From the Chair

Congratulations to the Class of 2019 and all the finishing graduate students. Congratulations to the members of class of 2018 and new Ph. D.s who are reading Fine Letters for the first time as alumni. As we all know, the Math major is a great foundation for a diverse range of endeavors. This is exemplified by seventeen '18's who have gone to industry and seventeen to grad school; ten to advanced study in math and seven in CS, Economics, Philosophy or Biostatistics.

This academic year we welcomed Instructors Kenneth Ascher, Clark Butler, Remy van Dobben de Bruyn, Theo Drivas, Jiequn Han *18, Casey Kelleher, Chao Li, Boyu Zhang, and Ian Zemke, and assistant professor Aleksandr Logunov. We are very happy to report that twelve instructors and assistant professors have accepted offers to join our ranks in upcoming years, including six women. In addition, Chenyang Xu *08 accepted our professorial offer starting Fall 2020.

Two extraordinary members of our community passed away in December. The Department lost Professor Emeritus Elias Stein, who made many deep and influential research contributions. He was an unusually effective and popular mentor and teacher at all levels, as well as a master expositor whose books are classics. As a citizen, Professor Stein was an essential figure in all aspects of the Math department

Professor Allan Sly Receives MacArthur Fellowship

Sly works on an area of probability theory with applications from the physics of magnetic materials to computer science and information theory. His work investigates thresholds at which complex networks suddenly change from having one set of properties to another. Such questions originally arose in physics, where scientists observed such shifts in the magnetism of certain metal alloys. Sly provided a rigorous mathematical proof of the shift and a framework for identifying when such shifts occur.

His work has extended into theoretical computer science, where a key goal often is to understand whether it is likely or unlikely that a large set of randomly imposed constraints on a system can be satisfied. Sly has shown mathematically how such systems often reach a threshold at which solving a particular problem shifts from likely or unlikely. Sly has used a party invitation list as an analogy for the work: As you add interpersonal conflicts among a group of potential guests, it can suddenly become effectively impossible to create a workable party.

"How long until I can no longer find 40 people who will all be OK in the
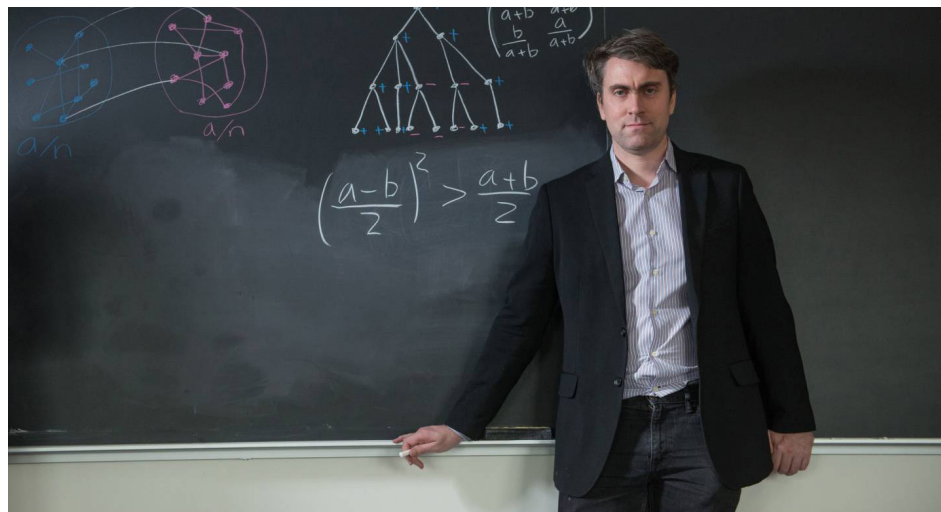
Courtesy of the John D. & Catherine T. MacArthur Foundation

from the Chair *...continued from previous page*

for many years, including two terms as Chair. We also lost Jean Bourgain, a Professor at the Institute for Advanced Study. An extraordinarily prolific and creative mathematician, he had many ties to our Department.

The Department's Minerva Program had its most active year with three Minerva Distinguished Visitors: Aaron Naber*09, Melanie Wood*09 and Xinwen Zhu in the fall. Hugo Duminil-Copin delivered our Minerva Lecture Series in the spring. All were very engaged with our students and faculty and gave beautiful, well-received research lectures.

In addition to busily learning mathematics in the classroom, our undergrads are learning to think and explore independently, first through their junior independent work and then through their senior theses. All juniors participate in a seminar, which sharpens the ability to pursue topics independently and to communicate their knowledge effectively, important skills in both aca-

demics and non-academic employment alike. Some of the independent research leads to publications in excellent journals, or serves as an entrée to coveted positions in the business, non-profit, or government sectors.

From graduate students to postdocs to junior faculty to long-time professors, we are all striving for essentially the same goals; solving the most interesting and fundamental mathematical problems and/or finding new directions and connections. For some of these efforts, our faculty have won major recognitions. These include Allan Sly (MacArthur Fellowship), Michael Aizenman (Poincaré Prize), Weinan E (Henrici Prize), Aleksandr Logunov (Salem Prize) and Francesco Lin (Sloan Fellowship). We are happy to report that Visiting Senior Lecturer Karen Uhlenbeck won the 2019 Abel Prize, Akshay Venkatesh *02 won a 2018 Fields Medal, and Visiting Associate Research Scholar June Huh won a 2018 New Horizons Prize.

We take teaching very seriously, and recognized Nicolas Boumal and Evita Nestoridi with Departmental Junior Faculty teaching awards, and Maggie Miller with the Departmental Graduate Student teaching award. We are very pleased that Hansheng Diao won his fourth consecutive Engineering Council Teaching Award and David Villalobos-Paz won one of seven Graduate School Teaching Awards.

Our extraordinary staff works behind the scenes to support the teaching and research mission of the Department. I'd like to take this opportunity to thank Michelle Matel, who is now our Undergraduate Administrator, for her six years of superb service as Assistant to the Chair and Department Manager. We welcome Kristie Dacey who is taking on the Assistant role. We are delighted that Gale Sandor, our

Events Specialist, won the President's Achievement Award, the University's highest recognition for a staff member. Her activities far exceed her job title. Gale also mentors newer staff, offers her ear to students and faculty, greets visitors, and when the elevators go out she dashes from the B-level to the 12th floor helping Fine Hall members.

This academic year concludes my seven years as Chair of the Department. Being Chair has been an amazing experience. Watching undergrads and grad students run with opportunity, and working with extraordinary colleagues, has been incredible. Among many other things, the Department has undergone generational change and the Common Room is once again an energetic center of activity. Whatever has been accomplished these last seven years is due to ever ready colleagues who step up when called, staff that go above and beyond, and our Nassau Hall administration that has steadfastly supported our efforts. I am grateful to all of you! Igor Rodnianski will become Chair as of July 1, 2019. Igor's outstanding leadership as Acting Chair in the 2015-16 academic year bodes well for the future.

Special thanks go to the Fernholz Foundation, the Class of 1971 Endowment and Wu-Chung Hsiang and Vicky Kwoh Ching for their generous support of the Department.

I hope that you can attend this year's Alumni Reception, 2:00 PM on Friday, May 31 in Fine Hall's Common Room. Reunions provide an opportunity not only for you to connect with former classmates and faculty, but to also meet our current students and hear about their projects. One of the highlights of being chair is hearing from our alumni. Please share your thoughts and stories!

David Gabai *77 *80
gabai@math.princeton.edu

Department Administration

Chair
David Gabai

Associate Chair
János Kollár (Fall)
Christopher Skinner (Spring)

Departmental Representative
János Kollár (Fall)
Ana Menezes (Spring)
Jennifer M. Johnson

Director of Graduate Studies
Javier Gómez Serrano
Zoltán Szabó

Senior Advisors
Zeev Dvir
John Pardon

**Junior Advisor**
Mark McConnell

Placement Officer
Ana Menezes

2018-19 Academic Year

Kenneth Ascher, Instructor
Algebraic Geometry
Kenneth Ascher received his Ph.D. from Brown University in 2017 after completing his undergraduate work at Stony Brook. Before coming to Princeton, Ascher was an NSF Postdoctoral Fellow at the Massachusetts Institute of Technology during the 2017-18 academic year.
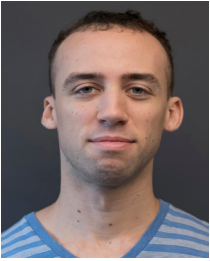
Clark Butler, Veblen Research Instructor
Dynamical Systems
Clark Butler completed his Ph.D. University of Chicago in 2018 and his B.S. at Ohio State University in 2012. While at the University of Chicago Butler received an NSF Graduate Research Fellowship as well as that school's Harper Dissertation Fellowship.

Remy van Dobben de Bruyn, Veblen Research Instructor
Algebraic Geometry
Remy van Dobben de Bruyn did his undergraduate work at Universiteit Leiden, followed by studies at the University of Cambridge and Université Paris-Sud XI before moving to Columbia University, where he completed his Ph.D. in 2018.

Theo Drivas, Instructor
Analysis
Theo Drivas received his Ph.D. in 2017 from Johns Hopkins University after completing his undergraduate work at the University of Chicago. Drivas was an NSF Postdoctoral Fellow in our department before being promoted to Instructor this year.
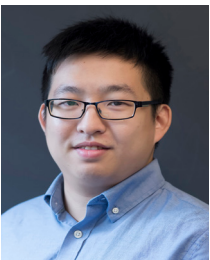
Jiequn Han, Instructor
Scientific Computing, Machine Learning
Jiequn Han did his doctoral work at Princeton's Program in Applied and Computational Mathematics, receiving his Ph.D. in 2018. Han completed his undergraduate work in mathematics with a minor in economics at Peking University.

Casey Kelleher, Instructor
Differential Geometry & Geometric Analysis
Casey Kelleher received her Ph.D. in 2017 from the University of California, Irvine after her undergraduate work at the California Polytechnic State University at San Luis Obispo. Before being promoted to Instructor Kelleher was an NSF Postdoctoral Fellow in our department.
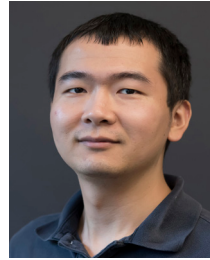
Chao Li, Instructor
Differential Geometry & Geometric Analysis
Chao Li completed his Ph.D. at Stanford University in 2018 after received his bachelors degree from Peking University in 2012. Li received the Chinese National Scholarship in 2012 in addition to being named Outstanding Student of Peking University for three consecutive years.

Aleksandr Logunov, Assistant Professor
Analysis and PDEs
Joins our department after spending the 2017-18 academic year as a member at the Institute for Advancecd Study and working as a Postdoctoral Fellow at Tel-Aviv University from 2015-17. Logunov received both his graduate and undergraduate degrees from St. Petersburg State University.
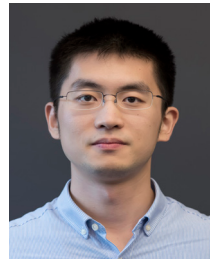
Boyu Zhang, Instructor
Symplectic Geometry & Low-dimensional Topology
Boyu Zhang completed his Ph.D. at Harvard University in 2018 and his undergraduate degree at Peking University in 2013. While at Harvard, Zhang received their Graduate School of Arts and Sciences Merit Fellowship.

Ian Zemke, Instructor
Symplectic Geometry & Low-dimensional Topology
Ian Zemke completed his Ph.D. in 2017 at the University of California, Los Angles after his undergraduate studies at the University of Washington, Seattle. Zemke joined our department in 2017 as an NSF Postdoctoral Fellow before being promoted to Instructor this year.

Upcoming Appointments

Daniel Álvarez-Gavela, Instructor

Chiara Damiolini, Instructor

Duncan Dauvergne, Instructor

Bariş Kartal, Instructor

Joaquin Moraga, Instructor

Evita Nestoridi, Assistant Professor

Sarah Peluse, Veblen Research Instructor

Sophie Spirkl, Instructor

Maxime van de Moortel, Instructor

Hong Wang, Instructor

Jingwei Xiao, Veblen Research Instructor

Andrew Yarmola, Instructor

Elias M. Stein 1931—2018 *by Emily Aronson, Office of Communications*

Elias Menachem Stein, a Princeton University mathematician for more than 50 years, died on Dec. 23 from complications related to mantle cell lymphoma. He was 87.

Stein, the Albert Baldwin Dod Professor of Mathematics Emeritus, was a pioneer in the field of harmonic analysis, an area of mathematics that has applications throughout the sciences.

For his contributions to the field, Stein received the 2002 National Medal of Science. Other awards include the Wolf Prize, one of the highest honors in mathematics; the Schock Prize, which is given by the Royal Swedish Academy of Sciences; and a Lifetime Achievement Award from the American Mathematical Society in recognition of Stein's fundamental contributions to different branches of mathematical analysis.

Stein joined Princeton's Department of Mathematics in 1963 and twice served as department chair.

"His death is a huge loss to the department, to mathematics and to Princeton," said Department Chair David Gabai, the Hughes-Rogers Professor of Mathematics.

Charles Fefferman, the Herbert E. Jones, Jr. '43 University Professor of Mathematics, said Stein was "a great mathematician, a great teacher and a great human being. It sounds like hype, but it is true. His discoveries from 50 years ago still play an important role in current research, and he kept on proving new theorems almost to the end of his life."

Before becoming his colleague in the Math department, Fefferman was one of Stein's Ph.D. students.

"Eli's mathematical descendants — his Ph.D. students, their Ph.D. students and so on — number over 600," Fefferman said. "He inspired generations of students and researchers. He will be sorely missed."

Stein was equally passionate about his research as he was about teaching graduate and undergraduate students.

"By so many different measures Elias Stein was truly an incredible and extraordinary mathematician," Gabai said. "As a research mathematician, he did incredible and influential work. He was an extraordinary mentor; many of his Ph.D. students have become extraordinary leaders in mathematics. As an undergraduate teacher, he was extremely popular with students. And as a citizen, he was an essential figure in all aspects of the Math department for many years."

Stein became an emeritus professor in 2012, though he continued to teach some classes. In his 70s, he helped create a series of advanced undergraduate math courses and co-wrote a four-volume textbook to accompany the courses.

Upon his transfer to emeritus status, colleagues wrote in tribute: "Eli's combined influence as a researcher, collaborator, teacher and expositor is unmatched. …His lectures are characterized by perfect clarity, concentration on essentials and impeccable taste. In his interaction with students and co-workers he has managed to convey the strong sense of optimism that is essential for mathematical discovery. He has been a major influence on many lives."

Stein held a life-long view of mathematics as a brilliant balance of imagination and rational investigation, said his daughter, Karen Stein.

He pioneered work in harmonic analysis, a field of mathematics originally developed to understand the flow of heat and the vibrations of a string. He also pioneered applications of harmonic analysis in other fields of mathematics. These advances led, in turn, to deeper understanding of a broad range of subjects including the stock market, gravitational waves and

sound recordings.

Born in Belgium in 1931, Stein and his family fled the country after the German invasion during World War II. They eventually immigrated to the United States and settled in New York City, where Stein served as captain of the math team at Stuyvesant High School.

He earned his undergraduate and graduate degrees from the University of Chicago, and held positions there and at the Massachusetts Institute of Technology before coming to Princeton.

Stein was the author of several books, including "Singular Integrals and Differentiability Properties of Functions"

He has managed to convey the strong sense of optimism that is essential for mathematical discovery.

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and "Harmonic Analysis: Real Variable Methods, Orthogonality, and Oscillatory Integrals." He also served on the editorial boards of the premiere journal *Annals of Mathematics* and several of Princeton's book series.

Stein is survived by Elly, his wife of 59 years; a brother, Daniel; a son, Jeremy, Princeton Class of 1983, the Moise Y. Safra Professor of Economics at Harvard University and a member of the Board of Governors of the U.S. Federal Reserve from 2012-14; a daughter Karen, Princeton Class of 1984, an architecture critic and former member of the jury of the Pritzker Architecture Prize; a daughter-in-law, Anne; and grandchildren Carolyn, Alison and Jason.

A conference honoring Stein's work will be held next year.

Jean Bourgain 1954—2018

Jean Bourgain, IBM von Neumann Professor in the School of Mathematics at the Institute for Advanced Study and a Visiting Lecturer with Rank of Professor at Princeton, revered for the exceptional range, depth, and power of his mathematical work, passed away in Bonheiden, Belgium, on December 22, at the age of 64.

Bourgain joined the Institute's School of Mathematics as a Professor in 1994, the same year he received a Fields Medal, and served as IBM von Neumann Professor at the time of his death. In awarding the 2018 Steele Prize for Lifetime Achievement to Bourgain, the American Mathematical Society recognized him as "a giant in the field of mathematical analysis, which he has applied broadly and to great effect.

In many instances, he provided foundations for entirely new areas of study and in other instances he gave mathematics new tools and techniques." A widely celebrated mathematician whose influence was acknowledged with many awards, including the 2017 Breakthrough Prize in Mathematics, Bourgain produced important work with impact across theoretical computer science, group theory, spectral theory, number theory, partial differential equations, harmonic analysis, and functional analysis.

Honoring the work of John N. Mather

The department hosted a conference October 1-3, 2018 to honor the memory and the lasting contributions of Professor John N. Mather. Speakers at the conference were:

James Damon
University of North Carolina

Albert Fathi
Georgia Institute of Technology

Charles Fefferman
Princeton University

Jacques Féjoz
University of Paris, Dauphine

Giovanni Forni
University of Maryland

Mark Goresky
Institute for Advanced Study

Vadim Kaloshin
University of Maryland

Leonid Polterovich
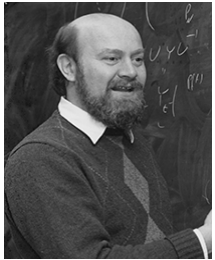*University of Tel Aviv*

Alfonso Sorrentino
University of Rome Tor Vergata

Dennis Sullivan
Stony Brook University

Honors and Awards

Michael Aizenman

was named the Aisenstadt Chair by the Centre de Recherches Mathématiques and received the Henri Poincaré Prize at the International Congree of Mathematical Physics.
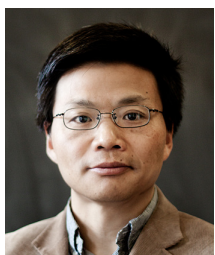
Sun-Yung Alice Chang

was selected for the 2019 class of AWM Fellows by the Association for Women in Mathematics "for shattering the glass ceiling and inspiring women mathematicians to follow her lead... and her extraordinary record of groundbreaking research in geometric analysis that has had worldwide impact."

Weinan E

was awarded the 2019 Peter Henrici Prize at the 9th International Congress on Industrial and Applied Mathematics for his "breakthrough contributions in various fields of applied mathematics and scientific computing..."

Charles Fefferman

received an Honorary Doctor of Science degree from the University of Warwick at their summer graduate ceremonies July 17-25.

June Huh

Visiting Professor at the Institute for Advanced Study and Visiting Associate Research Scholar at Princeton shares the 2019 New Horizons Prize in Mathematics with Karim Adiprasito
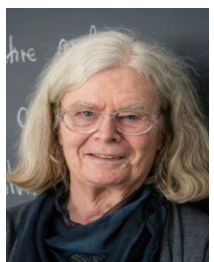
Franesco Lin

has been selected to received a 2019 Sloan Research Fellowship.

Aleksandr Logunov

has been awarded the 2018 Salem Prize for his work on the volumes of the zero sets of Laplacian eigenfunctions.

Karen Uhlenbeck

Professor Emerita of Mathematics at the University of Texas at Austin and a Visiting Senior Research Scholar at Princeton, will receive the 2019 Abel Prize "for her pioneering achievements in geometric partial differential equations, gauge theory and integrable systems, and for the fundamental impact of her work on analysis, geometry and mathematical physics."

ICM 2018
Akshay Venkatesh *02

was one of four recipients of the 2018 Fields Medal at the International Congress of Mathematicians in Rio de Janeiro. Venkatesh, who completed his Ph.D. at Princeton in 2002 under the supervision of Peter Sarnak, was cited for his synthesis of analytic number theory, homogeneous dynamics, topology, and representation theory, which has resolved long-standing problems in areas such as the equidistribution of arithmetic objects.

David Donoho '78

Princeton alum David Donoho '78, Stanford's Anne T. and Robert M. Bass Professor in the School of Humanities and Sciences, was awarded the 2018 Carl Friedrich Gauss Prize at the International Congress of Mathematicians in Rio de Janeiro for his fundamental contributions to the mathematical, statistical and computational analysis of important problems in signal processing.

National Academy

Congratulations to Jennifer Chayes *83, Barry Simon *70 and Karen Smith '87 for their elections to the National Academy of Sciences in 2019.

MacArthur Fellowship *...continued from front page*

same room?" Sly said.

Assaf Naor, a professor in the Department of Mathematics at Princeton, described Sly's work in this area as a "tour-de-force" in rigorously pinpointing the location of a satisfiability threshold of random formulas, "thus answering a question that resisted the efforts of many mathematicians, computer scientists, statisticians and physicists."

"Through his originality, spectacular analytic powers, and the depth of his insights, Sly is reshaping our understanding of fundamental probabilistic phenomena," Naor said.

In addition to interacting with physicists, Sly actively collaborates with computer scientists and information theorists. In related work, Sly currently is co-advising a graduate student with Emmanuel Abbe, associate professor of Electrical Engineering and Applied and Computational Mathematics.

"Probability is a really fascinating area at the intersection of many different fields," said Sly. "It's very exciting to take ideas or predictions from one area and apply them to problems from different fields."

"Allan Sly is a brilliant mathematician whose extraordinary work has resolved challenging problems in the fields of probability and statistics," said President Eisgruber. "We are fortunate that he is at Princeton, and we are delighted by the news of his selection as a MacArthur Fellow."

DEPARTMENT TEACHING AWARDS
Graduate Student and Junior Faculty

The Department annual teaching awards were announced at a special tea on Monday, October 15. This year's Junior Faculty Teaching Awards went to Assistant Professor Nicolas Boumal and Instructor Evita Nestoridi, while the Graduate Student Teaching Award went to Maggie Miller.

The awards are given by the senior faculty and are based largely on student evaluations. Boumal's students have noted he was "very receptive to questions, and genuinely cared that everyone understood."

Nestoridi's students also noted her approachable demeanor and commitment to ensuring every student understood the material, with one student writing "Evita was very careful about explaining the material coherently and in depth, continuously taking the initiative to check with students whether they are following. This is invaluable in a STEM class and I had not had such an engaged instructor at Princeton yet."

Miller, a fourth year graduate student, was called an "amazing instructor" who is "super great in helping to understand the material" by her students. They also praised her responsiveness to questions and her mastery of colored chalk.

Left to right: Evita Nestoridi, Maggie Miller, and Nicolas Boumal

Teaching tips from Hansheng Diao

Hansheng Diao, an instructor in our department since 2015, has received our departmental teaching award as well as being awarded the Excellence in Teaching Award by the Undergraduate and Graduate Engineering Student Council for four consecutive years. He has taught both introductory and advanced courses in the department, and here he shares his advice on connecting with students to convey complex ideas.

Here are two teaching tips for the first-time calculus teachers. Both tips are more or less cliché, but in reality, easier said than done. For this reason, I also include a couple of real classroom examples from my own teaching experiences.

Show your enthusiasm

Conveying your passion and enthusiasm for the subject, as well as your willingness to provide help, is the key to a successful semester. One can never emphasize this enough. Be physically active and animated, occasionally walk around in front of the blackboard, use your body language and voice to reflect your great fascination with calculus. Try to make eye contact as you lecture and try to make eye contact with each student equally. When the students see their instructor's passion and confidence, they become more engaged and want to participate.

On the first day of the semester, I always open with welcoming messages like: "Vector calculus is my favorite math course at Princeton. And it will be the best math class you're gonna take!" I also try to indicate how excited I am, conveying the impression that

Hansheng Diao (right) receiving his fourth consecutive teaching award from the Undergraduate and Graduate Engineering Student Council

there is literally nowhere else I'd rather be.

Here is another example. In MAT203 there was an entire week dedicated to multivariable extreme value problems, debatably the most important week for engineering and applied math majors. By that time some students were already stressed out after weeks of difficult material. At such moments, some reassuring messages go a long way. For instance, I started the week with: "This week is the min/max week, and you will LOVE it! Because, as you will see, it's exactly like the single-variable case." You may choose to follow by, "If you master this week's material, you

can easily survive on the Wall Street".

Understanding math in the ways of teaching

Being able to solve problems as a mathematician is not the same as being able to present those problems with a variety of strategies so that they are accessible to all students. This is about understanding math in the ways of teaching.

Allow me to demonstrate using the notion of "parameterized curve" in vector calculus. During the lecture, I give out three different approaches to the same concept. After two relatively formal definitions, I wrap up with a third one: a parameterized curve can be viewed as the trajectory of a "flying bug", and then emphasize how this third, more dynamical, approach is the "correct" way to think. This way, the bug becomes the "avatar" of an otherwise challenging concept. Consequently, the students, who are experiencing the concept for the first time, at least grasp the key idea from the lecture, and hence ready to digest the other two abstract approaches on their own time.

Surely, there is some danger in relying too much on such avatars. The most noticeable of which is losing mathematical accuracy. There is no clear rule here. Depending on the course goal and your personal teaching style, a decision needs to be made about the balance between "flying bugs" and formal math.

Mathematicians Disprove Conjecture Made to Save Black Holes

by Kevin Hartnett for Quanta Magazine

Nearly 40 years after it was proposed, mathematicians have settled one of the most profound questions in the study of general relativity. In a paper posted online last fall, Mihalis Dafermos, a mathematician at Princeton University, and Jonathan Luk have proven that the strong cosmic censorship conjecture, which concerns the strange inner workings of black holes, is false.

"I personally view this work as a tremendous achievement — a qualitative jump in our understanding of general relativity," emailed Igor Rodnianski, a mathematician at Princeton University.

Relativity's Cardinal Sin

In classical physics, the universe is predictable: If you know the laws that govern a physical system and you know its initial state, you should be able to track its evolution indefinitely far into the future. The dictum holds true whether you're using Newton's laws to predict the future position of a billiard ball, Maxwell's equations to describe an electromagnetic field, or Einstein's theory of general relativity to predict the evolution of the shape of space-time. "This is the basic principle of all classical physics going back to Newtonian mechanics," said Demetrios Christodoulou, a mathematician at ETH Zurich and a leading figure in the study of Einstein's equations. "You can determine evolution from initial data."

But in the 1960s mathematicians found a physical scenario in which Einstein's field equations — which form the core of his theory of general relativity — cease to describe a predictable universe. Mathematicians and physicists noticed that something went wrong when they modeled the evolution of space-time inside a rotating black hole.

To understand what went wrong, imagine falling into the black hole yourself. First you cross the event horizon, the point of no return (though to you it looks just like ordinary space). Here Einstein's equations still work as they should, providing a single, deterministic forecast for how space-time will evolve into the future.

But as you continue to travel into the black hole, eventually you pass another horizon, known as the Cauchy horizon. Here things get screwy. Einstein's equations start to report that many different configurations of space-time could unfold. They're all different, yet they all satisfy the equations. The theory cannot tell us which option is true. For a physical theory, it's a cardinal sin.

Roger Penrose proposed the strong cosmic censorship conjecture to restore predictability to Einstein's equations. The conjecture says that the Cauchy horizon is a figment of mathematical thought. It might exist in an idealized scenario where the universe contains nothing but a single rotating black hole, but it can't exist in any real sense.

The reason, Penrose argued, is that the Cauchy horizon is unstable. He said that any passing gravitational waves should collapse the Cauchy horizon into a singularity — a region of infinite density that rips space-time apart. Because the actual universe is rippled with these waves, a Cauchy horizon should never occur in the wild.

As a result, it's nonsensical to ask what happens to space-time beyond the Cauchy horizon because space-time, as it's regarded within the theory of general relativity, no longer exists. "This gives one a way out of this philosophical conundrum," said Dafermos.

This new work shows, however, that the boundary of space-time established at the Cauchy horizon is less singular than Penrose had imagined.

To Save a Black Hole

Dafermos and Luk, a mathematician at Stanford University, proved that the situation at the Cauchy horizon is not quite so simple. Their work is subtle — a refutation of Penrose's original statement of the strong cosmic censorship conjecture, but not a complete denial of its spirit.

Building on methods established a decade ago by Christodoulou, who was Dafermos's adviser in graduate school, the pair showed that the Cauchy horizon can indeed form a singularity, but not the kind Penrose anticipated. The singularity in Dafermos and Luk's work is milder than Penrose's — they find a weak "light-like" singularity where he had expected a strong "space-like" singularity. This weaker form of singularity exerts a pull on the fabric of space-time but doesn't sunder it. "Our theorem implies that observers crossing the Cauchy horizon are not torn apart by tidal forces. They may feel a pinch, but they are not torn apart," said Dafermos in an email.

Dafermos and Luk prove that space-time extends beyond the Cauchy horizon. They also prove that from the same starting point, it can extend in any number of ways: Past the horizon "there are many such extensions that one could entertain, and there is no good reason to prefer one to the other," said Dafermos.

Dafermos and Luk indicate that while space-time exists beyond the Cauchy horizon, this extended space-time isn't smooth enough to actually satisfy Einstein's equations. Thus, even with the strong cosmic censorship proven false, the equations are

RTG Summer Programs

In 2015 members of our department received a Research and Teaching Grant (RTG) from the National Science Foundation. The main purposes of this grant were to draw in students with interest but less background to the pursuit of mathematics, introducing them to exciting new realms within the areas of topology and geometry.

This goal is being realized through three summer programs, one last summer (2018), one this summer (2019), and one being planned for the future. These programs consist of a three-week intensive summer school for undergraduate and first-year graduate students—approximately 25 students, mostly from other Universities—along with conferences during these summer schools to introduce current research.

The 2018 summer school focused on low-dimensional topolgy and its connections to symplectic geometry, organized by David Gabai, Jonathan Hanselman, Henry Horton, Francesco Lin, Peter Ozsváth, John Pardon, and Zoltán Szabó. The organizers each taught an excellerated course, and dur-

ing each of the latter two weeks of the program we hosted small conferences, each bringing about ten outside speakers to share their research.

This upcoming June we will host a similar program on topics in geometric analysis, organized by Sun-Yung Alice Chang, Otis Chodosh, Casey Kelleher, Ana Menezes, Stephen McKeown, Rafael Montezuma, and Paul Yang. Again the format will be a three-week intensive summer school, with a conference featuring invited speakers in

the middle of the program.

In addition to three days of talks on current research, one day of this summer's conference be a festival focusing on diversity in mathematics.

A third summer school and conference are being planned for the future, and the department is grateful to the NSF for supporting these valuable programs.
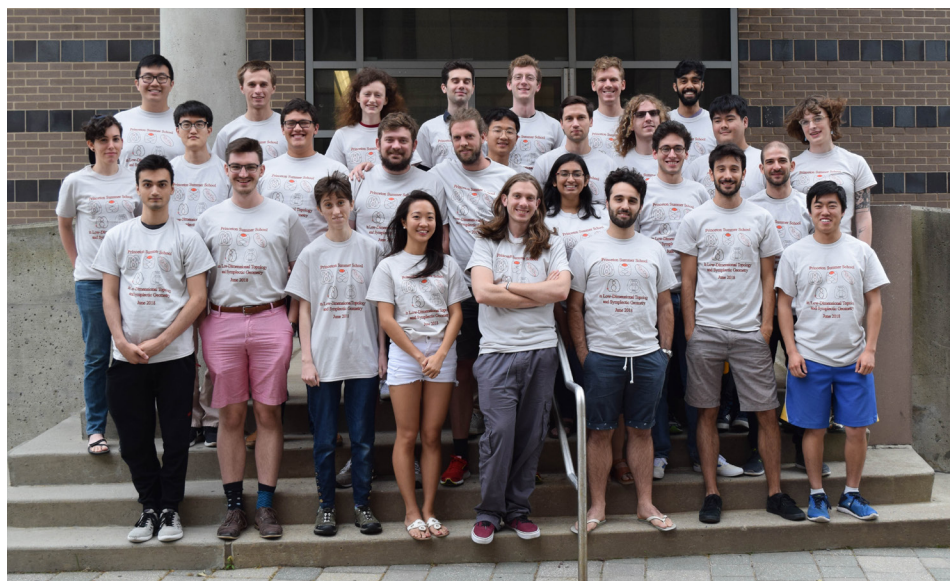

Participants in the 2018 Summer School on Low-Dimensional Topology and Symplectic Geometry.

Highlighting Diversity in Mathematics

As part of this summer's workshop highlighting diversity in mathematics, the department is producing a series of inspiring videos about senior mathematicians from underrepresented groups.

The first of these videos features our own Professor Sun-Yung Alice Chang sharing her story on the importance of community and encouraging young women to pursue studies in mathematics and other sciences.

View her story at: https://math.princeton.edu/chang-video
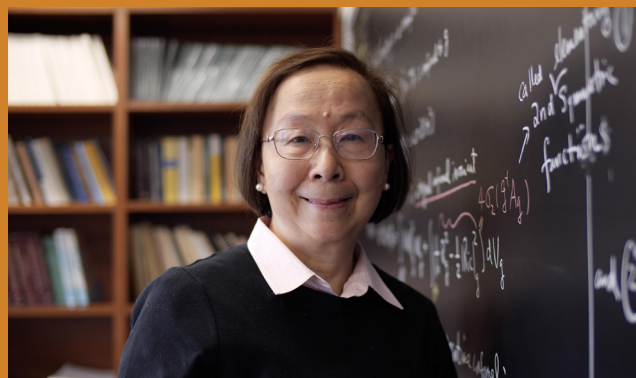
Closing the Gender Gap by Jenny Kaufmann '19

The 2018 class of math majors was 1/3 women, a department all-time record. This year, the fraction is 1/5. What causes this gender gap?

One of the biggest factors—and one that isn't often discussed—is underconfidence. Math has a pernicious reputation for being accessible only to geniuses. If you're a student in a challenging math class, it is easy to get intimidated and think, "Man, this is really hard, I must not be smart enough." It is especially easy to fall victim to this genius myth at places like Princeton, where some students enter already having a background in proof-based math. Freshmen who do not have this background may compare themselves to the ones that do, and ascribe the difference to talent instead of to a temporary head start.

Underconfidence doesn't exclusively afflict women. However, research has found that it does so disproportionately: on average, women consider themselves lower-performing than men at the same performance level. This lines up with my experience. I have heard from more than a few female math majors—no less talented than their male counterparts—who at some point doubted their ability to succeed in math. I also know of two female students in my year who would have liked to major in math, but didn't because they didn't believe they were smart enough.

To close the gender gap, we have to close the confidence gap. We need supportive mentors and female role models for the younger students. We need female math majors and grad students and professors to talk to freshmen, and say, "I've struggled too. Everyone does. It's not just you." Accomplishing this is hard. But the Princeton Noetherian Ring has risen to the challenge.

A year ago, math major Aria Wong spearheaded an initiative to encourage more women to major in math.

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The Noetherian Ring by Maggie Miller

The department's student & faculty mentoring program, the Noetherian Ring, began several years ago as a way to bring together female undergraduate students, graduate students, and faculty to create a community and structure for mentoring in the department.

What started as the occasional lunch gathering has expanded, and this semseter the group started a lecture series to feature the research of local and visiting women/nonbinary mathematicians. The seminar is organized by graduate students Dev Dabke (PACM), Mari Kawakatsu (PACM), Maggie Miller, and Boya Wen.

The overarching goal of the series is to highlight the work of a diverse set of speakers, who are asked to present their work at a general graduate level so that the whole department can participate.

Princeton Instructor Yunqing Tang gave the first lecture on March 6th, speaking about her research that certain density-zero sets of prime numbers are infinite. The series continued on April 19th with Yaim Cooper from the IAS.
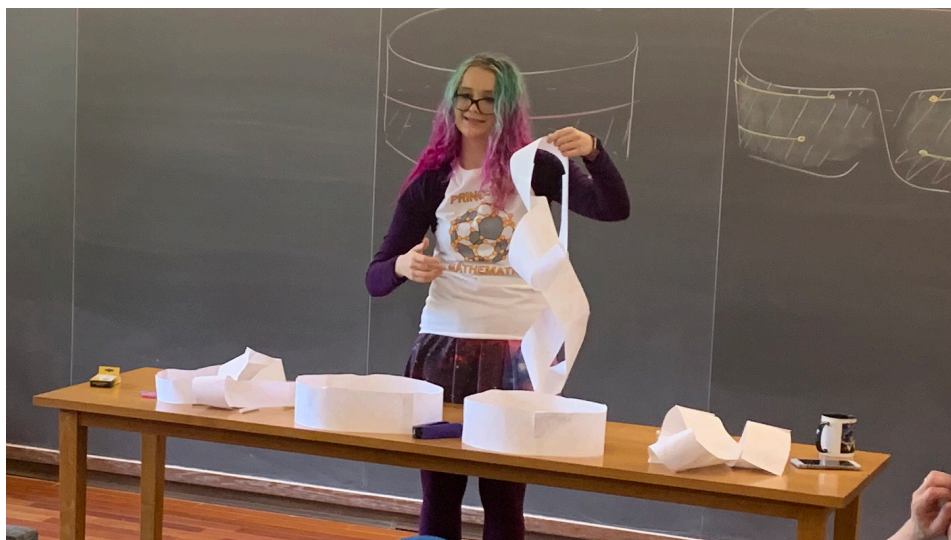
In addition to being an organizer of the Noetherian Ring, Maggie Miller spoke at the department's Bring Your Child to Work Day, giving a demonstration on slicing Möbius strips

The Minerva Programs

This year was one of the busiest yet for our Minerva Programs: the Minerva Distinguished Visitorship and the Minerva Lecture Series.

In the fall we hosted three Minerva Distinguished Visitors: Aaron Naber *09, Professor of Mathematics at Northwestern University; Melanie Matchett Wood *09, Vilas Distinguished Achievement Professor of Mathematics at the University of Wisconsin-Madison; and Xinwen Zhu, Professor of Mathematics at the California Institute of Technology.

Aaron Naber

Xinwen Zhu

Melanie Matchett Wood

Hugo Duminil-Copin

While the Minerva Distinguished Visitorship carries no official obligations, Naber, Wood, and Zhu each delivered a series of lectures on their recent research, which were all well attended by the department.

In the spring term Hugo Duminil-Copin, a Professor at both the Institut des Hautes Études Scientifiques and the Université de Genève, delivered our Minerva Lecture Series. Working in areas related to probability and mathematical physics, Duminil-Copin gave three talks on some intriguing aspects of the mathematical study of phase transitions.

Gender Gap *...continued from previous page*

She made a Noetherian Ring website with resources and advice from older students, and she sent personal welcome emails to every single one of the dozens of incoming freshman women who indicated an interest in math on their applications.

On top of that, Aria held a dinner for freshman women considering majoring in math. She invited all the female math majors, along with a handful of grad students and professors; we were there to give advice and answer questions for the freshmen. At one point during the dinner, we all went around one by one and talked about our experiences: the struggles we had faced, the friends we had found in the department who had helped us

through. Two of the then-seniors, who became friends during their first proof-based math class, said they would not have gotten through that class without each other. (They're both now getting Ph.D.s at top-15 math grad schools.)

In Fall 2018, inspired by Aria, I started running casual weekly study sessions for female math students. These sessions help younger female students form a support network. We also started hosting dinners around course selection time, where students give and receive advice about choosing courses, applying to REUs and internships, and so on. With the help of other math majors, we sent out welcome emails to this year's prospective female math students. And our group has more ideas in the works.

It is too soon to tell how successful our efforts will be at encouraging more female math majors. But with serious thought and persistent effort, I believe we can bring about a time when, if the gender ratio in a graduating class of math majors is 1/3, then that's a local minimum—not a global maximum.

For more guidance on supporting female students, see the "Guidelines on Best Practices" published by an NSF-funded initiative called WATCH US: https://www.womendomath.org/watch-us/

This article is excerpted from a post on Jenny Kaufmann's blog, Math Within Reach. You may read the full article at: http://mathwithinreach.blogspot.com/2019/04/closing-gender-gap.html

Updates from the Math Club

The Princeton Math Club has had a great start to 2019, and we are looking forward to continuing to spread our passion for mathematics throughout the undergraduate community.

This semester, we have continued to hold academic events, including our longstanding colloquium series, which has featured several talks from our distinguished faculty at Princeton as well as special guests to the university Eugenia Malinnikova and Tadashi Tokieda. Additionally, we have continued to run the Mentoring Möbius program, in which graduate students meet monthly with a small group of undergraduates to discuss math, life as a graduate student, and much more. Our outreach to the community continues through MathReach, a weekly program where undergraduate volunteers teach math to students at a nearby charter school, and

the Princeton University Math Competition, which draws more than 500 high school competitors to take a contest entirely organized by our own undergraduate volunteers. Monthly board game nights on Saturday evenings in the Fine Hall Common Room have been a great place for taking a break from problem sets to sit back and enjoy board games and the company of other Math Club members. We also recently held our annual Pi Day celebration, complete with pie (the sweet kind and the pizza kind!) and a pi-based trivia contest. It was a fun time for all who attended!

Later in the semester, we will also be holding Meet Your Professor dinners, as well as our annual end-of-year banquet in the Professor's Lounge of Fine Hall in May. We're looking forward to these events as well!

Lastly, there are some exciting new aspects of the Math Club that are forthcoming. We will be starting a series of talks by undergraduates about their independent research or other mathematical topics of interest. We are also working to revamp the Guide for Math Students on the club website, which will give comprehensive information about all aspects of life as a student of mathematics at Princeton. We hope that this will prove to be an invaluable resource for anyone and everyone remotely interested in math on campus.

That's all from the Math Club; we're looking forward to what the rest of the year has in store!

Zachary Stier
2019 Math Club President

Ryan Chen '19 awarded Churchill Scholarship

Princeton University senior Ryan Chen, a mathematics major who is planning to pursue a Ph.D. in mathematics with the goal of entering academia, has been selected as one of this year's Churchill Scholars.

Chen is one of 16 scholarship winners who will spend a year studying at the University of Cambridge while living at Churchill College, the only college at Cambridge focused on STEM subjects. He plans to complete Part III of the Mathematical Tripos, which confers a Master of Advanced Study in mathematics.

"In light of the vastness and diversity of mathematics involved in modern number theory, I am eager to strengthen my foundations and knowledge as much as possible," Chen said.

"My experience with math thus far has impressed upon me the diversity of tools involved," he said. "Connections between different techniques and subfields offer beautiful theorems and conjectures."

Black Holes

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still spared the ignominy of outputting nonunique solutions.

You could think of this outcome as a disappointing compromise: Even though you can extend space-time beyond the Cauchy horizon, Einstein's equations can't be solved. But it's precisely the fact that this middle ground seems to exist that makes Dafermos and Luk's work so interesting.

"This is people really discovering a new phenomenon in the Einstein equations," said Rodnianski.

This article was excerpted from Quanta Magazine. For the full article, visit https://www.quantamagazine.org/mathematicians-disprove-conjecture-made-to-save-black-holes-20180517/

Graduate Profile: Daniel Vitek

Hi, this is Daniel! I'm a fifth-year student here in Fine Hall. These days I work somewhere in the intersection of stable homotopy theory and low-dimensional topology. I definitely took a roundabout path to this project. I was fortunate enough to have my advisor, Peter Ozsváth, suggest several problems during my second and third year that were nicely aligned with my interests during my undergraduate studies at Duke University, though I didn't really get anywhere worthwhile on these problems. Despite all this, it wasn't until a conference the summer after my third year when I heard about the problems I've been thinking about (and ever-so-slightly solving) since. While I won't be continuing in academia—I'll be working at a think tank in town in the near term—I've tremendously enjoyed thinking about these problems and am very glad that I both chose to go to grad school and chose to come to Princeton.

As I leave Fine Hall, some memories stand out as highlights of everyday life here. Department athletic events, whether the F.C. Fine intramural soccer team, the Open Discs intramural ultimate Frisbee team, or the faculty-student soccer games (not to mention various pickup games), were always a blast, and I'm glad that the faculty-student soccer games are now happening more often than they used to. The graduate student community within Fine has offered some unique social events, from the intermittent movie nights to the now-very-successful tradition of Friday Socials. Finally, the department recital has always been a fantastic display of student and faculty talents, and I'm very glad I managed to participate this spring.

One common thread among these very distinct experiences is the support, often unnoticed, of the department administration, whether that's food for the faculty-student soccer games, support (and the freedom to buy our own supplies!) for Friday Socials, or organization for the recital. I've been here long enough to see some turnover in the administration, but the consistently high standard that they provide is an underrated reason for why Fine Hall functions as well as it does.

Daniel Vitek at this spring's recital

Javier Gómez Serrano: Director of Graduate Studies

This is my second year as one of the Directors of Graduate Studies (DGS) and it has been a great experience. Working with fellow DGS Zoltán Szabó has been easy, and he has been very effective at solving all the problems that arise on a day to day basis, both from the perspective of the students as well as the Graduate School. Our graduate administrator, Jill LeClair, puts in an enormous effort to keep our students on track and happy, which sometimes may be a challenging task, helping them navigate through any issues that arise.

I strongly feel that our students enjoy their time here.

We continue to work with the Graduate School and their representatives in the area of diversity and inclusion to guide us in the admissions process. There are always improvements that can be made. We will also be asking the graduate students to nominate representatives from each class year to serve as members of the Graduate Student Committee, making diversity and inclusion a priority, and addressing the concerns as well as any suggestions our students may have.

Admissions is one of the most challenging and at the same time rewarding parts of the job. It consists of several rounds: first a committee formed out of seven faculty members from different research areas and of varied seniority met to review the 325 applications we recieved this year. Then the committee presented its recommendations to the full faculty for final decisions. The Open House for admitted students was held March 7-8 and provided our guests the opportunity to talk to current faculty and students, attend talks, and also get a sense of how the town and life in Princeton. In the end, the incoming class will consist of 12 graduate students and we look forward to them joining the department this September!

Finally, on behalf of my fellow DGS and the Department, congratulations to the our 2019 Ph.D.s!

Name/ Field	Undergrad	Advisor	Thesis Title	Original Placement
Matthew de Courcy-Ireland *Analytic Number Theory*	McGill University	Sarnak	Fine-scale properties of random functions	Universit of Lusanne /Post-doctoral Researcher
Kathleen Emerson *Number Theory*	Cambridge University	Morel	Comparisons of different definitions of pseudocharacter	Heap, Inc./Software Engineer
Ross Granowski *Nonlinear Wave Equations*	Georgia Tech	Klainerman	Shock formation and illposedness of quasilinear wave equations	Pursuing entrepreneurship in property trading/ quantitative finance field
Artem Kotelskiy *Low-dimensional Topology*	Moscow State University	Szabó	Bordered invariants in low-dimensional topology	Indiana University/Zorn Postdoctoral Fellow
Daniel Kriz *Arithmetic Geometry/ Number Theory*	Princeton University	Zhang	A new p-adic Maass-Shimura operator and supersingular Rankin-Selberg p-adic L-functions	MIT/NSF Postdoctoral Research Fellow
Lucia Mocz *Arithmetic Geometry/ Number Theory*	Harvard University	Zhang	A new Northcott property for Faltings height	Hausdorff Center of Mathematics, University of Bonn/ Postdoctoral Research Fellow
Georgios Moschidis *General Relativity*	National Technical University of Athens	Dafermos	Two instability results in general relativity	UC Berkeley/Miller Research Fellow
Lue Pan *Number Theory*	Peking University	Taylor	Fontaina-Mazur conjecture in the residual reducible case	University of Chicago/ L.E. Dickson Instructor
Xiaojie Shi *Geometric Analysis*	National University of Singapore	Yang	Sobolev-type embedding on Cauchy-Riemann manifolds and nonlinear sub-elliptic PDE on Heisenberg group	Industry job/Chicago
Charlie Stibitz *Algebraic Geometry*	University of Michigan	Kollár	Topics in Fano varieties and singularities	Northwestern University/ Boas Assistant Professor
Yury Ustinovskiy *Complex Geometry*	Moscow State University	Tian	Hermitian curvature flow and curvature positivity conditions	Courant Institute, New York University/Courant Instructor
Anibal Velozo *Ergodic Theory*	Catholic University of Chile	Tian	The ergodic theory of geodesic flows	Yale University/Gibbs Assistant Professor
Yao Wang *Theoretical Machine Learning*	Xi'an Jiaotong University	E, Weinan	Estimation error for regression and optimal convergence rate	Orsus Research, NY/ Researcher
Junho Peter Whang *Number Theory*	McGill University	Sarnak	Diophantine analysis on moduli of local systems	MIT/C.L.E. Moore Instructor
Yuhou (Susan) Xia *Algebraic Number Theory*	Bryn Mawr College	Taylor	Irreducibility of Automorphic Galois Representations of Low Dimensions	Valassis Digital, NC/Data Scientist
Masoud Zargar *Algebraic Geometry*	University of Toronto	Cisinski (U. Regensburg), Weibel (Rutgers), Ozsváth	Voevodsky motives, stable homotopy theory, and integration	University of Regensburg, Germany/Postdoctoral Research Assistant

Annual Alumni Reception
Friday, May 31, 2019• 2:00-3:30pm
3rd Floor Common Room, Fine Hall

The department's faculty-student soccer games started some years ago as a casual affair, and have grown to a twice-per-year event complete with an after-game BBQ and team t-shirts.