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 offers a Bachelor of Science in Symbolic Systems, as well as a Bachelor of Science with Honors in Symbolic Systems (p. 13) and a Minor in Symbolic Systems (p. 13). A major in Symbolic Systems qualifies as a Science, Technology, Engineering, and Mathematics (STEM) major under the U.S. Department of Homeland Security’s Designated Degree Programs (https://studyinthesates.dhs.gov/eligible-cip-codes-for-the-stem-opt-extension/) list of STEM programs. Depending on the plan of study, Sym Sys students can be classified as studying Cognitive Science (2010 CIP Code 30.2501) and/or Informatics (2010 CIP Code 11.0104).

How to Declare the Major

To declare a major in Symbolic Systems, a student must:

• Be enrolled in or have completed SYMSYS 1 Minds and Machines
• Declare the major in Axess, and have the declaration approved by the program student services officer.
• Submit a preliminary Course Plan (https://symsys.stanford.edu/undergraduates/forms/) form for the major to a declaration interview with one of the Advising Fellows (https://symsys.stanford.edu/undergraduates/advising-fellows/) or with the Associate Director of the Program; see the calendar of Office Hours (https://symsys.stanford.edu/undergraduates/undergrad-adv/advising-fellows/advising-office-hours/) on the Symsys website for possible interview times.

Advising

Upon declaration approval, students are assigned to both the Program Director and Associate Director as major advisors. The student must also select and confirm a concentration advisor.

• Declared majors have until the Autumn Quarter of their junior year to select a concentration advisor. Juniors declaring the major must have a concentration advisor confirmed at the time of declaration.
• A hold is placed on Winter Quarter registration for juniors who do not have a concentration advisor by Autumn Quarter of their junior year. (See the COVID-19 Policies (p. 16) tab for a one-year extension to Winter Quarter for this requirement.)
• Any individual with an ongoing instructional appointment at Stanford (listed as such in Chapters 2, 6, or 9 of the Faculty Handbook (https://explorecourses.stanford.edu/CourseSearch/search?view=catalog&/38;catalog=& Stanford Bulletin 2019-20)
facultyhandbook.stanford.edu/) may serve as the concentration advisor. To confirm a concentration advisor after an eligible faculty member has agreed to fill this role, student must send an email message to symsys-sso@stanford.edu and the concentration advisor, including a statement of how the student plans to fulfill the capstone requirement of the major. Changes to capstone plans require the approval of the concentration advisor.

**Degree Requirements**

The Symbolic Systems major requires completion of:

- The core: a common set of foundations, breadth requirements, and experiential requirements that all students in the program must complete
- An approved concentration: depth in a particular specialization chosen by the student. See a list of Concentrations (p. 5) below.

Students must submit a course plan to the student services officer for Symbolic Systems at least two quarters prior to the planned graduation date, listing courses taken or that will be completed to fulfill the course requirements for the major.

Students must obtain approval for any courses not listed as approved for a major requirement.

All courses taken to fulfill a major requirement for Symbolic Systems must be passed for 3 units or more, with either a letter grade (‘C-’ or better for core courses, and a ‘D-’ or above for concentration courses) or an option pass grade (‘S’ or its equivalent in the Graduate School of Business, Stanford Law School, or School of Medicine, or in approved transfer credit course from another institution. A ‘CR’ cannot be used to fulfill a major requirement for Symbolic Systems), except as modified by the COVID-19 policies in effect during 2020-21. Students who have already completed a required course with a ‘CR’ grade may file a Replacement Petition to take a course in the same subject area at the same or a higher level in order to avoid having to retake the course.

Unless otherwise stated, each course that is counted for the major must be taken for 3 units or more. Taking a course for 3 units is sufficient unless the requirement specifically states otherwise.

Each course taken for the major may be counted toward at most one required course in either the Core or Concentration (not both), except in cases where double-counting is explicitly allowed.

Students in a dual degree program (http://exploredegrees.stanford.edu/undergraduatedegreesandprograms/#dual-degrees), students taking a minor, or students in coterminal program (http://exploredegrees.stanford.edu/cotermdegrees/), may not double-count courses towards different degree programs or minors unless a course is an introductory skill requirement (https://symsys.stanford.edu/undergraduatesminor-requirements/introductory-skill-requirements/) for both majors.

The program is open to requests to approving courses not listed as options to fulfill major requirements. Consult the student services office for details of this process.

**Core**

Core requirements are typically completed earlier than a student’s concentration, but the only requirements that impose explicit restrictions on when a course can be completed during a student’s undergraduate career are the gateway and capstone requirements.

## Course Requirements

### 1. Preparations

These courses should be completed early in the major.

#### a. Gateway Course

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 1</td>
<td>4</td>
</tr>
</tbody>
</table>

#### b. Single Variable Calculus

One of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 19, MATH 20, and MATH 21 (or MATH 21A)</td>
<td>10 units of Advanced Placement Calculus credit</td>
</tr>
</tbody>
</table>

Placement by the Mathematics Placement Diagnostic into MATH 20 or MATH 21 and completion of the rest of the series, or into MATH 51

#### c. Multivariate Systems

One of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>5</td>
</tr>
<tr>
<td>CME 100A</td>
<td>6</td>
</tr>
<tr>
<td>MATH 51</td>
<td>5</td>
</tr>
<tr>
<td>MATH 51A</td>
<td>6</td>
</tr>
<tr>
<td>MATH 61CM</td>
<td>5</td>
</tr>
<tr>
<td>MATH 61DM</td>
<td>5</td>
</tr>
</tbody>
</table>

#### d. Further Study in Multivariate Systems

Optional, but recommended, and may be used as contingent electives in a concentration. One or more of the following courses, which may be needed as preparation for some Core options and other advanced courses in the major.

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 102</td>
<td>5</td>
</tr>
<tr>
<td>CME 102A</td>
<td>6</td>
</tr>
<tr>
<td>CME 104</td>
<td>5</td>
</tr>
<tr>
<td>ENGR 108</td>
<td>3-5</td>
</tr>
<tr>
<td>MATH 52</td>
<td>5</td>
</tr>
<tr>
<td>MATH 53</td>
<td>5</td>
</tr>
<tr>
<td>MATH 62CM</td>
<td>5</td>
</tr>
<tr>
<td>MATH 62DM</td>
<td>5</td>
</tr>
<tr>
<td>MATH 63CM</td>
<td>5</td>
</tr>
<tr>
<td>MATH 104</td>
<td>3</td>
</tr>
<tr>
<td>MATH 113</td>
<td>3</td>
</tr>
</tbody>
</table>

### 2. Breadth Requirements

One three quarter sequence of training in each of four methodological areas, plus a Cross-Area Requirement.

#### a. Philosophical Analysis

##### i. An introductory course in the Philosophy Department

One of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>THINK 69</td>
<td>4</td>
</tr>
</tbody>
</table>

##### ii. Writing in the Major (WIM) course

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 80</td>
<td>5</td>
</tr>
</tbody>
</table>

##### iii. An advanced undergraduate Philosophy course that lists PHIL 80 as a prerequisite

One of the following:
One of the following:

- CS 106B
- CS 106X  

ii. Programming II
One of the following:

- CS 106A  Programming Methodology 3-5
- Equivalent preparation, as evidenced by successful completion of CS 106B or 106X

b. Formal Methods
Courses that focus on rigorous definitions, axioms, theorems, and proofs, and their use in developing mathematical theories and meta-theories. Each of the following:

i. Formal Logic
One of the following:

- CS 157  Computational Logic 3
- PHIL 150  Mathematical Logic 4
- PHIL 151  Metalogic (Prerequisite: PHIL 150 or instructor permission) 4

ii. Theory of Computation. One of the following:

- CS 103  Mathematical Foundations of Computing (Corequisite: CS 106B or X) 3-5
- CS 154  Introduction to the Theory of Computation (Prerequisite: CS 103 or significant proof-writing experience) 3-4

iii. Probability Theory and Statistics
A course that covers the theory of probability and is grounded in multivariable calculus. One of the following:

- CME 106  Introduction to Probability and Statistics for Engineers 4
- CS 109  Introduction to Probability for Computer Scientists 3-5
- EE 178  Probabilistic Systems Analysis 3-4
- MATH 151  Introduction to Probability Theory 3
- MATH 63DM  Modern Mathematics: Discrete Methods 5
- MS&E 120  Introduction to Probability 4
- MS&E 220  Probabilistic Analysis 3-4
- STATS 110  Statistical Methods in Engineering and the Physical Sciences 5
- STATS 116  Theory of Probability 4

c. Computational Methods
Courses that focus on software design, data structures, algorithms, development, applications, evaluation, and simulation. Each of the following:

i. Programming I
One of the following:

- CS 106A  Programming Methodology 3-5
- Equivalent preparation, as evidenced by successful completion of CS 106B or 106X

ii. Programming II
One of the following:

- CS 106B  Programming Abstractions 3-5
- CS 106X  Programming Abstractions (Accelerated) 3-5

iii. A post-CS 106B course covering one or more broad computational methods with a programming component.
One of the following:

- CS 107  Computer Organization and Systems 3-5
- CS 107E  Computer Systems from the Ground Up 3-5
- CS 129  Applied Machine Learning 3-4
- CS 147  Introduction to Human-Computer Interaction Design (Plus one of the following) 3-5
- CS 193A  Android Programming 3
- CS 193C  Client-Side Internet Technologies 3
- CS 193P  iOS Application Development 3
- CS 193X  Web Programming Fundamentals 3
- CS 194H  User Interface Design Project 3-4
- CS 221  Artificial Intelligence: Principles and Techniques 3-4
- CS 229  Machine Learning 3-4

d. Empirical Cognitive Science
Courses that focus on questions, hypotheses, models, predictions, and explanations that are derived from or testable in neural and behavioral data. Each of the following:

i. Overview of psychology.

- PSYCH 1  Introduction to Psychology 5

ii. An introductory area course in cognition, language, and neuroscience.
One of the following:

- BIO 150  Human Behavioral Biology 5
- LINGUIST 145  Introduction to Psycholinguistics 4
- LINGUIST 150  Language and Society 3-4
- PSYCH 30  Introduction to Perception 4
- PSYCH 45  Introduction to Learning and Memory 3
- PSYCH 50  Introduction to Cognitive Neuroscience 4
- PSYCH 60  Introduction to Developmental Psychology 3
- PSYCH 70  Self and Society: Introduction to Social Psychology 4
- PSYCH 75  Introduction to Cultural Psychology 5
- PSYCH 141  Cognitive Development 3
- PSYCH 154  Judgment and Decision-Making 3

iii. Linguistic Theory
A course introducing a core area of theoretical inquiry in linguistics. One of the following:

- LINGUIST 105  Phonetics 4
- LINGUIST 110  Introduction to Phonology 4
- LINGUIST 120  Introduction to Syntax 4
- LINGUIST 130A  Introduction to Semantics and Pragmatics 4
- LINGUIST 130B  Introduction to Lexical Semantics 3-4

Additional approved undergraduate courses offered on a semiregular basis:

- LINGUIST 21N  Linguistic Diversity and Universals: The Principles of Language Structure 3
- LINGUIST 30N  Linguistic Meaning and the Law 3
- LINGUIST 121A  The Syntax of English 4
- LINGUIST 121B  Crosslinguistic Syntax 4
- LINGUIST 134A  The Structure of Discourse: Theory and Applications 2-4
- LINGUIST 160  Introduction to Language Change 2-4

Cross-Area Requirement
A non-introductory course, which has as a prerequisite at least one Core course (or equivalent), and which combines methods and subject matter from at least two Breadth areas in the Core. One of the following:

i. Suggested courses for most students

Only one course must be chosen to fulfill the requirement - categories are for guidance only:

- **CS 147** Introduction to Human-Computer Interaction Design 3-5
- **CS 229** Machine Learning 3-4
- **LINGUIST 130A** Introduction to Semantics and Pragmatics 4
- **LINGUIST 180** From Languages to Information 3-4
- **PHIL 152** Computability and Logic 4
- **PHIL 154** Modal Logic 4
- **PHIL 167D** Philosophy of Neuroscience 4
- **PHIL 181** Philosophy of Language 4
- **PSYCH 204** Computation and Cognition: The Probabilistic Approach 3
- **PSYCH 209** Neural Network Models of Cognition 4

ii. Any other course on the full list of courses approved for this requirement below.

3. Experiential Requirements

Each of the following:

a. Advanced Small Seminar Requirement.

An approved course which (a) builds on the Core Preparations and Breadth Requirements, (b) is small – 20 students or fewer, and (c) is an interactive, discussion-based seminar. May be double-counted for an applicable Concentration requirement, but not for a Core requirement.

b. Capstone

A two-course requirement consisting of the following components, chosen in consultation with and approved by a student’s Concentration Advisor (3 or more units each):

i. Practicum

A project or internship-accompanying course. One of the following:

- **SYMSYS 190** Senior Honors Tutorial (continuation of the course taken for the Practicum requirement) 1-5

An approved project course with a SYMSYS listing in the 195-series (See list under ‘Practicum’ above - may be either the second quarter of a 2-quarter course, or a one-quarter course)

Supervised research with a faculty member on an approved symbolic-systems related project, taken as SYMSYS 196 Independent Study, or a department-based directed research course (may be either the second quarter of a 2-quarter course or a one-quarter course)

An approved Concentration-Specific Integrative Course taken within a Concentration.

Total Units: 75-90

Full List of Cross-Area Requirement Courses

<table>
<thead>
<tr>
<th>Cross-Area Requirement</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>The full list of approved courses for the Cross-Area Requirement.</td>
<td></td>
</tr>
<tr>
<td>Only one course must be chosen to fulfill the requirement - categories are for guidance only.</td>
<td></td>
</tr>
<tr>
<td><strong>Philosophical Analysis and Formal Methods</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PHIL 152</strong> Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 154</strong> Modal Logic</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 162</strong> Philosophy of Mathematics</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 181</strong> Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td><strong>Philosophical Analysis and Computational Methods</strong></td>
<td></td>
</tr>
<tr>
<td><strong>CS 181</strong> Computers, Ethics, and Public Policy</td>
<td>4</td>
</tr>
<tr>
<td><strong>CS 182</strong> Ethics, Public Policy, and Technological Change</td>
<td>5</td>
</tr>
<tr>
<td><strong>PHIL 152</strong> Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 167D</strong> Philosophy of Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td><strong>Philosophical Analysis and Empirical Cognitive Science</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PHIL 167D</strong> Philosophy of Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 181</strong> Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 186</strong> Philosophy of Mind</td>
<td>4</td>
</tr>
<tr>
<td><strong>Formal Methods and Computational Methods</strong></td>
<td></td>
</tr>
<tr>
<td><strong>CS 151</strong> Logic Programming</td>
<td>3</td>
</tr>
<tr>
<td><strong>CS 154</strong> Introduction to the Theory of Computation</td>
<td>3-4</td>
</tr>
<tr>
<td><strong>CS 161</strong> Design and Analysis of Algorithms</td>
<td>3-5</td>
</tr>
<tr>
<td><strong>CS 229</strong> Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td><strong>CS 238</strong> Decision Making under Uncertainty</td>
<td>3-4</td>
</tr>
<tr>
<td><strong>LINGUIST 130A</strong> Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td><strong>LINGUIST 180</strong> From Languages to Information</td>
<td>3-4</td>
</tr>
<tr>
<td><strong>PHIL 152</strong> Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td><strong>PHIL 154</strong> Modal Logic</td>
<td>4</td>
</tr>
<tr>
<td><strong>PSYCH 204</strong> Computation and Cognition: The Probabilistic Approach</td>
<td>3</td>
</tr>
<tr>
<td><strong>PSYCH 209</strong> Neural Network Models of Cognition</td>
<td>4</td>
</tr>
<tr>
<td><strong>PSYCH 221</strong> Image Systems Engineering</td>
<td>1-3</td>
</tr>
<tr>
<td><strong>PSYCH 242</strong> Theoretical Neuroscience</td>
<td>3</td>
</tr>
<tr>
<td><strong>PHIL 249</strong> Evidence and Evolution</td>
<td>3-5</td>
</tr>
</tbody>
</table>
Formal Methods and Empirical Cognitive Science
PSYCH 253 Advanced Statistical Modeling 3
CS 229 Machine Learning 3-4
ECON 178 Behavioral Economics 5
LINGUIST 130A Introduction to Semantics and Pragmatics 4
LINGUIST 180 From Languages to Information 3-4
PHIL 154 Modal Logic 4
PHIL 181 Philosophy of Language 4
PSYCH 204 Computation and Cognition: The Probabilistic Approach 3
PSYCH 209 Neural Network Models of Cognition 4
PSYCH 221 Image Systems Engineering 1-3
PSYCH 242 Theoretical Neuroscience 3
PSYCH 249 Large-Scale Neural Network Modeling for Neuroscience 1-3
PSYCH 253 Advanced Statistical Modeling 3

Computational Methods and Empirical Cognitive Science
CS 147 Introduction to Human-Computer Interaction Design 3-5
CS 229 Machine Learning 3-4
CS 448B Data Visualization 3-4
LINGUIST 130A Introduction to Semantics and Pragmatics 4
LINGUIST 180 From Languages to Information 3-4
PHIL 167D Philosophy of Neuroscience 4
PSYCH 164 Brain decoding 3
PSYCH 204 Computation and Cognition: The Probabilistic Approach 3
PSYCH 209 Neural Network Models of Cognition 4
PSYCH 221 Image Systems Engineering 1-3
PSYCH 204A Human Neuroimaging Methods 3
PSYCH 242 Theoretical Neuroscience 3
PSYCH 249 Large-Scale Neural Network Modeling for Neuroscience 1-3
PSYCH 253 Advanced Statistical Modeling 3

Concentration Areas
Please note: the concentrations areas are being revised, and new ones being added.

Applied Logic
See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/applied-logic-al-concentration/).

Introductory Requirements
CS 154 Introduction to the Theory of Computation 3-4
PHIL 151 Metalogic 4
PHIL 152 Computability and Logic 4

Computational
Select one of the following:
CS 151 Logic Programming
CS 157 Computational Logic

Set Theory
MATH 161 Set Theory 3

Formal Semantics
Select one of the following:
LINGUIST 130A Introduction to Semantics and Pragmatics 3-4
LINGUIST 230B Advanced Semantics

LINGUIST 230C Advanced Topics in Semantics & Pragmatics
PHIL 154 Modal Logic 6-8

Advanced
Select two of the following:
PHIL 156A Modal Logics - A Modern Perspective
PHIL 159 Non-Classical Logic
PHIL 188W Paradoxes
PHIL 351 Representation Theorems
PHIL 351B Proof Mining
PHIL 351C Formal Methods in Ethics
PHIL 351D Measurement Theory
PHIL 353 Seminar on Philosophy of Logic and Mathematics
PHIL 356 Applications of Modal Logic
PHIL 356C Logic and Artificial Intelligence
PHIL 357 Research Seminar on Logic and Cognition
PHIL 359 Topics in Logic, Information and Agency
PHIL 391 Seminar on Logic & Formal Philosophy

Note: PHIL 359 counts only if taken for 3 or more units, in accordance with the policy for all core courses.

Total Units 15-18

Artificial Intelligence
See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/artificial-intelligence-ai-concentration/).

Select five courses from the following six areas: 1

Knowledge Representation and Reasoning
CS 151 Logic Programming
CS 157 Computational Logic
CS 228 Probabilistic Graphical Models: Principles and Techniques
CS 238 Decision Making under Uncertainty
PHIL 154 Modal Logic

Natural Language Processing
CS 124 From Languages to Information
CS 224N Natural Language Processing with Deep Learning
CS 224S Spoken Language Processing
CS 224U Natural Language Understanding
CS 276 Information Retrieval and Web Search
SYMSYS 112 Challenges for Language Systems

Learning
CS 217 Hardware Accelerators for Machine Learning
CS 224W Machine Learning with Graphs
CS 229 Machine Learning
CS 230 Deep Learning
CS 234 Reinforcement Learning
CS 236 Deep Generative Models
CS 246 Mining Massive Data Sets
CS 325B Data for Sustainable Development
EE 104 Introduction to Machine Learning
MS&E 234 Data Privacy and Ethics
PSYCH 204 Computation and Cognition: The Probabilistic Approach
Robotics and Vision

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
</tr>
<tr>
<td>CS 148</td>
<td>Introduction to Computer Graphics and Imaging</td>
</tr>
<tr>
<td>CS 223A</td>
<td>Introduction to Robotics</td>
</tr>
<tr>
<td>CS 225A</td>
<td>Experimental Robotics</td>
</tr>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
</tr>
<tr>
<td>CS 231N</td>
<td>Convolutional Neural Networks for Visual Recognition</td>
</tr>
<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
</tr>
<tr>
<td>CS 331B</td>
<td>Representation Learning in Computer Vision</td>
</tr>
<tr>
<td>CS 333</td>
<td>Algorithms for Interactive Robotics</td>
</tr>
<tr>
<td>CS 348K</td>
<td>Visual Computing Systems</td>
</tr>
<tr>
<td>PSYCH 250</td>
<td>High-level Vision: From Neurons to Deep Neural Networks</td>
</tr>
</tbody>
</table>

Additional Topics

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
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<tbody>
<tr>
<td>BIOMEDIN 210</td>
<td>Modeling Biomedical Systems</td>
</tr>
<tr>
<td>BIOMEDIN 214</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
</tr>
<tr>
<td>CS 227B</td>
<td>General Game Playing</td>
</tr>
<tr>
<td>LAW 4039</td>
<td>Regulating Artificial Intelligence</td>
</tr>
<tr>
<td>MS&amp;E 135</td>
<td>Networks</td>
</tr>
<tr>
<td>MUSIC 220B</td>
<td>Compositional Algorithms, Psychoacoustics, and Computational Music</td>
</tr>
<tr>
<td>MUSIC 220C</td>
<td>Research Seminar in Computer-Generated Music</td>
</tr>
<tr>
<td>PHIL 20N</td>
<td>Philosophy of Artificial Intelligence</td>
</tr>
<tr>
<td>PHIL 153L</td>
<td>Computing Machines and Intelligence</td>
</tr>
<tr>
<td>PHIL 356C</td>
<td>Logic and Artificial Intelligence</td>
</tr>
<tr>
<td>PHIL 357</td>
<td>Research Seminar on Logic and Cognition</td>
</tr>
<tr>
<td>PSYCH 247</td>
<td>Topics in Natural and Artificial Intelligence</td>
</tr>
<tr>
<td>SYMSYS 207</td>
<td>Conceptual Issues in Cognitive Science</td>
</tr>
<tr>
<td>SYMSYS 208</td>
<td>Computer Machines and Intelligence</td>
</tr>
<tr>
<td>SYMSYS 275</td>
<td>Collective Behavior and Distributed Intelligence</td>
</tr>
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</table>

Mathematical Foundations

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>CME 263</td>
<td>Introduction to Linear Dynamical Systems</td>
</tr>
<tr>
<td>CS 154</td>
<td>Introduction to the Theory of Computation</td>
</tr>
<tr>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td>CS 168</td>
<td>The Modern Algorithmic Toolbox</td>
</tr>
<tr>
<td>CS 205L</td>
<td>Continuous Mathematical Methods with an Emphasis on Machine Learning</td>
</tr>
<tr>
<td>ECON 160</td>
<td>Game Theory and Economic Applications</td>
</tr>
<tr>
<td>EE 263</td>
<td>Introduction to Linear Dynamical Systems</td>
</tr>
<tr>
<td>EE 276</td>
<td>Information Theory</td>
</tr>
<tr>
<td>EE 364A</td>
<td>Convex Optimization I</td>
</tr>
<tr>
<td>EE 364B</td>
<td>Convex Optimization II</td>
</tr>
<tr>
<td>ENGR 205</td>
<td>Introduction to Control Design Techniques</td>
</tr>
<tr>
<td>ENGR 209A</td>
<td>Analysis and Control of Nonlinear Systems</td>
</tr>
<tr>
<td>MATH 104</td>
<td>Applied Matrix Theory</td>
</tr>
<tr>
<td>MATH 113</td>
<td>Linear Algebra and Matrix Theory</td>
</tr>
<tr>
<td>MS&amp;E 251</td>
<td>Introduction to Stochastic Control with Applications</td>
</tr>
</tbody>
</table>

Cognitive Science

See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/cognitive-science-cogsci-concentration/).

<table>
<thead>
<tr>
<th>Units</th>
<th>Cognitive Neuroscience</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following:

- PSYCH 30 Introduction to Perception
- PSYCH 45 Introduction to Learning and Memory
- PSYCH 50 Introduction to Cognitive Neuroscience
- PSYCH 162 Brain Networks
- PSYCH 164 Brain decoding
- PSYCH 202 Cognitive Neuroscience

Empirical Methods

<table>
<thead>
<tr>
<th>Units</th>
<th>Empirical Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td></td>
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</tbody>
</table>

Select one of the following:

- COMM 106 Communication Research Methods
- EE 104 Introduction to Machine Learning
- MS&E 231 Introduction to Computational Social Science
- PSYCH 204A Human Neuroimaging Methods
- PSYCH 251 Experimental Methods
- PSYCH 252 Statistical Methods for Behavioral and Social Sciences
- PSYCH 253 Advanced Statistical Modeling
- STATS 101 Data Science 101
- STATS 191 Introduction to Applied Statistics
- STATS 200 Introduction to Statistical Inference
- STATS 263 Design of Experiments

Three additional courses chosen across and/or within the following five areas:

<table>
<thead>
<tr>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-16</td>
</tr>
</tbody>
</table>

Select one of the following:

- CS 224N Natural Language Processing with Deep Learning
- LINGUIST 110 Introduction to Phonology
- LINGUIST 140 Learning to Speak: An Introduction to Child Language Acquisition
LINGUIST 180 From Languages to Information
LINGUIST 236 Seminar in Semantics: Conditionals
LINGUIST 248 Seminar in Developmental Psycholinguistics
PHIL 181 Philosophy of Language
PHIL 194D Capstone Seminar: Artificial Intelligence
PHIL 194K Slurs and Derogation: Semantic, Pragmatic and Ethical Perspectives
PHIL 348 Evolution of Signalling
PHIL 385D Advanced Topics in Philosophy of Language
PSYCH 132 Language and Thought
PSYCH 140 Introduction to Psycholinguistics
SYMSYS 112 Challenges for Language Systems

Perception
CS 131 Computer Vision: Foundations and Applications
CS 231A Computer Vision: From 3D Reconstruction to Recognition
LINGUIST 105 Phonetics
MUSIC 251 Psychophysics and Music Cognition
PSYCH 30 Introduction to Perception
PSYCH 221 Image Systems Engineering
PSYCH 250 High-level Vision: From Neurons to Deep Neural Networks

Higher Cognition
COMM 108 Media Processes and Effects
COMM 322 Advanced Studies in Behavior and Social Media
CS 229 Machine Learning
EDUC 368 Cognitive Development in Childhood and Adolescence
EE 104 Introduction to Machine Learning
PHIL 182A Naturalizing Representation
PHIL 183 Self-knowledge and Metacognition
PHIL 184 Topics in Epistemology
PHIL 185 Special Topics in Epistemology: Testimony in science and everyday life
PHIL 186 Philosophy of Mind
PHIL 187 Philosophy of Action
PHIL 194A Rationality Over Time
PHIL 386 Truth as the aim of belief and inquiry
PHIL 388 Topics in Normativity
PSYCH 45 Introduction to Learning and Memory
PSYCH 70 Self and Society: Introduction to Social Psychology
PSYCH 75 Introduction to Cultural Psychology
PSYCH 141 Cognitive Development
PSYCH 154 Judgment and Decision-Making
PSYCH 160 Seminar on Emotion
PSYCH 169 Advanced Seminar on Memory
PSYCH 175 Social Cognition and Learning in Early Childhood
PSYCH 205 Foundations of Cognition
PSYCH 266 Current Debates in Learning and Memory
PSYCH 285 Graduate Seminar on Theory of Mind
SYMSYS 203 Cognitive Science Perspectives on Humanity and Well-Being

BIO 150 Human Behavioral Biology
CS 234 Reinforcement Learning
EDUC 266 Educational Neuroscience
MUSIC 257 Neuroplasticity and Musical Gaming
NBIO 101 Social and Ethical Issues in the Neurosciences
NBIO 206 The Nervous System
NBIO 258 Information and Signaling Mechanisms in Neurons and Circuits
PHIL 167D Philosophy of Neuroscience
PHIL 360 Grad Seminar: Philosophy of Neuroscience
PSYCH 162 Brain Networks
PSYCH 164 Brain decoding
PSYCH 202 Cognitive Neuroscience
PSYCH 204A Human Neuroimaging Methods
PSYCH 204B Computational Neuroimaging
PSYCH 209 Neural Network Models of Cognition
PSYCH 232 Brain and Decision
PSYCH 248A fMRI Analysis Bootcamp
PSYCH 249 Large-Scale Neural Network Modeling for Neuroscience
PSYCH 251 Experimental Methods
PSYCH 254 Affective Neuroscience
PSYCH 287 Brain Machine Interfaces: Science, Technology, and Application

Theoretical Foundations
CS 154 Introduction to the Theory of Computation
ECON 160 Game Theory and Economic Applications
EE 276 Information Theory
MATH 113 Linear Algebra and Matrix Theory
PHIL 82T Philosophy of Cognitive Science
PHIL 152 Computability and Logic
PHIL 153L Computing Machines and Intelligence
PHIL 154 Modal Logic
PHIL 351D Measurement Theory
PHIL 356C Logic and Artificial Intelligence
PHIL 357 Research Seminar on Logic and Cognition
PSYCH 204 Computation and Cognition: The Probabilistic Approach
PSYCH 247 Topics in Natural and Artificial Intelligence
SYMSYS 202 Theories of Consciousness
SYMSYS 207 Conceptual Issues in Cognitive Science
SYMSYS 208 Computer Machines and Intelligence

Computer Music
See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/computer-music-cm-concentration/).

Music Fundamentals
MUSIC 220A Fundamentals of Computer-Generated Sound
MUSIC 220B Compositional Algorithms, Psychoacoustics, and Computational Music

Music and the Mind & Brain
Select one of the following:
MUSIC 1A Music, Mind, and Human Behavior

Total Units 15-25
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td>MUSIC 251</td>
<td>Psychophysics and Music Cognition</td>
</tr>
<tr>
<td>MUSIC 351A</td>
<td>Seminar in Music Perception and Cognition I</td>
</tr>
<tr>
<td>PSYCH 30</td>
<td>Introduction to Perception</td>
</tr>
<tr>
<td>PSYCH 50</td>
<td>Introduction to Cognitive Neuroscience</td>
</tr>
</tbody>
</table>

**Music HCI/Design** 3-5

Select one of the following:

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

**Advanced Research Topics/Electives** 3-5

Select one of the following:

- CS 108  Object-Oriented Systems Design
- LINGUIST 105 Phonetics
- LINGUIST 110 Introduction to Phonology
- MUSIC 220C Research Seminar in Computer-Generated Music
- MUSIC 222 Sound in Space
- MUSIC 253 Symbolic Musical Information
- MUSIC 254 Computational Music Analysis
- MUSIC 256B Music, Computing, Design II: Virtual and Augmented Reality for Music
- MUSIC 257 Neuroplasticity and Musical Gaming

**Total Units** 15-23

**Decision Making and Rationality**

See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/decision-making-and-rationality-dmr-concentration/).

Select five courses, including at least one course from each of the first four areas:

**Philosophical Inquiry**

Select one of the following:

- MS&E 234 Data Privacy and Ethics
- MS&E 254 The Ethical Analyst
- PHIL 164 Central Topics in the Philosophy of Science: Theory and Evidence
- PHIL 166 Probability: Ten Great Ideas About Chance
- PHIL 169 Evolution of the Social Contract
- PHIL 170 Ethical Theory
- PHIL 171 Justice
- PHIL 172 History of Modern Moral Philosophy
- PHIL 184 Topics in Epistemology
- PHIL 187 Philosophy of Action
- PHIL 194M Capstone Seminar: Consequences for Ethics
- PHIL 359 Topics in Logic, Information and Agency
- PHIL 377 Social Agency
- PHIL 386 Truth as the aim of belief and inquiry
- PHIL 388 Topics in Normativity
- POLISCI 131L Modern Political Thought: Machiavelli to Marx and Mill

**Formal Decision Theories**

Select one of the following:

- ECON 51 Economic Analysis II
- ECON 136 Market Design
- ECON 160 Game Theory and Economic Applications
- ECON 180 Honors Game Theory
- ECON 289 Advanced Topics in Game Theory and Information Economics
- INTLPOP 204A Microeconomics for Policy
- MGTECON 613 Foundations of Game Theory
- MGTECON 616 Topics in Microeconomic Theory
- MS&E 232 Introduction to Game Theory
- PHIL 154 Modal Logic
- PHIL 351 Representation Theorems
- PHIL 351C Formal Methods in Ethics
- PHIL 351D Measurement Theory
- PHIL 359 Topics in Logic, Information and Agency
- POLISCI 356A Formal Theory I: Game Theory for Political Science
- PUBLPOL 51 Microeconomics for Policy

Note: PHIL 359 counts only if taken for 3 or more units, in accordance with the policy for all core courses.

**Empirical Findings and Explanations**

Select one of the following:

- BIO 150 Human Behavioral Biology
- COMM 172 Media Psychology
- ECON 178 Behavioral Economics
- ECON 179 Experimental Economics
- ECON 279 Behavioral and Experimental Economics II
- GSBGEN 646 Behavioral Economics and the Psychology of Decision Making
- MS&E 389 Seminar on Organizational Theory
- POLISCI 351B Economic Analysis of Political Institutions
- POLISCI 351C Institutions and Bridge-Building in Political Economy
- PSYCH 45 Introduction to Learning and Memory
- PSYCH 50 Introduction to Cognitive Neuroscience
- PSYCH 70 Self and Society: Introduction to Social Psychology
- PSYCH 75 Introduction to Cultural Psychology
- PSYCH 80 Introduction to Personality and Affective Science
- PSYCH 154 Judgment and Decision-Making
- PSYCH 160 Seminar on Emotion
- PSYCH 205 Foundations of Cognition
- PSYCH 212 Classic and contemporary social psychology research
- PSYCH 215 Mind, Culture, and Society
- PSYCH 223 Social Norms
- PSYCH 232 Brain and Decision
- PSYCH 251 Experimental Methods
- PSYCH 270 The Self: Representations and Interventions
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>SOC 114</td>
<td>Economic Sociology</td>
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<tr>
<td>SOC 115</td>
<td>Topics in Economic Sociology</td>
</tr>
<tr>
<td>SOC 120</td>
<td>Interpersonal Relations</td>
</tr>
<tr>
<td>SOC 126</td>
<td>Introduction to Social Networks</td>
</tr>
<tr>
<td>SYMSYS 203</td>
<td>Cognitive Science Perspectives on Humanity and Well-Being</td>
</tr>
<tr>
<td>SYMSYS 275</td>
<td>Collective Behavior and Distributed Intelligence</td>
</tr>
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</table>

### Practical Tools and Applications

Select one of the following:

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>CEE 206</td>
<td>Decision Analysis for Civil and Environmental Engineers</td>
</tr>
<tr>
<td>CS 181</td>
<td>Ethics, Public Policy, and Technological Change</td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
</tr>
<tr>
<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
</tr>
<tr>
<td>CS 239</td>
<td>Advanced Topics in Sequential Decision Making</td>
</tr>
<tr>
<td>CS 325B</td>
<td>Data for Sustainable Development</td>
</tr>
<tr>
<td>ECON 135</td>
<td>Foundations of Finance</td>
</tr>
<tr>
<td>ECON 136</td>
<td>Market Design</td>
</tr>
<tr>
<td>ECON 137</td>
<td>Decision Modeling and Information</td>
</tr>
<tr>
<td>ECON 141</td>
<td>Public Finance and Fiscal Policy</td>
</tr>
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<td>ECON 150</td>
<td>Economic Policy Analysis</td>
</tr>
<tr>
<td>ECON 155</td>
<td>Environmental Economics and Policy</td>
</tr>
<tr>
<td>ECON 162</td>
<td>Games Developing Nations Play</td>
</tr>
<tr>
<td>ECON 247</td>
<td>Labor Economics II</td>
</tr>
<tr>
<td>MS&amp;E 152</td>
<td>Introduction to Decision Analysis</td>
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<tr>
<td>MS&amp;E 180</td>
<td>Organizations: Theory and Management</td>
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<tr>
<td>MS&amp;E 250A</td>
<td>Engineering Risk Analysis</td>
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<tr>
<td>MS&amp;E 250B</td>
<td>Project Course in Engineering Risk Analysis</td>
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<tr>
<td>MS&amp;E 251</td>
<td>Introduction to Stochastic Control with Applications</td>
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<td>MS&amp;E 252</td>
<td>Decision Analysis I: Foundations of Decision Analysis</td>
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<tr>
<td>MS&amp;E 352</td>
<td>Decision Analysis II: Professional Decision Analysis</td>
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<tr>
<td>MS&amp;E 353</td>
<td>Decision Analysis III: Frontiers of Decision Analysis</td>
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<tr>
<td>MS&amp;E 355</td>
<td>Influence Diagrams and Probabilistic Networks</td>
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<tr>
<td>POLISCI 152</td>
<td>Introduction to Game Theoretic Methods in Political Science</td>
</tr>
<tr>
<td>POLISCI 153</td>
<td>Thinking Strategically</td>
</tr>
<tr>
<td>SYMSYS 201</td>
<td>Digital Technology, Society, and Democracy</td>
</tr>
<tr>
<td>SYMSYS 271</td>
<td>Group Democracy</td>
</tr>
<tr>
<td>SYMSYS 275</td>
<td>Collective Behavior and Distributed Intelligence</td>
</tr>
<tr>
<td>URBANST 132</td>
<td>Concepts and Analytic Skills for the Social Sector</td>
</tr>
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### Methodological Foundations

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>BIOMEDIN 251</td>
<td>Outcomes Analysis</td>
</tr>
<tr>
<td>COMM 106</td>
<td>Communication Research Methods</td>
</tr>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
</tr>
<tr>
<td>CS 154</td>
<td>Introduction to the Theory of Computation</td>
</tr>
<tr>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
</tr>
<tr>
<td>CS 261</td>
<td>Optimization and Algorithmic Paradigms</td>
</tr>
<tr>
<td>ECON 50</td>
<td>Economic Analysis I</td>
</tr>
<tr>
<td>ECON 102B</td>
<td>Applied Econometrics</td>
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<tr>
<td>ECON 102C</td>
<td>Advanced Topics in Econometrics</td>
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<tr>
<td>ENGR 62</td>
<td>Introduction to Optimization</td>
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<tr>
<td>MS&amp;E 120</td>
<td>Introduction to Probability</td>
</tr>
<tr>
<td>MS&amp;E 121</td>
<td>Introduction to Stochastic Modeling</td>
</tr>
<tr>
<td>MS&amp;E 231</td>
<td>Introduction to Computational Social Science</td>
</tr>
<tr>
<td>PHIL 49</td>
<td>Survey of Formal Methods</td>
</tr>
<tr>
<td>PSYCH 251</td>
<td>Experimental Methods</td>
</tr>
<tr>
<td>PSYCH 252</td>
<td>Statistical Methods for Behavioral and Social Sciences</td>
</tr>
<tr>
<td>PSYCH 253</td>
<td>Advanced Statistical Modeling</td>
</tr>
<tr>
<td>STATS 200</td>
<td>Introduction to Statistical Inference</td>
</tr>
<tr>
<td>STATS 211</td>
<td>Meta-research: Appraising Research Findings, Bias, and Meta-analysis</td>
</tr>
<tr>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
<tr>
<td>STATS 218</td>
<td>Introduction to Stochastic Processes II</td>
</tr>
<tr>
<td>STATS 263</td>
<td>Design of Experiments</td>
</tr>
<tr>
<td>STATS 310A</td>
<td>Theory of Probability I</td>
</tr>
<tr>
<td>STATS 310B</td>
<td>Theory of Probability II</td>
</tr>
<tr>
<td>STATS 310C</td>
<td>Theory of Probability III</td>
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### Total Units

15-25

### Human-Computer Interaction

See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduateconcentrations/human-computer-interaction-hci-concentration/).

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
</tr>
</tbody>
</table>

### HCI-Project-Based Courses

3-4

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 194H</td>
<td>User Interface Design Project</td>
</tr>
<tr>
<td>CS 247A</td>
<td>Design for Artificial Intelligence</td>
</tr>
<tr>
<td>CS 247B</td>
<td>Design for Behavior Change</td>
</tr>
<tr>
<td>CS 247G</td>
<td>Introduction to Game Design</td>
</tr>
<tr>
<td>CS 247I</td>
<td>Design for Understanding</td>
</tr>
<tr>
<td>CS 247S</td>
<td>Service Design</td>
</tr>
<tr>
<td>CS 278</td>
<td>Social Computing</td>
</tr>
<tr>
<td>CS 347</td>
<td>Human-Computer Interaction: Foundations and Frontiers</td>
</tr>
<tr>
<td>CS 377E</td>
<td>Designing Solutions to Global Grand Challenges</td>
</tr>
<tr>
<td>CS 377G</td>
<td>Designing Serious Games</td>
</tr>
<tr>
<td>CS 377Q</td>
<td>Designing for Accessibility</td>
</tr>
<tr>
<td>CS 377U</td>
<td>Understanding Users</td>
</tr>
<tr>
<td>CS 448B</td>
<td>Data Visualization</td>
</tr>
<tr>
<td>EDUC 230</td>
<td>Learning Experience Design</td>
</tr>
<tr>
<td>EDUC 302</td>
<td>Behavior Design</td>
</tr>
<tr>
<td>EDUC 303</td>
<td>Designing Learning Spaces</td>
</tr>
<tr>
<td>EDUC 391</td>
<td>Engineering Education and Online Learning</td>
</tr>
<tr>
<td>ENGR 110</td>
<td>Perspectives in Assistive Technology (ENGR 110)</td>
</tr>
<tr>
<td>MED 275B</td>
<td>Biodesign Fundamentals</td>
</tr>
</tbody>
</table>
Symbolic Systems

SOC 167VP Justice + Poverty Innovation: Create new solutions for people to navigate housing, medical, & debt

HCI Social and Psychological Aspects 3-5
Select one of the following:
- COMM 1 Introduction to Communication
- COMM 1B Media, Culture, and Society
- COMM 120W The Rise of Digital Culture
- COMM 145 Personality and Digital Media
- COMM 166 Virtual People
- COMM 172 Media Psychology
- COMM 322 Advanced Studies in Behavior and Social Media
- COMM 326 Advanced Topics in Human Virtual Representation
- CS 80Q Race and Gender in Silicon Valley
- CS 181W Computers, Ethics, and Public Policy
- EDUC 281 Technology for Learners
- EDUC 328 Topics in Learning and Technology: Core Mechanics for Learning
- EDUC 342 Child Development and New Technologies
- ME 115A Introduction to Human Values in Design
- MS&E 135 Networks
- MS&E 234 Data Privacy and Ethics
- PSYCH 70 Self and Society: Introduction to Social Psychology
- STS 1 The Public Life of Science and Technology
- SYMSYS 201 Digital Technology, Society, and Democracy
- SYMSYS 245 Cognition in Interaction Design
- SYMSYS 255 Building Digital History: Informatics of Social Movements and Protest
- SYMSYS 275 Collective Behavior and Distributed Intelligence

HCI Programming 3-4
Select one of the following:
- CS 108 Object-Oriented Systems Design
- CS 142 Web Applications
- CS 148 Introduction to Computer Graphics and Imaging
- LINGUIST 180 From Languages to Information

HCI Empirical Methods 3-5
Select one of the following:
- COMM 106 Communication Research Methods
- CS 347 Human-Computer Interaction: Foundations and Frontiers
- CS 377U Understanding Users
- EDUC 407 Lytics Seminar
- EDUC 423 Introduction to Data Science
- ENGR 150 Data Challenge Lab
- HUMBIO 82A Qualitative Research Methodology
- ME 341 Design Experiments
- MED 147 Methods in Community Assessment, Evaluation, and Research
- MS&E 125 Introduction to Applied Statistics
- PSYCH 251 Experimental Methods
- PSYCH 252 Statistical Methods for Behavioral and Social Sciences
- STATS 101 Data Science 101
- STATS 191 Introduction to Applied Statistics

STATS 200 Introduction to Statistical Inference
STATS 202 Data Mining and Analysis
STATS 263 Design of Experiments

Total Units 15-23

Learning
See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduates/concentrations/learning-concentration/).

Select five courses from at least two of the following three areas: 15-25

Computational Learning
- CS 205L Continuous Mathematical Methods with an Emphasis on Machine Learning
- CS 224N Natural Language Processing with Deep Learning
- CS 228 Probabilistic Graphical Models: Principles and Techniques
- CS 229 Machine Learning
- CS 234 Reinforcement Learning
- CS 236 Deep Generative Models
- CS 325B Data for Sustainable Development
- EE 104 Introduction to Machine Learning
- EE 276 Information Theory
- MS&E 234 Data Privacy and Ethics
- PSYCH 204 Computation and Cognition: The Probabilistic Approach
- STATS 101 Data Science 101
- STATS 315A Modern Applied Statistics: Learning
- STATS 315B Modern Applied Statistics: Data Mining

Human Learning
- EDUC 101 Introduction to Teaching and Learning
- EDUC 115N How to Learn Mathematics
- EDUC 218 Topics in Cognition and Learning: Technology and Multitasking
- EDUC 266 Educational Neuroscience
- EDUC 368 Cognitive Development in Childhood and Adolescence
- LINGUIST 140 Learning to Speak: An Introduction to Child Language Acquisition
- LINGUIST 248 Seminar in Developmental Psycholinguistics
- PSYCH 45 Introduction to Learning and Memory
- PSYCH 50 Introduction to Cognitive Neuroscience
- PSYCH 60 Introduction to Developmental Psychology
- PSYCH 141 Cognitive Development
- PSYCH 145 Seminar on Infant Development
- PSYCH 169 Advanced Development
- PSYCH 202 Cognitive Neuroscience
- PSYCH 204 Computation and Cognition: The Probabilistic Approach
- PSYCH 251 Experimental Methods
- PSYCH 265 Social Psychology and Social Change
- PSYCH 266 Current Debates in Learning and Memory

Learning Environment Design
- COMM 322 Advanced Studies in Behavior and Social Media
- CS 147 Introduction to Human-Computer Interaction Design
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 194H</td>
<td>User Interface Design Project</td>
</tr>
<tr>
<td>EDUC 211</td>
<td>Beyond Bits and Atoms - Lab</td>
</tr>
<tr>
<td>EDUC 230</td>
<td>Learning Experience Design</td>
</tr>
<tr>
<td>EDUC 236</td>
<td>Beyond Bits and Atoms: Designing Technological Tools</td>
</tr>
<tr>
<td>EDUC 281</td>
<td>Technology for Learners</td>
</tr>
<tr>
<td>EDUC 298</td>
<td>Seminar on Teaching Introductory Computer Science</td>
</tr>
<tr>
<td>EDUC 303</td>
<td>Designing Learning Spaces</td>
</tr>
<tr>
<td>EDUC 328</td>
<td>Topics in Learning and Technology: Core Mechanics for Learning</td>
</tr>
<tr>
<td>EDUC 333A</td>
<td>Understanding Learning Environments</td>
</tr>
<tr>
<td>EDUC 342</td>
<td>Child Development and New Technologies</td>
</tr>
<tr>
<td>EDUC 391</td>
<td>Engineering Education and Online Learning</td>
</tr>
<tr>
<td>EDUC 426</td>
<td>Unleashing Personal Potential: Behavioral Science and Design Thinking Applied to Self</td>
</tr>
<tr>
<td>MUSIC 257</td>
<td>Neuroplasticity and Musical Gaming</td>
</tr>
<tr>
<td>SYMSYS 245</td>
<td>Cognition in Interaction Design</td>
</tr>
<tr>
<td>SYMSYS 255</td>
<td>Building Digital History: Informatics of Social Movements and Protest</td>
</tr>
</tbody>
</table>

**Total Units:** 15-25

### Natural Language

See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/natural-language-nl-concentration/).

#### Units

Select five courses from three or four of the following seven areas:

**Mathematical/Computational Foundations**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 154</td>
<td>Introduction to the Theory of Computation</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: The Probabilistic Approach</td>
</tr>
<tr>
<td>PSYCH 209</td>
<td>Neural Network Models of Cognition</td>
</tr>
<tr>
<td>PSYCH 251</td>
<td>Experimental Methods</td>
</tr>
<tr>
<td>PSYCH 254</td>
<td>Affective Neuroscience</td>
</tr>
</tbody>
</table>

**Computational Linguistics**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 124</td>
<td>From Languages to Information</td>
</tr>
<tr>
<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
</tr>
<tr>
<td>CS 224S</td>
<td>Spoken Language Processing</td>
</tr>
<tr>
<td>CS 224U</td>
<td>Natural Language Understanding</td>
</tr>
<tr>
<td>CS 276</td>
<td>Information Retrieval and Web Search</td>
</tr>
<tr>
<td>PSYCH 290</td>
<td>Natural Language Processing &amp; Text-Based Machine Learning in the Social Sciences</td>
</tr>
<tr>
<td>SYMSYS 112</td>
<td>Challenges for Language Systems</td>
</tr>
</tbody>
</table>

**Phonetics/Phonology/Speech**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINGUIST 105</td>
<td>Phonetics</td>
</tr>
<tr>
<td>LINGUIST 110</td>
<td>Introduction to Phonology</td>
</tr>
<tr>
<td>LINGUIST 112</td>
<td>Seminar in Phonology: Stress, Tone, and Accent</td>
</tr>
<tr>
<td>LINGUIST 157</td>
<td>Sociophonetics</td>
</tr>
<tr>
<td>LINGUIST 205B</td>
<td>Advanced Phonetics</td>
</tr>
<tr>
<td>LINGUIST 207A</td>
<td>Advanced Phonetics</td>
</tr>
<tr>
<td>LINGUIST 210A</td>
<td>Phonology</td>
</tr>
<tr>
<td>LINGUIST 213</td>
<td>Corpus Phonology</td>
</tr>
<tr>
<td>LINGUIST 260A</td>
<td>Historical Morphology and Phonology</td>
</tr>
</tbody>
</table>

**Morphosyntax**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINGUIST 121A</td>
<td>The Syntax of English</td>
</tr>
<tr>
<td>LINGUIST 121B</td>
<td>Crosslinguistic Syntax</td>
</tr>
<tr>
<td>LINGUIST 217</td>
<td>Morphosyntax</td>
</tr>
<tr>
<td>LINGUIST 222A</td>
<td>Foundations of Syntactic Theory I</td>
</tr>
<tr>
<td>LINGUIST 225D</td>
<td>Seminar in Syntax: Advanced Topics</td>
</tr>
<tr>
<td>LINGUIST 260B</td>
<td>Historical Morphosyntax</td>
</tr>
</tbody>
</table>

**Semantics/Pragmatics/Philosophy of Language**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINGUIST 130A</td>
<td>Introduction to Semantics and Pragmatics</td>
</tr>
<tr>
<td>LINGUIST 130B</td>
<td>Introduction to Lexical Semantics</td>
</tr>
<tr>
<td>LINGUIST 132</td>
<td>Lexical Semantic Typology</td>
</tr>
<tr>
<td>LINGUIST 230B</td>
<td>Advanced Semantics</td>
</tr>
<tr>
<td>LINGUIST 230C</td>
<td>Advanced Topics in Semantics &amp; Pragmatics</td>
</tr>
<tr>
<td>LINGUIST 232A</td>
<td>Lexical Semantics</td>
</tr>
<tr>
<td>LINGUIST 236</td>
<td>Seminar in Semantics: Conditionals</td>
</tr>
<tr>
<td>PHIL 137</td>
<td>Wittgenstein</td>
</tr>
<tr>
<td>PHIL 181</td>
<td>Philosophy of Language</td>
</tr>
<tr>
<td>PHIL 182</td>
<td>Advanced Philosophy of Language</td>
</tr>
<tr>
<td>PHIL 182A</td>
<td>Naturalizing Representation</td>
</tr>
<tr>
<td>PHIL 194D</td>
<td>Capstone Seminar: Artificial Intelligence</td>
</tr>
<tr>
<td>PHIL 194K</td>
<td>Slurs and Derogation: Semantic, Pragmatic and Ethical Perspectives</td>
</tr>
<tr>
<td>PHIL 348</td>
<td>Evolution of Signalling</td>
</tr>
<tr>
<td>PHIL 385D</td>
<td>Advanced Evolution of Signalling</td>
</tr>
</tbody>
</table>

**Neurosciences**

See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduatesconcentrations/neurosciences-neuro-concentration/).
Select five courses, from at least three of the following six areas, and at least two of the five courses must be from the first two areas:

### Basic Neuroscience
Select at least one course from the following:

- BIO 84: Physiology
- BIO 86: Cell Biology
- BIO 150: Human Behavioral Biology
- BIO 151: Mechanisms of Neuron Death
- BIO 153: Cellular Neuroscience: Cell Signaling and Behavior
- BIO 154: Molecular and Cellular Neurobiology
- HUMBIO 4A: The Human Organism
- NBIO 206: The Nervous System
- NBIO 258: Information and Signaling Mechanisms in Neurons and Circuits
- PSYCH 121: Ion Transport and Intracellular Messengers
- PSYCH 141: Cognitive Development
- PSYCH 205: Foundations of Cognition

Note: NBIO 206 is a 6-unit course, which counts as two concentration courses, from areas 1 and 2.

### Systems Neuroscience
Select at least one course from the following:

- BIO 158: Developmental Neurobiology
- BIO 222: Exploring Neural Circuits
- EDUC 266: Educational Neuroscience
- PSYC 124: Brain Plasticity
- PSYCH 30: Introduction to Perception
- PSYCH 45: Introduction to Learning and Memory
- PSYCH 50: Introduction to Cognitive Neuroscience
- PSYCH 162: Brain Networks
- PSYCH 169: Advanced Seminar on Memory
- PSYCH 232: Brain and Decision
- PSYCH 254: Affective Neuroscience
- PSYCH 266: Current Debates in Learning and Memory

### Computational Approaches

- BIOE 101: Systems Biology
- CS 223A: Introduction to Robotics
- CS 229: Machine Learning
- CS 379C: Computational Models of the Neocortex
- EE 124: Introduction to Neuroelectrical Engineering
- MUSIC 257: Neuroplasticity and Musical Gaming
- PSYCH 164: Brain decoding
- PSYCH 204A: Human Neuroimaging Methods
- PSYCH 204B: Computational Neuroimaging
- PSYCH 209: Neural Network Models of Cognition
- PSYCH 249: Large-Scale Neural Network Modeling for Neuroscience
- PSYCH 287: Brain Machine Interfaces: Science, Technology, and Application

### Biological and Computational Approaches to Vision

- CS 131: Computer Vision: Foundations and Applications
- CS 231A: Computer Vision: From 3D Reconstruction to Recognition
- CS 231N: Convolutional Neural Networks for Visual Recognition

### Philosophical and Theoretical Approaches

#### Area 1
Select two of the following:

- PHIL 180: Metaphysics
- PHIL 181: Philosophy of Language
- PHIL 182: Advanced Philosophy of Language
- PHIL 182A: Naturalizing Representation
- PHIL 183: Self-knowledge and Metacognition
- PHIL 184: Topics in Epistemology
- PHIL 185: Special Topics in Epistemology: Testimony in science and everyday life
- PHIL 185W: Metaontology
- PHIL 186: Philosophy of Mind

**Total Units: 15-25**
PHIL 186A  Self-fashioning
PHIL 187  Philosophy of Action
PHIL 188W  Paradoxes
PHIL 189G  Fine-Tuning Arguments for God’s Existence

**Area 2**  3-5

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 102</td>
<td>Modern Philosophy, Descartes to Kant</td>
</tr>
<tr>
<td>PHIL 170</td>
<td>Ethical Theory</td>
</tr>
<tr>
<td>PHIL 170B</td>
<td>Metaphor</td>
</tr>
<tr>
<td>PHIL 171</td>
<td>Justice</td>
</tr>
<tr>
<td>PHIL 171P</td>
<td>20th Century Political Theory: Liberalism and its Critics</td>
</tr>
<tr>
<td>PHIL 172</td>
<td>History of Modern Moral Philosophy</td>
</tr>
<tr>
<td>PHIL 172B</td>
<td>Recent Ethical Theory: Moral Obligation</td>
</tr>
<tr>
<td>PHIL 172C</td>
<td>The Ethics of Care</td>
</tr>
<tr>
<td>PHIL 173B</td>
<td>Metaethics</td>
</tr>
<tr>
<td>PHIL 173W</td>
<td>Aesthetics</td>
</tr>
<tr>
<td>PHIL 175</td>
<td>Philosophy of Law</td>
</tr>
<tr>
<td>PHIL 176</td>
<td>Political Philosophy: The Social Contract Tradition</td>
</tr>
<tr>
<td>PHIL 176A</td>
<td>Classical Seminar: Origins of Political Thought</td>
</tr>
<tr>
<td>PHIL 177C</td>
<td>Ethics of Climate Change</td>
</tr>
<tr>
<td>PHIL 178</td>
<td>Ethics in Society Honors Seminar</td>
</tr>
</tbody>
</table>

**Area 3**  3-4

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
</tr>
<tr>
<td>PHIL 351C</td>
<td>Formal Methods in Ethics</td>
</tr>
<tr>
<td>PHIL 356C</td>
<td>Logic and Artificial Intelligence</td>
</tr>
<tr>
<td>PHIL 357</td>
<td>Research Seminar on Logic and Cognition</td>
</tr>
<tr>
<td>PHIL 359</td>
<td>Topics in Logic, Information and Agency</td>
</tr>
</tbody>
</table>

**Area 4**  3-4

Select one of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 20N</td>
<td>Philosophy of Artificial Intelligence</td>
</tr>
<tr>
<td>PHIL 153L</td>
<td>Computing Machines and Intelligence</td>
</tr>
<tr>
<td>PHIL 162</td>
<td>Philosophy of Mathematics</td>
</tr>
<tr>
<td>PHIL 164</td>
<td>Central Topics in the Philosophy of Science: Theory and Evidence</td>
</tr>
<tr>
<td>PHIL 165</td>
<td>Philosophy of Physics: Space and Time</td>
</tr>
<tr>
<td>PHIL 166</td>
<td>Probability: Ten Great Ideas About Chance</td>
</tr>
<tr>
<td>PHIL 167D</td>
<td>Philosophy of Neuroscience</td>
</tr>
<tr>
<td>PHIL 169</td>
<td>Evolution of the Social Contract</td>
</tr>
<tr>
<td>PHIL 194Y</td>
<td>Capstone seminar: Common Sense Philosophy</td>
</tr>
<tr>
<td>PHIL 360</td>
<td>Grad Seminar: Philosophy of Neuroscience</td>
</tr>
<tr>
<td>PHIL 385B</td>
<td>Topics in Metaphysics and Epistemology: Situations and Attitudes</td>
</tr>
<tr>
<td>PSYCH 160</td>
<td>Seminar on Emotion</td>
</tr>
<tr>
<td>SYMSYS 112</td>
<td>Challenges for Language Systems</td>
</tr>
<tr>
<td>SYMSYS 202</td>
<td>Theories of Consciousness</td>
</tr>
<tr>
<td>SYMSYS 207</td>
<td>Conceptual Issues in Cognitive Science</td>
</tr>
<tr>
<td>SYMSYS 208</td>
<td>Computer Machines and Intelligence</td>
</tr>
</tbody>
</table>

**Total Units**  16-21

**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.

**Additional Information**

**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.

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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/).

Degree Requirements

Option 1

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

a. Cognition
Select one of the following:
- SYMSYS 1 Minds and Machines (formerly SYMSYS 100)
- PSYCH 45 Introduction to Learning and Memory
- PSYCH 50 Introduction to Cognitive Neuroscience

b. Logic and Computation
Select one of the following:
- PHIL 150 Mathematical Logic
- PHIL 151 Metalogic
- CS 103 Mathematical Foundations of Computing

c. Computer Programming
Select one of the following:
- CS 106B Programming Abstractions
- CS 106X Programming Abstractions
- CS 107 Computer Organization and Systems

d. Philosophical Foundations
Select one of the following:
- SYMSYS 1 Minds and Machines (formerly SYMSYS 100)
- PHIL 80 Mind, Matter, and Meaning

e. Linguistic Theory
Select one of the following:
- LINGUIST 105 Phonetics
- LINGUIST 110 Introduction to Phonology
- LINGUIST 120 Introduction to Syntax
- LINGUIST 121A The Syntax of English
- LINGUIST 121B Crosslinguistic Syntax
- LINGUIST 130A Introduction to Semantics and Pragmatics
- LINGUIST 130B Introduction to Lexical Semantics

f. Computation and Cognition
Select one of the following:
- APPPHYS 293 Theoretical Neuroscience
- CS 221 Artificial Intelligence: Principles and Techniques
- CS 228 Probabilistic Graphical Models: Principles and Techniques
- CS 229 Machine Learning
- CS 131 Computer Vision: Foundations and Applications
- LINGUIST 180 From Languages to Information
- LINGUIST 182 (no longer offered)
- NENS 220 Computational Neuroscience
- PSYCH 109 An introduction to computation and cognition
- PSYCH 204 Computation and Cognition: The Probabilistic Approach

Total Units: 15

Option 2

Introduction
SYMSYS 1 Minds and Machines (formerly SYMSYS 100)

Interdisciplinary Concentration
An interdisciplinary SSP concentration listed on the SSP 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.

Total Units: 19

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.

Applications for Coterminal admission of active Stanford undergraduates are reviewed in the Winter and Spring Quarters. For more details, see the Coterm admissions information (https://symsys.stanford.edu/graduatemastersadmissions/cotermadmissions/) on the Symbolic Systems Program website. Admission to the program as a coterminal student is subject to the policies and deadlines described in the 'Coterminal Bachelor's and Master's Degrees (https://explordegrees.stanford.edu/cotermdegrees/)' section of this bulletin. The GRE is not required for coterminal applicants to the Symbolic Systems M.S. program.

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://explordegrees.stanford.edu/cotermdegrees/)’ section. University requirements for the master’s degree are described in the 'Graduate Degrees (http://explordegrees.stanford.edu/graduatemasters/#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 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.

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 advisor 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' section of this bulletin.

The M.S. degree in Symbolic Systems is designed to be completed in the equivalent of one academic year by coterminus 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.

Admission to the program as a coterminus student is subject to the policies and deadlines described in the 'Coterminal Bachelor's and Master's Degrees' section of this bulletin. Applicants to the M.S. program are reviewed each Winter Quarter. Information on deadlines, procedures for applying, and degree requirements are available from the program's student services coordinator in the Linguistics Department office (460-127E) and at the Symbolic Systems web site (http://symsys.stanford.edu/viewing/html/document/13623/) web site.

Note, the GRE is required for external applicants.

Symbolic Systems also offers a Joint Degree with Law School (M.S./J.D.).

Director of Graduate Studies: Hyowon Gweon

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 for the M.S. degree in Symbolic Systems may be waived after a review by the program office. Waivers are granted at the discretion of the program, and only if evidence is provided that similar or more advanced courses have been taken and passed with a letter grade of B or its equivalent, either at Stanford or another institution, and as part of another degree program which the student has either completed or is pursuing in parallel with the Symbolic Systems M.S. degree.

Course requirements that are waived rather than fulfilled by courses taken at Stanford may not be counted toward the 45 units required for the Symbolic Systems 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 Program Director, Director of Graduate Studies, or Associate Director, in consultation with the student’s primary adviser (for students with an approved Project Area Statement), and designed to support a student’s project as well as the core course requirements for the M.S. degree (requirements 3 and 4 below). 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 which the student has taken and proposes in fulfillment of both the Program’s and the University’s course and 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).

3. Completion of the Master's Breadth Requirements. The Program Proposal 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 (based on the listing as any cross-listing departments): Computer Science, Linguistics, Philosophy, and Psychology. Courses to fulfill the Breadth Requirements must be taken for a letter grade if available.

Acceptable courses in each of the four required 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 the Theory of Computation
   - CS 157 Computational Logic
   - CS 161 Design and Analysis of Algorithms
   - 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
   - CS 376 Research Topics in Human-Computer Interaction
   - LINGUIST 230A Advanced Semantics
   - NBIO 206 The Nervous System
   - NBIO 258 Information and Signal Processing 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
- PHIL 283 Self-knowledge and Metacognition
- PHIL 286 Philosophy of Mind
- PHIL 286A Self-fashioning
- PHIL 287 Philosophy of Action
- 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


5. Completion of a substantial project appropriate to the Program Proposal, represented by the M.S. Thesis. The project and thesis normally take three quarters or more to complete, and work on the project may account for up to 15 units of a student's 45-unit 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 hard copy of the thesis must be submitted to the Associate Director of Symbolic Systems, 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. A digital copy must be uploaded to the Stanford Digital Repository by the same deadline. For more details, see the Master's Thesis information (https://symsys.stanford.edu/graduatesmasters-program/masters-thesis/) on the Symbolic Systems Program website.

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext) section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a "credit" or "no credit" grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a "credit" or "satisfactory" grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Undergraduate Degree Requirements

Grading

The Symbolic Systems Program counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade. The program also continues to count courses passed with a 'C-' letter grade or above towards the satisfaction of all core requirements, and with a 'D-' or above towards the satisfaction of concentration requirements.

Other Policies

The deadline for juniors to declare a concentration advisor has been extended to Winter Quarter. A registration hold will be placed on juniors who have not declared a concentration advisor before registration opens for Spring Quarter 2020-21.

Graduate Degree Requirements

Grading

The master's program in Symbolic Systems counts all courses taken in academic year 2020-21 with a grade of 'D-', 'CR' (credit) or 'S' (satisfactory) towards satisfaction of graduate degree requirements that otherwise require a letter grade, subject to a graduate GPA requirement of 3.0 or above in the courses that constitute a master's student's 45 required units.

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: Hyowon Gweon

Associate Director: Todd Davies

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

Executive Committee: Michael Bernstein, Todd Davies, Michael C. Frank, Hyowon Gweon, 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), Emma Brunskill (Assistant Professor), David Dill (Professor, emeritus), Chelsea Finn (Assistant Professor), Michael Genesereth (Associate Professor), Oussama Khatib (Professor), Daphne Koller (Adjunct Professor), James Landay (Professor), Jean-Claude Latombe (Professor, emeritus), Marc Levoy (Professor, emeritus), Christopher Manning (Professor), Andrew Ng (Adjunct Professor), Chris Piech (Assistant 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: Nick Haber (Assistant Professor), Raymond P. McDermott (Professor, emeritus), Roy Pea (Professor), Daniel Schwartz (Professor)

Electrical Engineering: Chelsea Finn (Assistant Professor), 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)

Law: Mark Lemley (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, emeritus), 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), John Ugander (Assistant 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), Johan van Benthem (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), Janil Zaki (Assistant Professor)

Statistics: Persi Diaconis (Professor), Susan P. Holmes (Professor)

Symbolic Systems: Todd Davies (Associate Director), Jeff Shrager (Adjunct Professor), Paul Skokowski (Adjunct Professor)

Other Affiliates: David Barker-Plummer (CSLI Engineering Research Associate), Keith Devlin H-STAR Operation Senior Researcher), Daniel Flickinger (CSLI Research and Development Engineer), Cheryl Phillips (Lecturer in Communications)

Courses

SYMSYS 1. Minds and Machines. 4 Units.
(Formerly SYMSYS 100). An overview of the interdisciplinary study of cognition, information, communication, and language, with an emphasis on foundational issues: What are minds? What is computation? What are rationality and intelligence? Can we predict human behavior? Can computers be truly intelligent? How do people and technology interact, and how might they do so in the future? Lectures focus on how the methods of philosophy, mathematics, empirical research, and computational modeling are used to study minds and machines. Students must take this course before being approved to declare Symbolic Systems as a major. All students interested in studying Symbolic Systems are urged to take this course early in their student careers. The course material and presentation will be at an introductory level, without prerequisites.
Same as: CS 24, LINGUIST 35, PHIL 99, PSYCH 35, SYMSYS 200

SYMSYS 1P. A Practical Introduction to Symbolic Systems. 2 Units.
An optional supplement to 'Minds and Machines' (SYMSYS 1), aimed at prospective majors in Symbolic Systems. Students will learn from the perspectives of faculty, alums, and advanced students about how to navigate the many paths available to a student: Sym Sys versus other majors, undergraduate core options, selecting courses and a concentration, research opportunities, internships, the honors program, graduate programs, careers, and life paths.
SYMSYS 2S. Introduction to Cognitive Science. 3 Units.
Cognitive Science explores one of sciences final frontiers; the scientific
study of the human mind. It is a broad interdisciplinary field that
encompasses research from areas in neuroscience, psychology,
philosophy, linguistics, and computer science and covers topics such
as the nature of knowledge, thinking, remembering, vision, imagery,
language, and consciousness. All of which we will touch upon in this
survey course and is intended to give students a sampler of each
discipline. This introductory class will expose students to some of the
major methodologies, experimental design, neuroscientific fundamentals,
and different cognitive disorders. More importantly, it will help students
refine their interest to a specific field within cognitive science for future
studies at their respective institutions. This 6-week summer course will
require a sizable amount of required reading, not all of the readings is
covered in the lectures. To extend and complement topics in this field,
there is material presented in the lectures that is not in the readings.

SYMSYS 8. The Logic Group. 1-2 Unit.
If all dogs bark and Fido is a dog, it follows that Fido barks. If Clark Kent
owns a car, it follows that Superman owns a car, since Clark Kent is
Superman. Yet you might wonder why these statements follow from
the said assumptions. Can this perhaps be explained in terms of the
statements meanings or their grammatical form? Will the explanation
be the same in both cases, or do statements follow from assumptions
for a variety of different reasons? Are there laws or principles which
conclusively prove the statements from the assignment? Can these
laws be doubted, or are they self-evident? The Logic Group will tackle
these and similar questions. You will gain a solid understanding of
both propositional and predicate logic, including a deductive proof
system. You will familiarise yourself with the central concepts of formal
reasoning, including syntax and semantics, truth and interpretation,
validity and soundness, and the concept of logical consequence.
Although formal and technical, the course is accessible to all students,
and all may benefit. Studying logic will improve your analytic and critical
thinking skills and help you develop a more rigorous and precise writing
style. Only open to students residing at Stanford House in Oxford (UK).
Same as: Oxford

SYMSYS 20Q. The Data-Driven World. 3 Units.
Recent technological advancements have enabled us to measure, record,
analyze more data than ever before. How can we effectively use
this data to solve real-world problems and better understand the world
around us? In this course, we will learn how computers can create a
statistical model to learn from human-generated data and find patterns
or make predictions. We will explore different algorithms that create a
wide variety of models, each with their own pros and cons. Through R
programming exercises integrated across the course, we will apply these
models to many different kinds of data sourced from urban development,
education, business, etc. and analyze our findings. Based on individual
interest, students will choose to investigate a specific research question
using domain-specific data as part of a quarter-long project. Lastly, we
will discuss important ethical debates on the possible uses of data and
their implications in today’s world. By the end of the course, students will
develop a technical coding skillset to investigate hypotheses in any given
dataset, and be able to connect the insights they derive to larger issues of
society, equity, and justice.

SYMSYS 112. Challenges for Language Systems. 3-4 Units.
Parallel exploration of philosophical and computational approaches
to modeling the construction of linguistic meaning. In philosophy of
language: lexical sense extension, figurative speech, the semantics/
pragmatics interface, contextualism debates. In CS: natural language
understanding, from formal compositional models of knowledge
representation to statistical and deep learning approaches. We will
develop an appreciation of the complexities of language understanding
and communication; this will inform discussion of the broader prospects
for Artificial Intelligence. Special attention will be paid to epistemological
questions on the nature of linguistic explanation, and the relationship
between theory and practice. PREREQUISITES: PHIL80; some exposure
to philosophy of language and/or computational language processing is
recommended.
Same as: SYMSYS 212

SYMSYS 115. Critique of Technology. 3-4 Units.
What is the character of technology? How does technology reveal
aspects of human nature and social practices? How does it shape human
experience and values? We will survey the history of philosophy of
technology – from ancient and enlightenment ideas, to positivist and
phenomenological conceptions – to develop a deeper understanding of
diverse technological worldviews. This will prepare us to consider
contemporary questions about the ‘ethos’ of technology. Specific
questions will vary depending upon the interests of participants, but may
include ethical and existential challenges posed by artificial intelligence;
responsible product design in the ‘attention economy’; industry regulation
and policy issues for information privacy; and the like. PREREQUISITES:
PHIL80.

SYMSYS 122. Artificial Intelligence: Philosophy, Ethics, & Impact. 3-4
Units.
Recent advances in computing may place us at the threshold of a
unique turning point in human history. Soon we are likely to entrust
management of our environment, economy, security, infrastructure,
food production, healthcare, and to a large degree even our personal activities,
to artificially intelligent computer systems. The prospect of ‘turning over the keys’
to increasingly autonomous systems raises many complex and
troubling questions. How will society respond as versatile robots and
machine-learning systems displace an ever-expanding spectrum of blue-
and white-collar workers? Will the benefits of this technological revolution
be broadly distributed or accrue to a lucky few? How can we ensure that
these systems respect our ethical principles when they make decisions
at speeds and for rationales that exceed our ability to comprehend?
What, if any, legal rights and responsibilities should we grant them?
And should we regard them merely as sophisticated tools or as a newly
emerging form of life? The goal of this course is to equip students with
the intellectual tools, ethical foundation, and psychological framework to
successfully navigate the coming age of intelligent machines.

SYMSYS 167D. Philosophy of Neuroscience. 4 Units.
How can we explain the mind? With approaches ranging from
computational models to cellular-level characterizations of neural
responses to the characterization of behavior, neuroscience aims to
explain how we see, think, decide, and even feel. While these approaches
have been highly successful in answering some kinds of questions,
they have resulted in surprisingly little progress in others. We’ll look at
the relationships between the neuroscientific enterprise, philosophical
investigations of the nature of the mind, and our everyday experiences as
creatures with minds. Prerequisite: PHIL 80 (Not open to freshmen.).
Same as: PHIL 167D, PHIL 267D

SYMSYS 190. Senior Honors Tutorial. 1-5 Unit.
Under the supervision of their faculty honors adviser, students work on
their senior honors project. May be repeated for credit.

SYMSYS 191. Senior Honors Seminar. 1 Unit.
Recommended for seniors doing an honors project. Under the leadership of the Symbolic Systems program coordinator, students discuss, and
present their honors project.
SYMSYS 192. Symbolic Systems in Practice. 3 Units.
A professionalization course that fulfills the Practicum requirement of the Symbolic Systems undergraduate major Capstone. Online lectures, readings, assigned exercises, and live discussions relate the Sym Sys curriculum to a substantial work experience. Must be accompanied by an approved internship totaling 64 hours or more of total work time, which must be completed in the quarter prior to, during, or immediately following the course.

SYMSYS 195A. Design for Artificial Intelligence. 3-4 Units.
A project-based course that builds on the introduction to design in CS147 by focusing on advanced methods and tools for research, prototyping, and user interface design. Studio based format with intensive coaching and iteration to prepare students for tackling real world design problems. This course takes place entirely in studios; you must plan on attending every studio to take this class. The focus of CS247A is design for human-centered artificial intelligence experiences. What does it mean to design for AI? What is HAI? How do you create responsible, ethical, human centered experiences? Let us explore what AI actually is and the constraints, opportunities and specialized processes necessary to create AI systems that work effectively for the humans involved. Prerequisites: CS147 or equivalent background in design thinking.
Same as: CS 247A

SYMSYS 195B. Design for Behavior Change. 3-4 Units.
Over the last decade, tech companies have invested in shaping user behavior, sometimes for altruistic reasons like helping people change bad habits into good ones, and sometimes for financial reasons such as increasing engagement. In this project-based hands-on course, students explore the design of systems, information and interface for human use. We will model the flow of interactions, data and context, and crafting a design that is useful, appropriate and robust. Students will design and prototype utility apps or games as a response to the challenges presented. We will also examine the ethical consequences of design decisions and explore current issues arising from unintended consequences. Prerequisite: CS147 or equivalent.
Same as: CS 247B

SYMSYS 195D. Research in Digital Democracy. 3-4 Units.
Digital democracy refers to social activity that is organized democratically at a group, institutional, or societal level, and that takes place within or is augmented by digital technology. This is a project-based research seminar designed to teach students methods for studying digital democracy, as well as collaborating in a group, the organization of a research project, and academic writing. The first few weeks of the course will be an overview of digital democracy research and its methods, as well as a time for students to organize into a group research project, The remainder of the class (about 7 weeks) will be spent performing and writing up the research for a targeted publication venue. Application required for enrollment. Prerequisite: At least one course in empirical methods or statistics. Prerequisites: At least one course in empirical methods or statistics.
Same as: SYMSYS 295D

SYMSYS 195E. Experimental Methods. 3 Units.
Graduate laboratory class in experimental methods for psychology, with a focus on open science methods and best practices in behavioral research. Topics include experimental design, data collection, data management, data analysis, and the ethical conduct of research. The final project of the course is a replication experiment in which students collect new data following the procedures of a published paper. The course is designed for incoming graduate students in psychology, but is open to qualified students from other programs who have some working knowledge of the R statistical programming language. Requirement: Psych 10/Stats 60 or equivalent.

SYMSYS 195G. Introduction to Game Design. 3-4 Units.
A project-based course that builds on the introduction to design in CS147 by focusing on advanced methods and tools for research, prototyping, and user interface design. Studio based format with intensive coaching and iteration to prepare students for tackling real world design problems. This course takes place entirely in studios; please plan on attending every studio to take this class. The focus of CS247G is an introduction to theory and practice of the design of games. We will make digital and paper games, do rapid iteration and run user research studies appropriate to game design. This class has multiple short projects, allowing us to cover a variety of genres, from narrative to pure strategy. Prerequisites: 147 or equivalent background.
Same as: CS 247G

SYMSYS 195L. Image Systems Engineering. 1-3 Unit.
This course is an introduction to digital imaging technologies. We focus on the principles of key elements of digital systems components; we show how to use simulation to predict how these components will work together in a complete image system simulation. The early lectures introduce the software environment and describe options for the course project. The following topics are covered and software tools are introduced:n- Basic principles of optics (Snell's Law, diffraction, adaptive optics).n- Image sensor and pixel designsn- Color science, metrics, and calibratn- Human spatial resolutionn- Image processing principlesn- Display technologien- Special theme of this course is that it explains how imaging technologies accommodate the requirements of the human visual system. The course also explains how image systems simulations can be useful in neuroscience and industrial vision applications. The course consists of lectures, software tutorials, and a course project. Tutorials and projects include extensive software simulations of the imaging pipeline. Some background in mathematics (linear algebra) and programming (Matlab) is valuable. nPrerequisite: EE 261 or equivalent. Or permission of instructor required.
Same as: PSYCH 221

SYMSYS 195L. Methods in Psycholinguistics. 4 Units.
Over the past ten years, linguists have become increasingly interested in testing theories with a wider range of empirical data than the traditionally accepted introspective judgments of hand-selected linguistic examples. Consequently, linguistics has seen a surge of interest in psycholinguistic methods across all subfields. This course will provide an overview of various standard psycholinguistic techniques and measures, including offline judgments (e.g., binary categorization tasks like truth-value judgments, Likert scale ratings, continuous slider ratings), response times, reading times, eye-tracking, ERPs, and corpus methods. Students will present and discuss research articles. Students will also run an experiment (either a replication or an original design, if conducive to the students' research) to gain hands-on experience with experimental design and implementation in html/javascript and Mechanical Turk; data management, analysis, and visualization in R; and open science tools like git/github.
Same as: LINGUIST 245B

SYMSYS 195N. Natural Language Processing with Deep Learning. 3-4 Units.
Methods for processing human language information and the underlying computational properties of natural languages. Focus on deep learning approaches: understanding, implementing, training, debugging, visualizing, and extending neural network models for a variety of language understanding tasks. Exploration of natural language tasks ranging from simple word level and syntactic processing to coreference, question answering, and machine translation. Examination of representative papers and systems and completion of a final project applying a complex neural network model to a large-scale NLP problem. Prerequisites: calculus and linear algebra; CS124, CS221, or CS229.
Same as: CS 224N, LINGUIST 284
SYMSYS 200. Minds and Machines. 4 Units.
(Formerly SYMSYS 100). An overview of the interdisciplinary study of cognition, information, communication, and language, with an emphasis on foundational issues: What are minds? What is computation? What are rationality and intelligence? Can we predict human behavior? Can computers be truly intelligent? How do people and technology interact, and how might they do so in the future? Lectures focus on how the methods of philosophy, mathematics, empirical research, and computational modeling are used to study minds and machines. Students must take this course before being approved to declare Symbolic Systems as a major. All students interested in studying Symbolic Systems are urged to take this course early in their student careers. The course material and presentation will be at an introductory level, without prerequisites.
Same as: CS 24, LINGUIST 35, PHIL 99, PSYCH 35, SYMSYS 1

SYMSYS 201. Digital Technology, Society, and Democracy. 3 Units.
The impact of information and communication technologies on social and political life. Interdisciplinary. Classic and contemporary readings focusing on topics such as social networks, virtual versus face-to-face communication, the public sphere, voting technology, and collaborative production. Prerequisite: Completion of a course in psychology, communication, human-computer interaction, or a related discipline, or consent of the instructor.

SYMSYS 202. Theories of Consciousness. 3 Units.
Are fish conscious? Are fetuses? Could we build a conscious computer? Much of the philosophical work on consciousness has focused on whether consciousness is wholly physical, but that question is orthogonal to the more specific questions about consciousness that most of us really care about. To answer those questions, we need a theory of how consciousness works in our world. Philosophers and scientists have put forward a spectrum of different candidates, from very abstract, philosophical theories through theories more informed by cognitive psychology down to neural and even quantum theories. In this seminar, students will learn about the major theories of consciousness as well as conceptual issues that arise on different approaches. Particularly important will be the question of how we might gain empirical evidence for a theory of consciousness.

SYMSYS 203. Cognitive Science Perspectives on Humanity and Well-Being. 3 Units.
In recent years, cognitive scientists have turned more attention to questions that have traditionally been investigated by historians, political scientists, sociologists, and anthropologists, e.g. What are the sources of conflict and disagreement between people?, What drives or reduces violence and injustice?, and What brings about or is conducive to peace and justice? In this advanced small seminar, we will read and discuss works by psychologists, neuroscientists, philosophers, and others, which characterize this growing research area among those who study minds, brains, and behavior. Required: Completion of a course in psychology beyond the level of Psych 1, or consent of the instructor.

SYMSYS 205. The Philosophy and Science of Perception. 3 Units.
Our senses tell us about our immediate environment, but what exactly do they tell us? Our color experiences tell us that the things around us have color properties, but what in the world are color properties? Do we visually represent absolute size as well as relative size? When we see an apple, do we literally see it as an apple, or do we infer that it is an apple based on its color and shape? Can we expect to see affect what we actually see? In this seminar we will bring both philosophical and empirical perspectives to bear on these and other issues related to figuring out just how our perceptual experiences represent the world as being. Prerequisite: PHIL 80 or permission of the instructor.

SYMSYS 207. Conceptual Issues in Cognitive Science. 3 Units.
This seminar will cover a selection of foundational issues in cognitive science. Topics may include modularity, representation, connectionism, neuroscience and free will, neuroimaging, implants, sensory experience, the nature of information, and consciousness. Course is limited to 15 students. Prerequisite: Phil 80, or permission of the instructor.
SYMSYS 208. Computer Machines and Intelligence. 3 Units.
It has become common for us to see in the media news about computer winning a masters in chess, or answering questions on the Jeopardy TV show, or the impact of AI on health, transportation, education, in the labor market and even as an existential threat to mankind. This interest in AI gives rise questions such as: Is it possible for a computer to think? What is thought? Are we computers? Could machines feel emotions or be conscious? Curiously, there is no single, universally accepted definition of Artificial Intelligence. However in view of the rapid dissemination of AI these questions are important not only for experts, but also for all other members of society. This course is intended for students from different majors interested in learn how the concept of intelligent machine is understood by the researchers in AI. We will study the evolution of AI research, its different approaches, with focus on the tests developed to verify if a machine is intelligent or not. In addition, we will examine the philosophical problems associated with the concept of intelligent machine. The topics covered will include: Turing test, symbolic AI, connectionist AI, sub-symbolic AI, Strong AI and Weak AI, AI singularity, unconventional computing, rationality, intentionality, representation, machine learning, and the possibility of conscious machines.

SYMSYS 212. Challenges for Language Systems. 3-4 Units.
Parallel exploration of philosophical and computational approaches to modeling the construction of linguistic meaning. In philosophy of language: lexical sense extension, figurative speech, the semantics/pragmatics interface, contextualism debates. In CS: natural language understanding, from formal compositional models of knowledge representation to statistical and deep learning approaches. We will develop an appreciation of the complexities of language understanding and communication; this will inform discussion of the broader prospects for Artificial Intelligence. Special attention will be paid to epistemological questions on the nature of linguistic explanation, and the relationship between theory and practice. PREREQUISITES: PHIL80; some exposure to philosophy of language and/or computational language processing is recommended.
Same as: SYMSYS 112

SYMSYS 245. Cognition in Interaction Design. 3 Units.
Note: Same course as 145 which is no longer active. Interactive systems from the standpoint of human cognition. Topics include skill acquisition, complex learning, reasoning, language, perception, methods in usability testing, special computational techniques such as intelligent and adaptive interfaces, and design for people with cognitive disabilities. Students conduct analyses of real world problems of their own choosing and redesign/analyze a project of an interactive system. Limited enrollment seminar taught in two sections of approximately ten students each. Admission to the course is by application to the instructor, with preference given to Symbolic Systems students of advanced standing. Recommended: a course in cognitive psychology or cognitive anthropology.

SYMSYS 255. Building Digital History: Informatics of Social Movements and Protest. 3-5 Units.
A participatory course focused on the online representation of oral and archival history research. This year’s thematic focus is the design and evaluation of history websites focused on social movements and protest. We will survey the field of digital history and its application to social movement research and teaching. The course will utilize materials developed in the 2014 version of the course, which focused on the history of student activism at Stanford. Class will apply lessons from digital history practice and theory to the design of an online repository and community for the collaborative representation and discussion of social movement history at Stanford, and to the further development of source material in a future version of the class. Topics will include participatory design, studies of historical learning, archiving issues, data integrity, and fair representation of different viewpoints, among others.

SYMSYS 255A. Building Digital History: Social Movements and Protest at Stanford. 1 Unit.
Lectures-only version of Symsys 255.

SYMSYS 271. Group Democracy. 2-4 Units.
This seminar will explore theoretical, empirical, and practical approaches to groups that come together around a common purpose or interest. Emphasis is on democratically structured, non-hierarchical and non-institutional decision making, e.g. by grassroots activists, student, or neighborhood organizations. Parliamentary, consensus, and informal procedures. How do groups form? How do they deliberate and make decision? What are the principles underlying different models for group process, and how well do different procedures work in practice? How do culture and identity affect the working of a group? And how are social technologies used? Readings from different disciplines and perspectives. Course is limited to 20 students. Prerequisite: A course in social psychology, decision making or group sociology. This course must be taken for a minimum of 3 units and a letter grade to be eligible for Ways credit.

SYMSYS 275. Collective Behavior and Distributed Intelligence. 3 Units.
This course will explore possibilities for student research projects based on presentations of faculty research. We will cover a broad range of topics within the general area of collective behavior, both natural and artificial. Students will build on faculty presentations to develop proposals for future projects.
Same as: BIO 175

SYMSYS 280. Symbolic Systems Research Seminar. 1 Unit.
A mixture of public lectures of interest to Symbolic Systems students (the Symbolic Systems Forum) and student-led meetings to discuss research in Symbolic Systems. Can be repeated for credit. Open to both undergraduates and Master’s students. First meeting is the second Monday of the quarter.

SYMSYS 290. Master’s Degree Project. 1-15 Unit.
Enrollment limited to students in the Symbolic Systems M.S. degree program. May be repeated for credit.

SYMSYS 295D. Research in Digital Democracy. 3-4 Units.
Digital democracy refers to social activity that is organized democratically at a group, institutional, or societal level, and that takes place within or is augmented by digital technology. This is a project-based research seminar designed to teach students methods for studying digital democracy, as well as collaborating in a group, the organization of a research project, and academic writing. The first few weeks of the course will be an overview of digital democracy research and its methods, as well as a time for students to organize into a group research project, The remainder of the class (about 7 weeks) will be spent performing and writing up the research for a targeted publication venue. Application required for enrollment. Prerequisite: At least one course in empirical methods or statistics. Prerequisites: At least one course in empirical methods or statistics.
Same as: SYMSYS 195D

SYMSYS 296. Independent Study. 1-15 Unit.
Independent work under the supervision of a faculty member. Can be repeated for credit.

SYMSYS 297. Teaching in Symbolic Systems. 1-5 Unit.
Leading sections, grading, and/or other duties of teaching or helping students. Must be taken for a minimum of 3 units and a letter grade to be eligible for Ways credit.
SYMSYS 298. Peer Advising in Symbolic Systems: Practicum. 1-2 Unit. Optional for students selected as Undergraduate Advising Fellows in the Symbolic Systems Program. AFs work with program administrators to assist undergraduates in the Symbolic Systems major or minor, in course selection, degree planning, and relating the curriculum to a career or life plan, through advising and events. Meeting with all AFs for an hour once per week under the direction of the Associate Director. Requires a short reflective paper at the end of the quarter on what the AF has learned about advising students in the program. Repeatable for credit. May not be taken by students who receive monetary compensation for their work as an AF.

SYMSYS 299. Curricular Practical Training. 1 Unit. Students obtain employment in a relevant research or industrial activity to enhance their professional experience consistent with their degree programs. Meets the requirements for curricular practical training for students on F-1 visas. Students submit a concise report detailing work activities, problems worked on, and key results. May be repeated for credit. Prerequisite: qualified offer of employment and consent of advisor.