APPLIED MATHEMATICS

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http://applied.math.yale.edu
M.S., M.Phil., Ph.D.

Director of Graduate Studies
Peter Jones

Professors Andrew Barron (Statistics & Data Science), Joseph Chang (Statistics & Data Science), Ronald Coifman (Mathematics; Computer Science), Stanley Eisenstat (Computer Science), John Emerson (Adjunct; Statistics & Data Science), Michael Fischer (Computer Science), Peter Jones (Mathematics), David Pollard (Statistics & Data Science), Nicholas Read (Physics; Applied Physics; Mathematics), Vladimir Rokhlin (Computer Science; Mathematics), Wilhelm Schlag (Mathematics), Martin Schultz (Emeritus, Computer Science), Mitchell Smooke (Mechanical Engineering & Materials Science; Applied Physics), Daniel Spielman (Computer Science; Mathematics), Van Vu (Mathematics), Günter Wagner (Ecology & Evolutionary Biology), John Wettlaufer (Geology & Geophysics; Mathematics; Physics), Huibin Zhou (Statistics & Data Science), Steven Zucker (Computer Science; Biomedical Engineering)

Associate Professors Thierry Emonet (Molecular, Cellular, & Developmental Biology; Physics), Josephine Hoh (Public Health), Yuval Kluger (Pathology), Michael Krauthammer (Pathology), Sekhar Tatikonda (Statistics & Data Science)

Assistant Professors Jeremy Hoskins, Ariel Jaffe, Gal Mishne, Krill Serkah, Gil Shabat

FIELDS OF STUDY
The graduate Program in Applied Mathematics comprises the study and application of mathematics to problems motivated by a wide range of application domains. Areas of concentration include the analysis of data in very high-dimensional spaces, the geometry of information, computational biology, and randomized algorithms. Topics covered by the program include classical and modern applied harmonic analysis, linear and nonlinear partial differential equations, numerical analysis, scientific computing and applications, discrete algorithms, combinatorics and combinatorial optimization, graph algorithms, geometric algorithms, discrete mathematics and applications, cryptography, statistical theory and applications, probability theory and applications, information theory, econometrics, financial mathematics, statistical computing, and applications of mathematical and computational techniques to fluid mechanics, combustion, and other scientific and engineering problems.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE
All students are required to: (1) complete twelve term courses (including reading courses) at the graduate level, at least two with Honors grades; (2) pass a qualifying examination on their general applied mathematical knowledge (in algebra, analysis, and probability and statistics) by the end of their second year; (3) submit a dissertation prospectus; (4) participate in the instruction of undergraduates; (5) be in residence for at least three years; and (6) complete a dissertation that clearly advances understanding of the subject it considers. Prior to registering for a second year of study, and in addition to all other academic requirements, students must successfully complete MATH 991, Ethical Conduct of Research, or another approved course on responsible conduct in research. Teaching is considered an integral part of training at Yale University, so all students are expected to complete two terms of teaching within their first two years. The normal time for completion of the Ph.D. program is four years.

Requirement (1) normally includes four core courses in each of the methods of applied analysis, numerical computation, algorithms, and probability; these should be taken during the first year. The qualifying examination is normally taken by the end of the third term and will test knowledge of the core courses as well as more specialized topics. The thesis is expected to be independent work, done under the guidance of an adviser. This adviser should be contacted not long after the student passes the qualifying examinations. A student is admitted to candidacy after completing requirements (1)–(5) and obtaining an adviser.

In addition to the above, all first-year students (including terminal M.S. students) must successfully complete one course on the responsible conduct of research (e.g., MATH 991 or CPSC 991) and AMTH 525, Seminar in Applied Mathematics.

HONORS REQUIREMENT
Students must meet the Graduate School's Honors requirement by the end of the fourth term of full-time study.

M.D./PH.D. STUDENTS
With permission of the DGS, M.D./Ph.D. students may request a reduction in the program's academic teaching requirement to one term of teaching. Only students who teach are eligible to receive a University stipend contingent on teaching.

MASTER’S DEGREES
M. Phil. See Degree Requirements under Policies and Regulations.

M.S. (en route to the Ph.D.) Applications for a terminal master’s degree are not accepted. Students who withdraw from the Ph.D. program may be eligible for the M.S. degree if they have completed ten graduate-level term courses, maintained a High Pass average, and
met the Graduate School's Honors requirement for the Ph.D. program. Students who are eligible for or who have already received the M.Phil. will not be awarded the M.S.

More information is available on the program's website, http://applied.math.yale.edu.

**COURSES**

**AMTH 525a or b, Seminar in Applied Mathematics**  Peter Jones  
This course consists of weekly seminar talks given by a wide range of speakers. Required of all first-year students.

**AMTH 663b / CPSC 663b, Deep Learning Theory and Applications**  Smita Krishnaswamy  
Deep neural networks have gained immense popularity in the past decade due to their outstanding success in many important machine-learning tasks such as image recognition, speech recognition, and natural language processing. This course provides a principled and hands-on approach to deep learning with neural networks. Students master the principles and practices underlying neural networks, including modern methods of deep learning, and apply deep learning methods to real-world problems including image recognition, natural language processing, and biomedical applications. Course work includes homework and a final project—either group or individual, depending on the total number enrolled—with both a written and oral (i.e., presentation) component.

**AMTH 667b / CPSC 576b / ENAS 576b, Advanced Computational Vision**  Steven Zucker  
Advanced view of vision from a mathematical, computational, and neurophysiological perspective. Emphasis on differential geometry, machine learning, visual psychophysics, and advanced neurophysiology. Topics include perceptual organization, shading, color, and texture.

**AMTH 745b / CB&B 745b / CPSC 745b, Advanced Topics in Machine Learning and Data Mining**  Smita Krishnaswamy and Guy Wolf  
An overview of advances in the past decade in machine learning and automatic data-mining approaches for dealing with the broad scope of modern data-analysis challenges, including deep learning, kernel methods, dictionary learning, and bag of words/features. This year, the focus is on a broad scope of biomedical data-analysis tasks, such as single-cell RNA sequencing, single-cell signaling and proteomic analysis, health care assessment, and medical diagnosis and treatment recommendations. The seminar is based on student presentations and discussions of recent prominent publications from leading journals and conferences in the field. Prerequisite: basic concepts in data analysis (e.g., CPSC 545 or 563) or permission of the instructor.

**AMTH 765b / CB&B 562b / ENAS 561b / INP 562b / MB&B 562b / MCDB 562b / PHYS 562b, Dynamical Systems in Biology**  Thierry Emonet and Jonathon Howard  
This course covers advanced topics in computational biology. How do cells compute, how do they count and tell time, how do they oscillate and generate spatial patterns? Topics include time-dependent dynamics in regulatory, signal-transduction, and neuronal networks; fluctuations, growth, and form; mechanics of cell shape and motion; spatially heterogeneous processes; diffusion. This year, the course spends roughly half its time on mechanical systems at the cellular and tissue level, and half on models of neurons and neural systems in computational neuroscience. Prerequisite: MCDB 561 or equivalent, or a 200-level biology course, or permission of the instructor.