

## **BRAIN AND COGNITIVE SCIENCES (COURSE 9)**

### **9.00 Introduction to Psychological Science**

Prereq: None

U (Spring)

4-0-8 units. HASS-S

A survey of the scientific study of human nature, including how the mind works, and how the brain supports the mind. Topics include the mental and neural bases of perception, emotion, learning, memory, cognition, child development, personality, psychopathology, and social interaction. Consideration of how such knowledge relates to debates about nature and nurture, free will, consciousness, human differences, self, and society.

*J. D. Gabrieli*

### **9.000 Constructive Criticism of Research in the Brain & Cognitive Sciences (New)**

Prereq: Permission of instructor

G (Fall)

Units arranged

Can be repeated for credit.

Provides training in the constructive analysis, critique, and defense of the content of scientific papers in the brain sciences. Instruction provided in analyzing, presenting, constructively reviewing, and defending the scientific claims of cutting-edge primary research from all areas of brain sciences: molecular, systems, cognitive, and computation. Training provided by example from the instructor and practice reviewing, critiquing, presenting, and defending. Practice with instructor feedback provided to each student through constructively critiquing research and presenting/defending research. Beyond preparing for the weekly class discussion, students are also expected to attend the Brain and Cognitive Sciences colloquium each week to practice critical analysis and constructive questioning. Open to first-year graduate students in Course 9.

*J. DiCarlo*

### **9.01 Introduction to Neuroscience**

Prereq: None

U (Fall)

4-0-8 units. REST

Introduction to the mammalian nervous system, with emphasis on the structure and function of the human brain. Topics include the function of nerve cells, sensory systems, control of movement, learning and memory, and diseases of the brain.

*M. Bear*

### **9.011 Systems Neuroscience Core I**

Prereq: Permission of instructor

G (Fall)

6-0-12 units

Survey of brain and behavioral studies. Examines principles underlying the structure and function of the nervous system, with a focus on systems approaches. Topics include development of the nervous system and its connections, sensory systems of the brain, the motor system, higher cortical functions, and behavioral and cellular analyses of learning and memory. Preference to first-year graduate students in BCS.

*R. Desimone, E. K. Miller*

### **9.012 Cognitive Science**

Prereq: Permission of instructor

G (Spring)

6-0-12 units

Intensive survey of cognitive science. Topics include visual perception, language, memory, cognitive architecture, learning, reasoning, decision-making, and cognitive development. Topics covered from behavioral, computational, and neural perspectives.

*E. Gibson, P. Sinha, J. Tenenbaum*

### **9.013[J] Molecular and Cellular Neuroscience Core II**

Same subject as 7.68[J]

Prereq: Permission of instructor

G (Spring)

3-0-9 units

Survey and primary literature review of major areas in molecular and cellular neurobiology. Covers genetic neurotrophin signaling, adult neurogenesis, G-protein coupled receptor signaling, glia function, epigenetics, neuronal and homeostatic plasticity, neuromodulators of circuit function, and neurological/psychiatric disease mechanisms. Includes lectures and exams, and involves presentation and discussion of primary literature. 9.015[J] recommended, though the core subjects can be taken in any sequence.

*G. Feng, L.-H. Tsai*

**9.014 Quantitative Methods and Computational Models in Neurosciences**

Prereq: None  
 G (Fall)  
 3-1-8 units

Provides theoretical background and practical skills needed to analyze and model neurobiological observations at the molecular, systems and cognitive levels. Develops an intuitive understanding of mathematical tools and computational techniques which students apply to analyze, visualize and model research data using MATLAB programming. Topics include linear systems and operations, dimensionality reduction (e.g., PCA), Bayesian approaches, descriptive and generative models, classification and clustering, and dynamical systems. Limited to 18; priority to current BCS Graduate students.

*M. Jazayeri, D. Zysman*

**9.015[[J](#)] Molecular and Cellular Neuroscience Core I**

Same subject as 7.65[[J](#)]  
 Prereq: None  
 G (Fall)  
 3-0-9 units

Survey and primary literature review of selected major topic areas in molecular and cellular neurobiology. Covers nervous system development, axonal pathfinding, synapse formation and function, synaptic plasticity, ion channels and receptors, cellular neurophysiology, glial cells, sensory transduction, and relevant examples in human disease. Includes lectures and weekly paper write-ups, together with student presentations and discussion of primary literature. A final two-page research write-up is also due at the end of the term.

*J. T. Littleton, M. Sheng*

**9.016[[J](#)] Introduction to Sound, Speech, and Hearing**

Same subject as HST.714[[J](#)]  
 Prereq: (6.003 and 8.03) or permission of instructor  
 G (Fall)  
 4-0-8 units

See description under subject HST.714[[J](#)].

*S. S. Ghosh, H. H. Nakajima, S. Puria*

**9.017 Systems Neuroscience Core II**

Prereq: 18.06 or (9.011 and 9.014)  
 G (Spring)  
 2-2-8 units

Focuses on forebrain systems that are most closely associated with cognition (cortex, thalamus, and basal ganglia) as well as on describing neural circuits as parametric objects that are hierarchical in nature, and whose operations can have biophysical interpretations. Uses parametric behavior to discover circuit parameters and define circuit form in a cognitive context. Divided into five modules in the following order: sensory systems, motor systems, associative systems (memory and decision making), basal ganglia loops, and single neuron computations (dendritic integration, plasticity rules). Discusses biophysical mechanisms in the first half of the term and problem sets/student-led discussions in the second half.

*M. Halassa*

**9.021[[J](#)] Cellular Neurophysiology and Computing**

Same subject as 2.794[[J](#)], 6.521[[J](#)], 20.470[[J](#)], HST.541[[J](#)]  
 Subject meets with 2.791[[J](#)], 6.021[[J](#)], 9.21[[J](#)], 20.370[[J](#)]  
 Prereq: (Physics II (GIR), 18.03, and (2.005, 6.002, 6.003, 10.301, or 20.110[[J](#)])) or permission of instructor  
 G (Spring)  
 5-2-5 units

See description under subject 6.521[[J](#)].

*J. Han, T. Heldt*

**9.07 Statistics for Brain and Cognitive Science**

Prereq: 6.0002  
 U (Fall)  
 4-0-8 units

Provides students with the basic tools for analyzing experimental data, properly interpreting statistical reports in the literature, and reasoning under uncertain situations. Topics organized around three key theories: probability, statistical, and the linear model. Probability theory covers axioms of probability, discrete and continuous probability models, law of large numbers, and the Central Limit Theorem. Statistical theory covers estimation, likelihood theory, Bayesian methods, bootstrap and other Monte Carlo methods, as well as hypothesis testing, confidence intervals, elementary design of experiments principles and goodness-of-fit. The linear model theory covers the simple regression model and the analysis of variance. Places equal emphasis on theory, data analyses, and simulation studies.

*E. N. Brown*

**9.073[J] Statistics for Neuroscience Research**

Same subject as HST.460[J]

Prereq: Permission of instructor

Acad Year 2021-2022: Not offered

Acad Year 2022-2023: G (Spring)

3-0-9 units

A survey of statistical methods for neuroscience research. Core topics include introductions to the theory of point processes, the generalized linear model, Monte Carlo methods, Bayesian methods, multivariate methods, time-series analysis, spectral analysis and state-space modeling. Emphasis on developing a firm conceptual understanding of the statistical paradigm and statistical methods primarily through analyses of actual experimental data.

*E. N. Brown*

**9.09[J] Cellular and Molecular Neurobiology**

Same subject as 7.29[J]

Prereq: 7.05 or 9.01

U (Spring)

4-0-8 units

See description under subject 7.29[J].

*T. Littleton, M. Heiman*

**9.110[J] Nonlinear Control**

Same subject as 2.152[J]

Prereq: 2.151, 6.241[J], 16.31, or permission of instructor

G (Spring)

3-0-9 units

See description under subject 2.152[J].

*J.-J. E. Slotine*

**9.12 Experimental Molecular Neurobiology**

Prereq: Biology (GIR) and 9.01

U (Spring)

2-4-6 units. Institute LAB

Experimental techniques in cellular and molecular neurobiology. Designed for students without previous experience in techniques of cellular and molecular biology. Experimental approaches include DNA manipulation, molecular cloning, protein biochemistry, dissection and culture of brain cells, synaptic protein analysis, immunocytochemistry, and fluorescent microscopy. One lab session plus one paper review session per week. Instruction and practice in written communication provided. Limited to 22 due to lab capacity.

*G. Choi*

**9.123[J] Neurotechnology in Action**

Same subject as 20.203[J]

Prereq: Permission of instructor

G (Spring)

3-6-3 units

Offers a fast-paced introduction to numerous laboratory methods at the forefront of modern neurobiology. Comprises a sequence of modules focusing on neurotechnologies that are developed and used by MIT research groups. Each module consists of a background lecture and 1-2 days of firsthand laboratory experience. Topics typically include optical imaging, optogenetics, high throughput neurobiology, MRI/fMRI, advanced electrophysiology, viral and genetic tools, and connectomics.

*E. Boyden, M. Jonas*

**9.13 The Human Brain**

Prereq: 9.00, 9.01, or permission of instructor

U (Spring)

3-0-9 units

Surveys the core perceptual and cognitive abilities of the human mind and asks how these are implemented in the brain. Key themes include the functional organization of the cortex, as well as the representations and computations, developmental origins, and degree of functional specificity of particular cortical regions. Emphasizes the methods available in human cognitive neuroscience, and what inferences can and cannot be drawn from each.

*N. Kanwisher*

**9.17 Systems Neuroscience Laboratory**

Prereq: 9.01 or permission of instructor

U (Fall)

2-4-6 units. Institute LAB

Consists of a series of laboratories designed to give students experience with basic techniques for conducting systems neuroscience research. Includes sessions on anatomical, neurophysiological, and data acquisition and analysis techniques, and how these techniques are used to study nervous system function. Involves the use of experimental animals. Assignments include weekly preparation for lab sessions, two major lab reports and a series of basic computer programming tutorials (MATLAB). Instruction and practice in written communication provided. Enrollment limited.

*M. Harnett, S. Flavell*

**9.175[J] Robotics**

Same subject as 2.165[J]

Prereq: 2.151 or permission of instructor

Acad Year 2021-2022: Not offered

Acad Year 2022-2023: G (Fall)

3-0-9 units

See description under subject 2.165[J].

*J.-J. E. Slotine, H. Asada*

**9.18[J] Developmental Neurobiology**

Same subject as 7.49[J]

Subject meets with 7.69[J], 9.181[J]

Prereq: 7.03, 7.05, 9.01, or permission of instructor

U (Spring)

3-0-9 units

Considers molecular control of neural specification, formation of neuronal connections, construction of neural systems, and the contributions of experience to shaping brain structure and function. Topics include: neural induction and pattern formation, cell lineage and fate determination, neuronal migration, axon guidance, synapse formation and stabilization, activity-dependent development and critical periods, development of behavior. Students taking graduate version complete additional readings that will be addressed in their mid-term and final exams.

*E. Nedivi, M. Heiman*

**9.181[J] Developmental Neurobiology**

Same subject as 7.69[J]

Subject meets with 7.49[J], 9.18[J]

Prereq: 9.011 or permission of instructor

G (Spring)

3-0-9 units

Considers molecular control of neural specification, formation of neuronal connections, construction of neural systems, and the contributions of experience to shaping brain structure and function. Topics include: neural induction and pattern formation, cell lineage and fate determination, neuronal migration, axon guidance, synapse formation and stabilization, activity-dependent development and critical periods, development of behavior. In addition to final exam, analysis and presentation of research papers required for final grade. Students taking graduate version complete additional assignments. Students taking graduate version complete additional readings that will be addressed in their mid-term and final exams.

*E. Nedivi, M. Heiman*

**9.19 Computational Psycholinguistics**

Subject meets with 9.190

Prereq: (6.0002 and (6.041, 9.40, or 24.900)) or permission of instructor

U (Fall)

4-0-8 units

Introduces computational approaches to natural language processing and acquisition by humans and machines, combining symbolic and probabilistic modeling techniques. Covers models such as n-grams, finite state automata, and context-free and mildly context-sensitive grammars, for analyzing phonology, morphology, syntax, semantics, pragmatics, and larger document structure. Applications range from accurate document classification and sentence parsing by machine to modeling human language acquisition and real-time understanding. Covers both theory and contemporary computational tools and datasets. Students taking graduate version complete additional assignments.

*R. P. Levy*

**9.190 Computational Psycholinguistics**

Subject meets with 9.19

Prereq: (6.0002 and (6.431, 9.40, or 24.900)) or permission of instructor

G (Fall)

4-0-8 units

Introduces computational approaches to natural language processing and acquisition by humans and machines, combining symbolic and probabilistic modeling techniques. Covers models such as n-grams, finite state automata, and context-free and mildly context-sensitive grammars, for analyzing phonology, morphology, syntax, semantics, pragmatics, and larger document structure. Applications range from accurate document classification and sentence parsing by machine to modeling human language acquisition and real-time understanding. Covers both theory and contemporary computational tools and datasets. Students taking graduate version complete additional assignments.

*R. P. Levy*

**9.21[J] Cellular Neurophysiology and Computing**

Same subject as 2.791[J], 6.021[J], 20.370[J]

Subject meets with 2.794[J], 6.521[J], 9.021[J], 20.470[J], HST.541[J]

Prereq: (Physics II (GIR), 18.03, and (2.005, 6.002, 6.003, 10.301, or 20.110[J])) or permission of instructor

U (Spring)

5-2-5 units

See description under subject 6.021[J]. Preference to juniors and seniors.

*J. Han, T. Heldt*

**9.24 Disorders and Diseases of the Nervous System**

Prereq: (7.29[*J*] and 9.01) or permission of instructor

U (Spring)

3-0-9 units

Topics examined include regional functional anatomy of the CNS; brain systems and circuits; neurodevelopmental disorders including autism; neuropsychiatric disorders such as schizophrenia; neurodegenerative diseases such as Parkinson's and Alzheimer's; autoimmune disorders such as multiple sclerosis; gliomas. Emphasis on diseases for which a molecular mechanism is understood. Diagnostic criteria, clinical and pathological findings, genetics, model systems, pathophysiology, and treatment are discussed for individual disorders and diseases. Limited to 18.

*M. Sur*

**9.26[*J*] Principles and Applications of Genetic Engineering for Biotechnology and Neuroscience**

Same subject as 20.205[*J*]

Prereq: Biology (GIR)

U (Spring)

3-0-9 units

Covers principles underlying current and future genetic engineering approaches, ranging from single cellular organisms to whole animals. Focuses on development and invention of technologies for engineering biological systems at the genomic level, and applications of engineered biological systems for medical and biotechnological needs, with particular emphasis on genetic manipulation of the nervous system. Design projects by students.

*F. Zhang*

**9.271[*J*] Pioneering Technologies for Interrogating Complex Biological Systems**

Same subject as 10.562[*J*], HST.562[*J*]

Prereq: None

G (Spring)

3-0-9 units

See description under subject HST.562[*J*]. Limited to 15.

*K. Chung*

**9.272[*J*] Topics in Neural Signal Processing**

Same subject as HST.576[*J*]

Prereq: Permission of instructor

Acad Year 2021-2022: G (Spring)

Acad Year 2022-2023: Not offered

3-0-9 units

Presents signal processing and statistical methods used to study neural systems and analyze neurophysiological data. Topics include state-space modeling formulated using the Bayesian Chapman-Kolmogorov system, theory of point processes, EM algorithm, Bayesian and sequential Monte Carlo methods. Applications include dynamic analyses of neural encoding, neural spike train decoding, studies of neural receptive field plasticity, algorithms for neural prosthetic control, EEG and MEG source localization. Students should know introductory probability theory and statistics.

*E. N. Brown*

**9.28 Current Topics in Developmental Neurobiology**

Prereq: None. *Coreq: 9.18[*J*]*

U (Spring)

3-0-6 units

Considers recent advances in the field of developmental neurobiology based on primary research articles that address molecular control of neural specification, formation of neuronal connections, construction of neural systems, and the contributions of experience to shaping brain structure and function. Also considers new techniques and methodologies as applied to the field. Students critically analyze articles and prepare concise and informative presentations based on their content. Instruction and practice in written and oral communication provided. Requires class participation, practice sessions, and presentations.

*E. Nedivi*

**9.285[*J*] Audition: Neural Mechanisms, Perception and Cognition**

Same subject as HST.723[*J*]

Prereq: Permission of instructor

G (Spring)

6-0-6 units

See description under subject HST.723[*J*].

*J. McDermott, D. Polley, B. Delgutte, M. C. Brown*

**9.301[JJ] Neural Plasticity in Learning and Memory**

Same subject as 7.98[JJ]  
Prereq: Permission of instructor  
G (Spring)  
3-0-6 units

Examination of the role of neural plasticity during learning and memory of invertebrates and mammals. Detailed critical analysis of the current literature of molecular, cellular, genetic, electrophysiological, and behavioral studies. Student-directed presentations and discussions of original papers supplemented by introductory lectures. Juniors and seniors require instructor's permission.

*S. Tonegawa*

**9.32 Genes, Circuits, and Behavior**

Prereq: 7.29[JJ], 9.16, 9.18[JJ], or permission of instructor  
Acad Year 2021-2022: U (Spring)  
Acad Year 2022-2023: Not offered  
3-0-9 units

Focuses on understanding molecular and cellular mechanisms of circuitry development, function and plasticity, and their relevance to normal and abnormal behaviors/psychiatric disorders. Highlights cutting-edge technologies for neuroscience research. Students build professional skills through presentations and critical evaluation of original research papers.

*G. Feng*

**9.34[JJ] Biomechanics and Neural Control of Movement**

Same subject as 2.183[JJ]  
Subject meets with 2.184  
Prereq: 2.004 or permission of instructor  
G (Spring)  
3-0-9 units

See description under subject 2.183[JJ].

*N. Hogan*

**9.35 Perception**

Prereq: 9.01 or permission of instructor  
U (Spring)  
4-0-8 units

Studies how the senses work and how physical stimuli are transformed into signals in the nervous system. Examines how the brain uses those signals to make inferences about the world, and uses illusions and demonstrations to gain insight into those inferences. Emphasizes audition and vision, with some discussion of touch, taste, and smell. Provides experience with psychophysical methods.

*J. McDermott*

**9.357 Current Topics in Perception**

Prereq: Permission of instructor  
G (Spring)  
2-0-7 units  
Can be repeated for credit.

Advanced seminar on issues of current interest in human and machine vision. Topics vary from year to year. Participants discuss current literature as well as their ongoing research.

*E. H. Adelson*

**9.40 Introduction to Neural Computation**

Prereq: (Physics II (GIR), 6.0002, and 9.01) or permission of instructor  
U (Spring)  
4-0-8 units

Introduces quantitative approaches to understanding brain and cognitive functions. Topics include mathematical description of neurons, the response of neurons to sensory stimuli, simple neuronal networks, statistical inference and decision making. Also covers foundational quantitative tools of data analysis in neuroscience: correlation, convolution, spectral analysis, principal components analysis. Mathematical concepts include simple differential equations and linear algebra.

*M. Fee*

**9.41 Research and Communication in Neuroscience and Cognitive Science**

Prereq: 9.URG and permission of instructor  
U (Fall)  
2-12-4 units

Emphasizes research and scientific communication. Instruction and practice in written and oral communication provided. Based on results of his/her UROP research, each student creates a full-length paper and a poster as part of an oral presentation at the end of the term. Other assignments include peer editing and reading/critiquing published research papers. Prior to starting class, students must have collected enough data from their UROP research projects to write a paper. Limited to juniors and seniors.

*L. Schulz*

**9.42 The Brain and Its Interface with the Body**

Prereq: 7.28, 7.29[()], or permission of instructor

U (Spring)

Not offered regularly; consult department

3-0-9 units

Covers a range of topics, such as brain-immune system interaction, the gut-brain axis, and bioengineering approaches for studying the brain and its interactions with different organs. Explores how these interactions may be involved in nervous system disease processes.

*F. Zhang*

**9.422[()] Principles of Neuroengineering**

Same subject as 20.452[()], MAS.881[()]

Subject meets with 20.352

Prereq: Permission of instructor

G (Fall)

3-0-9 units

See description under subject MAS.881[()].

*E. S. Boyden, III*

**9.455[()] Revolutionary Ventures: How to Invent and Deploy Transformative Technologies**

Same subject as 15.128[()], 20.454[()], MAS.883[()]

Prereq: Permission of instructor

G (Fall)

2-0-7 units

See description under subject MAS.883[()].

*E. Boyden, J. Bensen, J. Jacobson*

**9.46 Neuroscience of Morality**

Prereq: 9.00, 9.01, and (9.13 or 9.85)

U (Fall)

Not offered regularly; consult department

5-0-7 units. HASS-S

Advanced seminar that covers both classic and cutting-edge primary literature from psychology and the neuroscience of morality.

Addresses questions about how the human brain decides which actions are morally right or wrong (including neural mechanisms of empathy and self-control), how such brain systems develop over childhood and differ across individuals and cultures, and how they are affected by brain diseases (such as psychopathy, autism, tumors, or addiction). Instruction and practice in written and oral communication provided. Limited to 24.

*R. Saxe*

**9.48[()] Philosophical Issues in Brain Science**

Same subject as 24.08[()]

Prereq: None

Acad Year 2021-2022: Not offered

Acad Year 2022-2023: U (Fall)

3-0-9 units. HASS-H; CI-H

See description under subject 24.08[()].

*E. J. Green*

**9.49 Neural Circuits for Cognition**

Subject meets with 9.490

Prereq: 9.40, 18.06, or permission of instructor

U (Fall)

3-0-9 units

Takes a computational approach to examine circuits in the brain that perform elemental cognitive tasks: tasks that are neither directly sensory nor directly motor in function, but are essential to bridging from perception to action. Covers circuits and circuit motifs in the brain that underlie computations like integration, decision-making, spatial navigation, inference, and other cognitive elements. Students study empirical results, build dynamical models of neural circuits, and examine the mathematical theory of representations and computation in such circuits. Considers noise, stability, plasticity, and learning rules for these systems. Students taking graduate version complete additional assignments.

*I. Fiete*

**9.490 Neural Circuits for Cognition**

Subject meets with 9.49

Prereq: 9.40, 18.06, or permission of instructor

G (Fall)

3-0-9 units

Takes a computational approach to examine circuits in the brain that perform elemental cognitive tasks: tasks that are neither directly sensory nor directly motor in function, but are essential to bridging from perception to action. Covers circuits and circuit motifs in the brain that underlie computations like integration, decision-making, spatial navigation, inference, and other cognitive elements. Students study empirical results, build dynamical models of neural circuits, and examine the mathematical theory of representations and computation in such circuits. Considers noise, stability, plasticity, and learning rules for these systems. Students taking graduate version complete additional assignments.

*I. Fiete*

### **9.50 Research in Brain and Cognitive Sciences**

Prereq: 9.00 and permission of instructor

U (Fall, Spring)

0-12-0 units

Can be repeated for credit.

Laboratory research in brain and cognitive science, using physiological, anatomical, pharmacological, developmental, behavioral, and computational methods. Each student carries out an experimental study under the direction of a member of the faculty. Project must be approved in advance by the faculty supervisor and the undergraduate faculty officer. Written presentation of results is required.

*Consult L. Schulz*

### **9.520[J] Statistical Learning Theory and Applications**

Same subject as 6.860[J]

Prereq: 6.041, 6.867, 18.06, or permission of instructor

G (Fall)

3-0-9 units

Covers foundations and recent advances in statistical machine learning theory, with the dual goals of providing students with the theoretical knowledge to use machine learning and preparing more advanced students to contribute to progress in the field. The content is roughly divided into three parts. The first part is about classical regularization, margin, stochastic gradient methods, overparametrization, implicit regularization, and stability. The second part is about deep networks: approximation and optimization theory plus roots of generalization. The third part is about the connections between learning theory and the brain. Occasional talks by leading researchers on advanced research topics. Emphasis on current research topics.

*T. Poggio, L. Rosasco*

### **9.521[J] Mathematical Statistics: a Non-Asymptotic Approach**

Same subject as 18.656[J], IDS.160[J]

Prereq: (6.436[J], 18.06, and 18.6501) or permission of instructor

G (Spring)

3-0-9 units

Introduces students to modern non-asymptotic statistical analysis. Topics include high-dimensional models, nonparametric regression, covariance estimation, principal component analysis, oracle inequalities, prediction and margin analysis for classification. Develops a rigorous probabilistic toolkit, including tail bounds and a basic theory of empirical processes

*S. Rakhlin, P. Rigollet*

### **9.523[J] Aspects of a Computational Theory of Intelligence**

Same subject as 6.861[J]

Prereq: Permission of instructor

G (Fall)

Not offered regularly; consult department

3-0-9 units

Integrates neuroscience, cognitive and computer science to explore the nature of intelligence, how it is produced by the brain, and how it can be replicated in machines. Discusses an array of current research connected through an overarching theme of how it contributes to a computational account of how humans analyze dynamic visual imagery to understand objects and actions in the world.

*T. Poggio, S. Ullman*

### **9.53 Emergent Computations Within Distributed Neural Circuits**

Subject meets with 9.530

Prereq: 9.40 or permission of instructor

U (Spring)

4-0-8 units

Addresses the fundamental scientific question of how the human brain still outperforms the best computer algorithms in most domains of sensory, motor and cognitive function, as well as the parallel and distributed nature of neural processing (as opposed to the serial organization of computer architectures/ algorithms) required to answer it. Explores the biologically plausible computational mechanisms and principles that underlie neural computing, such as competitive and unsupervised learning rules, attractor networks, self-organizing feature maps, content-addressable memory, expansion recoding, the stability-plasticity dilemma, the role of lateral and top-down feedback in neural systems, the role of noise in neural computing. Students taking graduate version complete additional assignments.

*R. Ajemian*



**9.530 Emergent Computations Within Distributed Neural Circuits**

Subject meets with 9.53

Prereq: 9.40 or permission of instructor

G (Spring)

4-0-8 units

Addresses the fundamental scientific question of how the human brain still outperforms the best computer algorithms in most domains of sensory, motor and cognitive function, as well as the parallel and distributed nature of neural processing (as opposed to the serial organization of computer architectures/ algorithms) required to answer it. Explores the biologically plausible computational mechanisms and principles that underlie neural computing, such as competitive and unsupervised learning rules, attractor networks, self-organizing feature maps, content-addressable memory, expansion recoding, the stability-plasticity dilemma, the role of lateral and top-down feedback in neural systems, the role of noise in neural computing. Students taking graduate version complete additional assignments.

*R. Ajemian*

**9.55[J] Consumer Behavior**

Same subject as 15.8471[J]

Prereq: None

U (Spring)

3-0-6 units

Credit cannot also be received for 9.550[J], 15.847[J]

See description under subject 15.8471[J].

*D. Rand*

**9.550[J] Consumer Behavior**

Same subject as 15.847[J]

Prereq: 15.809, 15.814, or permission of instructor

G (Spring)

3-0-6 units

Credit cannot also be received for 9.55[J], 15.8471[J]

See description under subject 15.847[J].

*D. Rand*

**9.58 Projects in the Science of Intelligence**

Prereq: (6.036 and (9.40 or 18.06)) or permission of instructor

U (Fall)

3-0-9 units

Provides instruction on the mechanistic basis of intelligence - how the brain produces intelligent behavior and how we may be able to replicate intelligence in machines. Examines how human intelligence emerges from computations in neural circuits to reproduce similar intelligent behavior in machines. Working in teams, students complete computational projects and exercises that reinforce the theme of collaboration between (computer science + math) and (neuroscience + cognitive science). Culminates with student presentations of their projects. Instruction and practice in oral and written communication provided. Limited to 30.

*T. Poggio, S. Ullman*

**9.583[J] Functional Magnetic Resonance Imaging: Data Acquisition and Analysis**

Same subject as HST.583[J]

Prereq: 18.05 and (18.06 or permission of instructor)

Acad Year 2021-2022: Not offered

Acad Year 2022-2023: G (Fall)

2-3-7 units

See description under subject HST.583[J].

*J. Polimeni, A. Yendiki*

**9.59[J] Laboratory in Psycholinguistics**

Same subject as 24.905[J]

Prereq: None

U (Spring)

Not offered regularly; consult department

3-3-6 units. Institute LAB

Hands-on experience designing, conducting, analyzing, and presenting experiments on the structure and processing of human language. Focuses on constructing, conducting, analyzing, and presenting an original and independent experimental project of publishable quality. Develops skills in reading and writing scientific research reports in cognitive science, including evaluating the methods section of a published paper, reading and understanding graphical displays and statistical claims about data, and evaluating theoretical claims based on experimental data. Instruction and practice in oral and written communication provided.

*E. Gibson*

**9.60 Machine-Motivated Human Vision**

Prereq: None

U (Spring)

2-1-9 units. Institute LAB

Explores how studies of human vision can be motivated by, and enhance the capabilities of, machine-based systems. Considers the twin questions of how the performance of state-of-the-art machine vision systems compares with that of humans, and what kinds of strategies the human visual system uses in tasks where human performance exceeds that of machines. Includes presentations by engineers from companies with significant engineering efforts in vision. Based on these presentations, students define and conduct studies to address the two aforementioned questions and present their results to the public at the end of the term. Directed towards students interested in exploring vision from computational, experimental and practical perspectives. Provides instruction and practice in written and oral communication.

*P. Sinha*

**9.611[J] Natural Language and the Computer Representation of Knowledge**

Same subject as 6.863[J]

Prereq: 6.034

G (Spring)

3-3-6 units

See description under subject 6.863[J].

*R. C. Berwick*

**9.66[J] Computational Cognitive Science**

Same subject as 6.804[J]

Subject meets with 9.660

Prereq: 6.008, 6.036, 6.041, 9.40, 18.05, or permission of instructor

U (Fall)

3-0-9 units

Introduction to computational theories of human cognition. Focus on principles of inductive learning and inference, and the representation of knowledge. Computational frameworks covered include Bayesian and hierarchical Bayesian models; probabilistic graphical models; nonparametric statistical models and the Bayesian Occam's razor; sampling algorithms for approximate learning and inference; and probabilistic models defined over structured representations such as first-order logic, grammars, or relational schemas. Applications to understanding core aspects of cognition, such as concept learning and categorization, causal reasoning, theory formation, language acquisition, and social inference. Graduate students complete a final project.

*J. Tenenbaum*

**9.660 Computational Cognitive Science**

Subject meets with 6.804[J], 9.66[J]

Prereq: Permission of instructor

G (Fall)

3-0-9 units

Introduction to computational theories of human cognition. Focuses on principles of inductive learning and inference, and the representation of knowledge. Computational frameworks include Bayesian and hierarchical Bayesian models, probabilistic graphical models, nonparametric statistical models and the Bayesian Occam's razor, sampling algorithms for approximate learning and inference, and probabilistic models defined over structured representations such as first-order logic, grammars, or relational schemas. Applications to understanding core aspects of cognition, such as concept learning and categorization, causal reasoning, theory formation, language acquisition, and social inference. Graduate students complete a final project.

*J. Tenenbaum*

**9.67[J] Materials Physics of Neural Interfaces (New)**

Same subject as 3.056[J]

Subject meets with 3.64

Prereq: 3.033 or permission of instructor

U (Spring)

3-0-9 units

See description under subject 3.056[J].

*P. Anikeeva*

**9.72 Vision in Art and Neuroscience**

Subject meets with 9.720

Prereq: None

U (Fall)

2-2-8 units

Introduces and provides practical engagement with core concepts in vision neuroscience. Combination of seminar and studio work fosters interdisciplinary dialogue between visual art and vision neuroscience, culminating in a gallery exhibition of students' individual, semester-long projects. Treats the processes of visual perception and the creation of visual art in parallel, making use of the fact that both are constructive. Through lectures and readings in experimental and computational vision research, explores the hierarchy of visual processing, from the moment that light strikes the retina to the internal experience of a rich visual world. In the studio, students examine how each stage of this process manifests in the experience of art, wherein the perceptual system observes itself. Students taking graduate version complete additional assignments.

*P. Sinha, S. Riskin*

**9.720 Vision in Art and Neuroscience**

Subject meets with 9.72

Prereq: None

G (Fall)

2-2-8 units

Introduces and provides practical engagement with core concepts in vision neuroscience. Combination of seminar and studio work fosters interdisciplinary dialogue between visual art and vision neuroscience, culminating in a gallery exhibition of students' individual, semester-long projects. Treats the processes of visual perception and the creation of visual art in parallel, making use of the fact that both are constructive. Through lectures and readings in experimental and computational vision research, explores the hierarchy of visual processing, from the moment that light strikes the retina to the internal experience of a rich visual world. In the studio, students examine how each stage of this process manifests in the experience of art, wherein the perceptual system observes itself. Students taking graduate version complete additional assignments.

*P. Sinha, S. Riskin*

**9.822[J] Psychology and Economics**

Same subject as 14.137[J]

Prereq: None

G (Spring)

4-0-8 units

See description under subject 14.137[J].

*D. Prelec*

**9.85 Infant and Early Childhood Cognition**

Prereq: 9.00

U (Fall)

3-0-9 units. HASS-S

Introduction to cognitive development focusing on childrens' understanding of objects, agents, and causality. Develops a critical understanding of experimental design. Discusses how developmental research might address philosophical questions about the origins of knowledge, appearance and reality, and the problem of other minds. Provides instruction and practice in written communication as necessary to research in cognitive science (including critical reviews of journal papers, a literature review and an original research proposal), as well as instruction and practice in oral communication in the form of a poster presentation of a journal paper.

*L. Schulz*

**9.89 Off-Campus Undergraduate Research in Brain and Cognitive Sciences**

Prereq: None

U (Fall, IAP, Spring)

Units arranged

For Brain and Cognitive Sciences undergraduates participating in curriculum-related research off-campus. Before enrolling, students must consult the BCS Academic Office for details on procedures and restrictions, and have approval from their faculty advisor. Subject to departmental approval. Upon completion, the off-campus supervisor will provide an evaluation of the student's work. The student must also submit a write-up of the experience, approved by the MIT supervisor.

*Staff*

**9.90 Practical Experience in Brain and Cognitive Sciences**

Prereq: Permission of instructor

U (Summer)

0-1-0 units

For Brain and Cognitive Sciences undergraduates participating in curriculum-related off-campus professional experiences. Before enrolling, students must consult the BCS Academic Office for details on procedures and restrictions, and have approval from their faculty advisor. Subject to departmental approval. Upon completion, the student must submit a write-up of the experience, approved by the MIT supervisor.

*Staff*

**9.900 Clinical Connection Module**

Prereq: None. *Coreq: 9.011, 9.012, 9.013[J], 9.014, or 9.015[J];* permission of instructor

G (Fall, IAP, Spring)

0-1-0 units

Can be repeated for credit.

Provides students the opportunity to connect their core neuroscience training to clinical experience (pathogenesis, diagnosis, management and therapeutic clinical trials of nervous system diseases). Students attend, along with Harvard faculty, fellows, residents and medical students at Massachusetts General Hospital, clinical seminars at MGH conducted by clinical and basic science faculty of Harvard Medical School. Each clinical experience is one week in length; students have the option to attend up to four seminars in their individual week chosen from: neuroradiology, neuropathology, neurodegenerative diseases, epilepsy, movement disorders, psychiatry, neuropsychiatric diseases and behavioral neurology, and functional neurosurgery. Seminars are followed by one-on-one discussion with instructor to connect the clinical experience with parallel course material on the neurobiology of disease.

*T. Byrne*

**9.901 Responsible Conduct in Science**

Prereq: None

G (IAP)

1-0-1 units

Provides instruction and dialogue on practical ethical issues relating to the responsible conduct of human and animal research in the brain and cognitive sciences. Specific emphasis on topics relevant to young researchers including data handling, animal and human subjects, misconduct, mentoring, intellectual property, and publication. Preliminary assigned readings and initial faculty lecture followed by discussion groups of four to five students each. A short written summary of the discussions submitted at the end of each class. See IAP Guide for registration information.

*M. Wilson*

**9.91 Independent Study in Brain and Cognitive Sciences**

Prereq: 9.00, two additional subjects in Brain and Cognitive Sciences, and permission of instructor

U (Fall, IAP, Spring)

Units arranged

Can be repeated for credit.

Individual study of a topic under the direction of a member of the faculty.

*Consult Staff*

**9.919 Teaching Brain and Cognitive Sciences**

Prereq: None

G (Fall, Spring)

Units arranged

Can be repeated for credit.

For teaching assistants in Brain and Cognitive Sciences, in cases where teaching assignment is approved for academic credit by the department.

*Staff*

**9.921 Research in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall, Spring, Summer)

Units arranged

Can be repeated for credit.

Guided research under the sponsorship of individual members of the faculty. Ordinarily restricted to candidates for the doctoral degree in Course 9.

*Staff*

**9.941 Graduate Thesis Proposal**

Prereq: Permission of instructor

G (Fall, Spring, Summer)

Units arranged [P/D/F]

Can be repeated for credit.

Students submit written proposals for thesis according to stated deadlines.

*Staff*

**9.97 Introduction to Neuroanatomy**

Prereq: None

U (IAP)

1-0-0 units

Intensive introduction to neuroanatomy that consists of lectures, demonstrations, and interactive laboratories, including a brain dissection. No prior knowledge of neuroanatomy required, although general knowledge of brain structures is helpful. Pre-register on WebSIS; must attend first class. Limited to 24.

*R. Ellis-Behnke*

**9.S51 Special Subject in Brain and Cognitive Sciences**

Prereq: 9.00 and any other two subjects in Brain and Cognitive Sciences

U (Fall)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Undergraduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*I. Pepperberg*

**9.S52 Special Subject in Brain and Cognitive Sciences**

Prereq: 9.00 and any other two subjects in Brain and Cognitive Sciences

U (Spring)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Undergraduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*E. Fedorenko*

**9.S911 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall; partial term)

Units arranged [P/D/F]

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum. 9.S911 is graded P/D/F.

*N. G. Kanwisher***9.S912 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*L. Schulz***9.S913 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Spring)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*R. P. Levy, N. Feldman, R. Katzir***9.S914 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall)

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*R. Saxe***9.S915 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*Staff***9.S916 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Spring)

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*Staff***9.S917 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall)

Not offered regularly; consult department

Units arranged

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*J. DiCarlo***9.S918 Special Subject in Brain and Cognitive Sciences**

Prereq: Permission of instructor

G (Fall, Spring)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

Advanced graduate study in brain and cognitive sciences; covers material not offered in regular curriculum. 9.S918 is graded P/D/F.

*J. DiCarlo***9.S92 Special Subject in Brain and Cognitive Sciences**

Prereq: 9.00

U (Fall)

Units arranged

Can be repeated for credit.

Undergraduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*Consult F. Wang***9.S93 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Units arranged [P/D/F]

For undergraduate study in brain and cognitive sciences; covers material not offered in regular curriculum.

*Staff*

**9.S94 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Staff*

**9.S95 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Staff*

**9.S96 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Consult Staff*

**9.S97 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Staff*

**9.S98 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (IAP)

Not offered regularly; consult department

Units arranged [P/D/F]

Can be repeated for credit.

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Staff*

**9.S99 Special Subject in Brain and Cognitive Sciences**

Prereq: None

U (Spring)

Units arranged [P/D/F]

For undergraduate study in brain and cognitive sciences during Independent Activities Period; covers material not offered in regular curriculum. See IAP Guide for details.

*Staff*

**9.THG Graduate Thesis**

Prereq: Permission of instructor

G (Fall, IAP, Spring, Summer)

Units arranged

Can be repeated for credit.

Program of research leading to the writing of a Ph.D. thesis; to be arranged by the student and an appropriate MIT faculty member.

*Staff*

**9.UR Undergraduate Research**

Prereq: None

U (Fall, IAP, Spring, Summer)

Units arranged [P/D/F]

Can be repeated for credit.

Individual participation in an ongoing research project.

*Staff*

**9.URG Undergraduate Research**

Prereq: None

U (Fall, IAP, Spring, Summer)

Units arranged

Can be repeated for credit.

Individual participation in an ongoing research project.

*Consult Staff*