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 course work 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)

<table>
<thead>
<tr>
<th>Mathematics (MATH)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-variable calculus or AP credit.</td>
<td>10</td>
</tr>
<tr>
<td>MATH 19 Calculus</td>
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<tr>
<td>MATH 20 Calculus</td>
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<tr>
<td>MATH 21 Calculus</td>
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</tbody>
</table>

Students may choose one of the following sequences: 15

- Multivariable Calculus and Linear Algebra
  - MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications
  - MATH 52 Integral Calculus of Several Variables
  - MATH 53 Ordinary Differential Equations with Linear Algebra

- Modern Mathematics: Continuous Methods (a proof-oriented sequence)
  - MATH 61CM Modern Mathematics: Continuous Methods
  - MATH 62CM Modern Mathematics: Continuous Methods
  - MATH 63CM Modern Mathematics: Continuous Methods

- Modern Mathematics: Discrete Methods (a proof-oriented sequence)
  - MATH 61DM Modern Mathematics: Discrete Methods
  - MATH 62DM Modern Mathematics: Discrete Methods
  - MATH 63DM Modern Mathematics: Discrete Methods

Select one of the following: 3

- MATH 104 Applied Matrix Theory
- MATH 113 Linear Algebra and Matrix Theory
- CME 108 Introduction to Scientific Computing
- CS 107 Computer Organization and Systems
- CS 154 Introduction to Automata and Complexity Theory
- CS 161 Design and Analysis of Algorithms
- CS 181W Computers, Ethics, and Public Policy

Select two of the following: 7-9

- CS 103 Mathematical Foundations of Computing
- CS 106A Programming Methodology
- CS 106B Programming Abstractions
- CS 106X Programming Abstractions

Management Science and Engineering (MS&E) 7-11

- MS&E 211X Introduction to Optimization (Accelerated) 3-4
- MS&E 221 Stochastic Modeling 3

Stanford Bulletin 2018-19
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 Units
- STATS 116 Theory of Probability 2
  Select one of the following:
  - 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/advanced-placement) web site (AP (https://registrar.stanford.edu/students/transfer-credit-and-advanced-placement/advanced-placement/ap-credit-chart) or IB (https://registrar.stanford.edu/students/transfer-credit-and-advanced-placement/advanced-placement/ib-credit-chart) exams). Students who place 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:

- 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:

- 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
CS 143  Compilers
CS 157  Computational Logic
CS 161  Design and Analysis of Algorithms
CS 194  Software Project
CS 221  Artificial Intelligence: Principles and Techniques
CS 223A  Introduction to Robotics
CS 225A  Experimental Robotics
CS 228  Probabilistic Graphical Models: Principles and Techniques
CS 229  Machine Learning
CS 243  Program Analysis and Optimizations
CS 246  Mining Massive Data Sets
CS 248  Interactive Computer Graphics

Ejects that are not offered this year, but may be offered in subsequent years, are eligible for credit toward the major.

With the advisor’s approval, courses other than those listed or offered by the sponsoring departments may be used to fulfill part of the elective requirement. Courses must provide skills relevant to the MCS degree and do not overlap courses in the student’s program. Depending on student’s interests, these may be in fields such as, biology, economics, electrical engineering, industrial engineering, and medicine, are otherwise relevant to a mathematical sciences major.

Grade and Course Requirements:
- All courses used to fulfill major requirements must be taken for a letter grade with the exception of courses offered satisfactory/no credit only.
- The student must have a grade point average (GPA) of 3.0 or better in all course work used to fulfill the major requirement.
- Students who earn less than a ‘C+’ in STATS 116 Theory of Probability or STATS 200 Introduction to Statistical Inference must repeat the course.
- Only one MCS core course can be substituted by filing a petition with their adviser (with the exception of STATS 200 Introduction to Statistical Inference which cannot be substituted). The Course Substitution Form (https://mcs.stanford.edu/sites/default/files/mcs-course-substitution_form_0.pdf) must be submitted the quarter prior to enrolling in the course.
- Course transfer credit is subject to department evaluation and to the Office of the Registrar’s external credit evaluation. These courses may result in a replacement course for MCS required course or may establish placement in a higher-level course. Transfer requests must first be submitted to Student Services Center prior to being evaluated by your adviser. Submit the MCS Program Transfer Credit Form (https://mcs.stanford.edu/sites/default/files/mcs_ug_course_equiv_petition_1.pdf) to the student services office.
- At least three quarters before graduation, majors must file with their adviser a plan for completing degree requirements.

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</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4</td>
<td>BIO 104</td>
<td>Advance Molecular Biology: Epigenetics and Proteostasis</td>
</tr>
<tr>
<td>3-4</td>
<td>BIO 133</td>
<td>Conservation Biology: A Latin American Perspective</td>
</tr>
<tr>
<td>3-4</td>
<td>BIO 144</td>
<td>Conservation Biology: Applied Topics</td>
</tr>
<tr>
<td>3-4</td>
<td>BIO 183</td>
<td>Computational Biology of Genomes</td>
</tr>
<tr>
<td>3-4</td>
<td>BIO 230</td>
<td>Molecular and Cellular Immunology</td>
</tr>
</tbody>
</table>

Honors students select the following three courses: 1-4

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
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</thead>
<tbody>
<tr>
<td>1-4</td>
<td>STATS 155</td>
</tr>
<tr>
<td></td>
<td>BIO 113</td>
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<td>BIO 146</td>
</tr>
</tbody>
</table>

The following courses are no longer offered, but may be used by students who completed them in fulfillment of this requirement: BIOI02, 160A & 160B

1  STATS 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.

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</th>
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</thead>
<tbody>
<tr>
<td>15</td>
<td>CME 100</td>
</tr>
<tr>
<td></td>
<td>CME 102</td>
</tr>
<tr>
<td></td>
<td>CME 104/ENGR 155B</td>
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</tbody>
</table>

STATS 116 may be replaced by:

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5</td>
<td>STATS 110</td>
</tr>
<tr>
<td></td>
<td>STATS 191/STATS 203 may be replaced by:</td>
</tr>
<tr>
<td></td>
<td>STATS 202</td>
</tr>
</tbody>
</table>

Allowable Elective Course Substitutions:
Select one of the following: 3-4

<table>
<thead>
<tr>
<th>Units</th>
<th>Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>STATS/BIO 141</td>
</tr>
<tr>
<td>9</td>
<td>Select two of the following:</td>
</tr>
<tr>
<td>3-5</td>
<td>ENGR 15</td>
</tr>
<tr>
<td></td>
<td>ENGR 20</td>
</tr>
<tr>
<td></td>
<td>ENGR 25B</td>
</tr>
</tbody>
</table>
ENGR 40
ENGR 50 Introduction to Materials Science, Nanotechnology Emphasis
ENGR 105 Feedback Control Design

1 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)

Required: Units
Additional Courses for the Statistics Track: 9
STATS 217 Introduction to Stochastic Processes I
Advanced CS, such as: 3
CS 246 Mining Massive Data Sets
Advanced MS&E, such as: 3
MS&E 220 Probabilistic Analysis
or
MS&E 223 Simulation

Allowable Elective Course Substitutions: 9
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:

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:

Select one of the following: Units
MATH 51 Linear Algebra, Multivariable Calculus, and Modern Applications 3-5
or
MATH 104 Applied Matrix Theory
Select two of the following: 10
CS 106A Programming Methodology
and either
CS 106B Programming Abstractions
or CS 106X Programming Abstractions
Select one of the following: 3-4
MS&E 211 Introduction to Optimization
or
MS&E 221 Stochastic Modeling
Select two of the following: 7
STATS 116 Theory of Probability
and either
STATS 191 Introduction to Applied Statistics

Suggested electives for students pursuing Honors: Units
CME 206 Introduction to Numerical Methods for Engineering 3
CS/STATS 229 Machine Learning 3-4
CS 248 Interactive Computer Graphics 3-4
EE 364A Convex Optimization I 3
MATH 171 Fundamental Concepts of Analysis 3
MATH 172 Lebesgue Integration and Fourier Analysis 3
MATH 205A Real Analysis 3
STATS 202 Data Mining and Analysis 3
STATS 216 Introduction to Statistical Learning 3
STATS 217 Introduction to Stochastic Processes I 3
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>Select three of the following:</th>
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<tbody>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>CME 108</td>
<td>Introduction to Scientific Computing</td>
</tr>
<tr>
<td>CS 103</td>
<td>Mathematical Foundations of Computing</td>
</tr>
<tr>
<td>CS 107</td>
<td>Computer Organization and Systems</td>
</tr>
<tr>
<td>CS 154</td>
<td>Introduction to Automata and Complexity Theory</td>
</tr>
<tr>
<td>CS 161</td>
<td>Design and Analysis of Algorithms</td>
</tr>
<tr>
<td>ECON 160</td>
<td>Game Theory and Economic Applications</td>
</tr>
<tr>
<td>EE 261</td>
<td>The Fourier Transform and Its Applications</td>
</tr>
<tr>
<td>MS&amp;E 211</td>
<td>Introduction to Optimization</td>
</tr>
<tr>
<td>MS&amp;E 212</td>
<td>Mathematical Programming and Combinatorial Optimization</td>
</tr>
<tr>
<td>MS&amp;E 221</td>
<td>Stochastic Modeling</td>
</tr>
<tr>
<td>MS&amp;E 251</td>
<td>Introduction to Stochastic Control with Applications</td>
</tr>
<tr>
<td>MATH 104</td>
<td>Applied Matrix Theory</td>
</tr>
<tr>
<td>MATH 106</td>
<td>Functions of a Complex Variable</td>
</tr>
<tr>
<td>MATH 108</td>
<td>Introduction to Combinatorics and Its Applications</td>
</tr>
<tr>
<td>MATH 109</td>
<td>Applied Group Theory</td>
</tr>
<tr>
<td>MATH 110</td>
<td>Applied Number Theory and Field Theory</td>
</tr>
<tr>
<td>MATH 115</td>
<td>Functions of a Real Variable</td>
</tr>
<tr>
<td>MATH 131P</td>
<td>Partial Differential Equations</td>
</tr>
<tr>
<td>MATH 171</td>
<td>Fundamental Concepts of Analysis</td>
</tr>
<tr>
<td>PHIL 151</td>
<td>Metalogic</td>
</tr>
<tr>
<td>STATS 191</td>
<td>Introduction to Applied Statistics</td>
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<tr>
<td>STATS 200</td>
<td>Introduction to Statistical Inference</td>
</tr>
<tr>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
</tr>
<tr>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
</tr>
<tr>
<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 &