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

The Program in Mathematical and Computational Science (MCS) offers a Bachelor of Science in Mathematical and Computational Science. Eligible students may also pursue a Bachelor of Science with Honors (p. 4). The department also offers a minor in Mathematical and Computational Science (p. 5).

Suggested Preparation for 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 the Major

To declare the major, a student should first meet with an MCS peer advisor 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. Students should have an overall grade point average (GPA) of 3.0 to declare.

Degree Requirements

• The student must have a grade point average (GPA) of 3.0 or better in all course work used to fulfill the major requirement.
• At least three quarters before graduation, majors must file with their advisor a plan for completing degree 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.
• 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 advisor (with the exception of STATS 200 Introduction to Statistical Inference which cannot be substituted). The Course Substitution Form (https://mcs.stanford.edu/sites/mcs/files/media/file/mcs-course-sub-1819.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 advisor. Submit the MCS Program Transfer Credit Form (https://mcs.stanford.edu/academicsmajor/transfer-credit-mcs-declared-students/) to the student services office.
• Students may take their three electives courses for credit (CR).
• Students may be granted a one-time exception to take a core course for credit (CR) with the exception of STATS 116 and STATS 200.
• 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/undergraduate-students/writing-major-resources/) web site for a full description of the WIM (https://undergrad.stanford.edu/programs/pwr/courses/writing-major/requirement).
# Course Requirements

<table>
<thead>
<tr>
<th>Mathematics (MATH)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-variable calculus or AP credit.</td>
<td>28</td>
</tr>
<tr>
<td>MATH 19 Calculus</td>
<td>3</td>
</tr>
<tr>
<td>MATH 20 Calculus</td>
<td>3</td>
</tr>
<tr>
<td>MATH 21 Calculus</td>
<td>4</td>
</tr>
</tbody>
</table>

Students may choose one of the following sequences:

- 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:

- MATH 104 Applied Matrix Theory
- MATH 113 Linear Algebra and Matrix Theory

## Computer Science (CS)

- CS 103 Mathematical Foundations of Computing | 5 |
- CS 106A Programming Methodology | 5 |
- and either
- CS 106B Programming Abstractions | 5 |
- or CS 106X Programming Abstractions | 5 |

Select two of the following:

- CME 108 Introduction to Scientific Computing
- CS 107 Computer Organization and Systems
- CS 154 Introduction to the Theory of Computation
- CS 161 Design and Analysis of Algorithms
- CS 181W Computers, Ethics, and Public Policy
- CS 182W Ethics, Public Policy, and Technological Change

## Management Science and Engineering (MS&E)

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

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

## Statistics (STATS)

- STATS 116 Theory of Probability | 3-4 |
- or MATH 151 Introduction to Probability Theory
- STATS 200 Introduction to Statistical Inference | 4 |

Select one of the following:

- STATS 191 Introduction to Applied Statistics | 3 |

## Writing in the Major (WIM)

- STATS 203 Introduction to Regression Models and Analysis of Variance | 3-5 |

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
- CS 182W Ethics, Public Policy, and Technological Change

- STATS 155 Modern Statistics for Modern Biology

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
- 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 101 Data Science 101
- STATS 202 Data Mining and Analysis
Mathematical and Computational Science Tracks

MCS program has designed three tracks to allow majors to pursue their interests in fields where applied mathematics and statistical analysis is utilized. Declared MCS majors are not required to choose a track. These tracks are not declared in Axess and are not printed on the transcript or diploma.

Biology Track

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

Allowable Elective Course Substitutions:

Take three courses from Foundational Biology Core:

- BIO 82 Genetics
- BIO 83 Biochemistry & Molecular Biology
- BIO 84 Physiology
- BIO 85 Evolution
- BIO 86 Cell Biology

Or take two courses from the Biology core and one of the following:

- BIO 104 Advance Molecular Biology: Epigenetics and Proteostasis
- BIO 133 (no longer offered)
- BIO 144 Conservation Biology: A Latin American Perspective
- BIO 183 Theoretical Population Genetics (offered alternate years)
- BIO 230 Honors students select the following three courses:

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

- BIO 102, 160A & 160B

Engineering Track

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>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 100</td>
<td>Vector Calculus for Engineers</td>
<td>5</td>
</tr>
<tr>
<td>CME 102</td>
<td>Ordinary Differential Equations for Engineers</td>
<td>15</td>
</tr>
</tbody>
</table>
The honors program allows for a capstone experience, building upon to allow more opportunities in course planning and concentration area. Students interested in honors should consult with their faculty advisor as soon as possible of mathematical sciences than the B.S. program. Students interested in honors work, including the courses they intend to use, by the final study list deadline two quarters prior to the expected degree conferral. The honors final report 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 major coursework.
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/).

Statistics Track

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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 217</td>
<td>9</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 MS&amp;E 223</td>
<td>Simulation</td>
</tr>
</tbody>
</table>

Allowable Elective Course Substitutions: 9

Select three of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
</tr>
<tr>
<td>STATS 206</td>
<td>Applied Multivariate Analysis</td>
</tr>
<tr>
<td>STATS 207</td>
<td>Introduction to Time Series Analysis</td>
</tr>
<tr>
<td>STATS 208</td>
<td>Bootstrap, Cross-Validation, and Sample Re-use</td>
</tr>
<tr>
<td>STATS 216</td>
<td>Introduction to Statistical Learning</td>
</tr>
<tr>
<td>STATS 219</td>
<td>Stochastic Processes</td>
</tr>
<tr>
<td>STATS 270</td>
<td>A Course in Bayesian Statistics</td>
</tr>
</tbody>
</table>

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 advisor 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/sbipyb9376/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 major coursework.
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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CME 206</td>
<td>Introduction to Numerical Methods for Engineering</td>
</tr>
<tr>
<td>CS/STATS 229</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>CS 248</td>
<td>Interactive Computer Graphics</td>
</tr>
<tr>
<td>EE 364A</td>
<td>Convex Optimization I</td>
</tr>
<tr>
<td>MATH 171</td>
<td>Fundamental Concepts of Analysis</td>
</tr>
<tr>
<td>MATH 172</td>
<td>Lebesgue Integration and Fourier Analysis</td>
</tr>
<tr>
<td>MATH 205A</td>
<td>Real Analysis</td>
</tr>
<tr>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
</tr>
<tr>
<td>STATS 216</td>
<td>Introduction to Statistical Learning</td>
</tr>
<tr>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
</tr>
</tbody>
</table>

return to top of page (p. 1)
Minor in Mathematical and Computational Science

The minor in Mathematical and Computational Science is intended to provide an experience of the four constituent areas: Mathematics, Computer Science, Management Science and Engineering, and Statistics. The minor consists of nine courses for a minimum of 32 units. A grade point average (GPA) of 2.75 is required for courses fulfilling the minor. All courses for the minor must be taken for a letter grade, if offered.

Degree Requirements

<table>
<thead>
<tr>
<th>Mathematics (MATH)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 51 - Linear Algebra, Multivariable Calculus, and Modern Applications</td>
<td>3-5</td>
</tr>
<tr>
<td>MATH 104 - Applied Matrix Theory</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computer Science (CS)</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select two of the following:</td>
<td></td>
</tr>
<tr>
<td>CS 106A - Programming Methodology</td>
<td>5</td>
</tr>
<tr>
<td>and either</td>
<td></td>
</tr>
<tr>
<td>CS 106B - Programming Abstractions</td>
<td>5</td>
</tr>
<tr>
<td>or CS 106X - Programming Abstractions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Management Science and Engineering (MS&amp;E)</th>
<th>3-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select one of the following:</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 211 - Introduction to Optimization</td>
<td></td>
</tr>
<tr>
<td>MS&amp;E 221 - Stochastic Modeling</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistics (STATS)</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select two of the following:</td>
<td></td>
</tr>
<tr>
<td>STATS 116 - Theory of Probability</td>
<td>4</td>
</tr>
<tr>
<td>and either</td>
<td></td>
</tr>
<tr>
<td>STATS 191 - Introduction to Applied Statistics</td>
<td>3-4</td>
</tr>
<tr>
<td>or STATS 200 - Introduction to Statistical Inference</td>
<td></td>
</tr>
</tbody>
</table>

| Electives | 9 |

The minor requires three courses, two of which must be in different departments.

<table>
<thead>
<tr>
<th>Course</th>
<th>Department</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 191</td>
<td>Introduction to Applied Statistics</td>
<td></td>
</tr>
<tr>
<td>STATS 200</td>
<td>Introduction to Statistical Inference</td>
<td></td>
</tr>
<tr>
<td>STATS 202</td>
<td>Data Mining and Analysis</td>
<td></td>
</tr>
<tr>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
<td></td>
</tr>
<tr>
<td>STATS 217</td>
<td>Introduction to Stochastic Processes I</td>
<td></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.

Total Units: 32-34

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" 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 MCS 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 and minor that otherwise require a letter grade.

Faculty

Director: Professor Guenther Walther

Associate Director: Professor Chiara Sabatti

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

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)
Courses
MCS 198. Practical Training. 1 Unit.
For students majoring in Mathematical and Computational Science only. Students obtain employment in a relevant industrial or research activity to enhance their professional experience. Students may enroll in Summer Quarters only and for a total of three times. Students must first notify their MCS adviser before enrolling in their course section, and must submit a one-page written final report summarizing the knowledge/experience gained upon completion of the internship in order to receive credit.