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/) 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/undergraduatesundergradadvisingadvising-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://
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) a no-option pass grade (‘S’ or its equivalent in the Graduate School of Business, Stanford Law School, or School of Medicine, or in an 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): Calculus</td>
<td></td>
</tr>
<tr>
<td>10 units of Advanced Placement Calculus credit</td>
<td></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

<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

<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 or 106X
Equivalent preparation, as evidenced by successful completion of CS 106A

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

STATS 116

MS&E 220

MATH 151

EE 178

CS 109

CME 106

multivariable calculus. One of the following:
CS 154
CS 103

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:

ii. Theory of Computation. One of the following:

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

CS 109

EE 178

MATH 151

MATH 63DM

MS&E 120

MS&E 220

STATS 110

STATS 116

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:

ii. Programming II
One of the following:

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

One of the following:

CS 107

CS 107E

CS 129

CS 147

CS 193A

CS 193C

CS 193P

CS 193X

CS 194H

CS 221

CS 229

Cross-Area Requirement

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:

ii. Theory of Computation. One of the following:

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

CS 109

EE 178

MATH 151

MATH 63DM

MS&E 120

MS&E 220

STATS 110

STATS 116

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:

ii. Programming II
One of the following:
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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>LINGUIST 130A</td>
<td>Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 180</td>
<td>From Languages to Information</td>
<td>3-4</td>
</tr>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 167D</td>
<td>Philosophy of Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 181</td>
<td>Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: The Probabilistic Approach</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 209</td>
<td>Neural Network Models of Cognition</td>
<td>4</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 190</td>
<td>Senior Honors Tutorial</td>
<td>1-5</td>
</tr>
</tbody>
</table>

An approved project course with a SYMSYS listing in the 195-series. Any of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 195A</td>
<td>Design for Artificial Intelligence</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195B</td>
<td>Design for Behavior Change</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195D</td>
<td>Research in Digital Democracy</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195E</td>
<td>Experimental Methods</td>
<td>3</td>
</tr>
<tr>
<td>SYMSYS 195G</td>
<td>Introduction to Game Design</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195I</td>
<td>Image Systems Engineering</td>
<td>1-3</td>
</tr>
<tr>
<td>SYMSYS 195L</td>
<td>Methods in Psycholinguistics</td>
<td>4</td>
</tr>
<tr>
<td>SYMSYS 195N</td>
<td>Natural Language Processing with Deep Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195S</td>
<td>Service Design</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195U</td>
<td>Natural Language Understanding</td>
<td>3-4</td>
</tr>
<tr>
<td>SYMSYS 195V</td>
<td>Data Visualization</td>
<td>3-4</td>
</tr>
</tbody>
</table>

Supervised Research

Taken with a faculty member on an approved symbolic-systems related project, taken as SYMSYS 196: Independent Study, or a department-based directed research course.

SYMSYS 192: Symbolic Systems in Practice (must be taken in conjunction with an approved internship or service project)

ii. Integrative Requirement

Either an additional research project course (e.g., the second course of an Honors Project) or a Concentration-Specific Integrative Course, which must be completed no earlier than the Junior Year. Units must be applied to a student’s concentration.

One of the following (the first three bulleted options are the Standard Options available across all Concentrations):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYMSYS 190</td>
<td>Senior Honors Tutorial (continuation of the course taken for the Practicum requirement)</td>
<td>1-5</td>
</tr>
</tbody>
</table>

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

Cross-Area Requirement

The full list of approved courses for the Cross-Area Requirement. Only one course must be chosen to fulfill the requirement - categories are for guidance only.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 162</td>
<td>Philosophy of Mathematics</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 181</td>
<td>Philosophy of Language</td>
<td>4</td>
</tr>
</tbody>
</table>

Philosophical Analysis and Computational Methods

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 181</td>
<td>Computers, Ethics, and Public Policy</td>
<td>4</td>
</tr>
<tr>
<td>CS 182</td>
<td>Ethics, Public Policy, and Technological Change</td>
<td>5</td>
</tr>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 167D</td>
<td>Philosophy of Neuroscience</td>
<td>4</td>
</tr>
</tbody>
</table>

Philosophical Analysis and Empirical Cognitive Science

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHIL 167D</td>
<td>Philosophy of Neuroscience</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 181</td>
<td>Philosophy of Language</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 186</td>
<td>Philosophy of Mind</td>
<td>4</td>
</tr>
</tbody>
</table>

Formal Methods and Computational Methods

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 151</td>
<td>Logic Programming</td>
<td>3</td>
</tr>
<tr>
<td>CS 154</td>
<td>Introduction to the Theory of Computation</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
<td>3-4</td>
</tr>
<tr>
<td>LINGUIST 130A</td>
<td>Introduction to Semantics and Pragmatics</td>
<td>4</td>
</tr>
<tr>
<td>LINGUIST 180</td>
<td>From Languages to Information</td>
<td>3-4</td>
</tr>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
<td>4</td>
</tr>
<tr>
<td>PHIL 154</td>
<td>Modal Logic</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: The Probabilistic Approach</td>
<td>3</td>
</tr>
<tr>
<td>PSYCH 209</td>
<td>Neural Network Models of Cognition</td>
<td>4</td>
</tr>
<tr>
<td>PSYCH 221</td>
<td>Image Systems Engineering</td>
<td>1-3</td>
</tr>
<tr>
<td>PSYCH 242</td>
<td>Theoretical Neuroscience</td>
<td>3</td>
</tr>
<tr>
<td>PHIL 249</td>
<td>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 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/).

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
LINGUIST 230B Advanced Semantics

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

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:

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
<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 315A</td>
<td>Modern Applied Statistics: Learning</td>
</tr>
<tr>
<td>STATS 315B</td>
<td>Modern Applied Statistics: Data Mining</td>
</tr>
<tr>
<td><strong>Robotics and Vision</strong></td>
<td></td>
</tr>
<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>
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<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
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<tr>
<td>CS 231N</td>
<td>Convolutional Neural Networks for Visual Recognition</td>
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<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
</tr>
<tr>
<td>CS 331B</td>
<td>Representation Learning in Computer Vision</td>
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<tr>
<td>CS 333</td>
<td>Algorithms for Interactive Robotics</td>
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<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>
<tr>
<td><strong>Additional Topics</strong></td>
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<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>
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<tr>
<td>MS&amp;E 135</td>
<td>Networks</td>
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<tr>
<td>MUSIC 220B</td>
<td>Compositional Algorithms, Psychoacoustics, and Computational Music</td>
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<tr>
<td>MUSIC 220C</td>
<td>Research Seminar in Computer-Generated Music</td>
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<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>
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<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>
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<tr>
<td>SYMSYS 207</td>
<td>Conceptual Issues in Cognitive Science</td>
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<tr>
<td>SYMSYS 208</td>
<td>Computer Machines and Intelligence</td>
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<tr>
<td>SYMSYS 275</td>
<td>Collective Behavior and Distributed Intelligence</td>
</tr>
<tr>
<td><strong>Mathematical Foundations</strong></td>
<td></td>
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<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>
<tr>
<td>PHIL 152</td>
<td>Computability and Logic</td>
</tr>
<tr>
<td><strong>Total Units</strong></td>
<td>15-22</td>
</tr>
</tbody>
</table>

Three of the five courses must be chosen from the list below in at least two areas:


**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>
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</thead>
<tbody>
<tr>
<td>3-4</td>
<td>PSYCH 30 Introduction to Perception</td>
</tr>
<tr>
<td></td>
<td>PSYCH 45 Introduction to Learning and Memory</td>
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<tr>
<td></td>
<td>PSYCH 50 Introduction to Cognitive Neuroscience</td>
</tr>
<tr>
<td></td>
<td>PSYCH 162 Brain Networks</td>
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<tr>
<td></td>
<td>PSYCH 164 Brain decoding</td>
</tr>
<tr>
<td></td>
<td>PSYCH 202 Cognitive Neuroscience</td>
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</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>Empirical Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>COMM 106 Communication Research Methods</td>
</tr>
<tr>
<td></td>
<td>EE 104 Introduction to Machine Learning</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 231 Introduction to Computational Social Science</td>
</tr>
<tr>
<td></td>
<td>PSYCH 204A Human Neuroimaging Methods</td>
</tr>
<tr>
<td></td>
<td>PSYCH 251 Experimental Methods</td>
</tr>
<tr>
<td></td>
<td>PSYCH 252 Statistical Methods for Behavioral and Social Sciences</td>
</tr>
<tr>
<td></td>
<td>PSYCH 253 Advanced Statistical Modeling</td>
</tr>
<tr>
<td></td>
<td>STATS 101 Data Science 101</td>
</tr>
<tr>
<td></td>
<td>STATS 191 Introduction to Applied Statistics</td>
</tr>
<tr>
<td></td>
<td>STATS 200 Introduction to Statistical Inference</td>
</tr>
<tr>
<td></td>
<td>STATS 263 Design of Experiments</td>
</tr>
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</table>

Three additional courses chosen across and/or within the following five areas: 9-16

**Language**

<table>
<thead>
<tr>
<th>Units</th>
<th>Language</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>CS 224N Natural Language Processing with Deep Learning</td>
</tr>
<tr>
<td></td>
<td>LINGUIST 110 Introduction to Phonology</td>
</tr>
<tr>
<td></td>
<td>LINGUIST 140 Learning to Speak: An Introduction to Child Language Acquisition</td>
</tr>
</tbody>
</table>
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

Total Units  15-25

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

Music Fundamentals
Units
MUSIC 220A  Fundamentals of Computer-Generated Sound 6-8
MUSIC 220B  Compositional Algorithms, Psychoacoustics, and Computational Music 2-4

Music and the Mind & Brain
Units
Select one of the following:
MUSIC 1A  Music, Mind, and Human Behavior 3-5
### Symbolic Systems

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<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**

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**

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/).

**Units**: 15-25

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

- POLISCI 230A  Classical Seminar: Origins of Political Thought
- PSYCH 160  Seminar on Emotion

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>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC 114</td>
<td>Economic Sociology</td>
</tr>
<tr>
<td>SOC 115</td>
<td>Topics in Economic Sociology</td>
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<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>
</tbody>
</table>

**Practical Tools and Applications**

Select one of the following:

- **CEE 206** Decision Analysis for Civil and Environmental Engineers
- **CS 181** Computers, Ethics, and Public Policy
- **CS 182** Ethics, Public Policy, and Technological Change
- **CS 228** Probabilistic Graphical Models: Principles and Techniques
- **CS 238** Decision Making under Uncertainty
- **CS 239** Advanced Topics in Sequential Decision Making
- **CS 325B** Data for Sustainable Development
- **ECON 135** Foundations of Finance
- **ECON 136** Market Design
- **ECON 137** Decision Modeling and Information
- **ECON 141** Public Finance and Fiscal Policy
- **ECON 150** Economic Policy Analysis
- **ECON 155** Environmental Economics and Policy
- **ECON 162** Games Developing Nations Play
- **ECON 247** Labor Economics II
- **MS&E 152** Introduction to Decision Analysis
- **MS&E 180** Organizations: Theory and Management
- **MS&E 250A** Engineering Risk Analysis
- **MS&E 250B** Project Course in Engineering Risk Analysis
- **MS&E 251** Introduction to Stochastic Control with Applications
- **MS&E 252** Decision Analysis I: Foundations of Decision Analysis
- **MS&E 352** Decision Analysis II: Professional Decision Analysis
- **MS&E 353** Decision Analysis III: Frontiers of Decision Analysis
- **MS&E 355** Influence Diagrams and Probabilistic Networks
- **POLISCI 152** Introduction to Game Theoretic Methods in Political Science
- **POLISCI 153** Thinking Strategically
- **SYMSYS 201** Digital Technology, Society, and Democracy
- **SYMSYS 271** Group Democracy
- **SYMSYS 275** Collective Behavior and Distributed Intelligence
- **URBANST 132** Concepts and Analytic Skills for the Social Sector

**Methodological Foundations**

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

**Human-Computer Interaction**

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

**Units**

- **HCI Introduction** 3-5
- **HCI-Project-Based Courses** 3-4

Select one of the following:

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

### Learning Environment Design

**COMM 322**  
Advanced Studies in Behavior and Social Media

**CS 147**  
Introduction to Human-Computer Interaction Design

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**Learning Units**  
15-23

### HCI Programming

3-5

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

### Learning Units

15-23

### Computational Learning

15-25

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

- **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 Seminar on Memory
- **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 Units**  
15-23

### Learning Environment Design

- **COMM 322**  
  Advanced Studies in Behavior and Social Media
- **CS 147**  
  Introduction to Human-Computer Interaction Design
### Natural Language

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

<table>
<thead>
<tr>
<th>Units</th>
<th>Select five courses from three or four of the following seven areas:</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-21</td>
<td>Mathematical/Computational Foundations</td>
</tr>
<tr>
<td></td>
<td>Computational Linguistics</td>
</tr>
<tr>
<td></td>
<td>Phonetics/Phonology/Speech</td>
</tr>
<tr>
<td></td>
<td>Neurosciences</td>
</tr>
</tbody>
</table>

#### Mathematical/Computational Foundations
- **CS 194H** User Interface Design Project
- **EDUC 211** Beyond Bits and Atoms - Lab
- **EDUC 230** Learning Experience Design
- **EDUC 236** Beyond Bits and Atoms: Designing Technological Tools
- **EDUC 281** Technology for Learners
- **EDUC 298** Seminar on Teaching Introductory Computer Science
- **EDUC 303** Designing Learning Spaces
- **EDUC 328** Topics in Learning and Technology: Core Mechanics for Learning
- **EDUC 333A** Understanding Learning Environments
- **EDUC 342** Child Development and New Technologies
- **EDUC 391** Engineering Education and Online Learning
- **EDUC 426** Unleashing Personal Potential: Behavioral Science and Design Thinking Applied to Self
- **MUSIC 257** Neuroplasticity and Musical Gaming
- **SYMSYS 245** Cognition in Interaction Design
- **SYMSYS 255** Building Digital History: Informatics of Social Movements and Protest

**Total Units** 15-25

#### Computational Linguistics
- **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
- **PSYCH 290** Natural Language Processing & Text-Based Machine Learning in the Social Sciences
- **SYMSYS 112** Challenges for Language Systems

#### Phonetics/Phonology/Speech
- **LINGUIST 105** Phonetics
- **LINGUIST 110** Introduction to Phonology
- **LINGUIST 112** Seminar in Phonology: Stress, Tone, and Accent
- **LINGUIST 157** Sociophonetics
- **LINGUIST 205B** Advanced Phonetics
- **LINGUIST 207A** Advanced Phonetics

**LINGUIST 210A** Phonology
**LINGUIST 213** Corpus Phonology
**LINGUIST 260A** Historical Morphology and Phono

#### Morphosyntax
- **LINGUIST 121A** The Syntax of English
- **LINGUIST 121B** Crosslinguistic Syntax
- **LINGUIST 217** Morphosyntax
- **LINGUIST 222A** Foundations of Syntactic Theory I
- **LINGUIST 225D** Seminar in Syntax: Advanced Topics
- **LINGUIST 260B** Historical Morphosyntax

#### Semantics/Pragmatics/Philosophy of Language
- **LINGUIST 130A** Introduction to Semantics and Pragmatics
- **LINGUIST 130B** Introduction to Lexical Semantics
- **LINGUIST 132** Lexical Semantic Typology
- **LINGUIST 230B** Advanced Semantics
- **LINGUIST 230C** Advanced Topics in Semantics & Pragmatics
- **LINGUIST 232A** Lexical Semantics
- **LINGUIST 236** Seminar in Semantics: Conditionals
- **PHIL 137** Wittgenstein
- **PHIL 181** Philosophy of Language
- **PHIL 182** Advanced Philosophy of Language
- **PHIL 182A** Naturalizing Representation
- **PHIL 194D** Capstone Seminar: Artificial Intelligence
- **PHIL 194K** Slurs and Derogation: Semantic, Pragmatic and Ethical Perspectives
- **PHIL 348** Evolution of Signalling
- **PHIL 385D** Advanced Evolution of Signalling

#### Psycholinguistics
- **LINGUIST 140** Learning to Speak: An Introduction to Child Language Acquisition
- **LINGUIST 245B** Methods in Psycholinguistics
- **LINGUIST 246** Foundations of Psycholinguistics
- **LINGUIST 248** Seminar in Developmental Psycholinguistics
- **PSYCH 132** Language and Thought
- **PSYCH 140** Introduction to Psycholinguistics
- **PSYCH 209** Neural Network Models of Cognition

#### Sociolinguistics and Language Change
- **LINGUIST 65** African American Vernacular English
- **LINGUIST 116A** Introduction to Word-Formation
- **LINGUIST 150** Language and Society
- **LINGUIST 150E** Who Speaks Good English
- **LINGUIST 152** Sociolinguistics and Pidgin Creole Studies
- **LINGUIST 156** Language, Gender, & Sexuality
- **LINGUIST 157** Sociophonetics
- **LINGUIST 159** American Dialects
- **LINGUIST 168** Introduction to Linguistic Typology

**Total Units** 15-21

### 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

**Philosophical and Theoretical Approaches**
- APPPHYS 293 Theoretical Neuroscience
- NBIO 101 Social and Ethical Issues in the Neurosciences
- PHIL 167D Philosophy of Neuroscience
- PHIL 186 Philosophy of Mind
- PHIL 360 Grad Seminar: Philosophy of Neuroscience
- SYMSYS 202 Theories of Consciousness
- SYMSYS 207 Conceptual Issues in Cognitive Science

**Methodological Foundations**
- BIOE 291 Principles and Practice of Optogenetics for Optical Control of Biological Tissues
- CS 205L Continuous Mathematical Methods with an Emphasis on Machine Learning
- CS 448B Data Visualization
- EE 102A Signal Processing and Linear Systems I
- EE 102B Signal Processing and Linear Systems II
- EE 261 The Fourier Transform and its Applications
- EE 263 Introduction to Linear Dynamical Systems
- MATH 113 Linear Algebra and Matrix Theory
- MS&E 211 Introduction to Optimization
- PSYCH 10 Introduction to Statistical Methods: Precalculus
- PSYCH 187 Research Methods in Cognition & Development
- PSYCH 204A Human Neuroimaging Methods
- PSYCH 251 Experimental Methods
- PSYCH 252 Statistical Methods for Behavioral and Social Sciences
- PSYCH 253 Advanced Statistical Modeling
- STATS 110 Statistical Methods in Engineering and the Physical Sciences
- STATS 141 Biostatistics
- STATS 191 Introduction to Applied Statistics
- STATS 200 Introduction to Statistical Inference

**Philosophical Foundations**
See also the Symbolic Systems website (https://symsys.stanford.edu/undergraduates/concentrations/philosophical-foundations-concentration/).

**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
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.

(*p. 1*)
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:

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

b. Logic and Computation

Select one of the following:

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

c. Computer Programming

Select one of the following:

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

d. Philosophical Foundations

Select one of the following:

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

e. Linguistic Theory

Select one of the following:

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

f. Computation and Cognition

Select one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPPHYS 293</td>
<td>Theoretical Neuroscience</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
<td></td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td></td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td></td>
</tr>
<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
<td></td>
</tr>
<tr>
<td>LINGUIST 180</td>
<td>From Languages to Information</td>
<td></td>
</tr>
<tr>
<td>LINGUIST 182</td>
<td>(no longer offered)</td>
<td></td>
</tr>
<tr>
<td>NENS 220</td>
<td>Computational Neuroscience</td>
<td></td>
</tr>
<tr>
<td>PSYCH 109</td>
<td>An introduction to computation and cognition</td>
<td></td>
</tr>
<tr>
<td>PSYCH 204</td>
<td>Computation and Cognition: The Probabilistic Approach</td>
<td></td>
</tr>
</tbody>
</table>

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/graduatems-admissions/coterm-admissions/) 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://exploredegrees.stanford.edu/cotermdegrees/)” section. University requirements for the master’s degree are described in the ‘Graduate Degrees (http://explordegrees.stanford.edu/graduatedegrees/#masterstext)’ section of this bulletin.

After accepting admission to this coterminal master’s degree program, students may request transfer of courses from the undergraduate to the graduate 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 coterminal students or returning students who already have a B.S. degree in Symbolic Systems, and in two years or less by other students depending upon level of preparation. Admission is competitive, providing a limited number of students with the opportunity to pursue course and project work in consultation with a faculty adviser who is affiliated with the Symbolic Systems Program. The faculty adviser may impose requirements beyond those described here.

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' 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 (http://symsys.stanford.edu/viewing/htmldocument/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 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 230B Advanced Semantics
   • NBIO 206 The Nervous System
   • NBIO 258 Information and Signaling Mechanisms in Neurons and Circuits
   • PSYCH 204 Computation and Cognition: The Probabilistic Approach
   • PSYCH 204A Human Neuroimaging Methods
   • PSYCH 209 Neural Network Models of Cognition
   • PSYCH 251 Experimental Methods
   • PSYCH 252 Statistical Methods for Behavioral and Social Sciences
   • STATS 200 Introduction to Statistical Inference
   • SYMSYS 245 Cognition in Interaction Design
c) Computational: a course involving programming beyond the level of CS 107. The courses below have been approved. Other courses may be approved if appropriate.

- CS 108 Object-Oriented Systems Design
- CS 110 Principles of Computer Systems
- CS 124 From Languages to Information
- CS 142 Web Applications
- CS 143 Compilers
- CS 145 Data Management and Data Systems
- CS 148 Introduction to Computer Graphics and Imaging
- CS 210A Software Project Experience with Corporate Partners
- CS 221 Artificial Intelligence: Principles and Techniques
- CS 224N Natural Language Processing with Deep Learning
- CS 224W Machine Learning with Graphs
- CS 246 Mining Massive Data Sets

d) Philosophical: a course in the area of Philosophy of Mind/Language/Science/Epistemology or Metaphysics at the 200 level or above, certified by the instructor as worthy of graduate credit. The courses below are examples of those that have been approved. Other courses may be approved if appropriate.

- PHIL 264 Central Topics in the Philosophy of Science: Theory and Evidence
- PHIL 267D Philosophy of Neuroscience
- PHIL 281 Philosophy of Language
- PHIL 281C
- 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/#tempdeathemplateatetext) 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), Jean Bresnan (Professor, emerita), Eve Clark (Professor, emerita), Cleo Condoravdi (Professor Research), Judith Degen (Assistant Professor), Penelope Eckert (Professor), Vera Grishova (Associate Professor), Boris Harizanov (Assistant Professor), Daniel Jurafsky (Professor), Ronald Kaplan (Adjunct Professor), Laurie Karttunen (Adjunct Professor), Martin Kay (Professor), Paul Kiparsky (Professor), Daniel Lassiter (Assistant Professor), Beth Levin (Professor), Christopher Manning (Professor), Stanley Peters (Professor, emeritus), Christopher Potts (Professor), Meghan Sumner (Associate Professor), Thomas A. Wasow (Professor, emeritus), Annie Zaenen (Adjunct Professor)

Management Science and Engineering: Sharad Goel (Assistant Professor), Pamela Hinds (Professor), 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 Fjeldesdal (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 (Professor), Brian Knutson (Professor), Ellen Markman (Professor), James McClelland (Professor), Russell Poldrack (Professor), Barbara Tversky (Professor, emerita), Anthony Wagner (Professor), Brian Wandell (Professor), Daniel Yamins (Assistant Professor), Jamil Zaki (Assistant Professor)

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

Symbolic Systems: Todd Davies (Associate Director), Jeff Shragr (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 the 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 assumptions? 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: SYMSYS 212

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 worldvies. 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 116. Philosophy of Neuroscience. 4 Units.
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 118. 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. PREREQUISITES: 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 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: Basic principles of optics (Snell's Law, diffraction, adaptive optics). Image sensor and pixel design. Color science, metrics, and calibration. Human spatial resolution. Image processing principles. Display technologies. 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. Pre-requisite: 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 student's 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 195. Service 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; you must plan on attending every studio to take this class. The focus of CS247S is Service Design. In this course we will be looking at experiences that address the needs of multiple types of stakeholders at different touchpoints - digital, physical, and everything in between. If you have ever taken an Uber, participated in the Draw, engaged with your bank, or ordered a coffee through the Starbucks app, you have experienced a service that must have a coordinated experience for the customer, the service provider, and any other stakeholders involved. Let us explore what specialized tools and processes are required to created these multi-faceted interactions. Prerequisites: CS147 or equivalent background in design thinking.

Same as: CS 247S

SYMSYS 195T. Natural Language Processing & Text-Based Machine Learning in the Social Sciences. 4 Units.
Digital communications (including social media) are the largest data sets of our time, and most of it is text. Social scientists need to be able to digest small and big data sets alike, process it and extract psychological insight. This applied and project-focused course introduces students to a Python codebase developed to facilitate text analysis in the social sciences (see datat.wvbp.org – knowledge of Python is helpful but not required). The goal is to practice these methods in guided tutorials and project-based work so that the students can apply them to their own research contexts and be prepared to write up the results for publication. The course will provide best practices, as well as access to and familiarity with a Linux-based server environment to process text, including the extraction of words and phrases, topics and psychological dictionaries. We will also practice the use of machine learning based on text data for psychological assessment, and the further statistical analysis of language variables in R. Familiarity with Python is helpful but not required. Basic familiarity with R is expected. The ability to wrangle data into a spreadsheet-like format is expected. A basic introduction to SQL will be given in the course. Familiarity with SSH and basic Linux is helpful but not required. Understanding of regression is expected.

Same as: PSYCH 290, SOC 281

SYMSYS 195U. Natural Language Understanding. 3-4 Units.
Project-oriented class focused on developing systems and algorithms for robust machine understanding of human language. Draws on theoretical concepts from linguistics, natural language processing, and machine learning. Topics include lexical semantics, distributed representations of meaning, relation extraction, semantic parsing, sentiment analysis, and dialogue agents, with special lectures on developing projects, presenting research results, and making connections with industry. Prerequisites: one of LINGUIST 180/280, CS 124, CS 224N, or CS 224S.

Same as: CS 224U, LINGUIST 188, LINGUIST 288

SYMSYS 195V. Data Visualization. 3-4 Units.
Techniques and algorithms for creating effective visualizations based on principles from graphic design, visual art, perceptual psychology, and cognitive science. Topics: graphical perception, data and image models, visual encoding, graph and tree layout, color, animation, interaction techniques, automated design. Lectures, reading, and project. Prerequisite: one of CS147, CS148, or equivalent.

Same as: CS 448B

SYMSYS 196. Independent Study. 1-15 Unit.
Independent work under the supervision of a faculty member. Can be repeated for credit.

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 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 methodological 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 Sysms 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 295. 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.
Independent work under the supervision of a faculty member. Can be repeated for credit.

SYMSYS 298. Symbolic Systems Research Seminar. 1 Unit.
Enrollment limited to students in the Symbolic Systems M.S. degree program. May be repeated for credit.
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.