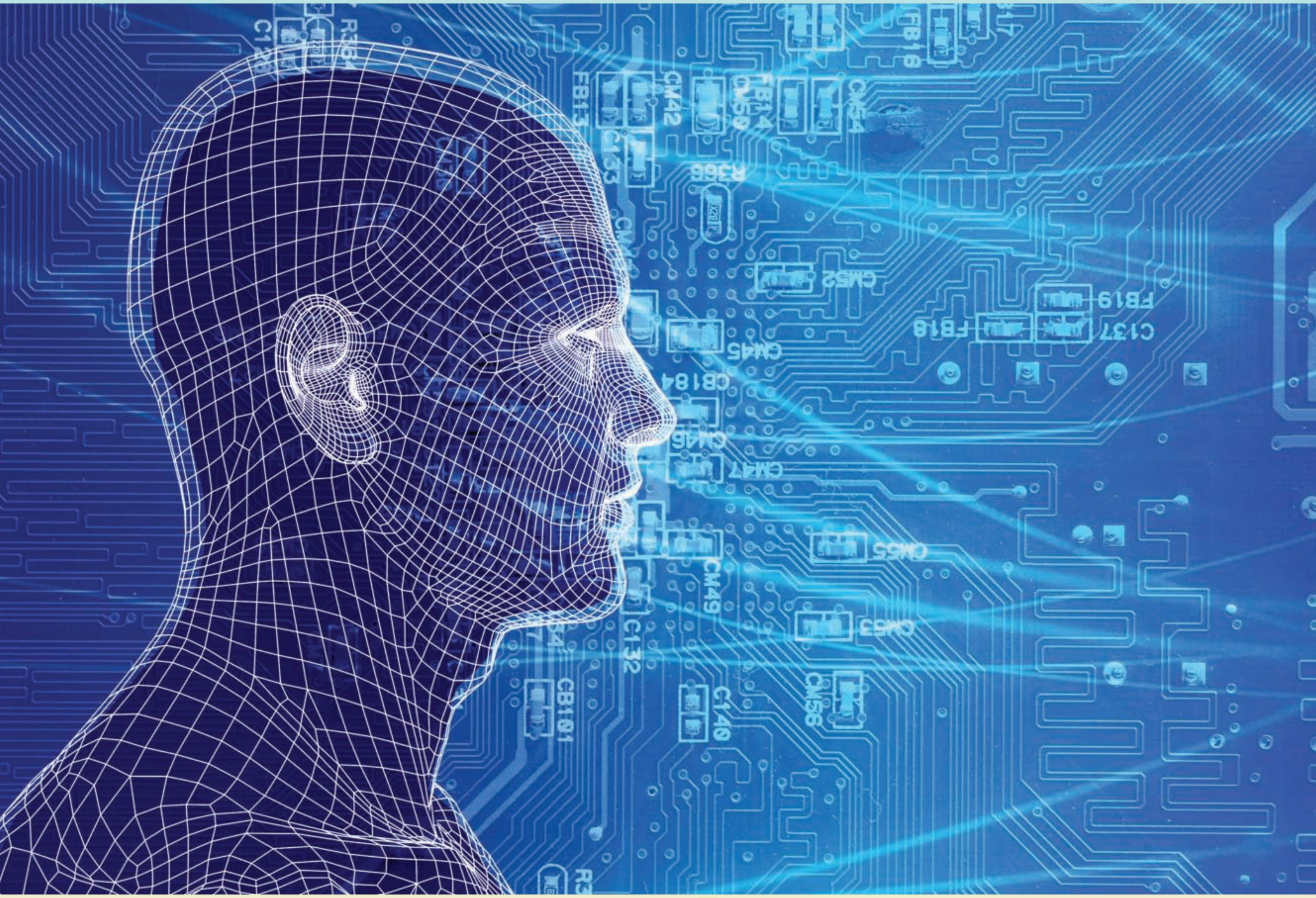
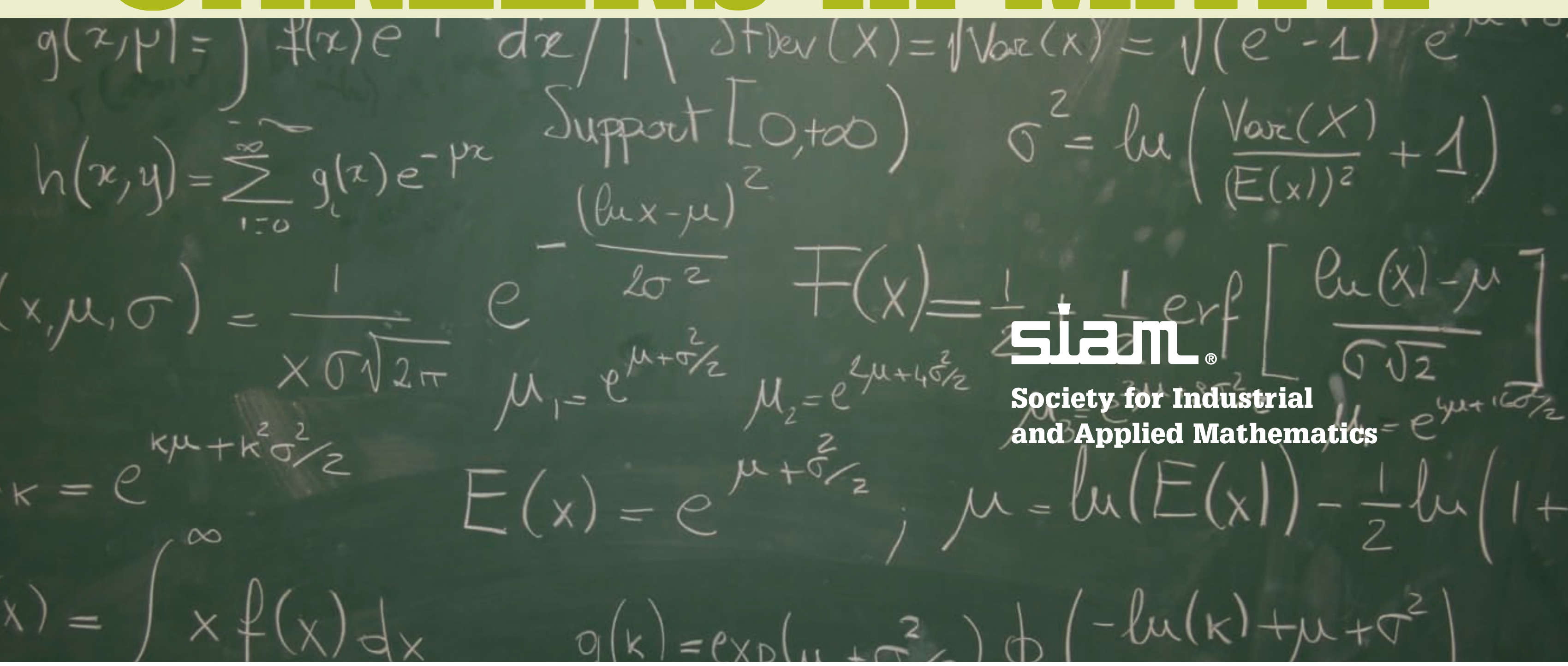
Science and Industry Advance with Mathematics



CAREERS in MATH



SIAM
Society for Industrial and Applied Mathematics

"There is no branch of mathematics, however abstract, which may not some day be applied to phenomena of the real world."

— Nikolai Lobachevsky
From N. Rose, *Mathematical Maxims and Minims*, Raleigh NC, Rome Press Inc., 1988.

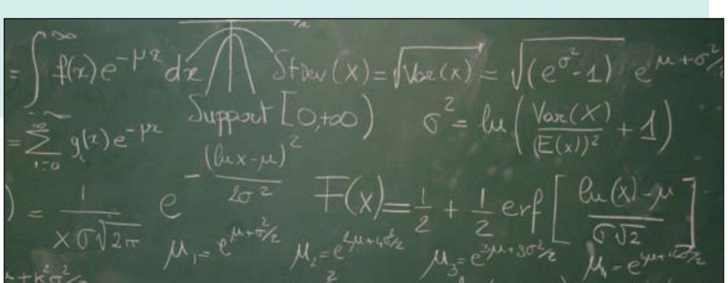
A surprising variety of career opportunities are open to people with mathematical talent and training — mathematics and computational science are utilized in almost every discipline of science, engineering, industry, and technology. New application areas are discovered constantly and older techniques are applied in new ways and in emerging fields. Industry relies on applied mathematics and computational science for the design and optimization of products such as aircraft, automobiles, textiles, computers, communication systems, and prescription drugs; processes such as supply chains, logistics, and scheduling; and a wide range of other products and services.

Applied mathematics and computational science have become essential tools in the development of advances in science and technology. Innovative mathematical and computational techniques have become prevalent in areas such as the biological sciences, information technology, climatology, combustion and emission control, and finance and investment.

Mathematical careers outside of academia rarely carry a simple title of "mathematician." The very idea of a career in mathematics has evolved and diversified and is often coupled with a specialty or area of research interest. Applied mathematicians and computational scientists working in industry, business, and government often hold jobs with titles such as statistician, scientific programmer, electrical engineer, computer scientist, operations researcher, systems engineer, analyst, research associate, or technical consultant.

Mathematics is involved in more fields than you may have thought possible and there are many options to consider when choosing a career. Applied mathematicians and computational scientists work for federal and state governments, the military, financial services, scientific research and development services, and consulting services specializing in management, science, and technology. Software publishers, insurance companies, aerospace, pharmaceutical, and other manufacturing companies also employ applied mathematicians and computational scientists. Many also work in academia, teaching the next generation and developing innovations through their own research.

In this guide, you will find answers to many of your questions about careers in applied mathematics and computational science, such as: What's out there for someone with my interests and background? Where can I work? Where are the up-and-coming job opportunities? How should I pursue my studies? Who are the people working in industry today?



What kind of problems can I solve?

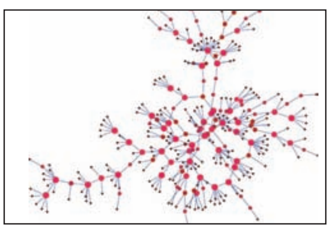
The careers may differ, but one thing remains constant—problem solving. Listed below are some examples of problems that someone with mathematical training might be asked to solve. It may be useful to note which problems you find most intriguing, and why. Examples of organizations doing each type of work are also given.

- How can an airline use smarter scheduling to reduce costs of aircraft parking and engine maintenance?
  American Airlines; IBM Research
- How can a detailed plan for a clinical trial be designed?
  Boston Scientific; Medtronic; Wyeth; Pfizer

- Is the replacement of gasoline with ethanol a viable solution to the world's dependence on fossil fuels? Can biofuel production be optimized to combat negative implications on the worlds' economy and environment?
  U.S. government agencies and labs; Amoco Exxon Research and Engineering; Petrobras
- How might the U.S. Social Security system be changed to guarantee the integrity of the system's future?
  U.S. Social Security Administration
- How can automotive systems become more efficient and reduce emissions as mandated by U.S. public policy?
  Ford Motor Company; General Motors

- How can the current uncertainty of nuclear stockpile stewardship and management be estimated for optimum efficiency and safety?
  U.S. government agencies and labs; Lockheed-Martin Energy Research Corporation; Schatz Energy Research Center (SERC)

- How can climate modeling at the global, regional, and local levels reduce uncertainties regarding long-term climate change, provide input for the formulation of energy and environmental policy, and abate the impact of violent storms?
  U.S. government agencies and labs such as the National Oceanic and Atmospheric Administration (NOAA)
- How can automotive and aircraft companies test performance, safety, and ergonomics, while at the same time lowering the cost of construction and prototype testing?
  The Aerospace Corporation; Lockheed Martin; Boeing; General Motors; Ford Motor Co.
- A pharmaceutical company wants to search a very large database of proteins to find one that is similar in shape or activity to one they have discovered. What's the most efficient way to do this?
  GlasoSmithKline; Merck & Co., Inc

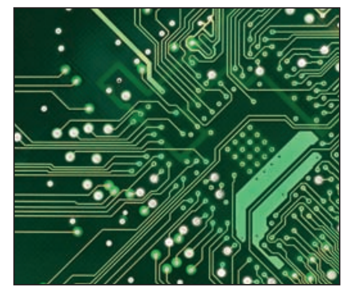


- How might disease spread in populated areas in the event of a bioterrorism incident?
  U.S. government agencies and labs; U.S. Department of Homeland Security
- How do you cram enough data through a high-bandwidth communications network to deliver large data sets reliably?
  Clear Channel Communications; Qwest Communications; Verizon
- When we pick up a quarter our brain sends complicated signals to our nerves and muscles. How do you design a mechanical hand to grip a coin and drop it in a slot?
  Shadow Robot Company; iRobot Corporation

Remember:

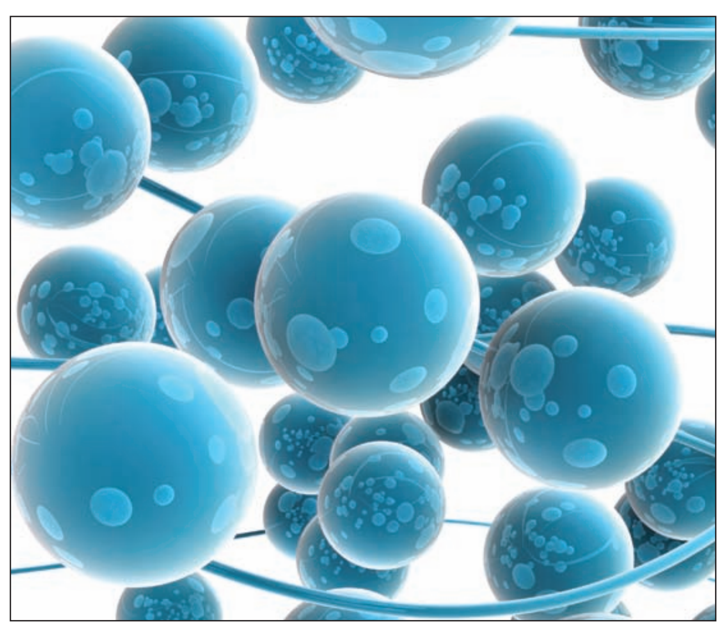
Mathematical and computational talent is a huge career asset that sets you apart and opens doors.

- How can you mathematically model the spread of a forest fire depending on weather, ground cover, and types of trees?
  Fire departments; U.S. government agencies such as the National Oceanic and Atmospheric Administration (NOAA)
- How can you allocate an investment among various financial instruments to meet a risk/reward tradeoff?
  Citibank; Moody's Corporation; Prudential
- Computer chips are "printed," much like photographs, from a negative, but manufacturing the "negative" is too expensive to permit cut-and-dry testing of proposed layouts and the corresponding "print." Are there accurate mathematical models of the exposure process? Can they be coupled with efficient computational implementations to obtain practical, low-cost simulations to guide chip design and manufacture?
  Bell Laboratories, Alcatel-Lucent; Hewlett-Packard; Honeywell; IBM Corp.; Motorola; Philips Research; SGI



- A chemical manufacturer must shift one of its product lines to a new family of compounds that will not harm the ozone layer. Can computational simulations show sufficient detail to capture the effects of the chemicals, but still be fast enough to permit studies of many different chemicals?
  U.S. government agencies and labs; DuPont; Kodak

These are just a small sample of the types of problems mathematicians and computational scientists might work on. As you consider your career options, think how you might parlay your talent into a field that interests you.



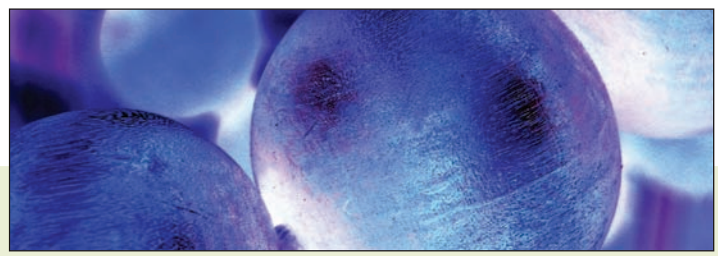
Part of the preparation for your future is obtaining a solid foundation in mathematical and computational knowledge — tools like differential equations, probability, combinatorics, applied algebra, and matrices, as well as central skills like the art of abstraction, communicating, and being able to do advanced computing and programming. Preparation for a career in applied mathematics and computational science also involves being able to apply this knowledge to real-life problems. With preparation in mathematics or computational science and a background in another field, you can enjoy the dual reward of utilizing your skills and achieving practical results. The next question is:

Where can I work?

Many different types of organizations, from governmental research organizations to independent consultants, hire mathematicians and computational scientists. Experience gained through internships and work-study opportunities can help you determine your personal preferences in a workplace, such as an organization's size, whether you prefer working for a non-profit or for-profit company, whether you prefer to work independently or on a team, and how much customer contact you prefer to have. You can easily search the websites of organizations and corporations that interest you to learn more about their locations, mission statements, objectives, history, and job requirements.

Here are some examples of organizations, corporations, and research institutions that hire mathematicians and computational scientists:

- Aerospace and transportation equipment manufacturers such as The Aerospace Corporation; Boeing; Ford Motor Co.; General Motors; Lockheed Martin; and United Technologies.
- Chemical and pharmaceutical manufacturers such as DuPont; GlaxoSmithKline; Kodak; Merck & Co., Inc.; Pfizer; and Wyeth.
- Communications service providers such as Clear Channel Communications; Qwest Communications; and Verizon.
- Computer service and software firms such as Adobe; Google, Inc.; Kuberre Systems; The MathWorks, Inc.; Mentor Graphics; Microsoft Research; Mosek; MSC Software Corporation; Palo Alto Research Center; ThomsonWest; and Yahoo Research.
- Consulting firms such as Daniel H. Wagner Associates and McKinsey & Company.
- Electronics and computer manufacturers such as Bell Laboratories, Alcatel-Lucent; Hewlett-Packard; Honeywell; IBM Corporation; Motorola; Philips Research; and SGI.
- Energy systems firms such as Lockheed-Martin Energy Research Corporation and the Schatz Energy Research Center (SERC).
- Engineering research organizations such as AT&T Laboratories – Research; Exxon Research and Engineering; NEC Laboratories America, Inc.; Schlumberger-Doll Research; and Telcordia Technologies.
- Federally funded contractors such as the Mitre Corporation and RAND.
- Financial service and investment management firms such as Citibank; Moody's Corporation; Morgan Stanley; and Prudential.
- International government agencies such as the Defence Science and Technology Organisation, DSTO (Australia); French Atomic Energy Commission, CEA/DAM; and National Research Council Canada.
- Medical device companies such as Baxter Healthcare; Boston Scientific; and Medtronic.
- Nonprofit organizations such as the American Institute of Mathematics (AIM) and SIAM.
- Producers of petroleum and petroleum products such as Amoco; Exxon Research and Engineering; and Petróleo Brasileiro S/A, Petrobras.
- Publishers such as Birkhauser and Springer.
- University-based research organizations such as the Institute for Advanced Study; the Institute for Mathematics and Its Applications (IMA); and the Mathematical Sciences Research Institute (MSRI).
- U.S. government agencies such as the Institute for Defense Analyses (IDA); NASA's Institute for Computer Applications in Science and Engineering; National Institute of Standards and Technology (NIST); National Security Agency (DIRSNA); Naval Surface Warfare Center, Dahlgren Division; Supercomputing Research Center; and the U.S. Department of Energy.
- U.S. government labs and research offices such as the Air Force Office of Scientific Research; Lawrence Berkeley National Laboratory; Los Alamos National Laboratory; Oak Ridge National Laboratory; Pacific Northwest National Laboratory; and Sandia National Laboratories.



What's out there for someone with my talent, interests, and background?

…Emerging fields to consider

Bioinformatics

A career in bioinformatics (computational biology) can include a wide range of biological fields from genomics to neuroscience and anywhere in between. For example, mapping and understanding the human genome relies on the use of sophisticated mathematical and computational tools. Although human and other genome projects are essentially complete, there are numerous others still left to sequence. Other research challenges include understanding how genes interact, how they are switched on or off, and how they differ from one individual to another.

Research in neuroscience ranges from the operation of single neurons to the dynamics of small circuits and the cooperative action of whole populations of cells. Current and future work will involve mathematics and computational research in neurological processes such as vision, learning, and decision-making, as well as in emerging treatments for neurological disorders such as Parkinson's disease.

There is a great need for newer and better mathematical and computational tools to make research quicker and cheaper, resulting in the creation of new career opportunities in technology, medicine, and drug development and design.

Data Mining

Data mining is a broad mathematical area with many applications. It involves the discovery of patterns and previously unknown information in large data sets. Emerging career opportunities can be found in applications of data mining in fields such as security, forensics, e-commerce, bioinformatics and genomics, astrophysics, medicine, and chemical and electric power engineering.

Materials Science

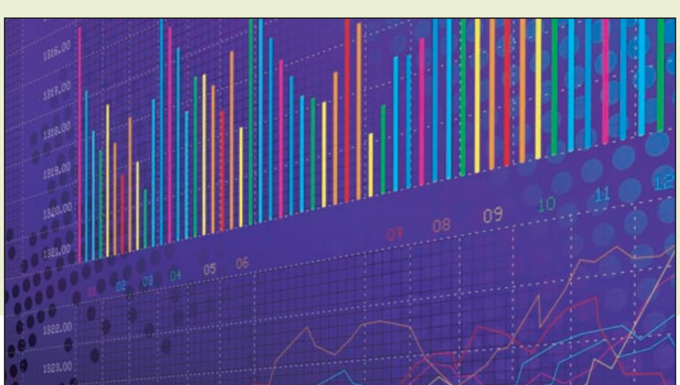
Materials science is the study of the properties, processing, and production of a broad range of existing and new materials, including metallic alloys, composites, liquid crystals, biological materials, and thin films. The rational design and analysis of materials depends on mathematical models and computational tools. Career opportunities abound in science, manufacturing, and materials design for applications in fields such as aerospace, engineering, electronics, biology, and nanotechnology.

Computer Animation and Digital Imaging

To get an idea of what this field entails, consider the following description from the Fields Institute in Toronto: "Computer animation is an eclectic science that uniquely combines mathematics, computer science, fine art, classical animation, physics, biomechanics, and anatomy, to name but a few fields. Algorithms for computer animation rely heavily on techniques from scientific computation, statistics, signal processing, linear algebra, control theory, and computational geometry." With a diverse and exciting set of applications in areas such as medical diagnostics, entertainment (film, television, and video games), and fine arts (dancing, sculpture, painting), there are many avenues and career opportunities to explore.

Finance and Economics

Financial mathematics is the development of mathematical tools and computational models used in the financial industry. As new quantitative techniques have transformed the financial industry, banks, insurance companies, investment and securities firms, energy companies and utilities, multinationals, government regulatory institutions, and other industries have come to rely on applied mathematics and computational science. Sophisticated math models and the computational methods and skills needed to implement them are used to support investment decisions, to develop and price new securities, to manage risk, and for portfolio selection, management, and optimization. For example, modern hedge funds depend on these sophisticated techniques as do pricing of bonds and commodity futures.

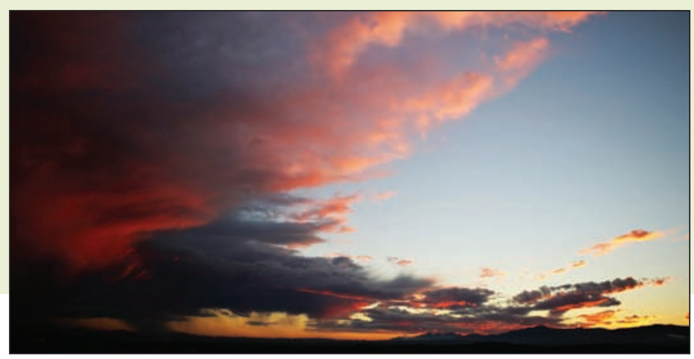


Ecology, Epidemiology, and Environmental Issues

Professionals in these fields might look at populations and their interactions and use systems of differential equations to model diseases in human populations (i.e. the spread of infection under various immunization protocols). Other applications in these fields include the management of ocean fisheries and the study of insect population growth, spread, and reaction to insecticides (ex: flea beetles in a collard patch).

Climatology

Climatology depends on simulating the component forces that drive the climate, for example, ocean circulation and heat exchange between land, air, and ocean. It requires very sophisticated models based on physical principles, expressed as complex partial differential equations. These are implemented in very large-scale numerical codes on high-performance computers, and use data from observations of satellites, ocean buoys, and other monitoring equipment to drive the solutions. Typically, these rely on input from researchers in academia. Teams of workers at institutions such as the Department of Energy National Laboratories, NASA, and the National Oceanic and Atmospheric Administration (NOAA) develop the computational codes.



How do I get there?

A wide range of possibilities are available to individuals studying applied mathematics or computational science. But how do you find them? To start, here is a sampling of degree programs in the mathematical sciences and academic disciplines requiring mathematical and computational skills:

Mathematical/Computational Science Disciplines

- Applied and Experimental Statistics
- Applied, Natural, and Mathematical Sciences
- Bioinformatics/Computational Biology
- Computational Mathematics/Science
- Computer and Information Sciences
- Computer Science
- Financial Mathematics
- Operations Research
- Mathematics and Applied Mathematics
- Statistical and Actuarial Sciences

Other Academic Disciplines

- Aerospace Engineering and Engineering Mechanics
- Atmospherics, Space, and Planetary Science
- Bioengineering, Biomedical Engineering, and Biotechnologies
- Biostatistics
- Business and Management Sciences
- Cell Biology, Biophysics, Microbiology, Molecular Biology, Biochemistry, and Genetics
- Chemistry and Chemical Engineering
- Civil and Environmental Engineering
- Earth and Environmental Sciences
- Ecology and Evolutionary Biology
- Electrical Engineering
- Epidemiology and Public Health
- Financial Engineering
- Geosciences/Geology
- Industrial Engineering
- Materials Science
- Mechanical Engineering
- Neuroscience
- Nuclear Science and Engineering
- Petroleum Engineering
- Physics and Mathematical Physics
- Software Engineering
- Systems Engineering
- Theoretical and Applied Mechanics

Universities make up a small portion of the potential co-op and post-grad employers in the applied sciences. "Recently, we've seen increased recruiting efforts by government agencies and a variety of scientific positions available from pharmaceutical companies and larger national and multi-national employers," Kohen said.

"Remember, your university's career center is there to make sure its students are well-equipped when making the transition from school to career, and to make that transition as smooth as possible."

"Whatever you decide to do, make sure it is something you like! Also, a friend says he always tries to work with people who are smarter than him so that he will get smarter in turn. Look into how to network with people in your field or interest area, especially through professional societies."

— Barbara Hamilton, Manager, Information Support Services, Institute for Defense Analyses, Center for Communications Research Division, Princeton

Experiment with internships, summer jobs, and work-study

What better way to determine the range of opportunities and explore possible areas of interest than to actually be in the workplace? Internships and work-study opportunities are a great way to start on your career path by allowing you to get a realistic feel for the field in which you are interested. Most importantly, internships provide opportunities to network and forge connections for future job possibilities. Many internships turn into permanent positions, and even if they don't, the experience will broaden your perspective and help narrow your career search. Check with your university's career center and online job portals for internships in your area(s) of interest.

The National Science Foundation and other groups offer programs such as Research Experiences for Undergraduates (REUs) that support active research participation by undergraduate students in many areas. According to the NSF, these projects involve students in meaningful ways in ongoing research programs or in research projects specifically designed for the REU program. A directory of active NSF REU sites and contact information can be found at ***www.nsf.gov/crssprgm/reu/reu_search.cfm.***

How do I find career opportunities?

Your school's career center can help you find a job in your area of interest. At the very least, services such as career assessments can help you narrow your search to suit your personality and interests. There are many resources available through a career services venue such as résumé help, interview preparation, and job opening announcements.

Arnie Kohen is a career counselor at Drexel University's Steinbright Career Development Center, which provides an interesting set of services for students – services that are not always utilized. "I help students with a career assessment through the administration of personality and interest inventories," said Kohen. "Interpretations are individualized and are gratis to the student. These assessments and subsequent interpretation with a career counselor will enable a student to identify and clarify their career motivators and satisfiers, and compare them to the elements of an academic program, major, or potential employer. Students can also learn about other available career center and university services, which will help them determine their field of interest."

"The career center has several events throughout the year where students can make contacts and network with employers: they can receive résumé critiques; go to job and career fairs; participate in on-campus recruiting; and attend various networking functions and information sessions," Kohen added. "If a student doesn't take advantage of these services, they are probably missing out on understanding the current job market."

James Osse, a University of Washington field engineer, skims ice from the surface of a hole used to retrieve a deep-sea mooring at the National Science Foundation's North Pole Environmental Observatory.

Photo courtesy of Peter West National Science Foundation

Do your research

There is an incredible amount of information available on the Internet, in libraries, and in bookstores. This may sound like simple advice, but while you are obtaining your degree, be aware of the career options that correspond to your studies. Too often, students emerge from college without a point of reference or direction. Check out the career and job resources on the SIAM website at ***www.siam.org/careers***, especially the SIAM Job Board, internship opportunities, and career websites of SIAM corporate members and sponsors. Search for career opportunities, explore job descriptions for keywords to do more extensive searches, and get acquainted with the many types of opportunities available.

Network

Join a professional organization (see suggestions below). Attend conferences, symposia, lectures, and meetings to connect with other individuals in your field.

SIAM conferences provide venues for networking with mathematicians and computational scientists working in industry, and hearing about their work. Published research articles are also a window to the research and activities that take place within an industrial organization.

Where can I find more information?

Check out the information listed below for sample resources, opportunities, and career options in the mathematical sciences.

Professional Societies

American Chemical Society..www.acs.org

American Geophysical Union......................................www.agu.org

American Institute of Aeronautics and Astronautics ..www.aiaa.org

American Mathematical Society ....www.ams.org

American Physical Society ....www.aps.org

American Society for Microbiology ....www.asm.org

American Society of Civil Engineers ....www.asce.org

American Society of Mechanical Engineers ....www.asme.org

American Statistical Association ....www.amstat.org

Association for Computing Machinery ....www.acm.org

Association for Women in Mathematics ....www.awm-math.org

Institute for Operations Research and the Management Sciences...www.informs.org

Institute of Electrical and Electronics Engineers..........www.ieee.org

Mathematical Association of America.......................www.maa.org

Materials Research Society...www.mrs.org

Society of Automotive Engineers ....www.sae.org

Society for Industrial and Applied Mathematics ....www.siam.org

Society for Mathematical Biology ....www.smb.org

Society for Neuroscience..www.sfn.org

SPIE, The International Society for Optical Engineering ....http://spie.org

Books

101 Careers in Mathematics, Second Edition
Andrew Sterrett, Editor; Mathematical Association of America, 2003

A Mathematician's Survival Guide: Graduate School and Early Career Development
Steven G. Krantz; American Mathematical Society, 2003

Careers for Number Crunchers & Other Quantitative Types, Second Edition
Rebecca Burnett; McGraw-Hill, 2002

Great Jobs for Math Majors, Second Edition
Stephen Lambert & Ruth DeCotis; McGraw-Hill, 2005

Secrets to Success in Industry Careers: Essential Skills for Science and Business
L. Borbye; Academic Press, 2007

She Does Math: Real-Life Problems from Women on the Job
Marla Parker, Editor; Mathematical Association of America, 1995

Websites

Art of Problem Solving
www.artofproblemsolving.com
Includes forums, free online classes, games, and resources for the young mathematician.

Careers in Mathematics
www.msri.org/ext/CareersInMathematics.html
Explore the career paths of people with degrees in mathematics working in industry, business, and government.

The Math Forum @ Drexel
http://mathforum.org
A leading online resource for improving math learning, teaching, and communication, includes forums, problems, puzzles, and other resources for mathematicians, teachers, researchers, students, and parents.

MentorNet
www.mentornet.net
A mentoring network, particularly for women and minorities in science and engineering.

PhDs.org
www.PhDs.org
A website created to help students prepare for the challenging demands of today's job market and provide a voice for early career scientists. Includes career resources for mathematicians, engineers, and scientists at all levels, from undergraduates to Ph.D.s and beyond.

Sloan Career Cornerstone Series
www.careercornerstone.org/math/math.htm
SIAM, MAA, and AMS contributed resources to the Alfred P. Sloan Foundation to develop the pages of this site on how business, industry, and government use mathematical expertise.

Young Mathematician's Network
www.youngmath.net
Includes numerous forums to serve the community of young mathematicians including discussions on paths to math, job searches, careers, undergrad life, graduate life, work and family life, research, and teaching.

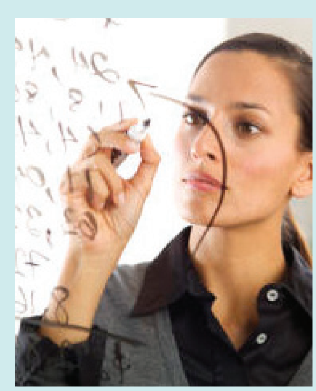


Image courtesy of Sloan Career Cornerstone Center

Profiles of Professional Mathematicians

Dimitris Agrafiotis

Vice President of Informatics

Johnson & Johnson Pharmaceutical Research & Development
Exton, PA

Adjunct Professor of Informatics
Indiana University School of Informatics, Bloomington

B.S. chemistry, University of Patras, Greece
Ph.D. theoretical organic chemistry, Imperial College, University of London

Background

I pursued computational chemistry as a graduate topic based on my undergraduate advisor's recommendation, but the turning point was my postdoctoral tenure at Harvard, where I was introduced to the beauty of expert systems, computer programming, and algorithm and software development. I converged on informatics and software development because I found them extremely fulfilling. It was the practical use of computers and modeling that ultimately defined my career; I pursued an industrial career because several opportunities presented themselves.

To get to where I am today, I developed many innovative algorithmic methods and published extensively. Most importantly, I embedded these algorithms into software that appealed to end users, who were not computationally inclined.

Job Characteristics

In my position, I develop algorithms and visualization techniques for analyzing and mining large data sets, with special emphasis on chemo- and bio-informatics. During a typical day, there are a lot of management duties and relentless email. The best parts of my job are algorithm development, software engineering, and working on projects that have real impact. My least favorite parts are the administrative duties that come with a managerial position. My work schedule consists of 40 hours per week in theory, 70 in practice; I never leave my job.

I believe the future of math in the pharmaceutical industry will involve mining of large data and heterogeneous sets and information integration. Someone looking to get involved in this field should expect to do algorithm and software development as it applies to drug discovery projects.

I am very happy with my career. I have managed to do the things I enjoy and make an impact within my organization and the broader scientific community. Balancing utility with innovation has been the key.

Salary Range

Salaries vary greatly. For Ph.D.-level positions, it could range from $80,000 to over $200,000 for managerial positions.

"There are so many learning opportunities for students in engineering, science, and mathematics. I would recommend that students seek out those opportunities and apply for every one. For example, summer internship programs. The Navy has an internship program that generally gets few applicants who are math majors."

— Kimberly Drake, Naval Surface Warfare Center, Carderock Division

Kimberly J. Drake

Mathematician

Naval Surface Warfare Center, Carderock Division
Machinery Research and Silencing Division
Philadelphia, PA

B.S. mathematics and computer science (double major with a teaching certificate), Montclair State University, NJ
M.S. mathematics, North Carolina State University
Ph.D. applied mathematics, concentration in computational science, North Carolina State University

Background

During college, I participated in a semester-long internship at the Lawrence Livermore National Laboratory (LLNL) sponsored by the Department of Energy. The intern program was extremely well-run and students were exposed to all kinds of science and technology in the northern California area. I was exposed to world-class scientists who were using their scientific skills to solve problems that could really impact people's lives. By the time I left LLNL, my career plans had changed: I'd planned on studying pure math as a graduate student and then teaching, but after my time there, I decided to pursue a career in applied math instead.

Job Characteristics

I develop algorithms and technologies to solve problems related to diagnostics and prognostics on machinery systems typically used by the Navy. Much of the work that I do on a daily basis relates to using computers to solve problems. Once we develop or find an interesting algorithm for solving problems, we have to actually implement and test the algorithm. This usually involves running experiments and analyzing the results. I also have a small test project, where we are implementing algorithms that have already been developed on real machinery systems to evaluate their usefulness to the Navy. Finally, I'm building a video and image processing laboratory, which will have the 12 different varieties of video cameras used by the Navy. We will have state of the art computing power and will be working on the development and implementation of video and image processing technologies of interest to the Navy.

People working in these areas should expect to work in interdisciplinary groups. While my work is mathematical, I work with engineers, chemists, and physicists to solve problems. There are many opportunities for mathematicians in our area. Mathematical modeling is an area that the Navy invests more time, energy, and money in every year.

Salary Range

Salaries range from $70,000 to $150,000 or more for starting, mid-level, and senior positions. It really depends on education level, length of service, and location.

Anshul Gupta

Research Staff Member

Mathematical Sciences Department
IBM T. J. Watson Research Center
Yorktown Heights, NY

Bachelor of Technology (B.Tech), computer science,
Indian Institute of Technology, New Delhi
Ph.D. computer science, University of Minnesota

Background

I did not start out with a major in mathematics; instead, my background is in computer science. During my undergraduate years, parallel computing (using several processors simultaneously to run a large computer program faster) was an emerging and exciting new area of computer science. In graduate school, I learned that some of the most challenging problems requiring parallel computing are numerical in nature. I therefore focused my attention on applying parallel computing to numerical problems.

Job Characteristics

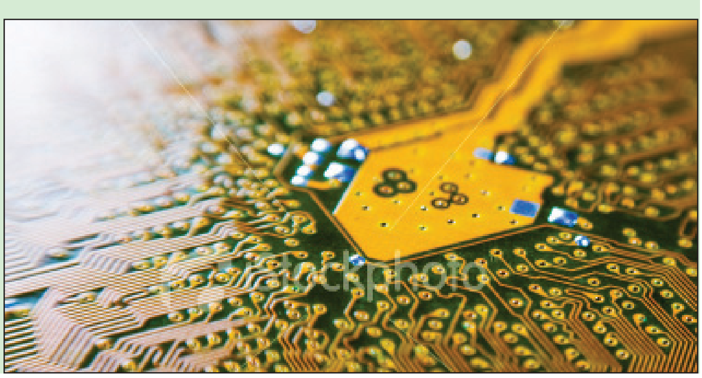
I do basic research and develop algorithms and software to solve problems in science, engineering, and optimization. Many of these problems involve simulating a physical system using a computer program, where real-world experiments might be too costly or impractical. For example, with the help of software, an automobile company can simulate a large number of crash scenarios to improve the safety of a vehicle. Real crash tests may be expensive and not accurate enough. These problems are usually so complex that they are often solved either on clusters of several computers or on supercomputers containing several processors. The algorithms and software that I develop help solve some of the underlying mathematical equations involved in these simulations efficiently on a large number of processors.

The stress level and the number of hours worked fluctuate a lot; however, a typical research career affords a lot of flex time, which helps keep stress levels down even during long days.

I believe the future of math in the computer industry lies in computer chip technology. Interestingly, just like a lot of other things, computer chips and the circuits laid out on them are also simulated to detect possible defects before a chip goes into manufacturing. In order to build faster processor chips, one needs to create larger and more complex simulations, which in turn, requires faster processors.

Salary Range

Starting: around $80,000 to $100,000; mid-level: $150,000 to $200,000; senior positions $250,000 or more.



Bill Mawby

Manager of Statistical and Mathematical Support Services

Michelin America Research and Development Corporation
Greenville, SC

B.S. natural systems, The Defiance College, Defiance, OH
Ph.D. biomathematics, North Carolina State University, Raleigh

Background

I arrived at my career path through a mixture of chance and necessity. My undergraduate training and interest was in biology, but I soon concluded that this field would require mathematics if any progress in understanding biological processes and systems was ever going to be made, and so I went to graduate school for biomathematics in order to pursue this dream. There were two professors, Dr. Bernie Mikula at Defiance and Dr. Harvey Gold at NCSU, who nurtured my interest, but it was the book series on "Towards a Theoretical Biology" that probably did the most to convert me. Work-study experiences at Argonne National Laboratory and Roswell Park Memorial Institute also largely influenced my choices.

After graduate school I tried being an independent consultant, but, mostly due to my distaste for the business end of the endeavor, I chose a more mainstream job as a statistician at Michelin Tire Corporation. I found that mathematics, like quickness in sports, can find profitable application in any field. Over the last 25 years, I have held positions as Principal Statistician for Research and Development, Corporate Statistician, and Manager of STATMATH (statistical and mathematical support services).

Job Characteristics

In my role as manager of statistical and mathematical support, I help create proposals, lead projects, guide technical personnel, contribute technically to projects, and evaluate results.

My position has two features that really motivate me to do better work: a constant variety of problems and a direct impact on business results. Workload and schedule are dictated entirely by project needs, but this does not typically involve a lot of overtime. Daily work is split rather evenly between administrative work, project meetings, creating documents, and doing mathematical research. Employees without the managerial role spend most of their time doing mathematical research, with perhaps 25% of the remaining time spent on meetings and documentation.

The applications of mathematics, including quality control statistics, design of experiments, sampling plans, finite element work, physical modeling via differential and partial differential equations, reliability, forecasting, data mining, optimization, and stochastic processes can be seen in all manner of research, industry, and commercial and administrative processes.

Salary Range

Salaries range from about $75,000 to about $150,000.

Ed Moylan

Research Engineer, Methods & Systems Analyst, Project Leader, Supervisor, and Manager (retired)

Ford Motor Company, Dearborn, MI

B.S. mathematics, University of Detroit
M.S. mathematics, University of Detroit
M.B.A. University of Michigan

Background

I earned my B.S. in mathematics in 1962 and M.A. in 1964, taught full-time for three years, and joined Ford Motor Company in 1967 as a member of the team that developed Computer Aided Design (CAD). CAD was being developed simultaneously at Ford, General Motors, Boeing, and other large companies; computer graphics technology was in its infancy. My initial contributions at Ford were to analyze what earlier developers had achieved, to evaluate what methods and technologies were available, to learn the theory of automotive design, to create additional methods, and to implement software that teamed the skill of the designer with the speed of the computer. My knowledge of calculus, differential geometry, linear algebra, and numerical analysis, was critical in doing this work.

Computer aided design, computer aided manufacturing, and computer aided engineering simulation systems began to be used worldwide throughout Ford for developing vehicle exteriors, interiors, structures, electrical circuitry, and powertrains. Data exchange standards and software for communication with suppliers had to be established. Plans had to be coordinated with counterparts in Europe and other international locations. My title evolved along with my career: Research Engineer, Methods & Systems Analyst, Project Leader, Supervisor, and Manager.

Having management responsibility involves not only being able to oversee technology development, but also being able to build business cases for technology investments or process changes. It was essential to communicate effectively with business partners in other departments, including finance, human resources, purchasing, and engineering. I needed to better understand their viewpoints, tenets, needs, and constraints. I felt that a formal education in these areas would be a good complement to my on-the-job education. I therefore went to night school, and earned an MBA in 1989; I retired in 2000.

The most satisfying aspects of my experiences were interacting with research mathematicians, working with people in other fields, contributing to joint solutions, seeing those solutions implemented worldwide, and teaching others what I learned.

Job Characteristics

I was not a researcher, but rather a "productionizer"; that is, I was able to read and comprehend published mathematical articles and adapt the results to an industrial environment. By adapting the theory and applying new methods to improve an existing production process, the impact can be significant, such as reducing costs by hundreds of millions of dollars.

Most important industrial problems initially are ill-defined and are rarely posed in mathematical terms. The critical first steps are to employ one's "mathematical mindset" by defining terms, distinguishing between independent variables and dependent variables, and understanding the relationships among those variables. The next steps are to employ one's "mathematical toolset" by testing assumptions against data and, if possible, using classical solution techniques. However, if new tools are needed, a literature search may be appropriate. Once sources are found, their assumptions need to be adapted to the problem at hand, applied, and validated. They then become part of one's expanded "mathematical toolset."

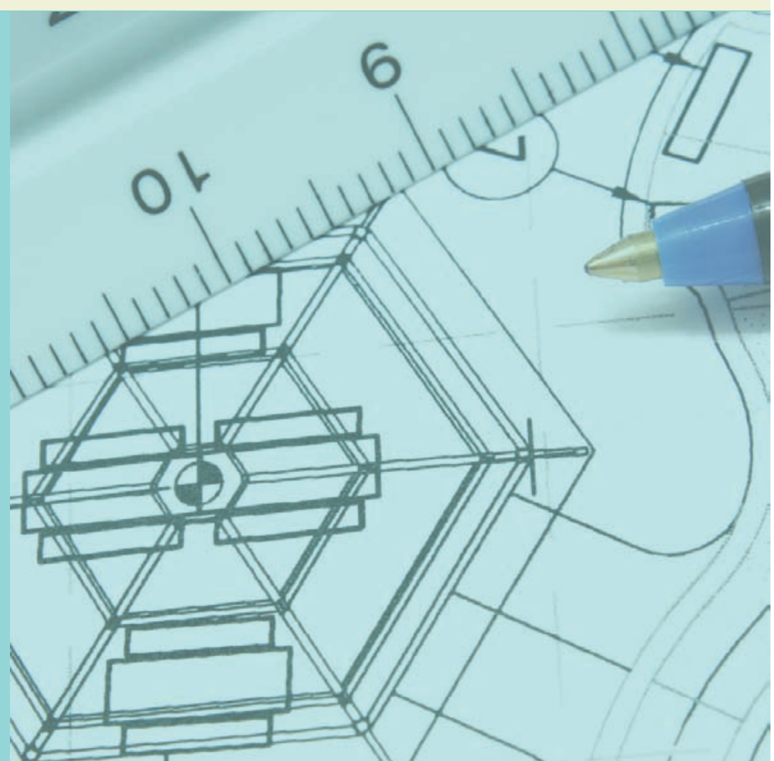
Salary Range

Salary range: $75,000 to $150,000.

What is important to industry?

"Mathematical training enables one to identify and analyze intricate relationships among various aspects of complex problems. This capability is marketable if it is documented and communicated in language that is understood outside of the mathematics classroom. Mathematics majors can augment their communications skills if they develop the ability to listen and continually ask deeper questions in order to define the structure of a problem or a process, to identify the most highly leveraged variables, to develop pragmatic solutions, and to carry them through to implementation. One must be willing to continue learning and taking on additional diverse tasks. Mathematical methods and thought processes are universally applicable. For the future, much groundbreaking mathematics can be done in life sciences, data mining, supply chain management, agent-based modeling, network analysis, and many other areas and fields."

— Ed Moylan,
Ford Motor Company, retired



Nancy Heinschel

Applied Research Mathematician

National Security Agency (NSA)
Fort Meade, MD

B.S. mathematics, University of California, Davis
M.A and PhD. mathematics, University of California, Santa Barbara

Background

The National Security Agency (NSA) is the agency of the Defense Department responsible for solving cryptographic problems for the federal government, and is the largest employer of mathematicians in the U.S. The NSA sponsors several paid summer internship programs for undergraduate and graduate students. I first became aware of the NSA through one such program that allowed me to spend two summers as an intern during graduate school working on real problems with intelligent and enthusiastic Agency mentors. Summer internships are a great way to learn firsthand what the NSA does and what it is like to be an Agency employee.

Like nearly all NSA mathematicians, I spent my first three years at NSA in a training program, during which I worked in five different offices. I also took courses in cryptography, statistics, and math, and attended a variety of talks and conferences to improve my technical skills. The training program allowed me to gain experience in a wide variety of project areas, to develop a network of valuable contacts, and to find an office that best fit my interests and strengths.

My graduate research was in pure mathematics, but the idea of applying mathematics to important real-world problems always appealed to me and working at the NSA has given me the opportunity to do just that. NSA mathematicians use tools from diverse areas including number theory, Fourier analysis, and statistics, but being an expert in these areas is not a requirement to become an NSA mathematician, nor is having a Ph.D. Working at the NSA, I have utilized essential problem-solving skills gained by working on problems involving diverse math disciplines. I have also seen potential to apply these abilities to new challenges. The complex problems we work on generally require computers to solve, and because of this, some computer programming experience can be helpful. However, I have learned most of my programming skills on the job.

Job Characteristics

Much of my day is spent working on a computer, but it is far from solitary work. With such challenging problems to solve, I work on project teams with mathematicians, computer scientists, engineers, and many other colleagues. Some of my projects have tight deadlines, but others are longer range. In addition to computer work, I do a fair amount of writing and speaking in order to communicate my results to coworkers. Due to the classified nature of what I work on, I'm not allowed to take any work home, so I have evenings and weekends to recharge, pursue other interests, and return to work refreshed and prepared for new challenges.

Salary Range

In 2008, math and statistics positions at the NSA had starting salaries of $49,685 for those with bachelor's degrees, $59,811 for master's, and $83,720 for Ph.D.'s. The best place to find out more about careers at NSA is on the website, ***www.nsa.gov***.

Edmond Chow

Computational Scientist

D. E. Shaw Research
New York, NY

Bachelor of Applied Science (B.A.Sc.), systems design engineering, University of Waterloo, Ontario
Ph.D. computer science, University of Minnesota

Background

I've always liked math, but it was computers in junior high school that triggered the math questions I would pursue for a long time afterward. Questions like "how do computers know how to compute sin(x)?" were the beginnings of applied math for me. I was lucky to have encouraging teachers, particularly one in high school who arranged a number of meetings for me with Professor Tom Hull at the University of Toronto, with whom I did a small project on computing elementary functions. Later, I participated in Lawrence Livermore National Laboratory's high school program and got a chance to try programming on Cray supercomputers. By then, I was hooked.

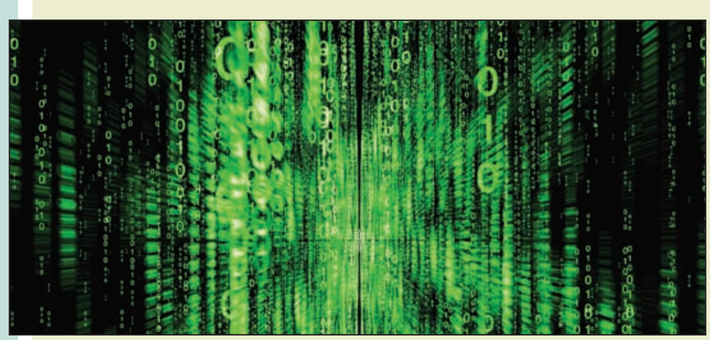
In addition to math, I was also interested in science, and I decided very early on that I wanted to apply numerical methods to science by doing computer simulations. Unfortunately, as an engineering undergraduate at that time, I didn't find anyone doing this until my senior year, when I took three courses in numerical analysis and did a project in the computer science and applied math department. Professor Wei-Pai Tang was my project advisor. He took me under his wing and introduced me to numerical linear algebra. He also introduced me to Yousef Saad, who later became my Ph.D. advisor.

Job Characteristics

In my current position, I work on the algorithms and software used in molecular dynamics simulations. It is a highly varied and interdisciplinary role. Almost daily, I talk to chemists about their scientific problems, as well as hardware and software engineers who want to find accurate and efficient ways to implement chemistry algorithms. In computational science, math and algorithm problems pop up everywhere. Often these are very specific problems that require specialized solutions. There may be a complicated potential energy function we want to minimize, and we may want a minimizer tailored for a specific computer architecture. Sometimes the problems seem easy, but they're made difficult because of constraints, even if the constraint is that the solution is robust yet easy to implement.

Salary Range

Starting about $100,000, depending on location and company (urban areas of California and New York are higher).



Barbara Hamilton

Manager, Information Support Services

Institute for Defense Analyses (IDA)
Center for Communications Research Division, Princeton, NJ

B.S. mathematics (computer science), Central Michigan University
M.A. mathematics, Central Michigan University
M.L.S. library science, Rutgers University, NJ

Background

I was always good in math and enjoyed it. I had excellent math teachers in both the sixth and seventh grade who made math fun and showed me there were many areas of math to study. In sixth grade, my teacher told us we could work as much or as little as we wanted and what we did would be reflected in our grade. The first day of class in seventh grade, my teacher gave us a test to see where everyone was, after which she broke the class into two groups based on ability. However, I wasn't put in either group. She took me to a filing cabinet and told me, "You're going to work your way through this." I had my first independent study, doing beginning statistics, probability, and all sorts of other interesting mathematical things. I took math as an undergraduate and graduate student because I found it fun, but I think my career path decided on me.

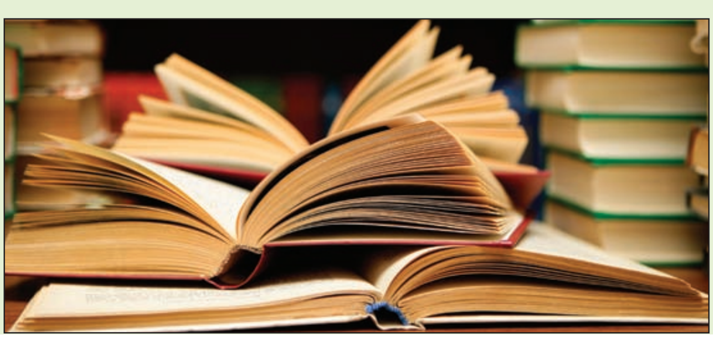
I worked as a cryptologic mathematician for the Department of Defense and as a documentation specialist for Renaissance Technologies, a commodities trading firm. Both jobs required understanding and implementing mathematical models to real world problems. When I was offered the library job, I was looking for something new and I thought it would be interesting. I took the job with the condition that I complete a library degree.

Job Characteristics

I supervise the running of our mathematics research library and oversee our production of research reports and the paper publication process. I help the research staff find information that they need, which sometimes means obtaining a hard-to-find book or article, or doing searches on the Internet or in subscription databases such as MathSciNet. Because I have a degree in mathematics, it is easier for the research staff to explain to me what it is they are looking for since we speak the same language.

Salary Range

Starting: $40,000–50,000; mid-level: $64,000–$82,000; senior positions $104,000 or more.



"Math has become a mainstay of economics. Without strong mathematical underpinnings, economics loses its rigor and thus its credibility. A necessary condition to be a good economist is thus to be at least a proficient mathematician. Math is vital to formulating economic theory, constructing accurate data sets, and applying theory to the data."

— Mark Zandi
Moody's Economy.com

Mark Zandi

Chief Economist

Moody's Economy.com
West Chester, PA

B.S. economics, Wharton School at the University of Pennsylvania
Ph.D. economics, University of Pennsylvania

Background

I knew I wanted to be an economist just a couple of weeks into my Econ 101 class as a freshman at the University of Pennsylvania. The course made clear to me that economics is an intriguing combination of mathematics and the social sciences. I wasn't completely enamored with the abstraction of pure math nor the casual empiricism of most social sciences. Economics is grounded in mathematical theory and comes alive when the theory is tested against data and empirical analysis.

I have been a professional economist since leaving graduate school. I briefly worked for Wharton Econometrics (an economic consulting firm), started my own economic consulting firm, and sold that firm to Moody's two and half years ago.

Job Characteristics

As Chief Economist for Moody's Economy.com, I set the research agenda for a staff of approximately 60 economists located in the U.S., London, and Sydney. We produce analyses and forecasts for economies ranging from India to Indianapolis, and for clients ranging from the U.S. State Department to New York hedge funds. I spend much of my time assessing the global economy's growth prospects, considering different economic policy proposals, and evaluating different risks to the economy and financial system.

My job entails a substantial amount of research, writing, and speaking. I also travel extensively, giving speeches and talks at conferences and to clients. The most interesting thing about my job is that nearly each day brings a new economic issue or concern that I must work to understand and evaluate and then to articulate what I've learned to my clients. I suspect that, like for most professions, as an economist if you are right just a bit more than you are wrong, you will be successful.

Salary Range

Salaries range widely for economists depending on the industry and region of the country. The best place to find out more about salaries for business economists is to go to the National Association of Business Economics ***www.nabe.com***.

Wu Li

Senior Research Engineer

Aeronautics Systems Analysis Branch
NASA Langley Research Center
Hampton, VA

B.S. in mathematics from Zhejiang Normal University, China
M.S. in mathematics, Zhejiang University, China
M.S. in computer sciences, Pennsylvania State University
Ph.D. in mathematics, Pennsylvania State University

Background

I wanted to do something that would have a lasting influence on science or society. My best ability was in mathematics, and so that determined my career path. I believe mathematics has its own elegance and beauty, just like arts or music, but in an intellectual and logical sense.

Before working for NASA, I was a professor of applied mathematics at Old Dominion University in Norfolk, Virginia. While there, I also worked as a consultant at the Institute for Computer Applications in Science and Engineering (ICASE) on a multidisciplinary research project (robust optimization under uncertainties) funded by NASA Langley Research Center, which led to my career change from a university professor to a civil servant at NASA.

It was when I started working as a consultant for NASA that I began to understand the huge gap between mathematical research and practice. The paper titled "Real Life Mathematics" by Bernard Beauzamy (*Irish Math. Soc. Bulletin*, 48 (2002), 43-46) struck a chord in my heart and best described my conversion from mathematical research to mathematical practice; it gave me some confidence that real life mathematics could make a difference.

Job Characteristics

I am currently a NASA senior research engineer working on the supersonic research project, under the Fundamental Aeronautics Program of NASA Aeronautics Mission Directorate, as the technical lead to develop a low-boom and low-drag supersonic configuration design optimization process. Our objective is to help the research and development of economically and environmentally viable supersonic aircraft. The low-boom and low-drag design goal requires a seamless integration of low-fidelity low-boom design tools and high-fidelity computational fluid dynamics (CFD) analysis/design tools. One of the design challenges is to use optimization methods for finding a low-boom supersonic configuration using high-fidelity CFD analysis.

I usually work on a vertical integration from theory to practice: discussing with customers to understand the required technical capabilities, developing a practical solution strategy based on as much theoretical foundation as possible, implementing the solution by using a computer code, and building an easy-to-use interface for the customers. This process usually goes through a few iterations because of potential miscommunications between developers and customers about the requirements.

Some of my daily activities include developing mathematical models, solution algorithms, or user interfaces; discussing modeling or solution issues with customers or team members; planning future research tasks or activities; researching relevant literature; and documenting research results. I also evaluate proposals funded by NASA, serve as technical monitor for funded proposals, and supervise graduate students working on NASA projects.

Someone in this type of position should expect to use computational mathematics, software development skills, and communication skills to develop system-level analysis and design capabilities for technology development.

Salary Range

At NASA, the pay is based on civil servant grade and step. The 2008 salary range from Grade 9 (Step 1) to Grade 15 (Step 10) is $45,040 to $140,355. You can find more information about jobs at NASA at ***www.nasa.gov***.

A variety of lenses used by the gimbal-mounted lidar device are visible through the opening in its ball-shaped housing.

Photo courtesy of NASA/Tony Landis.

Technicians inspect the sub-scale X-48B Blended Wing Body concept demonstrator in the full-scale wind tunnel at NASA's Langley Research Center.

Photo courtesy of Boeing.

Peter Norvig

Director of Research

Google, Inc.
Mountain View, CA

B.S. applied mathematics, Brown University, RI
Ph.D. computer science, University of California, Berkeley

Background

I was always interested in math; I thought it was one of the most fun subjects in school, and my dad was a math professor. As I progressed through school, I found that the computer science courses were more fun and much easier for me. In college the computer courses always seemed to be easy, and while I liked my math courses, I remember my number theory final exam as a turning point — it was a take-home final and after working on it for at least five hours, I had zero out of ten problems answered. I kept working on it, and eventually did fine, but I realized that it made more sense for me to concentrate on computer science, which I found easier, rather than the areas of math where I had to struggle. I also remember that teaching was a great experience for me. Brown had a program of undergraduate teaching assistants (TAs), instituted by Andy van Dam, and I learned a lot from having to explain things to other students. I also learned a lot from being a TA at Berkeley.

Job Characteristics

In previous jobs, I was more involved in hands-on software development and I've been lucky to have had a number of exciting jobs. I worked at NASA, where my team developed the first artificial intelligence program to control a spacecraft. Continuations of that work now schedule operations for the Mars rovers and several other space missions. I worked at a small startup doing integration of Internet job and shopping ads where we built the company up from nothing and eventually sold it to Amazon.com. I worked at Sun Microsystems Laboratories doing search/information retrieval — a precursor to Google today. And I also taught at USC and at Berkeley.

My current job is overseeing research projects at Google. That means working with the team to help decide strategic directions; which projects are important now, and which can wait until later; finding connections between technologies and products (e.g. this algorithm for clustering looks like it would be useful for Google News); and directing others to the right people to talk to about problems. To do this job I needed to develop intuitions about what will work and what won't, something that I continue to do. There are so many things to try; so much data available, so many alternative ways to process the data, build learning algorithms for it, and deploy the results, that you need a feel for what is likely to work — and you need a lot of bright colleagues who sometimes prove you wrong.

What I like best is solving problems that help people — we can develop a better algorithm and immediately see that we've helped hundreds of millions of people in their daily lives. What I like least is being overwhelmed with too much email — but we're working on that, too.

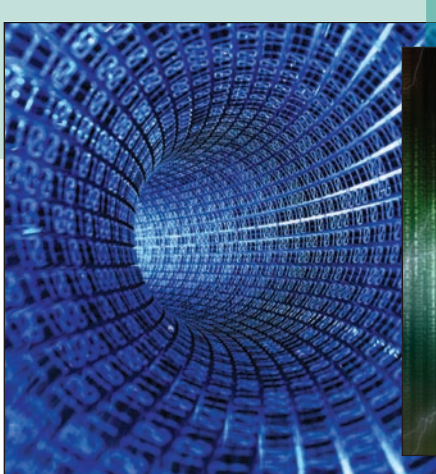
Salary Range

I think it is about $70,000 starting; twice that mid-level, and potentially many millions for the lucky ones at successful companies. To find out more about this field, read the news, Internet groups, and journal articles. There's no shortage of information.

Mathematics in the software development and research technology fields

"It is a fantastic time to be involved in this field. The Internet has made so much information available, and now we need smart people to help make sense of it all — to get the right data to the right people at the right time with the right presentation. And if that's not enough work, so many other fields require an increasing amount of computational sophistication. For example: biology, genomics, and synthetic biology are all at heart information sciences; the challenges we face in climate modeling will require better computational models and methods; the entertainment industry increasingly relies on computer graphics for animation and special effects, and on artificial intelligence for games. The field of robotics is just starting to emerge; it has the potential to address major societal issues, for example autonomous cars can allow for a more efficient transportation system that helps with the energy crisis and home service robots can help care for the elderly. There are tremendous opportunities for exciting work that matters to society, and new students and graduates are needed to do the work."

— Peter Norvig
Google, Inc.



Craig Trost

Independent Quantitative Research Consultant

Physician/Statistician, Senior Director, Translational and Molecular Medicine
Pfizer Global Research and Development (retired)

B.S. general science, University of Iowa
M.D. University of Iowa
M.S. preventive medicine and environmental health, University of Iowa
Ph.D. biostatistics, University of North Carolina – Chapel Hill
Post Doc, cardiovascular biostatistics, National Heart, Lung, and Blood Institute, NIH
Residency, clinical pathology, University of Florida

I grew up on a farm in the Midwest and really didn't consider going to college until sometime in high school. While in junior high school, I was introduced to the "new math," which no one seemed to like except me. Since I liked solving puzzles, I found this fascinating. After taking geometry in high school, I decided that proving theorems didn't interest me, and it still doesn't. In the small high school I attended, the most advanced course was pre-calculus. During that class, I discovered functions and had the epiphany that they might be useful in modeling the real world, which led me to finding something in applied mathematics. I decided to pursue mathematical physics.

Soon after I arrived on campus, the market for physicists hit bottom. My major then changed from physics to chemistry to biochemistry and then to early admission to medical school after my junior year. Although I took math and computer science courses to raise my GPA, at that time I had given up on using mathematics in my career. While in the middle of medical school, I discovered that biostatistics and computers were being used in medical research and I immediately gravitated in this direction. It also became obvious that physicians did not know enough about math or computer science and that massive amounts of data were being generated for patient care, literally untapped mathematically. In my third year of medical school, I decided to devote my career to creating computer algorithms to provide better care to patients. In particular, I wanted to take an applied mathematics approach since most others were trying this through artificial intelligence. Unfortunately, there were essentially no programs in biomathematics or mathematical biology at that time and certainly no career path, even in academia. I had to settle for biostatistics instead.

Over the years I have taken many paths to find a home for my ideas working for six different entities: a pathology faculty, a medical software startup company, a clinical IT, management, statistical research, and computational medicine in pharmaceuticals. Although the financial rewards have been good, all of these paths have been uphill.

Over the past decade, I have gravitated toward mathematical biology, studying diagnostic patterns in clinical data, which is abundant in the pharmaceutical world. Most of the mathematics that I currently use have been self-taught and often I have had to write my own computer code in varying hardware and software environments. My approach combines stochastic processes and stochastic calculus with parameter estimation procedures and confidence regions, and my medical training has been helpful. An inordinate proportion of my career has been spent finding or generating and restructuring data for analysis and modeling. The minority of time has been spent thinking about, developing, or testing models.

Mathematics in the biology fields

"Mathematical biology will be an important field in the coming decades. Consider that even non-math majors or double-majors in fields such as a quantitative discipline and a biological discipline may provide the skills you need to get the job and do the work."

— Craig Trost
Pfizer Global Research and Development

Katya Scheinberg

Research Staff Member

IBM T. J. Watson Research Center,
Business Analytics and Mathematical Sciences Department
Yorktown Heights, NY

B.S. (equivalent) applied mathematics and computer science, Moscow University
M.S. and Ph.D. operations research, Columbia University

Background

I grew up in Russia and my parents both have Ph.D.s in mathematics, so from early childhood I was surrounded by mathematicians. I attended a special mathematical high school, which I loved not simply because of the good academic program, but because of outstanding fellow students, many of whom became life-long friends. Ultimately what really made me choose mathematics for a career was simply the fact that I enjoyed it, found it fascinating, and it was easily my best subject in school. In fact, I was considering medical school during my junior year in high school, and it was my math teacher who told my parents that it would be a shame if I didn't go into mathematics. In those days in Russia, it was not a very common thing to tell the parents of a girl! I am very grateful for his encouragement.

In college one of my favorite courses was a course on general optimization. I decided that I liked the field and wanted to work in it and so I chose the professor of the class as my college advisor. As it turned out, even though the course covered little of the modern state of optimization, it did introduce me to the fundamental mathematics involved.

Importance and future of mathematics in industry

"I expect the applications and use of optimization in industry to grow for many years to come. Industry has only now started to accept sophisticated approaches to linear and integer programming problems. There are still many possibilities for other kinds of optimization and the applications are becoming more challenging with the growth of available data.

"IBM started as a computer company and it is obvious why mathematics is essential in the computer industry. Math is still extremely important to hardware business like IBM for product design, manufacturing, and the distribution of products. Also, applied mathematics and specifically optimization have become extremely important to the IBM services industry. Optimization is used to model and address clients' business problems, which involve scheduling, workforce management, project management, supply chain management, and other common professional needs."

— Katya Scheinberg
IBM T. J. Watson Research Center

Job Characteristics

I develop theoretical and computational algorithms to solve difficult continuous optimization problems. These problems may arise in engineering design (such as tuning of circuits), in production planning (such as optimization of production in an industrial lab), in biology applications (such as constructing models of the human brain response), and in finance (such as portfolio optimization). I study general problems of optimizing linear and nonlinear functions subject to linear and nonlinear constraints. Various applications result in different structures of the underlying functions and I develop algorithms that target this structure to be able to find the optimal solution efficiently. Theoretical aspects involve proving that the resulting algorithms have convergence guarantees. The computational aspect involves developing software that can handle large scale and difficult cases in practice and in reasonable time.

I became a research staff member at IBM after I finished my Ph.D. Before I was hired for this position, I was a recipient of a special IBM student fellowship and spent two summers working at T. J. Watson Research Center. This fellowship and the work that I did during those summers were central to my joining IBM after graduation.

On a daily basis, I think about new ideas and prove theorems, write them down for a scientific publication, write code to test ideas or to generate software and numerical results supporting my ideas, referee papers, organize conferences, and perform other duties in the scientific community. When I am working on a project with a customer, I attend regular meetings where the application and possible solutions are discussed in various levels of details. I also perform internal administrative duties, such as participating in or running various committees. A typical day is spent in front of my computer with an occasional meeting to discuss ideas with colleagues. The best aspect of my profession is the flexibility and creativity involved. Even though I have superiors, I am able to decide what and how to work on something and when to do it. Another very important benefit is the amazingly intelligent people around me. My least favorite part is that I never feel smart enough! Something always seems too difficult to understand or to solve.

My work hours are dictated by my own commitment to different projects and deadlines and to my colleagues both inside and outside IBM. No one tells me that I have to work a certain number of hours and I can take a day off very easily if I need to. On the other hand work is never out of my mind and is always ongoing, as in any other creative process.

Career Expectations

Unless a researcher has administrative aspirations, the scientific career at IBM is quite straightforward. One expects to grow as an important contributor to the scientific community and as an experienced problem solver. Those from our department who choose to move on outside IBM typically go on to academia or another research lab. A few people go to Wall Street.

Salary Range

Starting $115,000; mid-level $170,000; senior positions $200,000 or more. The best place to find out about this field is at conferences on optimization and mathematical programming (ISMP and SIAM in Optimization and ICCOPT, INFORMS). Also, the IBM Research website, ***www.research.ibm.com*** is a good place for more information.

Karim Azer

Senior Research Associate

Applied Computer Science and Mathematics Department
Merck Research Laboratories
Rahway, NJ

B.S. mathematics and computer science (double major), Rutgers University, NJ
M.S. applied mathematics, Courant Institute of Mathematical Sciences, New York University
Ph.D. applied mathematics, Courant Institute of Mathematical Sciences, New York University

Background

One of the running jokes in my family is that I was born with a special interest in mathematics. It was my dream as a child to grow up to be a mathematician.

I started working full-time at Merck developing object-oriented software libraries in the information technology department while I was enrolled as a part-time Ph.D. student at the Courant Institute. When Dr. Jeffrey Saltzman arrived at Merck and established the applied computer science and mathematics department, I started learning about applications of mathematics in industry and became very excited about applying the skills I was learning in school to projects at work.

I became interested in modeling blood flow in arteries after reading an article that was given to me by Dr. Jeff Sachs, my current boss at Merck. For my Ph.D. thesis, I worked with Dr. Charles Peskin at the Courant Institute on developing a fluid dynamical model of blood flow in the systemic circulation. My thesis work set the stage for me to work on cardiovascular modeling coupled with vascular imaging here at Merck, which is the main topic of research in my current position.

Mathematics in the pharmaceutical field

"In the future, I see applied mathematics as being as integral to drug development as is basic biology and chemistry, and being critical not only for development of innovative medicine, but also for survival in the business of drug development. This will be especially true as we find new ways and technologies to probe the human body and collect native information about how our body functions, how it is designed, and how it is altered with age, disease, or drug intervention.

"What I like best about my profession is that I can contribute to improving people's quality of life by being part of a large body that strives and thrives to provide improvements in human health. Not only can I contribute to this great cause, but I can do so in an environment where I'm continually learning, I'm on the cutting-edge of research, and I'm surrounded by brilliant researchers, many of whom are principal thought leaders in their fields."

— Karim Azer
Merck Research Laboratories

Job Characteristics

As an applied mathematician, I interface with people with a very diverse set of educational backgrounds, including imaging scientists, biologists, physiologists, physicians, and others. My primary function is to work closely with these scientists to provide mathematical solutions that address the medical and business needs as defined by decision makers within Merck. Once the problem is identified, I work with my team on formulating a mathematical model and delivering the solution within agreed upon timelines and expectations.

Salary Range

Median starting salary: $90,000; increases with level and expertise; mid- and senior-level salaries differ depending on career path. Merck's website, ***www.merck.com***, provides useful information regarding current events and resources as well as job opportunities.

More Advice from Professionals

"I strongly encourage undergraduates and high school students to take as many mathematics courses as possible, even if they do not choose mathematics as their major. The role of math in almost every field is expanding and will continue to expand in the near future. In addition to giving your career a boost, strong quantitative skills come in handy in ways that are not always obvious, but nevertheless have a strong impact on your everyday life. For example, an understanding of probability and statistics makes you a better decision-maker when faced with uncertainty. A strong mathematical background may also help you make smarter savings and financial planning decisions."

— Anshul Gupta, IBM T. J. Watson Research Center

"Be voracious in your appetite for applying your mathematical skills to real problems, be careful not to become narrow in your skills, and constantly remind yourself that others in the company may not see your skills as critical.

"There is no doubt that a sound mathematical basis is more sought-after than ever in all areas of business, but the requirement of achieving measurable gains more quickly does lead to the need for more than sheer mathematical skill. In addition, the successful mathematician must be results-oriented, must prefer workable over ideal solutions, must work well in teams as both member and leader, and must be willing to adapt quickly to new needs. Generally, the most valuable employees are those that can identify a useful tool and adapt it to company's needs rather than creating something from scratch.

"I foresee that the tendency to 'share' resources between industry and academia will accelerate more quickly. Also, since most customers of mathematics cannot distinguish between the mathematical idea and the software in which it is embedded, it is critical to have a working knowledge of various packages, databases, and delivery systems."

— Bill Mawby,
Michelin America Research and Development Corporation

"Learn the language of other disciplines by 'going to where they hang out,' especially during junior and senior years of college. For example, attend seminars sponsored by other academic departments to gain awareness of their nomenclature and topical issues. Attend professional conferences and trade shows to view the latest technologies and applications. Engage in conversations with the other attendees and listen to how they describe their processes and problems.

"Practice structuring problems encountered in other fields. Start with simple examples; describe algebraically the relationships among a few variables. What would it mean to the application if one of the variables changed slowly? Quickly? How well does the mathematical model fit or predict the data from the problem? What insights does it offer that are not as readily available via physical experimentation? Discuss the solutions and interpretations with practitioners in the subject field. This will hone both mathematical skills and the ability to communicate with non-mathematicians.

"Draft a résumé as early as freshman year and periodically update it in terms of goals, credentials, and experiences; compare the phrasing of your résumé with the words used in job descriptions found in placement offices and on job boards."

— Ed Moylan, Ford Motor Company (retired)

"Math has become a mainstay of economics. Without strong mathematical underpinnings, economics loses its rigor and thus its credibility. A necessary condition to be a good economist is thus to be at least a proficient mathematician. Math is vital to formulating economic theory, constructing accurate data sets, and applying theory to the data.

"Key advice: be sure that you are very proficient in math and statistics before going to graduate school in economics. I would also suggest working during and between undergraduate and graduate school at consulting firms, think tanks, different types of businesses, and in government to see how economics is applied to everyday problems. This is important even for those who ultimately plan to go on to academia."

— Mark Zandi, Moody's Economy.com

"My advice to mathematics students is to develop both a breadth and depth of knowledge and understanding of fundamental areas of mathematics. Do your best to take courses from other disciplines and expose yourself to a wide range of fields and applications. Get advice from academics and practitioners from different industries, and learn about their work. Finally, engage in the area of research that you enjoy most and find most fulfilling.

"As a hiring manager, I see that students coming into the workplace are extremely well prepared, having mastered more than one technical area, and with a diverse educational background. Mathematics students pursuing biomathematics careers have solid background in biology, in addition to the standard dose of mathematics taught at the Ph.D. level. Expect to be immersed in a multi-disciplinary environment alongside scientists with cross-disciplinary expertise."

— Karim Azer, Merck Research Laboratories

"Get involved in projects beyond your coursework. Whether it is a pet project of your own, a research project with a professor, a contribution to an open-source project, work at a company outside of school, or a competition such as the ACM programming contests, the FIRST Robotics League, or Moody's Mega Math Challenge, you learn a lot by doing a project: how to work with others, how to meet deadlines, to compare yourself to others, and the thrill of accomplishing something worthwhile.

"My second piece of advice (which ties in with the first) is that you tend to regress to the mean of your peers, so surround yourself with the best peers you can find, and learn from them. You definitely learn something by being the biggest fish in a small pond, and you should make sure you get that experience a few times, but you learn more from being surrounded by the best in your field."

— Peter Norvig, Google, Inc.

"Students should realize that they are responsible for their own future. For those who wish to pursue an industrial career, they need to understand why they are on their company's payroll. They need to work not only on what is interesting to them, but on what is important to the company. Solve real problems, not imaginary ones."

— Dimitris Agrafiotis,
Johnson & Johnson Pharmaceutical Research

About SIAM

The Society for Industrial and Applied Mathematics (SIAM), headquartered in Philadelphia, Pennsylvania, is an international community of almost 12,000 individual members. These include applied and computational mathematicians and computer scientists, as well as other scientists and engineers. Members are researchers, educators, students, and practitioners from over 90 countries working in industry, government, laboratories, and academia. The Society, which also includes almost 500 institutional members worldwide, represents academia, manufacturing, research and development, service and consulting organizations, the government, and the military.

SIAM fosters the development of mathematical and computational methodologies needed in various application areas. Applied mathematics in partnership with computational science is essential in solving many real-world problems. SIAM serves and advances these disciplines by publishing a variety of books and prestigious peer-reviewed research journals, by conducting conferences, and by hosting activity groups in various areas of mathematics. SIAM provides many opportunities for students, including regional sections and student chapters.

SIAM was incorporated in 1952 as a non-profit organization. SIAM's goals have remained:

- To advance the application of mathematics and computational science to engineering, industry, science, and society;
- To promote research that will lead to effective new mathematical and computational methods and techniques for science, engineering, industry, and society;
- To provide media for the exchange of information and ideas among mathematicians, engineers, and scientists.

Further information is available at ***www.siam.org.***

"Never assume that some subject of mathematics will not be useful to you in the future. In college, I did not like statistics and decided not to study it any further since I assumed I would choose work that didn't involve statistical methods. Now one of my biggest research interests is in applications of optimization in statistical machine learning, and I wish I knew more statistical theory.

"Choose your first subject of research carefully, so it is not too competitive but also not too obscure. Definitely learn to write code to demonstrate usefulness of your algorithmic ideas."

— Katya Scheinberg
IBM T. J. Watson Research Center

"In practice, mathematics is a tool. New mathematical results are only important if they have some impact in useful practical applications. Teamwork is critical for the success of mathematics in practice. Students should realize that promotion is based on leadership and technical excellence. Having one special skill might not be the best option in this dynamic information age."

– Wu Li, NASA Langley Research Center

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"The math problems that you'll encounter at work normally will not be related to the ones you studied or wrote your thesis on. My advice is to take advantage of a wide variety of classes while you are at school, as they will help you work on diverse sets of problems later on. It is really true that the theoretical ideas you learn in school actually apply very well when you put them to work in practice.

"I cannot express enough how important it is to develop clear communication skills, both in speaking and writing. This is not just a language skill, but also a skill for clear thinking. After you've proven yourself with your technical skills, it's these communication skills that will take you farther in your career. With the increasing advantages of using computing in science and engineering, I believe the opportunities in computational science can only grow."

— Edmond Chow, D. E. Shaw Research

10/08

Science and Industry Advance with Mathematics