG, H.xxx, pre- and post-processing, scalable image and video coding, image and video communication over noisy channels. Offered once per year, semester varies.

EE 226A. Random Processes in Systems. Probability, random variables and their convergence, random processes. Filtering of wide sense stationary processes, spectral density, Wiener and Kalman filters. Markov processes and Markov chains. Gaussian, birth and death, Poisson and shot noise processes. Elementary queuing analysis. Detection of signals in Gaussian and shot noise, elementary parameter estimation. Offered once per year, semester varies.

EE 227A. Introduction to Convex Optimization. Convex optimization is a class of nonlinear optimization problems where the objective to be minimized, and the constraints, are both convex. Contrarily to the more classical linear programming framework, convex programs often go unrecognized, and this is a pity since a large class of convex optimization problems can now be efficiently solved. In addition, it is possible to address hard, non-convex problems (e.g. "combinatorial optimization" problems) using convex approximations that are more efficient than classical linear ones. The 3-unit course covers some convex optimization theory and algorithms, and describes various applications arising in engineering design, modelling and estimation, finance, and operations research. Every Spring.

EE 229. Information Theory and Coding. Fundamental bounds of Shannon theory and their application. Source and channel coding theorems. Galois field theory, algebraic error-correction codes. Private and public-key cryptographic systems. Every Spring.

BIOENGINEERING

BIO ENG C265: Principles of Magnetic Resonance Imaging. [3 units]. Fundamentals of MRI including signal-to-noise ratio, resolution, and contrast as dictated by physics, pulse sequences, and instrumentation. Image reconstruction via 2D FFT methods. Fast imaging reconstruction via convolution-back projection and gridding methods and FFTs. Hardware for modern MRI scanners including main field, gradient fields, RF coils, and shim supplies. Software for MRI including imaging methods such as 2D FT, RARE, SSFP, spiral and echo planar imaging methods. The modern MRI "toolbox" will be introduced, including selecting a slice or volume, fast imaging methods to avoid image artifacts due to physiologic motion, and methods for functional imaging. Fall, Spring.

BIO ENG C218: Stem Cells and Directed Organogenesis. This course will provide an overview of basic and applied embryonic stem cell (ESC) biology. Topics will include early embryonic development, ESC laboratory methods, biomaterials for directed differentiation and other stem cell manipulations, and clinical uses of stem cells. Also listed as Molecular and Cell Biology C237. Spring.

BIO ENG C219. Protein Engineering. An in-depth study of the current methods used to design and engineer proteins. Emphasis on how strategies can be applied in the laboratory. Relevant case studies presented to illustrate method variations and applications. Intended for graduate students. Fall.

BIO ENG 231: Introduction to Computational Molecular and Cellular Biology. Topics include computational approaches and techniques to gene structure and genome annotation, sequence alignment using dynamic programming, protein domain analysis, RNA folding and structure prediction, RNA sequence design for synthetic biology, genetic and biochemical pathways and networks, UNIX and scripting languages, basic probability and information theory. Various "case studies" in these areas are reviewed and web-based computational biology tools will be used by students and programming projects will be given. Fall.

BIO ENG 243: Computational Methods in Biology. Three hours of lecture, two hours of laboratory, and one hour of discussion per week. An introduction to biophysical simulation methods and algorithms, including molecular dynamics, Monte Carlo, mathematical optimization, and "non-algorithmic" computation such as neural networks. Various case studies in applying these areas in the areas of protein folding, protein structure prediction, drug docking, and enzymatics will be covered. Fall.

BIO ENG 263: Principles of Molecular and Cellular Biophotonics [4 units] Topics in the emerging field of biophotonics with an emphasis on fluorescence spectroscopy, biosensors, and devices for optical imaging and detection of biomolecules. The course will cover the photophysics and photochemistry of organic molecules, the design and characterization of biosensors, and their applications within diverse environments, ranging from the detection of single molecules in vitro and in cells to studies of detection, diagnosis, and monitoring of specific health conditions and disease. Spring.

VISION SCIENCE

Vision Science 260A. Optical and Neural Limits to Vision. This course will provide an overview of the early stage limits to human vision, from the eye's optics to sampling and processing in the retina. Students will learn basic optical properties of the eye as well as objective and subjective techniques on how to measure limits of human vision. The class will comprise a combination of lectures and active learning by the students in the form of a project, to be presented at the end of the semester. Fall. Roorda. 3 units.

Vision Science 260D. Seeing in Time, Space, and Color. This course will provide an overview of how we see in time (temporal signal processing, eye motion, motion detection), space (stereo vision, depth perception), and color as well as the anatomical and physiological factors that facilitate these capabilities. The course will be series of didactic lectures. Fall. Banks. 3 units.