Vision Science

Vision is one of the most valuable sensory modalities. It is also the source of a rich array of research questions relating to how we see, how and why vision fails, and what can be done about it. Investigators in Vision Science conduct human and animal research and modeling, yielding cutting-edge discoveries and applications in disciplines that include molecular genetics, clinical care, adaptive optics, neurobiology, cell biology, infectious disease, bioengineering, perception, and public health.

This PhD program (http://vision.berkeley.edu) emphasizes the interdisciplinary nature of vision science research through broad exposure to the basic concepts and techniques used in specialized fields. Engaged in both laboratory-based and clinical research, our students (http://vision.berkeley.edu?page_id=37) are working with faculty (http://vision.berkeley.edu/cat=2) advisers whose research matches their own interests. Current research topics include biomedical optics, perception and visual cognition, molecular and cell biology, neuroscience, computational vision, genetics, immunology, microbiology and clinical science.

Vision Science alumni (http://vision.berkeley.edu?page_id=2019) are represented on the faculty of world-class universities — in medical schools, schools of optometry, and a wide range of other disciplines spanning psychology, physiology, bioengineering, and ophthalmology. Many others hold research positions in private institutes and federally sponsored agencies, including NASA and the NIH. Still, others can be found in the research and development divisions of the industry. Ophthalmic and biotechnology companies are among the major recruiters of our graduates.

Due to the interdisciplinary nature of the program, we accept students with various backgrounds including psychology, optometry, engineering, computer science, physics, chemistry, biophysics, neuroscience, mathematics, molecular and cell biology, and integrative biology.

Due to the interdisciplinary nature of the program, we accept students with various backgrounds including psychology, optometry, engineering, computer science, physics, chemistry, biophysics, neuroscience, mathematics, molecular and cell biology and integrative biology. Because this program is designed to develop research scientists, it is also important that applicants are familiar with an experimental lab setting. Program specific admissions guidelines can be found here (http://vision.berkeley.edu?page_id=165).

**Admission to the University**

**Minimum Requirements for Admission**

The following minimum requirements apply to all graduate programs and will be verified by the Graduate Division:

1. A bachelor’s degree or recognized equivalent from an accredited institution;
2. A grade point average of B or better (3.0);
3. If the applicant comes from a country or political entity (e.g., Quebec) where English is not the official language, adequate proficiency in English to do graduate work, as evidenced by a TOEFL score of at least 90 on the iBT test, 570 on the paper-and-pencil test, or an IELTS Band score of at least 7 on a 9-point scale (note that individual programs may set higher levels for any of these); and
4. Sufficient undergraduate training to do graduate work in the given field.

**Applicants Who Already Hold a Graduate Degree**

The Graduate Council views academic degrees not as vocational training certificates, but as evidence of broad training in research methods, independent study, and articulation of learning. Therefore, applicants who already have academic graduate degrees should be able to pursue new subject matter at an advanced level without the need to enroll in a related or similar graduate program.

Programs may consider students for an additional academic master’s or professional master’s degree only if the additional degree is in a distinctly different field.

Applicants admitted to a doctoral program that requires a master’s degree to be earned at Berkeley as a prerequisite (even though the applicant already has a master’s degree from another institution in the same or a closely allied field of study) will be permitted to undertake the second master’s degree, despite the overlap in field.

The Graduate Division will admit students for a second doctoral degree only if they meet the following guidelines:

1. Applicants with doctoral degrees may be admitted for an additional doctoral degree only if that degree program is in a general area of knowledge distinctly different from the field in which they earned their original degree. For example, a physics PhD could be admitted to a doctoral degree program in music or history; however, a student with a doctoral degree in mathematics would not be permitted to add a PhD in statistics.
2. Applicants who hold the PhD degree may be admitted to a professional doctorate or professional master’s degree program if there is no duplication of training involved.

Applicants may apply only to one single degree program or one concurrent degree program per admission cycle.

**Required Documents for Applications**

1. **Transcripts:** Applicants may upload unofficial transcripts with your application for the departmental initial review. If the applicant is admitted, then official transcripts of all college-level work will be required. Official transcripts must be in sealed envelopes as issued by the school(s) attended. If you have attended Berkeley, upload your unofficial transcript with your application for the departmental initial review. If you are admitted, an official transcript with evidence of degree conferral will not be required.
2. **Letters of recommendation:** Applicants may request online letters of recommendation through the online application system. Hard copies of recommendation letters must be sent directly to the program, not the Graduate Division.
3. **Evidence of English language proficiency:** All applicants from countries or political entities in which the official language is not English are required to submit official evidence of English language proficiency. This applies to applicants from Bangladesh, Burma, Nepal, India, Pakistan, Latin America, the Middle East, the People's Republic of China, Taiwan, Japan, Korea, Southeast Asia, most European countries, and Quebec (Canada). However, applicants who, at the time of application, have already completed at least one year of full-time academic course work with grades of B or better at a US university may submit an official transcript from the US university
to fulfill this requirement. The following courses will not fulfill this requirement:
• courses in English as a Second Language,
• courses conducted in a language other than English,
• courses that will be completed after the application is submitted, and
• courses of a non-academic nature.

If applicants have previously been denied admission to Berkeley on the basis of their English language proficiency, they must submit new test scores that meet the current minimum from one of the standardized tests. Official TOEFL score reports must be sent directly from Educational Test Services (ETS). The institution code for Berkeley is 4833. Official IELTS score reports must be mailed directly to our office from the British Council. TOEFL and IELTS score reports are only valid for two years.

Where to Apply
Visit the Berkeley Graduate Division application page (http://grad.berkeley.edu/admissions/apply).

Curriculum
Courses Required

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Core Curriculum

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Electives per approved individualized study list

Additional Requirements

Please refer to the Vision Science website (http://vision.berkeley.edu/?page_id=167).

Vision Science

Expand all course descriptions [+]Collapse all course descriptions [-]

VIS SCI 201A Seminar in Vision Science 2 Units
Offered through: Optometry
Terms offered: Fall 2015, Fall 2014, Fall 2013
Graduate seminar in vision science.
Seminar in Vision Science: Read More [+]

Rules & Requirements

Prerequisites: Consent of instructor
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of seminar per week

Additional Details

Subject/Course Level: Vision Science/Graduate
Grading: Offered for satisfactory/unsatisfactory grade only.
Instructor: VS faculty

VIS SCI 201B Seminar in Vision Science 2 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Spring 2017
Graduate seminar in vision science.
Seminar in Vision Science: Read More [+]

Rules & Requirements

Prerequisites: Consent of instructor
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of seminar per week

Additional Details

Subject/Course Level: Vision Science/Graduate
Grading: Offered for satisfactory/unsatisfactory grade only.
Instructor: Gronert
VIS SCI 203A Geometric Optics 4 Units
Offered through: Optometry
Terms offered: Fall 2016, Fall 2015, Fall 2014
Geometrical methods applied to the optics of lenses, mirrors, and prisms. Thin lens eye models, magnification, astigmatism, prism properties of lenses, thick lenses.

VIS SCI 205 Visual Perception Sensitivity 4.5 Units
Offered through: Optometry
Terms offered: Fall 2016, Fall 2015, Fall 2014

VIS SCI 203B Optical System and Physical Optics 4 Units
Offered through: Optometry
Terms offered: Spring 2016, Spring 2015, Spring 2014
Principles of optical systems, principles and clinical applications of apertures and stops, aberrations and optical instruments. Optics of the eye. Selected topics in physical optics, diffraction, interference, polarization.

VIS SCI 203A Geometric Optics: Read More [+]

VIS SCI 205 Visual Perception Sensitivity: Read Less [-]

VIS SCI 206A Anatomy and Physiology of the Eye 2 Units
Offered through: Optometry
Terms offered: Fall 2015, Fall 2014, Fall 2013
This course focuses on the anatomy and physiology of the eyeball. Overview of the gross anatomy of the eye followed by eye-relevant cellular and molecular biology. Cellular and molecular details of structure and function of each of the various non-neural components.

VIS SCI 203B Optical System and Physical Optics: Read More [+]

VIS SCI 206A Anatomy and Physiology of the Eye: Read Less [-]

VIS SCI 203A Geometric Optics:
Read Less [-]

VIS SCI 205 Visual Perception Sensitivity:
Read Less [-]

VIS SCI 206A Anatomy and Physiology of the Eye:
Read Less [-]
VIS SCI 206B Anatomy and Physiology of the Eye and Visual System 3 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Spring 2017
Structure and function of the tissues of the eye, ocular appendages, and the central visual pathways. Basic concepts of physiological, neurological, embryological, and immunological processes as they relate to the eye and vision. Foster an appreciation of the pathophysiology of various disease processes. Convey the importance of anatomy and physiology in the medical approach to ocular disease processes.
Anatomy and Physiology of the Eye and Visual System: Read More [+]

Rules & Requirements
Prerequisites: VIS Sci 206A
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 15 weeks - 2.5 hours of lecture and 0.5 hours of laboratory per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.

VIS SCI 206C Anatomy and Physiology of the Eye and Visual System 2 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Spring 2017
Problem-based learning approach using clinical case examples. Continuation of 206A-206B.
Anatomy and Physiology of the Eye and Visual System: Read More [+]

Rules & Requirements
Prerequisites: 206A-206B
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 7.5 weeks - 4 hours of seminar per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Formerly known as: half of 206A

VIS SCI 206D Neuroanatomy and Neurophysiology of the Eye and Visual System 2 Units
Offered through: Optometry
Terms offered: Fall 2015, Fall 2014, Fall 2013
Structure and function of the neurosensory retina, photoreceptors, RPE including blood supply. Current concepts of etiology and management of major retinal conditions. Overview of diagnostic techniques in retinal imaging, electrophysiologic testing and new genetic approaches. Structure and function of the early visual pathway including retinal ganglion cells, optic nerves, lateral geniculate nucleus and visual cortex. Pupillary responses. Specialization in the visual cortex.
Neuroanatomy and Neurophysiology of the Eye and Visual System: Read More [+]

Rules & Requirements
Prerequisites: 206A (must be taken concurrently)

Hours & Format
Fall and/or spring: 7.5 weeks - 4 hours of lecture per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Instructors: Flannery, Freeman
Formerly known as: half of 206A

VIS SCI 215 Visual System Development 2 Units
Offered through: Optometry
Terms offered: Fall 2015, Fall 2014, Fall 2013
Visual System Development: Read More [+]

Rules & Requirements
Prerequisites: 206B

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Formerly known as: 115
Visual System Development: Read Less [-]
VIS SCI 217 Oculomotor Functions and Neurology 2 Units
Offered through: Optometry
Terms offered: Spring 2016, Spring 2015, Spring 2014
Neuro-anatomical pathways for the control of eye position and movement; gaze holding, image stabilization and tracking eye movement systems; oculomotor signs of disorders of the central nervous system (palsies, nystagmus, ophthalmoplegia, cog-wheel pursuits, saccadic dysmetria); the near visual-motor response and the synergistic coupling of accommodation and convergence; binocular misalignment (heterophoria and fixation disparity); and presbyopia.
Oculomotor Functions and Neurology: Read More [+]
Rules & Requirements
Prerequisites: 203B or consent of instructor

VIS SCI 219 Binocular Vision and Space Perception 2 Units
Offered through: Optometry
Terms offered: Spring 2016, Spring 2015, Spring 2014
Perception of space, direction, and distance. Binocular retinal correspondence, horopters, differential magnification effects and anomalies of binocular vision development. Sensory vision, local stereopsis, static and dynamic stereopsis, binocular depth cues.
Binocular Vision and Space Perception: Read More [+]

VIS SCI 230 Ethics in Scientific Research 2 Units
Offered through: Optometry
Terms offered: Spring 2018, Spring 2016, Spring 2015
This seminar will examine a range of ethical issues that arise in the process of doing science. Beginning with the philosophical and social foundations, we will consider the pathogenesis of fraud, statistics and deception, the ethics of authorship and publication, research with human subjects, the use of animals, the definition(s) of misconduct and the difference between misconduct and questionable research practices, the relationship between industry and science, and finally, the responsibilities and obligations of the scientist in society.
Ethics in Scientific Research: Read More [+]

VIS SCI 260A Optical and Neural Limits to Vision 3 Units
Offered through: Optometry
Terms offered: Fall 2019, Fall 2018, Fall 2017
The 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. This is one of the four courses that form the Vision Science core curriculum.
Optical and Neural Limits to Vision: Read More [+]

VIS SCI 260B Visual Alternation 2 Units
Offered through: Optometry
Terms offered: Fall 2019, Fall 2018, Fall 2017
Visual alternation is an illusion of the sense of vision in which two separate visual perceptions appear to alternate spontaneously.
Visual Alternation: Read More [+]

VIS SCI 261 Vision Science 1 Unit
Offered through: Optometry
This course introduces the student to the basic concepts and principles of vision science. It covers the anatomy and physiology of the eye, visual perception, and visual processing.
Vision Science: Read More [+]

VIS SCI 262 Vision Science 1 Unit
Offered through: Optometry
This course covers the basic principles of vision science, including anatomy and physiology of the eye, visual perception, and visual processing.
Vision Science: Read Less [-]

VIS SCI 263A Vision Science 1 Unit
This course covers the basic principles of vision science, including anatomy and physiology of the eye, visual perception, and visual processing.
Vision Science: Read Less [-]

VIS SCI 263B Vision Science 1 Unit
This course covers the basic principles of vision science, including anatomy and physiology of the eye, visual perception, and visual processing.
Vision Science: Read Less [-]
VIS SCI 260B Introduction to Ocular Biology
3 Units
Offered through: Optometry
Terms offered: Fall 2019, Fall 2018, Fall 2017
The course will provide an overview of eye development, anterior eye
ocular anatomy and physiology and ocular disease. The course will be a
combination of didactic lectures and problem-based learning. This is one
of the four courses that form the Vision Science core curriculum.
Introduction to Ocular Biology: Read More [+]

Rules & Requirements
Repeat rules: Course may be repeated for credit with instructor consent.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture and 1 hour of
discussion per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Instructor: Suzanne Fleiszig

Introduction to Ocular Biology: Read Less [-]

VIS SCI 260C Introduction to Visual Neuroscience 3 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018
The 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. This is one of the four courses that
form the Vision Science core curriculum.
Introduction to Visual Neuroscience: Read More [+]

Rules & Requirements
Repeat rules: Course may be repeated for credit with instructor consent.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture and 1 hour of
discussion per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Instructor: Michael Silver

Introduction to Visual Neuroscience: Read Less [-]

VIS SCI 260D Seeing in Time, Space and Color 3 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018
The 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. This is one of the four courses that form the Vision
Science core curriculum
Seeing in Time, Space and Color: Read More [+]

Rules & Requirements
Repeat rules: Course may be repeated for credit with instructor consent.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture and 1 hour of
discussion per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Instructor: Martin Banks

Seeing in Time, Space and Color: Read Less [-]

VIS SCI 262 Visual Cognitive Neuroscience 3 Units
Offered through: Optometry
Terms offered: Fall 2019, Fall 2018, Spring 2016
The course will provide 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 will 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, development, and adult plasticity,
perceptual learning, multisensory integration, and visual awareness.
Visual Cognitive Neuroscience: Read More [+]

Rules & Requirements
Prerequisites: Consent of instructor
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture per week

Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Instructor: Silver

Visual Cognitive Neuroscience: Read Less [-]
VIS SCI 265 Neural Computation 3 Units
Offered through: Optometry
Terms offered: Fall 2018, Fall 2016, Fall 2015
This course provides an introduction to the theory of neural computation. The goal is to familiarize students with the major theoretical frameworks and models used in neuroscience and psychology, and to provide hands-on experience in using these models. Topics include neural network models, supervised and unsupervised learning rules, associative memory models, probabilistic/graphical models, and models of neural coding in the brain.

Neural Computation: Read More [+]

Rules & Requirements

Prerequisites: Calculus, differential equations, basic probability and statistics, linear algebra, and familiarity with high level programming languages such as Matlab.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details

Subject/Course Level: Vision Science/Graduate

Grading: Letter grade.

Instructor: Olshausen

Neural Computation: Read Less [-]

VIS SCI C265 Neural Computation 3 Units
Offered through: Optometry
Terms offered: Prior to 2007
This course provides an introduction to the theory of neural computation. The goal is to familiarize students with the major theoretical frameworks and models used in neuroscience and psychology, and to provide hands-on experience in using these models. Topics include neural network models, supervised and unsupervised learning rules, associative memory models, probabilistic/graphical models, and models of neural coding in the brain.

Neural Computation: Read More [+]

Rules & Requirements

Prerequisites: Calculus, differential equations, basic probability and statistics, linear algebra, and familiarity with high level programming languages such as Matlab.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details

Subject/Course Level: Vision Science/Graduate

Grading: Letter grade.

Instructor: Olshausen

Also listed as: NEUROSC C265

Neural Computation: Read Less [-]

VIS SCI C280 Computer Vision 3 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Spring 2017

Computer Vision: Read More [+]

Rules & Requirements

Prerequisites: Knowledge of linear algebra and calculus. Mathematics 1A-1B, 53, 54 or equivalent.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details

Subject/Course Level: Vision Science/Graduate

Grading: Letter grade.

Instructor: Malik

Also listed as: COMPSCI C280

Computer Vision: Read Less [-]

VIS SCI 298 Group Studies, Seminars, or Group Research 1 - 6 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Fall 2017
Group studies of selected topics. Advanced studies in various subjects through special seminars on topics to be selected each year, informal groups studying special problems, group participation in experimental problems and analysis.

Group Studies, Seminars, or Group Research: Read More [+]

Rules & Requirements

Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 2-6 hours of lecture per week

Additional Details

Subject/Course Level: Vision Science/Graduate

Grading: Letter grade.

Group Studies, Seminars, or Group Research: Read Less [-]
VIS SCI 299 Research in Vision Science 1 - 12 Units
Offered through: Optometry
Terms offered: Fall 2019, Summer 2019 Second 6 Week Session, Spring 2019 Research.
Rules & Requirements
Prerequisites: Consent of instructor
Hours & Format
Fall and/or spring: 15 weeks - 0 hours of independent study per week
Summer: 6 weeks - 1-16 hours of independent study per week
8 weeks - 1-12 hours of independent study per week
Additional Details
Subject/Course Level: Vision Science/Graduate
Grading: Letter grade.
Research in Vision Science: Read Less [-]

VIS SCI 300 Teaching Methods in Vision Science 1 Unit
Offered through: Optometry
Terms offered: Fall 2019, Spring 2019, Fall 2018
Instruction in teaching methods and materials, in vision science and optometry; practice teaching in classrooms and laboratory.
Teaching Methods in Vision Science: Read More [+]
Rules & Requirements
Prerequisites: Graduate standing in vision science
Repeat rules: Course may be repeated for credit without restriction.
Hours & Format
Fall and/or spring: 15 weeks - 1 hour of lecture per week
Additional Details
Subject/Course Level: Vision Science/Professional course for teachers or prospective teachers
Grading: Offered for satisfactory/unsatisfactory grade only.
Instructor: Silver
Teaching Methods in Vision Science: Read Less [-]

VIS SCI 601 Individual Study for Master's Students 1 - 6 Units
Offered through: Optometry
Terms offered: Spring 2019, Spring 2018, Spring 2017
Individual study for the comprehensive requirements in consultation with the adviser in vision science
Individual Study for Master's Students: Read More [+]
Rules & Requirements
Prerequisites: Consent of instructor
Credit Restrictions: Course does not satisfy unit or residence requirements for master's degree.
Hours & Format
Fall and/or spring: 15 weeks - 0 hours of independent study per week
Additional Details
Subject/Course Level: Vision Science/Graduate examination preparation
Grading: Offered for satisfactory/unsatisfactory grade only.
Individual Study for Master's Students: Read Less [-]

VIS SCI 602 Individual Study for Doctoral Students 1 - 6 Units
Offered through: Optometry
Terms offered: Fall 2019, Spring 2019, Fall 2018
Individual study in consultation with the adviser in vision science, intended to provide an opportunity for qualified students to prepare themselves for the various examinations required for the Ph. D.
Individual Study for Doctoral Students: Read More [+]
Rules & Requirements
Prerequisites: Consent of instructor
Credit Restrictions: Course does not satisfy unit or residence requirements.
Hours & Format
Fall and/or spring: 15 weeks - 0 hours of independent study per week
Additional Details
Subject/Course Level: Vision Science/Graduate examination preparation
Grading: Offered for satisfactory/unsatisfactory grade only.
Individual Study for Doctoral Students: Read Less [-]