Mathematical and Computational Science

Courses offered by Mathematical and Computational Science program are listed under the subject code MCS on the Stanford Bulletin's ExploreCourses (http://exploreCourses.stanford.edu) website.

This interdisciplinary undergraduate degree program in MCS is sponsored by Stanford's departments of Statistics, Mathematics, Computer Science, and Management Science & Engineering, providing students with a core of mathematics basic to all the mathematical sciences and an introduction to concepts and techniques of computation, optimal decision making, probabilistic modeling, and statistical inference.

Utilizing the faculty and courses of the departments listed above, this major prepares students for graduate study or employment in the mathematical and computational sciences or in those areas of applied mathematics which center around the use of computers and are concerned with the problems of the social and management sciences. A biology option is offered for students interested in applications of mathematics, statistics, and computer science to the biological sciences (bioinformatics, computational biology, statistical genetics, neurosciences); and in a similar spirit, an engineering and statistics option.

Undergraduate Mission Statement for Mathematical and Computational Science

The mission of the Mathematical and Computational Science Program is to provide students with a core of mathematics basic to all the mathematical sciences and an introduction to concepts and techniques of computation, optimal decision making, probabilistic modeling and statistical inference. The program is interdisciplinary in its focus, and students are required to complete coursework in mathematics, computer science, statistics, and management science and engineering. A computational biology track is available for students interested in biomedical applications. The program prepares students for careers in academic, financial and government settings as well as for study in graduate or professional schools.

Learning Outcomes

The program expects undergraduate majors to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department’s undergraduate program. Students are expected to be able to demonstrate:

1. understanding of principles and tools of statistics
2. command of optimization and its applications and the ability to analyze and interpret problems from various disciplines.
3. an understanding of computer applications emphasizing modern software engineering principles.
4. an understanding of multivariate calculus, linear algebra, and algebraic and geometric proofs.

Bachelor of Science in Mathematical and Computational Science

Suggested Preparation for the Major

Undeclared students looking for an introduction to MCS may take Data Science 101 (STATS 101, 5 units). If the MCS major is declared, STATS 101 may be used for elective credit toward the major. Students ordinarily would have taken two of the required Math courses (MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications/MATH 52 Integral Calculus of Several Variables/MATH 53 Ordinary Differential Equations with Linear Algebra) and one of the required Statistics core courses (STATS 116 Theory of Probability, STATS 191 Introduction to Applied Statistics) before declaring MCS during their freshman or sophomore year.

How to Declare

To declare the major, a student should first meet with an MCS adviser to create a proposed study plan and then with the MCS student services officer to discuss the major. Students ordinarily have taken two of the required MATH 50 series courses and a core Statistics course prior to declaration. Once the student has created a proposed study plan, they should connect with the MCS student services officer and declare the major through Axess.

Course Requirements for the MCS Bachelor's Degree (78-86 units)
Or select three of the following:

- MS&E 111 Introduction to Optimization
- MS&E 121 Introduction to Stochastic Modeling
- MS&E 211 Introduction to Optimization
- MS&E 213 Introduction to Optimization Theory
- MS&E 221 Stochastic Modeling
- MS&E 251 Introduction to Stochastic Control with Applications

Statistics (STATS) 9-10
- STATS 116 Theory of Probability 2
- STATS 200 Introduction to Statistical Inference

Select one of the following: 3
- STATS 191 Introduction to Applied Statistics
- STATS 203 Introduction to Regression Models and Analysis of Variance

1. Students who scored a 5 on both the Calculus AB and BC advanced placement exams (total of 10 units) can be waived out of MATH 19 Calculus, MATH 20 Calculus, MATH 21 Calculus; See also the Registrar’s Advanced Placement (https://registrar.stanford.edu/students/transfer-credit-and-advanced-placement) web site (AP (https://registrar.stanford.edu/students/transfer-credit-and-advanced-placement) or IB (https://registrar.stanford.edu/students/transfer-credit-and-advanced-placement) (total of 10 units) can be waived out of MATH 19, 20, and 21 are required to take additional Math classes as discussed with MCS student services and the student’s faculty adviser.

2. MATH 151 Introduction to Probability Theory is equivalent to STATS 116.

Writing in the Major Requirement

The University requires students to complete at least one approved writing-intensive course in each of their majors. See the Hume Center for Writing and Speaking (https://undergrad.stanford.edu/tutoring-support/hume-center/writing/writing-major) web site for a full description of the WIM (https://undergrad.stanford.edu/tutoring-support/hume-center/writing/writing-major/overview-wim-requirement) requirement.

Choose one from the MCS-designated WIM courses to fulfill the Writing in the Major requirement: 3-4 units

- MATH 109 Applied Group Theory
- MATH 110 Applied Number Theory and Field Theory
- MATH 120 Groups and Rings
- MATH 171 Fundamental Concepts of Analysis
- CS 181W Computers, Ethics, and Public Policy
- STATS 155 Statistical Methods in Computational Genetics

WIM courses offered by other majors may be used in cases of specific concentrations (e.g., biology, decision theory). Advisor approval required.

Mathematical and Computational Science Approved Electives

Choose three courses in Mathematical and Computational Science 100-level or above, at least 3 units each from two different departments.

Choose three electives: 9 units

- ECON 102C Advanced Topics in Econometrics
- ECON 140 Introduction to Financial Economics
- ECON 160 Game Theory and Economic Applications
- ECON 179 Experimental Economics
- EE 261 The Fourier Transform and Its Applications
- EE 263 Introduction to Linear Dynamical Systems
- EE 278 Introduction to Statistical Signal Processing
- EE 282 Computer Systems Architecture
- EE 364A Convex Optimization I
- EE 364B Convex Optimization II
- MS&E 220 Probabilistic Analysis
- MS&E 223 Simulation
- MS&E 226 Fundamentals of Data Science: Prediction, Inference, Causality
- MS&E 251 Introduction to Stochastic Control with Applications
- MS&E 334 Topics in Social Data
- MATH 104 Applied Matrix Theory
- MATH 106 Functions of a Complex Variable
- MATH 107 Graph Theory
- MATH 108 Introduction to Combinatorics and Its Applications
- MATH 113 Linear Algebra and Matrix Theory
- MATH 114 Introduction to Scientific Computing
- MATH 115 Functions of a Real Variable
- MATH 116 Complex Analysis
- MATH 131P Partial Differential Equations
- MATH 136 Stochastic Processes
- MATH 158 Basic Probability and Stochastic Processes with Engineering Applications
- MATH 159 Discrete Probabilistic Methods
- MATH 171 Fundamental Concepts of Analysis
- MATH 172 Lebesgue Integration and Fourier Analysis
- PHIL 151 Metalogic
- STATS 100 Mathematics of Sports
- STATS 202 Data Mining and Analysis
- STATS 206 Applied Multivariate Analysis
- STATS 207 Introduction to Time Series Analysis
- STATS 208 Bootstrap, Cross-Validation, and Sample Re-use
- STATS 215 Statistical Models in Biology
- STATS 216 Introduction to Statistical Learning
- STATS 217 Introduction to Stochastic Processes I
- STATS 218 Introduction to Stochastic Processes II
- STATS 219 Stochastic Processes
- STATS 240 Statistical Methods in Finance
- STATS 270 A Course in Bayesian Statistics

For Computer Science (CS), electives can include courses not taken as units under the CS list above and the following:

- CME 206 Introduction to Numerical Methods for Engineering
- CME 211 Software Development for Scientists and Engineers
- CME 302 Numerical Linear Algebra
- CS 108 Object-Oriented Systems Design
- CS 110 Principles of Computer Systems
- CS 140 Operating Systems and Systems Programming
<table>
<thead>
<tr>
<th>Units</th>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>BIOL 100</td>
<td>General Biology</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 101</td>
<td>Principles of Zoology and Ecology</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 102</td>
<td>Principles of Zoology and Ecology</td>
</tr>
<tr>
<td>4</td>
<td>BIOL 104</td>
<td>Introduction to Molecular Genetics</td>
</tr>
<tr>
<td>4</td>
<td>BIOL 105</td>
<td>Introduction to Molecular Genetics</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 106</td>
<td>Genetics</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 107</td>
<td>Molecular Genetics</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 108</td>
<td>Biochemistry &amp; Molecular Biology</td>
</tr>
<tr>
<td>3</td>
<td>BIOL 109</td>
<td>Advanced Biochemistry and Molecular Biology</td>
</tr>
</tbody>
</table>

**Mathematical and Computational Science Biology Track (Option)**

Students in the Biology track take the introductory courses for the Mathematics and Computational Science major with the following allowable substitutions as electives.

<table>
<thead>
<tr>
<th>Units</th>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>STAT/BIO 141</td>
<td>Biostatistics ¹</td>
</tr>
</tbody>
</table>

**Allowable Elective Course Substitutions:**

Take three courses from Foundational Biology Core:

- BIOL 82 Genetics
- BIOL 83 Biochemistry & Molecular Biology

**Mathematical and Computational Science Engineering Track (Option)**

Students in the Engineering track take the introductory courses for the Mathematics and Computational Sciences major with the following allowable substitutions.

<table>
<thead>
<tr>
<th>Units</th>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
</tr>
<tr>
<td>3-5</td>
<td>CME 102</td>
<td>Ordinary Differential Equations for Engineers</td>
</tr>
<tr>
<td>3-5</td>
<td>ENGR 155B</td>
<td>Linear Algebra and Partial Differential Equations for Engineers</td>
</tr>
<tr>
<td>3-5</td>
<td>STATS 116 may be replaced by:</td>
<td></td>
</tr>
<tr>
<td>3-4</td>
<td>STATS 110</td>
<td>Statistical Methods in Engineering and the Physical Sciences</td>
</tr>
<tr>
<td>3-4</td>
<td>STATS 191/STATS 203 may be replaced by:</td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
</tr>
</tbody>
</table>

**Allowable Elective Course Substitutions:**

Select one of the following:

- MATH 106 Functions of a Complex Variable
- MATH 108 Introduction to Combinatorics and Its Applications
- MATH 116 Complex Analysis
- PHIL 151 Metalogic

Select two of the following:

- ENGR 15 Dynamics
- ENGR 20 Introduction to Chemical Engineering
- ENGR 25B Biotechnology

¹ STAT 141 (https://explorecourses.stanford.edu/search?view=catalog&filter-coursestatus-Active=on&page=0&catalog=&academicYear=&q=stats141&collapse=): Biostatistics (BIO 141) can replace STATS 191 Introduction to Applied Statistics or STATS 203 Introduction to Regression Models and Analysis of Variance from the major’s Statistics core requirement.
ENGR 40
ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis
ENGR 105 Feedback Control Design

Only MCS majors pursuing the engineering track may petition their advisor to substitute the required Math series for CME courses listed above.

Mathematical and Computational Science Statistics Track (Option)

Students in the Statistics track take the introductory courses for the Mathematics and Computational Sciences major with the following additional courses - (87 units total)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
<tr>
<td>Advanced CS, such as:</td>
<td>3</td>
</tr>
<tr>
<td>CS 246</td>
<td>Mining Massive Data Sets</td>
</tr>
<tr>
<td>Advanced MS&amp;E, such as:</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 220</td>
<td>Probabilistic Analysis</td>
</tr>
<tr>
<td>or</td>
<td>MS&amp;E 223 Simulation</td>
</tr>
</tbody>
</table>

Allowable Elective Course Substitutions: (9 units)

Select three of the following:

- STATS 202 Data Mining and Analysis
- STATS 206 Applied Multivariate Analysis
- STATS 207 Introduction to Time Series Analysis
- STATS 208 Bootstrap, Cross-Validation, and Sample Re-use
- STATS 216 Introduction to Statistical Learning
- STATS 219 Stochastic Processes
- STATS 270 A Course in Bayesian Statistics

Honors Program

The honors program is designed to encourage a more intensive study of mathematical sciences than the B.S. program. Students interested in honors should consult with their faculty adviser as soon as possible to allow more opportunities in course planning and concentration area. The honors program allows for a capstone experience, building upon the student's current academic knowledge and strengthening their understanding in a specific field of study/concentration. Honors work may be concentrated in fields such as biological sciences and medicine, environment, physics, sports analytics, investment science, AI/machine learning, etc.

Students are required to submit an MCS Honors Proposal Form (https://mcs.stanford.edu/sites/g/files/sbiybj9376/f/mcs_honors_proposal_form_2019-20.pdf) describing the concentration for honors work, including the courses they intend to use, by the final study list deadline two quarters prior to the expected degree conferral quarter. The honors final report is due no later than the last day of classes of the quarter the student expects to graduate. More information can be found on the MCS Honors Website. (https://mcs.stanford.edu/academics/honors)

In addition to meeting all requirements for the B.S., the student must:

1. Maintain a GPA of at least 3.5 in all academic work.
2. Students should complete 15 units of graduate level coursework. Included in these 15 units can be any of the following:
   a. Related research from a 199 course
   b. Participation for credit in a small group seminar
   c. Directed reading
3. Complete a final report which should:
   a. Include their name, degree and the title of their work.
   b. Be typed with 12pt font, single-spaced, minimum 1 page (no longer than 2 pages) with a one-inch margin at the top and bottom of each page.
   c. Explain a theme between the student's coursework, their interests, and how they relate to MCS.
   d. Describe how each course selected added to the student's knowledge and understanding in the chosen area of concentration.
   e. The student's work must demonstrate in-depth learning of a topic or shared idea in the breadth of the MCS major (examples are on MCS webpage), and all students are held to Stanford's Honor Code (https://communitystandards.stanford.edu/policies-and-guidance/honor-code).

Suggested electives for students pursuing Honors:

- MATH 171 Fundamental Concepts of Analysis: 3 units
- MATH 172 Lebesgue Integration and Fourier Analysis: 3 units
- STATS 205A Real Analysis: 3 units
- STATS 202 Data Mining and Analysis: 3 units
- STATS 216 Introduction to Statistical Learning: 3 units
- STATS 217 Introduction to Stochastic Processes I: 3 units
- STATS 219 Stochastic Processes: 3 units
- STATS 270 A Course in Bayesian Statistics: 3 units
- MATH 104 Applied Matrix Theory: 3 units
- MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications: 3 units
- MATH 106A Programming Methodology: 3 units
- MATH 106B Programming Abstractions: 3 units
- MATH 221 Introduction to Optimization: 3 units
- MATH 222 Stochastic Modeling: 3 units

Minor in Mathematical and Computational Science

The minor in Mathematical and Computational Science is intended to provide an experience of the four constituent areas: Computer Science, Mathematics, Management Science and Engineering, and Statistics. The MCS minor requires 32-34 units. Five basic courses are required:

- MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications: 3-5 units
- MATH 104 Applied Matrix Theory: 10 units
- or
- MATH 106A Programming Methodology: 3 units
- MATH 106B Programming Abstractions: 3 units
- MATH 221 Introduction to Optimization: 3 units
- or
- MATH 222 Stochastic Modeling: 3 units
- and either
- MATH 116 Theory of Probability: 4 units
- or
- STATS 191 Introduction to Applied Statistics: 4 units
In addition to the above, the minor requires three courses from the following, two of which must be in different departments:

<table>
<thead>
<tr>
<th>Units</th>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>CME 108</td>
<td>Introduction to Scientific Computing</td>
</tr>
<tr>
<td></td>
<td>CS 103</td>
<td>Mathematical Foundations of Computing</td>
</tr>
<tr>
<td></td>
<td>CS 107</td>
<td>Computer Organization and Systems</td>
</tr>
<tr>
<td></td>
<td>CS 154</td>
<td>Introduction to Automata and Complexity Theory</td>
</tr>
<tr>
<td></td>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td></td>
<td>ECON 160</td>
<td>Game Theory and Economic Applications</td>
</tr>
<tr>
<td></td>
<td>EE 261</td>
<td>The Fourier Transform and Its Applications</td>
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<tr>
<td></td>
<td>MS&amp;E 211</td>
<td>Introduction to Optimization</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 212</td>
<td>Mathematical Programming and Combinatorial Optimization</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 221</td>
<td>Stochastic Modeling</td>
</tr>
<tr>
<td></td>
<td>MS&amp;E 251</td>
<td>Introduction to Stochastic Control with Applications</td>
</tr>
<tr>
<td></td>
<td>MATH 104</td>
<td>Applied Matrix Theory</td>
</tr>
<tr>
<td></td>
<td>MATH 106</td>
<td>Functions of a Complex Variable</td>
</tr>
<tr>
<td></td>
<td>MATH 108</td>
<td>Introduction to Combinatorics and Its Applications</td>
</tr>
<tr>
<td></td>
<td>MATH 109</td>
<td>Applied Group Theory</td>
</tr>
<tr>
<td></td>
<td>MATH 110</td>
<td>Applied Number Theory and Field Theory</td>
</tr>
<tr>
<td></td>
<td>MATH 115</td>
<td>Functions of a Real Variable</td>
</tr>
<tr>
<td></td>
<td>MATH 131P</td>
<td>Partial Differential Equations</td>
</tr>
<tr>
<td></td>
<td>MATH 171</td>
<td>Fundamental Concepts of Analysis</td>
</tr>
<tr>
<td></td>
<td>PHIL 151</td>
<td>Metalogic</td>
</tr>
<tr>
<td></td>
<td>STATS 191</td>
<td>Introduction to Applied Statistics</td>
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<tr>
<td></td>
<td>STATS 200</td>
<td>Introduction to Statistical Inference</td>
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<tr>
<td></td>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
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<tr>
<td></td>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
</tr>
<tr>
<td></td>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
</tbody>
</table>

Other upper-division courses appropriate to the program major may be substituted with consent of MCS program director. Undergraduate majors in the constituent programs may not count courses in their own departments.

**Faculty**

*Director:* Professor Guenther Walther  
*Undergraduate Director:* Professor Guenther Walther  
*Undergraduate Associate Director:* Professor Chiara Sabatti

*Faculty Advisers:* Assistant Professor John Duchi, Professor Bradley Efron, Associate Professor David Rogosa, Assistant Professor Johan Ugander

*Steering Committee:* Takeshi Amemiya (Economics, emeritus), Emmanuel Candès (Mathematics, Statistics), Brian Conrad (Mathematics), Richard Cottle (Management Science and Engineering, emeritus), John Duchi (Electrical Engineering & Statistics), Darrel Duffie (Economics & GSB), Bradley Efron (Statistics), Peter Glynn (Management Science and Engineering), Ramesh Johari (Management Science and Engineering), Percy Liang (Computer Science & Statistics), Parviz Moin (Mechanical Engineering), George Papanicolaou (Mathematics), David Rogosa (Education & Statistics), Chiara Sabatti (Biomedical Data Science & Statistics), David Siegmund (Statistics), Jonathan Taylor (Statistics), Brian White (Mathematics)