SYMBOLOC SYSTEMS

Courses offered by the Symbolic Systems Program are listed under the subject code SYMSYS on the Stanford Bulletin’s ExploreCourses web site.

The observation that both human beings and computers can manipulate symbols lies at the heart of Symbolic Systems, an interdisciplinary program focusing on the relationship between natural and artificial systems that represent, process, and act on information. Computer programs, natural languages, the human mind, and the Internet embody concepts whose study forms the core of the Symbolic Systems curriculum, such as computation, representation, communication, and intelligence. A body of knowledge and theory has developed around these notions, from disciplines such as philosophy, computer science, linguistics, psychology, statistics, neurobiology, and communication. Since the invention of computers, researchers have been working across these disciplines to study questions such as: in what ways are computers and computer languages like human beings and their languages; how can the interaction between people and computers be made easier and more beneficial?

The core requirements of the Symbolic Systems Program (SSP) include courses in symbolic logic, the philosophy of mind, formal linguistics, cognitive psychology, programming, the mathematics of computation, statistical theory, artificial intelligence, and interdisciplinary approaches to cognitive science. These courses prepare students with the vocabulary, theoretical background, and technical skills needed for study and research at the advanced undergraduate and graduate levels. Most of the courses in SSP are drawn from affiliated departments. Courses designed specifically for the program are aimed at integrating and supplementing topics covered by the department-based offerings. The curriculum includes humanistic approaches to questions about language and intelligence, as well as training in science and engineering.

SSP offers B.S. and M.S. degree programs. Both programs require students to master a common core of required courses and to choose an area of specialization.

Mission of the Undergraduate Program in Symbolic Systems

The undergraduate program in Symbolic Systems is an interdisciplinary program focusing on the relationships between natural and artificial systems that use symbols to communicate and to represent information. The mission of the program is to prepare majors with the vocabulary, theoretical background, and technical skills necessary to research questions about language, information, and intelligence, both human and machine. The curriculum offers a combination of traditional humanistic approaches to these questions as well as a training and familiarity with contemporary developments in the science and technology of computation. Students in the major take courses in cognitive science, computer programming, logic and computational theory, probability, cognitive psychology, philosophy of mind, linguistics, and artificial intelligence. The program prepares students for a variety of careers in the private and public sectors, especially those involving the human-facing sides of information systems/technology, as well as for further study and research in the cognitive and/or information sciences.

Learning Outcomes (Undergraduate)

The program expects its undergraduate majors to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the Symbolic Systems Program. Students are expected to demonstrate:

1. ability to apply formal, philosophical, and/or computational analysis to experimental designs and data and vice versa.
2. ability to understand multiple formal, philosophical, and/or computational frameworks and how they are related to each other.
3. ability to map real world problems or observed phenomena onto formal, philosophical and/or computational frameworks and vice versa.

Learning Outcomes (Graduate)

The purpose of the master’s program is to further develop knowledge and skills in Symbolic Systems and to prepare students for a professional career or doctoral studies. This is achieved through completion of courses representing each of the core disciplines of Symbolic Systems as well as an individualized course program in support of the completion of a Master’s thesis.

Bachelor of Science in Symbolic Systems

The program leading to a B.S. in Symbolic Systems provides students with a core of concepts and techniques, drawing on faculty and courses from various departments. The curriculum prepares students for advanced training in the interdisciplinary study of language and information, or for postgraduate study in any of the main contributing disciplines. It is also excellent preparation for employment immediately after graduation.

Symbolic Systems majors must complete a core of required courses plus a field of study consisting of five additional courses. All major courses are to be taken for letter grades unless an approved course is offered satisfactory/no credit only. All core courses must be passed with a grade of "C-" or better. Students who receive a grade lower than this in a core course must alert the program of this fact so that a decision can be made about whether the student should continue in the major.

Core Requirements

In order to graduate with a B.S. in Symbolic Systems, a student must complete the following requirements. Some of these courses have other courses as prerequisites; students are responsible for completing each course's prerequisites before they take it. With the exception of the advanced small seminar requirement, courses cannot be used towards more than one area of the core requirements. For additional information, see the Symbolic Systems web site (http://symsys.stanford.edu/undergraduate_programs).

Note: Students matriculating in the Class of 2018 or later must take SYMSYS 1 Minds and Machines (formerly SYMSYS 100) before their declaration of the Symbolic Systems undergraduate major can be approved.

1. Introductory Core Course

Students matriculating in the Class of 2018 or later must take SYMSYS 1 Minds and Machines (formerly SYMSYS 100) before their declaration of the Symbolic Systems undergraduate major can be approved.

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 1 Minds and Machines (formerly SYMSYS 100)</td>
<td>4</td>
</tr>
</tbody>
</table>

2. Continuous Fundamentals Level 1—Single Variable Calculus

Select one of the following Series:

<table>
<thead>
<tr>
<th>Series A</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 units of Advanced Placement Calculus credit</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Series B</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 19 Calculus</td>
<td>10</td>
</tr>
<tr>
<td>&amp; MATH 20 and Calculus</td>
<td></td>
</tr>
<tr>
<td>&amp; MATH 21 and Calculus</td>
<td></td>
</tr>
<tr>
<td>Series C</td>
<td></td>
</tr>
</tbody>
</table>
5. Discrete Fundamentals Level 2—Multivariable Calculus

Select one of the following:  

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
<td>5</td>
</tr>
<tr>
<td>CME 100A</td>
<td>Vector Calculus for Engineers, ACE</td>
<td>6</td>
</tr>
<tr>
<td>MATH 51</td>
<td>Linear Algebra, Multivariable Calculus, and Modern Applications</td>
<td>5</td>
</tr>
<tr>
<td>MATH 51A</td>
<td>Linear Algebra, Multivariable Calculus, and Modern Applications, ACE</td>
<td>6</td>
</tr>
<tr>
<td>MATH 61CM</td>
<td>Modern Mathematics: Continuous Methods</td>
<td>5</td>
</tr>
<tr>
<td>MATH 61DM</td>
<td>Modern Mathematics: Discrete Methods (Discrete Alternative)</td>
<td>5</td>
</tr>
<tr>
<td>MATH 151</td>
<td>Introduction to Probability Theory</td>
<td>3</td>
</tr>
</tbody>
</table>

1. The following are optional but recommended and may be required for some higher level courses:
   - Additional courses in the Math 50 series
     - MATH 52 Integral Calculus of Several Variables
     - MATH 53 Ordinary Differential Equations with Linear Algebra
   - Or additional courses in the CME 100 series
     - CME 102 Ordinary Differential Equations for Engineers (same as ENGR 155A)
     - CME 104 Linear Algebra and Partial Differential Equations for Engineers (same as ENGR 155B)
   - Or additional courses in the Math 60 CM series
     - MATH 62CM Modern Mathematics: Continuous Methods
     - MATH 63CM Modern Mathematics: Continuous Methods

4. Continuous Fundamentals Level 3—Probability and Statistics

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 109</td>
<td>Introduction to Probability for Computer Scientists</td>
<td>3-5</td>
</tr>
<tr>
<td>CME 106/ENGR 155C</td>
<td>Introduction to Probability and Statistics for Engineers</td>
<td>4</td>
</tr>
<tr>
<td>EE 178</td>
<td>Probabilistic Systems Analysis</td>
<td>4</td>
</tr>
<tr>
<td>MS&amp;E 120</td>
<td>Probabilistic Analysis</td>
<td>5</td>
</tr>
<tr>
<td>MS&amp;E 220</td>
<td>Probabilistic Analysis</td>
<td>3-4</td>
</tr>
<tr>
<td>STATS 110</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
<td>5</td>
</tr>
<tr>
<td>STATS 116</td>
<td>Theory of Probability</td>
<td>4</td>
</tr>
</tbody>
</table>

5. Discrete Fundamentals

<table>
<thead>
<tr>
<th>Level</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Computing Level 1</td>
<td>3-5</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
</tr>
<tr>
<td>CS 106A</td>
<td>Programming Methodology</td>
</tr>
<tr>
<td>CS 106AP</td>
<td>(last offered Summer 2019)</td>
</tr>
<tr>
<td>Or equivalent preparation, as judged by student</td>
<td></td>
</tr>
<tr>
<td>b. Computing Level 2</td>
<td>3-5</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
</tr>
<tr>
<td>CS 106B</td>
<td>Programming Abstractions</td>
</tr>
<tr>
<td>CS 106X</td>
<td>Programming Abstractions</td>
</tr>
<tr>
<td>c. Logic and Computational Theory</td>
<td>3-5</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td></td>
</tr>
<tr>
<td>CS 103</td>
<td>Mathematical Foundations of Computing</td>
</tr>
<tr>
<td>PHIL 150</td>
<td>Mathematical Logic</td>
</tr>
</tbody>
</table>

6. Technical Depth

Two courses chosen from the list below (from either the same or different areas), appropriate to a student’s concentration. Students concentrating in HCI, AI, or Computer Music must take CS 107 or CS 107E. Other concentrations may also restrict the particular courses that can be taken to fulfill this requirement.

<table>
<thead>
<tr>
<th>Area</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Computer Organization and Systems (required for HCI, AI, or Computer Music)</td>
<td>3-5</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td></td>
</tr>
<tr>
<td>Area B. Computational Theory</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CS 154</td>
<td>Introduction to Automata and Complexity Theory</td>
</tr>
<tr>
<td></td>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td></td>
<td>PHIL 151A</td>
<td>Recursion Theory</td>
</tr>
<tr>
<td>Area C. Logic</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CS 157</td>
<td>Computational Logic</td>
</tr>
<tr>
<td></td>
<td>PHIL 151</td>
<td>Metalogic</td>
</tr>
<tr>
<td></td>
<td>PHIL 152</td>
<td>Computability and Logic</td>
</tr>
<tr>
<td></td>
<td>PHIL 154</td>
<td>Modal Logic</td>
</tr>
<tr>
<td>Area D. Decision Theory/Game Theory</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
</tr>
<tr>
<td></td>
<td>ECON 160</td>
<td>Game Theory and Economic Applications</td>
</tr>
<tr>
<td></td>
<td>ECON 180</td>
<td>Honors Game Theory</td>
</tr>
<tr>
<td></td>
<td>MGTECON 613</td>
<td>Foundations of Game Theory</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 232</td>
<td>Introduction to Game Theory</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 252</td>
<td>Decision Analysis I: Foundations of Decision Analysis</td>
</tr>
<tr>
<td></td>
<td>POLISCI 356A</td>
<td>Formal Theory I: Game Theory for Political Science</td>
</tr>
<tr>
<td>Area E. Probability and Statistics</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
</tr>
<tr>
<td></td>
<td>CS 246</td>
<td>Mining Massive Data Sets</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 121</td>
<td>Introduction to Stochastic Modeling</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 221</td>
<td>Stochastic Modeling</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 226</td>
<td>Fundamentals of Data Science: Prediction, Inference, Causality</td>
</tr>
<tr>
<td></td>
<td>STATS 200</td>
<td>Introduction to Statistical Inference</td>
</tr>
<tr>
<td></td>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
<tr>
<td></td>
<td>EE 276</td>
<td>Information Theory</td>
</tr>
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</table>

7. Philosophical Foundations Level 1

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESF 7</td>
<td>Education as Self-Fashioning: The Transformation of the Self</td>
<td>7</td>
</tr>
<tr>
<td>ESF 8</td>
<td>Education as Self-Fashioning: Recognizing the Self and Its Possibilities</td>
<td>7</td>
</tr>
<tr>
<td>OSPOXFRD 20</td>
<td>(last offered Winter 2017)</td>
<td></td>
</tr>
<tr>
<td>PHIL 1</td>
<td>Introduction to Philosophy</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 2</td>
<td>Introduction to Moral Philosophy</td>
<td>5</td>
</tr>
<tr>
<td>PHIL 20N</td>
<td>Philosophy of Artificial Intelligence</td>
<td>3</td>
</tr>
<tr>
<td>PHIL 60</td>
<td>Introduction to Philosophy of Science</td>
<td>5</td>
</tr>
<tr>
<td>PHIL 70</td>
<td>Introduction to social and political philosophy</td>
<td>4</td>
</tr>
</tbody>
</table>
### 8. Philosophical Foundations Level 2

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 80</td>
<td>Mind, Matter, and Meaning (WIM Course)</td>
<td>5</td>
</tr>
</tbody>
</table>

### 9. Philosophical Foundations Level 3

Select one of the following advanced undergraduate course in metaphysics/epistemology (post-PHIL 80):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 106A</td>
<td>(last offered Spring 2017)</td>
<td></td>
</tr>
<tr>
<td>PHIL 107B</td>
<td>Plato’s Later Metaphysics and Epistemology</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 167D</td>
<td>Philosophy of Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 173B</td>
<td>Metaethics</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 175</td>
<td>Philosophy of Law</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 180</td>
<td>Metaphysics</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 180A</td>
<td>Realism, Anti-Realism, Irrealism, Quasi-Realism</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 181</td>
<td>Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 182</td>
<td>Advanced Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 182A</td>
<td>Naturalizing Representation</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 184</td>
<td>Epistemology</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 186</td>
<td>Philosophy of Mind</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 187</td>
<td>Philosophy of Action</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 189G</td>
<td>Fine-Tuning Arguments for God's Existence</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: Symbolic Systems majors must take PHIL 182 for 3 or more units.

### 10. Cognition and Neuroscience

#### Introductory Cognition and Neuroscience

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSYCH 30</td>
<td>Introduction to Perception</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 45</td>
<td>Introduction to Learning and Memory</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 50</td>
<td>Introduction to Cognitive Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 141</td>
<td>Cognitive Development</td>
<td>3</td>
</tr>
</tbody>
</table>

An additional undergraduate course in cognition and/or neurosciences

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO 150</td>
<td>Human Behavioral Biology</td>
<td>5</td>
</tr>
<tr>
<td>HUMBIO 3B</td>
<td>Environmental and Health Policy Analysis</td>
<td>5</td>
</tr>
<tr>
<td>PSYCH 30</td>
<td>Introduction to Perception</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 45</td>
<td>Introduction to Learning and Memory</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 50</td>
<td>Introduction to Cognitive Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 60</td>
<td>Introduction to Developmental Psychology</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 60B</td>
<td>(last offered Autumn 2015)</td>
<td></td>
</tr>
<tr>
<td>PSYCH 70</td>
<td>Self and Society: Introduction to Social Psychology</td>
<td>4</td>
</tr>
</tbody>
</table>

### 11. Natural Language

#### Linguistic Dynamics: Language Processing, Learning, Variation, and Change

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINGUIST 1</td>
<td>Introduction to Linguistics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 52N</td>
<td>Spoken Sexuality: Language and the Social Construction of Sexuality</td>
<td>3</td>
</tr>
<tr>
<td>LINGUIST 61S</td>
<td>Language Evolution and Change</td>
<td>2-3</td>
</tr>
<tr>
<td>LINGUIST 67S</td>
<td>The Role of Language in Perception and Cognition</td>
<td>3</td>
</tr>
<tr>
<td>LINGUIST 140</td>
<td>Learning to Speak: An Introduction to Child Language Acquisition</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 150</td>
<td>Language and Society</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 152</td>
<td>Sociolinguistics and Pidgin Creole Studies</td>
<td>2-4</td>
</tr>
<tr>
<td>LINGUIST 156</td>
<td>Language and Gender</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 157</td>
<td>Sociophonetics</td>
<td>1-4</td>
</tr>
<tr>
<td>LINGUIST 159</td>
<td>American Dialects</td>
<td>2-4</td>
</tr>
<tr>
<td>LINGUIST 160</td>
<td>Introduction to Language Change</td>
<td>2-4</td>
</tr>
<tr>
<td>PSYCH 140</td>
<td>Introduction to Psycholinguistics</td>
<td>4</td>
</tr>
</tbody>
</table>

#### Linguistic Theory

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINGUIST 21N</td>
<td>Linguistic Diversity and Universals: The Principles of Language Structure</td>
<td>3</td>
</tr>
<tr>
<td>LINGUIST 105</td>
<td>Phonetics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 110</td>
<td>Introduction to Phonology</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 112</td>
<td>Seminar in Phonology: Stress, Tone, and Accent</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 120</td>
<td>Introduction to Syntax</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 121A</td>
<td>The Syntax of English</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 121B</td>
<td>Crosslinguistic Syntax</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 130A/230A</td>
<td>Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 130B</td>
<td>Introduction to Lexical Semantics</td>
<td>3-4</td>
</tr>
<tr>
<td>LINGUIST 272</td>
<td>Structure of Finnish</td>
<td>2-4</td>
</tr>
<tr>
<td>LINGUIST 281</td>
<td>Computational Models of Linguistic Formalism</td>
<td>1-4</td>
</tr>
</tbody>
</table>

### 12. Computation and Cognition

A course applying core technical skills to cognition

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td>3-4</td>
</tr>
</tbody>
</table>
Individually Designed Concentrations (IDCs)

Individually Designed Concentrations (IDCs) consist of five courses in a coherent subject area related to symbolic systems. This relationship may be established through inclusion in an IDC of two or more courses that connect the proposed concentration to the core, i.e. courses that (a) directly apply disciplines included in the core and (b) are related by topic or methodology to the other courses in the proposed concentration.

Course selection is to be made in consultation with the student’s adviser and is subject to approval by the adviser, the Associate Director, and the Director. For examples of IDCs completed by past SSP students, consult the list of alumni and apply the filter “Individually Designed Concentration”.

Approval of an IDC must take place no less than two full quarters before a student plans to graduate, e.g. prior to the first day of Winter Quarter of the senior year if a student intends to graduate in June of that year. Failure to obtain approval by the required date will necessitate either completing the requirements for one of the suggested concentrations, or delaying graduation to the end of the second full quarter following approval of an IDC.

To get a proposed IDC approved, send an email message to symsys-directors at lists.stanford.edu, cc’d to your prospective concentration adviser, stating that the adviser has approved your proposal, and giving a title, one-paragraph description, and course plan for your proposed concentration.

### Undergraduate Research

The program encourages all SSP majors to gain experience in directed research by participating in faculty research projects or by pursuing independent study. In addition to the Symbolic Systems Honors Program (see below), the following avenues are offered.

- **Summer Internships**: students work on SSP-related faculty research projects. Application procedures are announced in the Winter Quarter for SSP majors.
- **Research Assistantships**: other opportunities to work on faculty research projects are typically announced to SSP majors as they arise during the academic year.
- **Independent Study**: under faculty supervision. For course credit, students should enroll in SYMSYS 196 Independent Study.

Contact SSP for more information on any of these possibilities, or see the Symbolic Systems (http://symsys.stanford.edu) web site. In addition, see the Undergraduate Advising and Research (https://undergrad.stanford.edu/opportunities/research.html) web site for information on UAR grants and scholarships supporting student research projects at all levels.

### Honors Program

Seniors in SSP may apply for admission to the Symbolic Systems honors program prior to the beginning of their final year of study. Students who are accepted into the honors program can graduate with honors by completing an honors thesis under the supervision of a faculty member. Course credit for the honors project may be obtained by registering for SYMSYS 190 Senior Honors Tutorial any quarter while a student is working on an honors project. SYMSYS 191 Senior Honors Seminar, is recommended for honors students during the senior year. Contact SSP or visit the program’s web site for more information on the honors program, including deadlines and policies.

### Minor in Symbolic Systems

Students may minor in Symbolic Systems by completing either Option 1 or Option 2. For additional information see the Symbolic Systems minors web site (http://symsys.stanford.edu/viewing/htmldocument/13635).

**Option 1**

One course in each of the following core areas (please note that several of these courses have prerequisites):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSYCH 109</td>
<td>An introduction to computation and cognition</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: TheProbabilistic Approach</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 209</td>
<td>Neural Network Models of Cognition</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 242</td>
<td>Theoretical Neuroscience</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 249</td>
<td>Large-Scale Neural Network Modeling for Neuroscience</td>
<td>3</td>
</tr>
</tbody>
</table>
a. Cognition
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 1</td>
<td>Minds and Machines (formerly SYMSYS 100)</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 45</td>
<td>Introduction to Learning and Memory</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 50</td>
<td>Introduction to Cognitive Neuroscience</td>
<td>4</td>
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</tbody>
</table>

b. Logic and Computation
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 150</td>
<td>Mathematical Logic</td>
<td>4</td>
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<tr>
<td>PHIL 151</td>
<td>Metalogic</td>
<td>4</td>
</tr>
<tr>
<td>CS 103</td>
<td>Mathematical Foundations of Computing</td>
<td>3-5</td>
</tr>
</tbody>
</table>

c. Computer Programming
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>CS 106B</td>
<td>Programming Abstractions</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 106X</td>
<td>Programming Abstractions</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 107</td>
<td>Computer Organization and Systems</td>
<td>3-5</td>
</tr>
</tbody>
</table>

d. Philosophical Foundations
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 1</td>
<td>Minds and Machines (formerly SYMSYS 100)</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 80</td>
<td>Mind, Matter, and Meaning</td>
<td>5</td>
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</tbody>
</table>

e. Linguistic Theory
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>LINGUIST 105</td>
<td>Phonetics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 110</td>
<td>Introduction to Phonology</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 120</td>
<td>Introduction to Syntax</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 121A</td>
<td>The Syntax of English</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 121B</td>
<td>Crosslinguistic Syntax</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 130A</td>
<td>Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 130B</td>
<td>Introduction to Lexical Semantics</td>
<td>3-4</td>
</tr>
</tbody>
</table>

f. Computation and Cognition
Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPPHYS 293</td>
<td>Theoretical Neuroscience</td>
<td>3</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
<td>3-4</td>
</tr>
<tr>
<td>LINGUIST 180</td>
<td>From Languages to Information</td>
<td>3-4</td>
</tr>
<tr>
<td>LINGUIST 182</td>
<td>Computational Theories of Syntax</td>
<td>3-4</td>
</tr>
<tr>
<td>NENS 220</td>
<td>Computational Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 109</td>
<td>An introduction to computation and cognition</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: The Probabilistic Approach</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 209</td>
<td>Neural Network Models of Cognition</td>
<td>4</td>
</tr>
</tbody>
</table>

SYMSYS 1 Minds and Machines (formerly SYMSYS 100) may not be counted for both areas ‘a’ and ‘d’.

Option 2
SYMSYS 1 Minds and Machines (formerly SYMSYS 100), plus an interdisciplinary SSP concentration listed on the SSP (http://symsys.stanford.edu/viewing/htmldocument/16190) web site. To qualify, the selection of courses used for the minor must be interdisciplinary; it must either include courses from at least three departments, or include more than one course from each of two departments.

Coterminal Master's Degrees in Symbolic Systems
The Symbolic Systems M.S. Program admits a handful of coterminal students each year. Coterminal students usually complete the program in one academic year.

The GRE is not required for coterm applicants.

Many SSP majors also complete coterminal M.S. or M.A. degrees in affiliated departments. In addition to the Symbolic Systems M.S. program, the Department of Philosophy offers a Special Program in Symbolic Systems track for interdisciplinary graduate level work leading to the Master of Arts in Philosophy (http://www.stanford.edu/dept/registrar/bulletin/6567.htm).

University Coterminal Requirements
Coterminal master’s degree candidates are expected to complete all master’s degree requirements as described in this bulletin. University requirements for the coterminal master’s degree are described in the “Coterminal Master’s Program (http://exploredegrees.stanford.edu/cotermdegrees)” section. University requirements for the master’s degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)” section of this bulletin.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate program to satisfy requirements for the master’s degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor’s degree has been conferred.

The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science in Symbolic Systems
The University's basic requirements for the M.S. degree are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)” section of this bulletin.

The M.S. degree in Symbolic Systems is designed to be completed in the equivalent of one academic year by coterminal students or returning students who already have a B.S. degree in Symbolic Systems, and in two years or less by other students depending upon level of preparation. Admission is competitive, providing a limited number of students with the opportunity to pursue course and project work in consultation with a faculty adviser who is affiliated with the Symbolic Systems Program. The faculty adviser may impose requirements beyond those described here.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master’s degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

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The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master’s Degree Program Proposal be completed by the student and approved by the department by the end of the student’s first graduate quarter.

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The University requires that the graduate adviser be assigned in the student’s first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master’s Degree Program Proposal be completed by the student and approved by the department by the end of the student’s first graduate quarter.
Degree Requirements

A candidate for the M.S. degree in Symbolic Systems must complete a program of 45 units. All courses must be 100-level and above. At least 36 of these must be graded units, passed with an average grade of 3.0 (B) or better, and any course taken as part of the 45 unit program must be taken for a letter grade unless the course is offered S/NC only. None of the 45 units to be counted toward the M.S. degree may include units counted toward an undergraduate degree at Stanford or elsewhere.

Course requirements are waived only if evidence is provided that similar or more advanced courses have been taken, either at Stanford or another institution. Courses that are waived rather than taken may not be counted toward the M.S. degree. For additional information, see the Symbolic Systems web site (http://symsys.stanford.edu/graduate_programs).

Each candidate for the M.S. degree must fulfill the following requirements:

1. Submission to the Symbolic Systems Program office and approval of the following pre-project research documents:
   a. Project Area Statement, endorsed with a commitment from a student’s prospective project adviser no later than May 1 of the academic year prior to the expected graduation year; and
   b. Qualifying Research Paper due no later than the end of the Summer Quarter prior to the expected graduation year.

2. Completion of a coherent plan of study, to be approved by the advisor and designed to support a student’s project. An initial plan of study should be delineated on the Program Proposal Form prior to the end of the student’s first quarter of study, as required by the University. The final version of the Program Proposal, which should specify all the courses the student has taken and proposes as fulfillment of the unit requirements for the degree, is due by the end of Finals Week in the quarter prior to the student’s expected graduation quarter (i.e. end of Winter Quarter for a student graduating in the Spring). The plan of study must include courses taken for 3 units or more each that are more advanced than the Symbolic Systems undergraduate core in four main skill areas: formal, empirical, computational, and philosophical; and in at least three of the following departments: Computer Science, Linguistics, Philosophy, and Psychology. More advanced courses in each of the skill areas are defined as follows:

   a) Formal: a course in logic and computational theory beyond the level of PHIL 151 Metalogic. The courses below have been approved. Other courses may be approved if appropriate.
      • PHIL 252 Computability and Logic
      • PHIL 254 Modal Logic
      • PHIL 356C Logic and Artificial Intelligence
      • PHIL 357 Research Seminar on Logic and Cognition
      • CS 154 Introduction to Automata and Complexity Theory
      • CS 157 Computational Logic
      • CS 261 Optimization and Algorithmic Paradigms

   b) Empirical: a course drawing on experimental or observational data or methods, beyond the level of PSYCH 55, LINGUIST 120 or 130A. The courses below are examples of those that have been approved. Other courses may be approved if appropriate.
      • CS 224N Natural Language Processing with Deep Learning
      • CS 224U Natural Language Understanding
      • CS 229 Machine Learning
      • LINGUIST 230B Advanced Semantics
      • NBIO 206 The Nervous System
      • NBIO 258 Information and Signaling Mechanisms in Neurons and Circuits
      • PSYCH 204 Computation and Cognition: The Probabilistic Approach
      • PSYCH 204A Human Neuroimaging Methods
      • PSYCH 209 Neural Network Models of Cognition
      • PSYCH 251 Experimental Methods
      • PSYCH 252 Statistical Methods for Behavioral and Social Sciences
      • STATS 200 Introduction to Statistical Inference
      • SYMSYS 245 Cognition in Interaction Design

   c) Computational: a course involving programming beyond the level of CS 107. The courses below have been approved. Other courses may be approved if appropriate.
      • CS 108 Object-Oriented Systems Design
      • CS 110 Principles of Computer Systems
      • CS 124 From Languages to Information
      • CS 142 Web Applications
      • CS 143 Compilers
      • CS 145 Data Management and Data Systems
      • CS 148 Introduction to Computer Graphics and Imaging
      • CS 210A Software Project Experience with Corporate Partners
      • CS 221 Artificial Intelligence: Principles and Techniques
      • CS 224N Natural Language Processing with Deep Learning
      • CS 224W Machine Learning with Graphs
      • CS 246 Mining Massive Data Sets

   d) Philosophical: a course in the area of Philosophy of Mind/Language/Science/Epistemology or Metaphysics at the 200 level or above, certified by the instructor as worthy of graduate credit. The courses below are examples of those that have been approved. Other courses may be approved if appropriate.
      • PHIL 264 Central Topics in the Philosophy of Science: Theory and Evidence
      • PHIL 267D Philosophy of Neuroscience
      • PHIL 281 Philosophy of Language
      • PHIL 281C Slurs and derogatory language
      • PHIL 283 Self-knowledge and Metacognition
      • PHIL 286 Philosophy of Mind
      • PHIL 286A Self-fashioning
      • PHIL 327 Scientific Philosophy: From Kant to Kuhn and Beyond
      • PHIL 348 Evolution of Signalling
      • PHIL 359 Topics in Logic, Information and Agency
      • PHIL 377 Social Agency

3. Completion of three quarters of SYMSYS 291 Master’s Program Seminar.

4. Completion of a substantial project appropriate to the program plan, represented by the M.S. Thesis, the last of the the M.S research documents (http://symsys.stanford.edu/viewing/htmldocument/13678). The project normally takes three quarters, and work on the project may account for up to 15 units of a student’s program. The thesis must be read and approved for the master’s degree in Symbolic Systems by two
 qualified readers approved by the program, at least one of whom must be a member of the academic council. A copy of the thesis must be submitted (in both print and electronic forms) to the Associate Director of Symbolic Systems, with the print version including the signatures of each reader indicating approval of the thesis for the degree of Master of Science, no later than 12 noon on the day of the University Dissertation/Thesis Submission Deadline (https://studentaffairs.stanford.edu/registrar/students/dissertation-thesis) for the quarter of a student's graduation.

Graduate Advising Expectations
The Symbolic Systems Program is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program. Students are expected to meet regularly with their advisers and to keep them informed about their academic progress. Each student and their adviser should mutually agree on the frequency of these meetings when the advising relation begins and reassess their frequency at the start of every quarter.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

Faculty

Director: Michael C. Frank

Director of Graduate Studies: Michael C. Frank (on leave Autumn, 2019), Christopher Potts (Autumn, 2019)

Associate Director: Todd Davies

Faculty Advisory Board: Jeremy Bailenson, Michael Bernstein, Ray Briggs, Todd Davies, Judith Degen, Michael C. Frank, Noah Goodman, Thomas Icard, Daniel Jurafsky, Daniel Lassiter, Krista Lawlor, Christopher Manning, James McClelland, Stanley Peters, Christopher Potts, Mehran Sahami, Kenneth A. Taylor, Johan van Bentheim, Thomas A. Wasow

Executive Committee: Michael Bernstein, Todd Davies, Michael C. Frank, Thomas Icard, Christopher Potts

Program Faculty:

Aeronautics and Astronautics: Mykel Kochenderfer (Assistant Professor)

Biology: Deborah Gordon (Professor)

Classics: Reviel Netz (Professor)

Communication: Jeremy Bailenson (Professor), Jeff Hancock (Professor), Byron Reeves (Professor), Frederick Turner (Professor)

Computer Science: Maneesh Agrawala (Professor), Michael Bernstein (Assistant Professor), David Dill (Professor, emeritus), Michael Genesereth (Associate Professor), Oussama Khatib (Professor), Daphne Koller (Adjunct Professor), James Landay (Professor), Jean-Claude Latombe (Professor, emeritus), Marc Levy (Professor, emeritus), Christopher Manning (Professor), Andrew Ng (Adjunct Professor), Vaughan Pratt (Professor, emeritus), Eric Roberts (Professor, emeritus), Mehran Sahami (Professor, Teaching), Yoav Shoham (Professor, emeritus), Terry Winograd (Professor, emeritus)

Economics: Muriel Niederle (Professor)

Education: Raymond P. McDermott (Professor, emeritus), Roy Pea (Professor), Daniel Schwartz (Professor)

Electrical Engineering: Krishna Shenoy (Professor), Sebastian Thrun (Adjunct Professor)

French and Italian: Jean-Pierre Dupuy (Professor)

Genetics: Russ B. Altman (Professor)

Graduate School of Business: Baba Shiv (Professor)

History: Jessica G. Riskin (Professor)

Linguistics: Arto Anttila (Associate Professor), Joan Bresnan (Professor, emerita), Eve Clark (Professor, emerita), Cleo Condoravdi (Professor Research), Judith Degen (Assistant Professor), Penelope Eckert (Professor), Vera Grishanova (Associate Professor), Boris Harizanov (Assistant Professor), Daniel Jurafsky (Professor), Ronald Kaplan (Adjunct Professor), Lauri Karttunen (Adjunct Professor), Martin Kay (Professor), Paul Kiparsky (Professor), Daniel Lassiter (Assistant Professor), Beth Levin (Professor), Christopher Manning (Professor), Stanley Peters (Professor, emeritus), Christopher Potts (Professor), Meghan Sumner (Associate Professor), Thomas A. Wasow (Professor, emeritus), Annie Zaenen (Adjunct Professor)

Management Science and Engineering: Sharad Goel (Assistant Professor), Pamela Hinds (Professor)

Mathematics: Persi Diaconis (Professor)

Mechanical Engineering: Sean Follmer (Assistant Professor)

Medicine: Russ B. Altman (Professor), Mark Musen (Professor)

Music: Jonathan Berger (Professor), Christopher Chafe (Professor), Eleanor Selfridge-Field (Adjunct Professor), Ge Wang (Associate Professor)

Neurobiology: William T. Newsome (Professor), Jennifer Raymond (Professor)

Philosophy: Michael Bratman (Professor), Ray Briggs (Professor), Rosa Cao (Assistant Professor), Mark Crimmins (Associate Professor), John Etchemendy (Professor), Dagfinn Fallesdal (Professor, emeritus), Thomas Icard III (Assistant Professor), Krista Lawlor (Professor), Anna-Sara Malmgren (Assistant Professor), John Perry (Professor, emeritus), Brian Skyrms (Professor), Kenneth Taylor (Professor), Johan van Bentheim (Professor), Thomas A. Wasow (Professor, emeritus)

Psychiatry and Behavioral Sciences: Vinod Menon (Professor)

Psychology: Herbert H. Clark (Professor, emeritus), Anne Fernald (Associate Professor), Michael C. Frank (Associate Professor), Justin Gardner (Assistant Professor), Noah Goodman (Associate Professor), Kalanit Grill-Spector (Professor), Hyowon Gweon (Assistant Professor), Brian Knutson (Professor), Ellen Markman (Professor), James McClelland (Professor), Russell Poldrack (Professor), Barbara Tversky (Professor, emerita), Anthony Wagner (Professor), Brian Wandell (Professor), Daniel Yamins (Assistant Professor), Jamil Zaki (Assistant Professor)

Statistics: Persi Diaconis (Professor), Susan P. Holmes (Professor)
Concentration Areas
In addition to the Core, SSP majors choose an area of concentration. For undergraduates, a concentration comprises an approved list of 5 courses of 3 or more units each.

Applied Logic

Introductory Requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 154</td>
<td>Introduction to Automata and Complexity Theory</td>
<td>3-4</td>
</tr>
<tr>
<td>PHIL 151</td>
<td>Metalogic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
<td>4</td>
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Computational

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<tr>
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</thead>
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<tr>
<td>CS 151</td>
<td>Logic Programming</td>
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<tr>
<td>CS 157</td>
<td>Computational Logic</td>
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Set Theory

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<tr>
<td>MATH 161</td>
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Formal Semantics

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<th>Units</th>
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<tr>
<td>LINGUIST 130A</td>
<td>Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 230B</td>
<td>Advanced Semantics</td>
<td>2-4</td>
</tr>
<tr>
<td>LINGUIST 230C</td>
<td>Advanced Topics in Semantics &amp; Pragmatics</td>
<td>1-4</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
<td>4</td>
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</tbody>
</table>

Advanced

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<th>Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>PHIL 156A</td>
<td>Modal Logics - A Modern Perspective</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 159</td>
<td>Non-Classical Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 188W</td>
<td>Paradoxes</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 351</td>
<td>Representation Theorems</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 351B</td>
<td>Proof Mining</td>
<td>1-3</td>
</tr>
<tr>
<td>PHIL 351C</td>
<td>Formal Methods in Ethics</td>
<td>2-4</td>
</tr>
<tr>
<td>PHIL 351D</td>
<td>Measurement Theory</td>
<td>2-4</td>
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<td>PHIL 353</td>
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<td>Applications of Modal Logic</td>
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<td>Logic and Artificial Intelligence</td>
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<td>Topics in Logic, Information and Agency</td>
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<td>Seminar on Logic &amp; Formal Philosophy</td>
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(Note: Phil 359 counts only if taken for 3 or more units, in accordance with the policy for all core courses)

Artificial Intelligence

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<td>CS 157</td>
<td>Computational Logic</td>
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<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td>3-4</td>
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<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
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<td>PHIL 154</td>
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Natural Language Processing

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<td>From Languages to Information</td>
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<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
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<td>CS 224S</td>
<td>Spoken Language Processing</td>
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<td>CS 224U</td>
<td>Natural Language Understanding</td>
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<td>CS 276</td>
<td>Information Retrieval and Web Search</td>
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<td>SYMSYS 112</td>
<td>Challenges for Language Systems</td>
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Learning

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<td>Hardware Accelerators for Machine Learning</td>
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<td>Machine Learning with Graphs</td>
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<td>Deep Generative Models</td>
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<td>CS 246</td>
<td>Mining Massive Data Sets</td>
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<td>CS 325B</td>
<td>Data for Sustainable Development</td>
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<td>Introduction to Machine Learning</td>
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<td>Data Privacy and Ethics</td>
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<td>Computation and Cognition: The Probabilistic Approach</td>
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<td>Modern Applied Statistics: Learning</td>
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<td>Modern Applied Statistics: Data Mining</td>
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Robots and Vision

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<td>Introduction to Robotics</td>
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<td>Experimental Robotics</td>
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<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
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<td>Convolutional Neural Networks for Visual Recognition</td>
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<td>Reinforcement Learning</td>
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<td>Representation Learning in Computer Vision</td>
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<td>Algorithms for Interactive Robotics</td>
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<td>CS 348K</td>
<td>Visual Computing Systems</td>
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<td>High-level Vision: From Neurons to Deep Neural Networks</td>
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Additional Topics

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<td>Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
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<td>BIOMEDIN 214</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
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<td>CS 227B</td>
<td>General Game Playing</td>
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<td>MS&amp;E 135</td>
<td>Networks</td>
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<td>MUSIC 220B</td>
<td>Compositional Algorithms, Psychoacoustics, and Computational Music</td>
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<td>Research Seminar in Computer-Generated Music</td>
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<td>Philosophy of Artificial Intelligence</td>
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<td>Conceptual Issues in Cognitive Science</td>
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<td>Computer Machines and Intelligence</td>
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<td>Collective Behavior and Distributed Intelligence</td>
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<td>Introduction to Linear Dynamical Systems</td>
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<td>Introduction to Automata and Complexity Theory</td>
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<td>Design and Analysis of Algorithms</td>
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<td>The Modern Algorithmic Toolbox</td>
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<td>Continuous Mathematical Methods with an Emphasis on Machine Learning</td>
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<td>Game Theory and Economic Applications</td>
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<td>Introduction to Control Design Techniques</td>
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<td>Analysis and Control of Nonlinear Systems</td>
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<td>Applied Matrix Theory</td>
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<td>Linear Algebra and Matrix Theory</td>
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**Cognitive Science**

**Cognitive Neuroscience**

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<td>PSYCH 45</td>
<td>Introduction to Learning and Memory</td>
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<td>PSYCH 50</td>
<td>Introduction to Cognitive Neuroscience</td>
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<td>PSYCH 162</td>
<td>Brain Networks</td>
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<td>PSYCH 164</td>
<td>Brain decoding</td>
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<td>PSYCH 202</td>
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**Empirical Methods**

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<td>Introduction to Computational Social Science</td>
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<td>PSYCH 204A</td>
<td>Human Neuroimaging Methods</td>
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<td>PSYCH 251</td>
<td>Experimental Methods</td>
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<td>Statistical Methods for Behavioral and Social Sciences</td>
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<td>High-Dimensional Methods for Behavioral and Neural Data</td>
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<td>Introduction to Statistical Inference</td>
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**Language**

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<td>Natural Language Processing with Deep Learning</td>
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<td>LINGUIST 110</td>
<td>Learning to Phonology</td>
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<td>LINGUIST 140</td>
<td>Learning to Speak: An Introduction to Child Language Acquisition</td>
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<td>LINGUIST 180</td>
<td>From Languages to Information</td>
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<td>LINGUIST 236</td>
<td>Seminar in Semantics: Causation</td>
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**LINGUIST 248** Seminar in Developmental Psycholinguistics | 4 |

**PHIL 181** Philosophy of Language | 4 |
**PHIL 194D** Capstone Seminar | 4 |
**PHIL 194K** Slurs and Derogation: Semantic, Pragmatic and Ethical Perspectives | 4 |
**PHIL 348** Evolution of Signalling | 2-4 |
**PHIL 385D** Topics in Philosophy of Language | 2-4 |
**PSYCH 132** Language and Thought | 3 |
**PSYCH 140** Introduction to Psycholinguistics | 4 |
**SYMSYS 112** Challenges for Language Systems | 3-4 |

**Perception**

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<td>Introduction to Perception</td>
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<td>Image Systems Engineering</td>
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**Higher Cognition**

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<td>Advanced Studies in Behavior and Social Media</td>
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<td>Cognitive Development in Childhood and Adolescence</td>
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<td>Social Cognition and Learning in Early Childhood</td>
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**Neuroscience**

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<td>CS 234</td>
<td>Reinforcement Learning</td>
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<td>EDUC 266</td>
<td>Educational Neuroscience</td>
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NBIO 101 Social and Ethical Issues in the Neurosciences 2-4
NBIO 206 The Nervous System 6
NBIO 258 Information and Signaling Mechanisms in Neurons and Circuits 4
PHIL 167D Philosophy of Neuroscience 4
PHIL 360 Grad Seminar: Philosophy of Neuroscience 2-4
PSYCH 162 Brain Networks 3
PSYCH 164 Brain decoding 3
PSYCH 202 Cognitive Neuroscience 3
PSYCH 204A Human Neuroimaging Methods 3
PSYCH 204B Computational Neuroimaging 1-3
PSYCH 209 Neural Network Models of Cognition 4
PSYCH 232 Brain and Decision 3
PSYCH 248A fMRI Analysis Bootcamp 3
PSYCH 249 Large-Scale Neural Network Modeling for Neuroscience 1-3
PSYCH 251 Experimental Methods 3
PSYCH 254 Affective Neuroscience 3
PSYCH 287 Brain Machine Interfaces: Science, Technology, and Application 1-3

Theoretical Foundations

CS 154 Introduction to Automata and Complexity Theory 3-4
ECON 160 Game Theory and Economic Applications 5
EE 276 Information Theory 3
MATH 113 Linear Algebra and Matrix Theory 3
PHIL 82T Philosophy of Cognitive Science 4
PHIL 152 Computability and Logic 4
PHIL 153L Computing Machines and Intelligence 4
PHIL 154 Modal Logic 4
PHIL 351D Measurement Theory 2-4
PHIL 356C Logic and Artificial Intelligence 2-4
PHIL 357 Research Seminar on Logic and Cognition 2-4
PSYCH 204 Computation and Cognition: The Probabilistic Approach 3
PSYCH 247 Topics in Natural and Artificial Intelligence 3
SYMSYS 207 Conceptual Issues in Cognitive Science 3
SYMSYS 208 Computer Machines and Intelligence 3

Computer Music

Music Fundamentals

Music and the Mind & Brain

Music HCI/Design

CS 147 Introduction to Human-Computer Interaction Design 3-5
MUSIC 128 Stanford Laptop Orchestra: Composition, Coding, and Performance 1-5
MUSIC 250A Physical Interaction Design for Music 3-4
MUSIC 256A Music, Computing, Design I: The Art of Design 3-4

Advanced Research Topics/Electives

CS 108 Object-Oriented Systems Design 3-4
LINGUIST 105 Phonetics 4
LINGUIST 110 Introduction to Phonology 4
MUSIC 220C Research Seminar in Computer-Generated Music 2-4
MUSIC 222 Sound in Space 1-4
MUSIC 253 Symbolic Musical Information 2-4
MUSIC 254 Music Query, Analysis, and Style Simulation 2-4
MUSIC 256B Music, Computing, Design II: Virtual and Augmented Reality for Music 3-4
MUSIC 257 Neuroplasticity and Musical Gaming 3-5
MUSIC 364 Data-Driven Research in Music Cognition 2-4

Decision Making and Rationality

Philosophical Inquiry

MS&E 234 Data Privacy and Ethics 3
MS&E 254 The Ethical Analyst 1-3
PHIL 164 Central Topics in the Philosophy of Science: Theory and Evidence 4
PHIL 166 Probability. Ten Great Ideas About Chance 4
PHIL 169 Evolution of the Social Contract 4
PHIL 170 Ethical Theory 4
PHIL 171 Justice 4-5
PHIL 172 History of Moral Philosophy 4
PHIL 184 Epistemology 4
PHIL 187 Philosophy of Action 4
PHIL 194M Capstone Seminar: Consequences for Ethics 4
PHIL 359 Topics in Logic, Information and Agency 2-4
PHIL 377 Social Agency 2-4
PHIL 386 Truth as the aim of belief and inquiry 2-4
PHIL 388 Topics in Normativity 2-4
POLISCI 131L Modern Political Thought: Machiavelli to Marx and Mill 5
POLISCI 230A Classical Seminar: Origins of Political Thought 3-5
PSYCH 160 Seminar on Emotion 3
(Note: Phil 359 counts only if taken for 3 or more units, in accordance with the policy for all core courses)

Formal Decision Theories

ECON 51 Economic Analysis II 5
ECON 136 Market Design 5
ECON 160 Game Theory and Economic Applications 5
ECON 180 Honors Game Theory 5
ECON 182 Honors Market Design 5
ECON 289 Advanced Topics in Game Theory and Information Economics 2-5
INTLPOP 204A Microeconomics for Policy 4-5
MGTECON 613 Foundations of Game Theory 3
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**Empirical Findings and Explanations**

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**Methodological Foundations**

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### Learning

#### Computational Learning

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<td>Probabilistic Graphical Models: Principles and Techniques</td>
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<td>Deep Generative Models</td>
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<td>Building Digital History: Informatics of Social Movements and Protest</td>
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### Natural Language

#### Mathematical/Computational Foundations

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<td>Artificial Intelligence: Principles and Techniques</td>
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#### Computational Linguistics

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<td>Natural Language Processing with Deep Learning</td>
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<td>Information Retrieval and Web Search</td>
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<td>Challenges for Language Systems</td>
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#### Phonetics/Phonology/Speech

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<td>Seminar in Phonology: Stress, Tone, and Accent</td>
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<td>Corpus Phonology</td>
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#### Morphosyntax

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<td>LINGUIST 121B</td>
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<td>Foundations of Syntactic Theory I</td>
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<td>Seminar in Syntax: Advanced Topics</td>
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#### Semantics/Pragmatics/Philosophy of Language

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<td>Slurs and derogatory language</td>
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<td>Slurs and Derogation: Semantic, Pragmatic and Ethical Perspectives</td>
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<td>Evolution of Signalling</td>
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#### Psycholinguistics

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<td>Seminar in Developmental Psycholinguistics</td>
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#### Sociolinguistics and Language Change

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### Neurosciences

#### Basic Neuroscience

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<td>Human Behavioral Biology</td>
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<td>BIO 151</td>
<td>Mechanisms of Neuron Death</td>
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<td>Cellular Neuroscience: Cell Signaling and Behavior</td>
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<td>Ion Transport and Intracellular Messengers</td>
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Note: NBIO 206 is a 6-unit course, which counts as two concentration courses, from areas 1 and 2.

#### Systems Neuroscience

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<td>Exploring Neural Circuits</td>
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<td>PSYC 124</td>
<td>Brain Plasticity</td>
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### Computational Approaches

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<td>Computational Models of the Neocortex</td>
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<td>Introduction to Neuroelectrical Engineering</td>
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<td>Brain decoding</td>
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<td>Individually Supervised Practicum</td>
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### Biological and Computational Approaches to Vision

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<td>Computer Vision: From 3D Reconstruction to Recognition</td>
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<td>Convolutional Neural Networks for Visual Recognition</td>
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<td>Introduction to Perception</td>
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<td>PSYCH 250</td>
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### Philosophical and Theoretical Approaches

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<td>PHIL 186</td>
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### Methodological Foundations

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<td>Signal Processing and Linear Systems I</td>
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<td>The Fourier Transform and Its Applications</td>
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<td>Statistical Methods for Behavioral and Social Sciences</td>
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### Philosophical Foundations

#### Area 1

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<td>Self-knowledge and Metacognition</td>
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<td>Philosophy of Creativity</td>
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