# DEPARTMENT OF MATHEMATICS

Get a new perspective into the mathematics beyond calculus

Meet the faculty and graduate students

Find out why people decide to be mathematicians

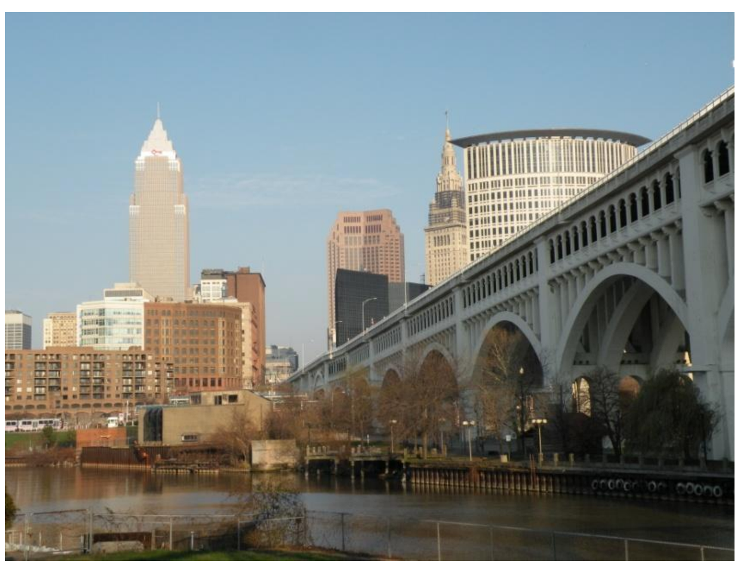
Discover the many hidden faces of mathematics

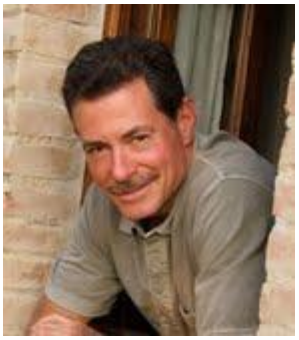
What is mathematics? The question can be answered in many different ways depending on whom you ask and what aspect of mathematics you are interested in. My first answer would be that mathematics is a language, which once learned well can be used in many different ways depending on what we want to do with it. And the second that mathematics is much more than numbers,  like a language is much more than the letters of its alphabet or the rule of its grammar, which nonetheless have to be mastered. Mathematics is different things to different mathematicians. Some are interested in the discipline itself, and work towards establishing new theoretical results. Others, interested in the mathematics which needs to be developed for specific applications, dedicate themselves at creating an interface by which theoretical results can find very practical applications in day to day life.

Pure or applied mathematics?   Whatever your call is, a lot is shared between pure and applied mathematics. The core of mathematics, which shapes the way of thinking in a mathematical way, is a common starting point, as are many technical tools which are routinely used in mathematical reasoning. So, if while pursuing a degree in pure mathematics you find out that your call is for applied mathematics, or vice versa, it not too far a stretch to change the path. In fact, a large portion of the mathematics core is the same, and the specific courses which are core for one flavor of mathematics can always be used as technical electives for the other.

In the following, faculty and students of the department of Mathematics at Case Western Reserve University describe in their own words what mathematics is to them, how they got into it, and what is like being a mathematician. In addition, you will find a short description of the activities which the department is planning for the near future and a few pointers on where to find the latest information about what is going on in our webpage.

Mathematics is different things to different people. The common theme which emerges from those of us who fell under its spell is that it gives perspectives and builds bridges.





My mother was an artist and my father was a physicist. So it may not be that surprising that I like concrete topics in geometry which have visual appeal or make a connection to some other scientific field. For instance, I have studied shapes of springy wires and motions of vortex filaments in fluids. I have also enjoyed developing and teaching a course on the mathematical theory of knots (Math 363). This spring will be my third experiment in "Art and Math"--- the title of my SAGES Seminar (USSY 209).

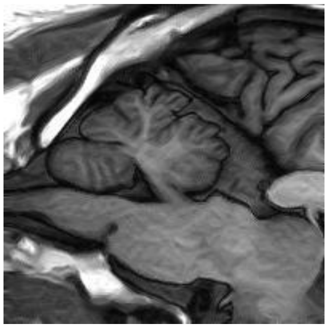
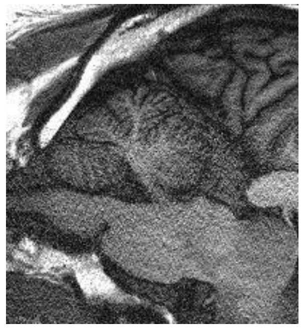
Joel Langer, Professor

To me, much of the attraction of mathematics is that is provides a means, a language, to describe precisely and clearly patterns and relationships between various objects, patterns, and processes. Much of its value arises from the capability it provides someone to communicate understanding of such matters to others. Learning some of this capability from studying mathematics carries over in important ways to understanding and communicating carefully in other areas as well, not only the fairly obvious ones such as science and engineering, but also law, writing, and public policy to name a few.

Michael Hurley, Professor

How did I end up in mathematics? I was always drawn to fundamental questions about the physical world. In college I majored in philosophy and physics, and took exactly one course in the mathematics department (multivariate calculus). I entered graduate school hoping to study the implications of some well known features of nonlinear dynamical systems (sensitive dependence on initial conditions, chaos, and so on) for understanding volition in a deterministic universe. I wanted to know whether free will comes about as an emergent property of large networks of interacting neurons comprising the human brain. However, I rapidly realized that in order to make sense of such questions I had to learn a lot more mathematics. After several years of very hard work learning analysis, differential equations, linear algebra, and advanced versions of these topics, I wrote a dissertation on the growth of patterned neural circuitry in the human visual system that used mathematical ideas to make biological predictions. Since then I have worked both as a neuroscientist and as a mathematician, applying ideas from stochastic processes, information theory, and dynamical systems to understanding principles of communication and control in biological systems. Today I work on a variety of topics including the effects of noise on rhythms in the nervous system, information processing inside cells in the immune system, the structure of biological networks, and improving diagnosis of drug resistant malaria. In each of these areas, mathematics provides a powerful language for answering fundamental biological questions.

Peter Thomas, Assistant Professor

Mathematics provides logic and reasoning food. A person with a undergraduate degree in Mathematics is ready to work in mathematics involved fields or others that require the ability to reason and express oneself clearly. He/she can work in fields like actuary, image analysis, algorithm design and to pursue a higher degree in Mathematics, Statistics, Engineering, Medicine, Management etc.

I, myself, use Partial Differential Equations, Optimization, Linear Algebra etc. to do image processing and reconstruction. Some specific topics are image compression that is used every day to increase the efficiency of store, transfer, and view images on internet, smart phones, digital camera and so on; image enhancement that improve quality of images used in medical devices like MRI, CT; image segmentation that automatically extracts abnormal tissues from a MRI scan of a patient's brain.

Weihong Guo, Assistant Professor

Once upon a time, I thought I'd probably be a theoretical physicist. But the more math classes I took, and especially when I took abstract algebra and real analysis, I found that the way my mind worked seemed perfectly suited to being a mathematician. Math classes were certainly hard for me, but hard in a different way from other classes; math made sense to me in a way that physics didn't. I'd found my niche, and never really considered doing anything else.

Math is in a lot of ways like a highly structured art form, and it can (and should) be appreciated for its beauty alone. My sole motivation in the problems I work on is that I find them interesting enough that I really want to know their solutions. Not just how they turn out, but how you get there. My PhD advisor once told me, "It feels good to prove a theorem," and I'm lucky to have a job that lets me spend a lot of my time trying to prove whatever theorems I find interesting.

My general area of research is probability theory, and I particularly like applying probability in other areas of mathematics. My work has intersected a lot with a couple kinds of geometry and with algebraic topology.

Elizabeth Meckes, Assistant Professor

As an undergrad (at CWRU) I started out majoring in both physics and mathematics, expecting to become a physicist. As I got deeper into both subjects, I realized that even in my physics classes I was more interested in the mathematical tools than in the physics problems they were used to solve. So I became a mathematician instead.

The problems I work on involve finding hidden regularity in complicated situations. I study high-dimensional geometric objects, or situations involving lots of randomness, and try to find how, when you look at them the right way, things are less complicated than they at first appear.

One piece of advice I'd like to pass on is to remember that your major (and your education more generally) is a starting point, not an ending point. Even after I dropped my physics major, I kept taking physics classes that interested me (and learned some interesting math in them). And these days, although I don't personally work on applications outside of math, my mathematical results have been used by people working in computer science and statistics, which are subjects I've never studied at all. A strong math background is a great starting point for lots of different things; and even if you don't decide to major in math you're very welcome to take classes in the math department!

Mark Meckes, Assistant Professor

A group picture of the attendees of the meeting on August 2010

Being a mathematician at a university allows me to communicate the subject I love to students - and hope to convey some of the enthusiasm I have for it. I come from a little village with 30 inhabitants in southern Germany but as a mathematician in my research, I travel all over the world and I meet fellow researchers from all over the world. My research areas are: Functional analysis, convex geometry and applications to quantum information theory.
In August 2010 we hosted a week-long international conference in my areas of research on the campus of Case Western Reserve University, which was attended by around 100 mathematicians from more than 10 different countries.

Elisabeth Werner, Professor

I have always liked the problem solving component of mathematics. In high-school I participated in the Mathematical Olympiads in Romania, which for me was a great venue to solve challenging mathematical problems. This experience made me want to explore mathematics in more detail, as often times the tools and ideas needed to solve some of the problems in mathematical competitions originated in advanced mathematical theories. As a student in mathematics in college I had the chance to be exposed to a wide range of mathematical fields, among which I found Partial Differential Equations most interesting to me.

Partial Differential Equations (PDE) are mathematical models of the physical reality. Therefore, the capability to obtain solutions of PDE has an enormous impact on every applied field. By studying PDEs as an undergrad I saw that except in very few particular cases, none of the meaningful physical equations can be solved explicitly, although beautiful mathematical theories can explain properties of solutions of those equations. I have also become aware that the only possibility to gain further insight into the solutions of PDEs is to use numerical simulations to compute meaningful approximations to such solutions. At the time the personal computers started to become more powerful and more available, so I started to play with numerical simulations and I got into this field deeper. What drove and still drives me to this field is the possibility to learn and experiment constantly new algorithms and new implementation strategies so that the numerical simulations run faster and produce more faithful results. I decided to pursue a doctoral degree in numerical solutions of PDEs and I had the chance to be accepted at the University of Minnesota, an institution which played a very important role in the history of numerical solutions of PDE as well as in the history of high performance computing.

My area of research is numerical solutions of large scale wave propagation phenomena relevant to applications such as radars, communication systems (antennas), and materials which can store solar energy more efficiently. On the one hand, I use in my research a variety of mathematical techniques from geometry, differential equations and linear algebra which I combine to produce numerical algorithms to solve wave propagation problems in complex media. On the other hand, I try to unleash the power of high performance computing such as parallel computing using CPUs and GPUs so that I can simulate solutions of very complex problems in short computational times.

Catalin Turc, Assistant Professor

My personal interests lie in Applied Mathematics. Along with computing and experiment/observation it can provide useful tools in many areas of research, from physical sciences and engineering to Biology, medicine and social studies. Specific research topics include

1. Geophysical modeling (turbulence, transport, Atmospheric chemistry

2. Biomedical research (epidemiology, immunology and biochemistry of infectious diseases).

David Gurarie, Professor

I started my studies as a astronomy major but switched soon to theoretical physics – I thought that quantum physics and relativity were so cool! During my studies, however, it became clear to me that if I really want to understand the theory, I need a solid background in mathematics, and so finally I ended up studying mathematics, and I never had to regret it.

In my research, I apply mathematics to fascinating real world problems involving physics, chemistry, and, increasingly, biology. Mathematics for me is a tool to reduce complex problems to their bare essentials. Using an analog, to draw the human body, one needs to understand how the skeleton works to get the proportions and movements right. Similarly, mathematics is that skeleton inside science, and if you know it, your imagination is the limit for what you can do. And that's not a bad limit.

Erkki Somersalo, Professor

I have been fascinated by mathematics since elementary school. My mother was a mathematics teacher, and I read lots of wonderful books that were around the house when I was young -- books like Dan Pedoe's Gentle Art of Mathematics, Kasner and Newman's Mathematics and the Imagination, and the collection of short stories, poems, and articles called Fantasia Mathematica. Later, thanks to inspiring teachers like Albert Nijenhuis, Chih-Han Sah, and my eventual thesis advisor Herman Gluck, I became a professional mathematician, specializing in differential geometry. While geometry of all kinds is the main source for my research efforts, I am fascinated by other subjects such as number theory and cryptography, which I have the pleasure of teaching on a regular basis.

David Singer, Professor

By the time I was five years old, it was clear that mathematics was special for me. Although I had great interest in the sciences, and in particular physics, mathematics was always my first priority. Throughout college I never even considered doing anything other than mathematics. Later, my outside curiosity and interests led me into applied mathematics.

As an applied mathematician, I can live in the theoretical world of mathematics, yet at the same time I can use the mathematics that I love to help solve practical, real world problems. I interact with scientists, engineers, and doctors. I am always excited to learn about the particular niches in the scientific, industrial, and medical fields in which they live. With my background, I can bring new perspectives to bear on their problems, and their problems provide the impetus for me to advance mathematical knowledge. It is a very satisfying symbiosis.

Steven Izen , Professor

As an undergraduate, I hesitated between mathematics and physics. The attraction of physics was strong: it provided insight on how the universe *really* works. On the other hand, mathematics was in some ways more satisfying and esthetically pleasing: with sufficient effort, one could understand even a difficult problem *completely*. So ultimately I focused on *functional analysis*, which is a way of studying geometry in very high, or even infinite dimension. This is not as far from reality as it may seem; complex systems or phenomena can be related to high-dimensional spaces or objects, with every degree of freedom being represented by a separate dimension. This way, my interests drifted back to physics. About half of my papers in the past few years deal with geometric and functional-analytic properties of *quantum states* and *quantum channels* or, more generally, with various mathematical aspects of one of the most exciting scientific and engineering challenges of our time: building quantum computers and quantum communication devices.

Stanislaw Szarek, Professor

I did not plan consciously to become a mathematician; rather, I got there incrementally. I did not even want to go to college. I ended up at RPI (Rensselaer Polytechnic Institute) because my dad filled out the application. I started out as a metallurgical engineering student, since he and I thought it would be interesting. (My parents had a friend who was a very successful metallurgical engineer.) After one semester it was clear that this was not for me. Instead of quitting entirely, I searched for a major that had the fewest requirements. In those days engineering had a very confining and rigid curriculum. After a bit of checking around, I found the department of Mechanics in the School of Science. They then had no undergraduate majors and, more important, no curriculum. This was for me! I talked my way into being accepted as their only undergraduate student. For the rest of my four years there I made up my own curriculum, subject only to the approval of the Chairman. I ended up with a background in mathematics and mechanics courses. Somewhere along the way I became really serious about the subject. Professor Michael Sadowsky, a senior and well know researcher in the theory of elasticity, became a sort of unofficial mentor. He suggested that I go to Brown, which at the time was the top place for mechanics. My interests remained in mechanics but became more and more mathematical thanks to many fine teachers, especially Professor Morton Gurtin, who became my thesis advisor. With a degree in Applied Mathematics I became a "card carrying" applied mathematician. (Brown University has a Department of Applied Mathematics and a Department of Mathematics) After some postdoctoral work at Brown and a flirt with industry, I came to the Mathematics Department of Case Institute of Technology. Certainly my view of mathematics and its applications has evolved over time. However, I thought then, and continue to believe, that Applied Mathematics is not a distinct discipline; there is just mathematics. However, there are applied mathematicians, those mathematicians who by temperament and training are externally motivated to do and create mathematics by questions and problems arising elsewhere. Nowadays that outside world is vastly rich in subjects and problems which demand our attention. In this sense, the world of mathematics is richer than ever before.

Marshall Leitman, Professor

I spent my high school years studying classics, and by the time I graduated I could translate pages from Latin without a dictionary and I had never heard about derivatives. Philosophy and ignorance did it to me. I was interested in the interplay between philosophy and science through the centuries, and soon realized how little I knew about the latter and decided to compensate by signing up for mathematics at the university. In Italy, when you study mathematics, it is 100% immersion. It was neither easy nor fun at first, a lot of hard work. But it was challenging and fascinating, and the possibilities of what one can in mathematics and with mathematics never ceased to amaze me.

My interests for the last several years have been in modeling and computational mathematics, with most of the target applications coming from medicine. One of the projects that I am presently involved with targets the mathematics needed to study the brain, which has inspired the course Math and Brain that we offer, another combines probability with scientific computing. Never a boring moment!

Daniela Calvetti, Professor and Chair

I like both pure and applied math. Pure math is so beautiful like art. Taking pure math courses, such as real analysis, abstract algebra and topology, and thinking deeply upon the topics, you will feel as if you are challenging your imagination.

Also, I feel comfortable using math to solve real world problems. You need to compromise on reasonable assumptions in order to come up with mathematical models. But it's much more convenient, efficient and humane to do experiments on coded models on your computer than on a little white mouse. We are actually saving lives!

Xiaoxia Wang, PhD Graduate

I’ve always had a thing for puzzles. Word searches, crosswords, ciphers… you name it! I love using logic and reasoning (and some tricks that come with experience!) to dive into a puzzle and work my way to a solution. The more challenging (and often frustrating) the puzzle is, the more gratifying its completion becomes. I think that it is this type of challenge that attracts me to math. Let’s face it… the study of mathematics is definitely not a walk in the park. But like any good puzzle, the more time and effort you put into a math problem, the more rewarding it is when you find the solution!

I flirted with the idea of focusing my studies on pure mathematics, but coming to Case really opened my eyes to all that applied mathematics has to offer. I enjoy seeing how pure math concepts can be applied in the modeling of real-world problems. As a second-year graduate student, my study of mathematics has really just begun, but I look forward to the challenge and all the puzzles left to solve.

Andrea Arnold, Chair of the Mathematics Graduate Student Association ☺

Throughout my numerous years of schooling I have always been drawn towards mathematics. When I was younger it didn't require so much explanation because it always seemed to make sense. It is not so easy to figure out now; however, I still know that it makes sense. It is in the background of basically any science one can hope to pursue. When I began my undergraduate schooling, I initially decided that I was going to study engineering along with mathematics but after two years of classes I decided that it was enough to study only math. It was the most consistent subject I had ever encountered. I felt as though the possibilities were endless when it came to mathematics. The funny thing is that even today in my classes I am still awe struck at the possibilities of what can be done with mathematics.

During my undergraduate education at Fisk University, my first mathematics course was Pre-Calculus. I can still remember my first day of class like it was yesterday. I walked into the classroom, looked on the board and saw a collection of letters and symbols that made my jaw drop. I thought to myself, "What's all that about!" I hoped that this class wasn't going to be starting off with that. There was less than a hand-full of numbers on the board. It was like the board was littered with hieroglyphs. Two minutes later, Professor Leroy Murray walked into the room with a stack of papers. He gave us a test! I thought to myself, "But we haven’t learned anything yet, what are we being tested on?" Surely, I was only able to answer two or three of the questions; however things turned out okay. At the end of class he told us that we should know all of that material by the end of semester. He was right. That was my first big step in learning Mathematics. I hope to continue making steps up the "mathematics ladder". The possibilities are endless!

Charles Joseph, Graduate Student