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

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 ordinarily first meet with an MCS peer adviser to create a proposed study plan and with the program director 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 may submit the plan to MCS student services and declare the major through Axess.

Course Requirements for the MCS Bachelor's Degree (78-84 units)

		Units
Mathematics (MATH)		28
Single-variable calculus or AP credit. [1]		10
MATH 19	Calculus	
MATH 20	Calculus	
MATH 21	Calculus	
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	
Computer Science (CS)		22-24
CS 103	Mathematical Foundations of Computing	5
CS 106A	Programming Methodology	5
and either		
CS 106B	Programming Abstractions	5
or CS 106X	Programming Abstractions (Accelerated)	
Select two of the following:		7-9
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	
Management Science and Engineering (MS&E)		7-11
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	Introduction to Stochastic Control with Applications	
Statistics (STATS)		11-12
STATS 116	Theory of Probability	5
STATS 200	Introduction to Statistical Inference	3
Select one of the following:		3-4
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, & 21 will be required to take additional Math classes as discussed with MCS Student Services and the student's faculty adviser.

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.

		Units
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). Adviser 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. At least one must be from following list:

		Units
Choose three courses from the following:		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	"Small" Data: Prediction, Inference, Causality	
MS&E 251	Introduction to Stochastic Control with Applications	
MS&E 334	Topics in Social Data	
MCS 100	Mathematics of Sports	
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 202	Data Mining and Analysis	
STATS 206	Applied Multivariate Analysis	
STATS 207	Introduction to Time Series Analysis	
STATS 208	Introduction to the Bootstrap	
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

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

With the adviser'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.

		Units
STATS/BIO 141	Biostatistics [1]	5
Allowable Elective Course Substitutions:		
Take three courses from Foundational Biology Core:		10
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:		3-4
BIO 104	Advance Molecular Biology: Epigenetics and Proteostasis	
BIO 133	Network analysis for community ecology and conservation research	
BIO 144	Conservation Biology: A Latin American Perspective	
BIO 183	Theoretical Population Genetics (offered alternate years)	
BIO 230	Molecular and Cellular Immunology	
Honors students select the following three courses:		1-4
STATS 155	Statistical Methods in Computational Genetics	
BIO 113	Fundamentals of Molecular Evolution	
BIO 146	Population Studies	

The following courses are no longer offered, but may be used by students who completed them in fulfillment of this requirement: BIO102, 160A & 160B

[1] 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.

		Units
With consent of an MCS adviser, MATH 51, MATH 52, MATH 53 series may be substituted for CME 100, CME 102, CME 104. Depending on the exact material taught in relevant years, an additional math course may be necessary [1]		15
CME 100	Vector Calculus for Engineers	
CME 102	Ordinary Differential Equations for Engineers	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
STATS 116 may be replaced by:		3-5
STATS 110	Statistical Methods in Engineering and the Physical Sciences	
STATS 191/STATS 203 may be replaced by:		3-4
STATS 202	Data Mining and Analysis	
Allowable Elective Course Substitutions:		9
Select one of the following:		3-4
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:		3-5
ENGR 15	Dynamics	
ENGR 20	Introduction to Chemical Engineering	
ENGR 25B	Biotechnology	
ENGR 40	Introductory Electronics	
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	
ENGR 105	Feedback Control Design	

[1] Only M&CS majors pursuing the engineering track may petition their adviser 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	Introduction to the Bootstrap	
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 adviser no later than winter quarter of their junior year to prepare their program of study. Honors work may be concentrated in fields such as biological sciences, environment, physics, etc. Students are required to submit an outline describing the concentration for honors work, including the courses they intend to use, two quarters prior to expected degree conferral. An MCS Honors Proposal Form (https://mcs.stanford.edu/sites/default/files/mcs_honors_proposal_form_2016-17_2.pdf) is due no later than the Preliminary Study List deadline of the quarter in which the degree is expected to be conferred. Additional 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 an average letter grade equivalent to at least a 3.5 in all academic work.
2. Complete at least 15 units in mathematical sciences in addition to the requirements for the major listed above. Include in these 15 units at least one of the following:
   a. An approved upper-level or graduate course
   b. Participation in a small group seminar
   c. At least 3 units of directed reading
3. Prepare a statement describing major area of concentration for honors work.
4. Describe how each course selected added to the student's knowledge and understanding in area chosen for concentration.
5. Honors statement should be submitted to the adviser by the late application deadline of the student's graduation quarter using the MCS Honors Approval form (https://mcs.stanford.edu/sites/default/files/mcs_honors_approval_form_2016-17_3.pdf).

		Units
Suggested electives for students pursuing Honors:		
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

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. Five basic courses are required:

		Units
Select one of the following:		3-5
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
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 (Accelerated)	
Select one of the following:		3-4
MS&E 211	Introduction to Optimization	
or		
MS&E 221	Stochastic Modeling	
Select two of the following:		8
STATS 116	Theory of Probability	5
and either		
STATS 191	Introduction to Applied Statistics	
or		
STATS 200	Introduction to Statistical Inference	

In addition to the above, the minor requires three courses from the following, two of which must be in different departments:

		Units
Select three of the following:		9
CME 108	Introduction to Scientific Computing	
CS 103	Mathematical Foundations of Computing	
CS 107	Computer Organization and Systems	
CS 154	Introduction to Automata and Complexity Theory	
CS 161	Design and Analysis of Algorithms	
ECON 160	Game Theory and Economic Applications	
EE 261	The Fourier Transform and Its Applications	

MS&E 211	Introduction to Optimization
MS&E 212	Mathematical Programming and Combinatorial Optimization
MS&E 221	Stochastic Modeling
MS&E 251	Introduction to Stochastic Control with Applications
MATH 104	Applied Matrix Theory
MATH 106	Functions of a Complex Variable
MATH 108	Introduction to Combinatorics and Its Applications
MATH 109	Applied Group Theory
MATH 110	Applied Number Theory and Field Theory
MATH 115	Functions of a Real Variable
MATH 131P	Partial Differential Equations
MATH 171	Fundamental Concepts of Analysis
PHIL 151	Metalogic
STATS 191	Introduction to Applied Statistics
STATS 200	Introduction to Statistical Inference
STATS 202	Data Mining and Analysis
STATS 203	Introduction to Regression Models and Analysis of Variance
STATS 217	Introduction to Stochastic Processes I

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: Bradley Efron

Faculty Advisers: Assistant Professor John Duchi, Professor Bradley Efron, Associate Professor David Rogosa, Professor Chiara Sabatti

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), Tim Roughgarden (Computer Science), Chiara Sabatti (Biomedical Data Science & Statistics), David Siegmund (Statistics), Jonathan Taylor (Statistics), Brian White (Mathematics)