Adding Gravitas

Math can be a challenge, an art form, or "really cool stuff." It's also a University cornerstone — and a key to life itself.

By Neill S. Rosenfeld

SOAP BUBBLES. Candle flames. War games. Financial engineering. Neurons. Gravity. Elections. These are some of the passions that drove — and are driving — the stellar mathematicians who have taught and studied at the City University of New York over the past 150 years. They have won Nobel Prizes, Fields Medals and the National Medal of Science. They helped lay the groundwork for computers, contemporary cryptography and machine vision.

Today's mathematicians veer in directions that were never imagined in 1853, when The Free Academy awarded one of its first 17 four-year baccalaureate degrees to Alfred George Compton, who would become City College's preeminent math instructor until his retirement in 1911. His modern successors study stars and brains, Shakespeare and Wall Street, set theory, number theory and geometric constructs in multiple dimensions that twist in ways that would give a pretzel-maker headaches.

City University "is plastered with people who are extraordinary" in mathematics, number theory, analysis topology and geometry, said Chancellor Matthew Goldstein, a mathematician and graduate of City College who has published extensively on mathematics and statistics.

Reflecting the University's Decade of Science, which Goldstein conceived, CUNY is hiring many junior professors in the math-heavy STEM fields — science, technology, engineering and math, itself. Pushing the frontiers of pure and applied mathematics, they are predicting the flow of ocean waves, forecasting the movement of the stock market and invoking string theory to explain particle physics.

And they're inspiring interest among a new generation of students. More than 2,700 undergraduates signed up for the University's first Math Challenge this winter. In recent years one undergraduate, Jan Siwanowicz (City College 2008), won the nation's toughest math competition, the Mathematical Association of America's William Lowell Putnam Competition; another, Joseph Hirsch (Macaulay Honors College at Queens College, 2008), captured a National Science Foundation graduate scholarship for pure mathematics and is pursuing a doctorate at the CUNY Graduate Center.

The mathematical ferment attracts students like Eugene Krel, who graduated *summa cum laude* from the Macaulay Honors College at Baruch College in 2008 and is pursuing a master's in financial engineering at Baruch. "I was always into mathematics. It was always better for me to solve problems than ponder something in my philosophy class," said Krel, who nonetheless majored in math, philosophy and New York City studies. "I figured that if mathematics could be so nice in theory, it could be even more so in practice."

A LOOK INTO THE PAST

The accomplishments of today's math faculty and students stand on a foundation of scholarship and instruction that stretches back to The Free Academy, the precursor of The City College of New York and CUNY.

Alfred George Compton laid the first stones of that foundation. After earning his bachelor's degree at The Free Academy in 1853, he became a leading teacher of math, physics and technical/mechanical studies. More practical than theoretic, Compton was committed to students. In 1878, when transcontinental travel was arduous, he led a group to the Rocky Mountains to make observations of a solar eclipse.

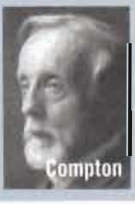
When he retired in 1911, mathematicians were roaming another frontier — the great unsolved theoretical problems of the new century. At the Second International Congress of Mathematicians in Paris in 1900, German mathematician David Hilbert had unleashed 23 dazzling problems that set much of the mathematical agenda for nine decades.

Those who solved them won renown. One studied at Brooklyn College, Paul J. Cohen. Another taught at Queens College, Leo Zippin. And a third, Martin Davis, graduated from City College.

Cohen, a prodigy, attended Brooklyn College from 1950 to 1953, until the University of Chicago invited him to pursue graduate studies without bothering with a B.A. He was best known for solving Hilbert's first problem, which concerns set theory (the continuum hypothesis or, as Ben Yandell phrased it in *The Honors Class: Hilbert's Problems and their Solvers:* "Is there any size bigger than the counting numbers but too small to be matched up one-to-one with the reals [real numbers]?") Cohen showed that the continuum hypothesis could be neither proved nor disproved. He held two of mathematics' highest honors, the Bôcher Prize

CUNY MILESTONES *in* MATH

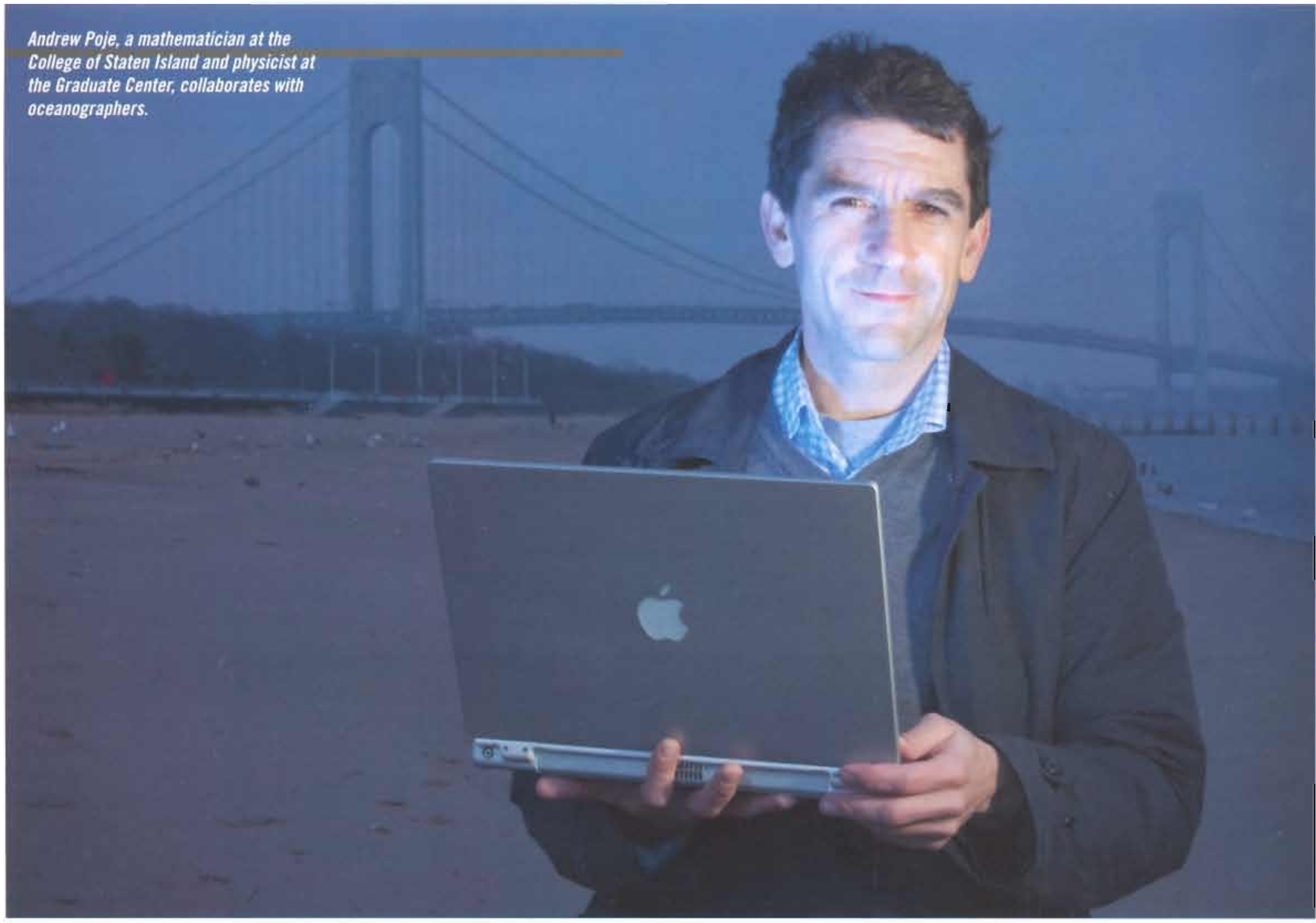
1853
Alfred George Compton graduates from Free Academy; beloved teacher of math, physics and technology who lays foundation for math instruction at City College; retires in 1911.



1900
German mathematician **David Hilbert** poses 23 problems, setting math agenda for 20th century.

1917
Emil Post and **Bennington Gill**, legendary mathematicians and CCNY professors, graduate from CCNY.

1921
Post publishes first proof of completeness and decidability of the propositional fragment of *Principia Mat matica*, a landmark atten to develop the logical four dations of mathematics ir fixed axiomatic system.



Andrew Poje, a mathematician at the College of Staten Island and physicist at the Graduate Center, collaborates with oceanographers.

(for analysis) and the Fields Medal (for logic) and he was working on Hilbert's unsolved eighth problem, about number theory, when he died in 2007.

During the Depression, Zippin studied with a founder of the field of topology at the Institute for Advanced Studies in Princeton, where he met Deane Montgomery. Zippin, who moved to the year-old Queens College in 1938, and Montgomery produced a series of papers, including the 1952 solution to Hilbert's fifth problem ("Are continuous groups automatically differential groups?"). Joseph Malkevitch, Zippin's young student at Queens and now professor *emeritus* of mathematics from York College, recalled "a special excitement in taking a course with someone who had solved one of the world-famous Hilbert problems."

Davis' pioneering work at NYU in automated deduction helped set the stage for contemporary computer science. He told *Salute to Scholars* that one of the most renowned City College professors, Emil Post, in essence challenged him to attack Hilbert's 10th problem ("Is there a general algorithm to solve Diophantine equations, that is, polynomial equations whose solutions must be integers?").

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Post contributed to pure mathematics and helped pave the way for computer science years before the first computers were built. When he graduated from City College in 1917, he had "already done much of the work for a paper on generalized differentiation that was eventually published in 1930," according to the American Philosophical Society, which houses his papers. His 1920 doctoral dissertation at Columbia "involved the mathematical study of systems of logic, specifically the application of the truth table method to the propositional calculus of Whitehead and Russell's *Principia Mathematica*." He showed "that the axioms of propositional calculus were both complete and consistent with respect to the truth table method. This dissertation was to help form the foundation of modern proof theory."

And yet, Post would realize, there is a fundamental incompleteness to any formal logic — in other words, certain things can't be proved. This was revolutionary, for it contradicted Plato's contention that

1936
Jesse Douglas (CCNY 1916) wins first Fields Medal; teaches at CCNY 1955-1965.

1937
Banesh Hoffman, Einstein collaborator on gravitation and relativity, joins first Queens College faculty; teaches into late 1970s.

1938
Leo Zippin, research assistant to the founder of the field of topology, joins Queens College faculty.

1940
About half of CCNY's Math Club would later teach at Stanford, where this photo was on display. Nobelist **Kenneth Arrow** is bottom, 2nd from left.

there is a reason for everything that is true, as well as Euclid's millennia-old structure for proving mathematical hypotheses using axioms and reason.

Unfortunately, Post could not whip this insight into a publishable form before the Austrian Kurt Gödel announced his groundbreaking Incompleteness Theorems in 1931. Post later graciously wrote to him that "for fifteen years I carried around the thought of astounding the mathematical world with my unorthodox ideas … As for any claims I might make[,] perhaps the best I can say is that I would have proved Gödel's Theorem in 1921 — had I been Gödel."

Paul Chessin, once chief mathematician at Westinghouse and an IBM analyst/programmer on NASA's Project Mercury, studied with Post, who had lost an arm in a childhood accident. "Invariably dressed in a three piece suit, empty sleeve carefully tucked into the side suitcoat pocket," Post would pace, lecture and write vigorously on the blackboard, his sleeve pulling loose and flapping like a cape, Chessin once recalled. "That freedom of motion seemed to us to liberate his thinking."

Nobel Laureate Robert Aumann, who studied real variable theory under Post, recalled that the class consisted almost completely of problems; Post assigned them as homework and students would present their solutions at the blackboard. "He made us figure things out for ourselves, never giving answers, only suggesting the next problem, the next place to go," Aumann told *Salute to Scholars* from his office at the Center for Rationality at the Hebrew University in Jerusalem. "You never really understand something until you figure it out yourself."

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Post's career overlapped that of Jesse Douglas, who had graduated a year earlier from City College and eventually returned to teach there. Douglas won the first Fields Medal in 1936 for solving a problem in differential geometry first posed in 1760 by Joseph-Louis Lagrange. Douglas proved that a minimal surface exists for a given boundary, such as a circle having the least perimeter to enclose a given area or a sphere having the least surface to enclose a specified volume. Soap films and soap bubbles are nature's handiest examples, and a blind 19th-century physicist who studied their properties, Joseph Plateau, bequeathed his name to the problem.

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Bennington Pearson Gill, Post's CCNY classmate, made his mark as a teacher and mentor in the tradition of Compton, the beloved teacher, during 47 years at the college. A testimonial statement found in the City College Archives deemed him "our department's leader on curricular matters" who "continuously … broadened and deepened" the curriculum. "So many of our students have gone on to distinguished careers in mathematics" because of him, they wrote. Among them was Aumann, who said Gill gave him "a feeling of excitement about mathematics. He encouraged me and oversaw the progress of my education."

Kenneth Arrow, another Nobel laureate and National Medal of Science winner, was also a student of Gill. "The word 'great' is only one I can apply to him as a teacher." Arrow told *Salute to Scholars* that Gill's two-term course in advanced calculus was "original, very thorough and rigor-

Lehman College's Christina Sormani explains a point about curved surfaces to student John DeJesus.

1943
Through 1946, Hunter professor **Mina Rees** (Hunter 1923) mobilizes mathematicians to solve military problems in wartime federal Applied Mathematics Panel.

Mina Rees

1946
Through mid-1953, **Rees** sets stage for modern federal funding of academic research while leading math and computer development at Office of Naval Research.

1948
Informal "math corner" at CCNY cafeteria includes subsequently prominent mathematicians **Robert Aumann** (Nobelist), **Martin Davis**, **Leon Ehrenpreis**, **Leopold Flatto** (teaching at CCNY since 2007), **Melvin Hendrickson**, **Donald J. Newman**, **Jacob T. Schwartz**, **Harold S. Shapiro** and **Allen L. Shields**.

Leo Zippin

1952
Zippin solves Hilbert's 5th problem.

ous, but very lively." Arrow, a Stanford professor *emeritus*, added: "He was a natural born teacher. I just do my best."

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The underpinnings of graduate-level mathematics at CUNY today can be traced to three people: Gov. Nelson Rockefeller, who in 1961 forged the city's disconnected public colleges into the City University of New York and granted CUNY the power to award doctoral degrees; Albert Bowker, a pioneering statistician who was recruited as CUNY's second chancellor (1963-1971) partly because of his success in fostering graduate education at Stanford; and mathematician Mina Rees (Hunter 1923), whom Bowker picked as the Graduate Center's first president. (Bowker's influence continued after he stepped down as chancellor, for he mentored Goldstein, like him a statistician who would go on to become chancellor.)

Rees was a pioneer, a woman in a male-dominated field who had to fight for her doctorate. Columbia admitted her to a master's program, but let her know it "was really not interested in having women candidates for Ph.D.s," she said. She earned hers at the University of Chicago.

In the pivotal event of her life, during World War II she became deputy to the chief of the Applied Mathematics Panel (AMP), a federal civilian agency that contracted with mathematicians to solve military problems, such as understanding gas dynamics in air and water explosions. She defined the mathematical essence of all requests for research, found the best-suited talent and flew around the country ensuring that jobs got done.

After the war, AMP disbanded and the Office of Naval Research (ONR) became Washington's prime source for funding basic scientific research until the National Science Foundation opened shop in 1950. In 1946 ONR pulled Rees from Hunter to run its Mathematical Sciences Branch; in 1949 she became deputy science director. She saw to it that ONR financed almost all of the early development of computer hardware and software, demanding faster machines, greater memory and visual display. In 1954 she rightly predicted that, with the right mathematics, computers would model experiments in areas like nuclear physics, where direct observation is impossible.

"The decisions that Rees and her staff made about what research and researchers to fund, and how to implement that funding, inaugurated the era of university research that continues today," wrote her biographer, mathematician Amy Shell-Gellasch. In 1949 alone, ONR awarded contracts for applied and pure mathematical research worth $247 million in today's dollars; that supported 1,200 projects and 5,000 researchers at more than 200 universities.

Rees returned to Hunter in 1953 as a math professor and dean of faculty. She was appointed the University's dean of graduate studies in 1961 — the first woman to head a coeducational graduate school in the country — and Bowker named her founding president of the Graduate Center. Rees turned to Leo Zippin, the Hilbert problem solver at Queens College, to establish the mathematics doctoral program.

Rees had funded Bowker's research when he was a graduate student at Columbia during the war, working on bombsights and how ships could avoid aerial torpedoes. "I have always thought that Mina and ONR have not been given enough credit for the development of mathematical statistics in this country. In most major universities it is the only new discipline (until the recent addition of

First CUNY Math Challenge Attracts 2,700 Students

More than 2,700 students signed up for the first CUNY Math Challenge, a contest designed to engage the finest mathematical minds among University undergraduates.

"CUNY has many students who are not recognized for their ability to be creative in mathematics," said Ted Brown, executive officer of the Graduate Center's Ph.D. program in computer science and executive director of CUNY's Institute for Software Design and Development, the latter of which is co-sponsoring the contest with CUNY's Office of Academic Affairs. "Our idea also was to promote the idea that math can be fun and, perhaps, generate interest in mathematics for any major."

The first four rounds take place online, with students having two weeks for each round. Approximately 30 students will make it to the final, in-person examination on May 10, vying for 14 cash prizes that range from $500 to the grand prize of $2,500. Each round includes five problems, some of which get tougher as the contest goes on. The prizes are funded by the Academic Leadership Award, which Chancellor Goldstein received from the Carnegie Corporation of New York.

Professors from nine CUNY institutions devised the questions, which require high school-level math but, quite consciously, not calculus. "We didn't want this to be just for math majors," Brown explained.

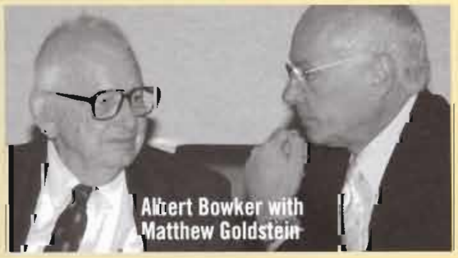
HERE'S A PROBLEM FROM ROUND 2:

Two CUNY math professors arrange to meet to prepare a test. Each will arrive at a random time between 1:00 p.m. and 2:00 p.m. and will wait up to 15 minutes for the other before leaving. What is the probability that the meeting takes place?

The solution appears on page 29.

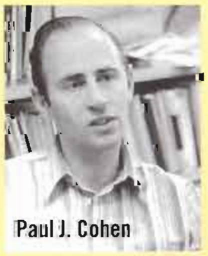
1961
Rees named University dean of graduate studies.

1963
Statistician **Albert Bowker** becomes 2nd CUNY chancellor.


Albert Bowker with Matthew Goldstein

1964
Rees names **Zippin** to found Graduate Center math department; he ran the department through 1968.

1966
Paul J. Cohen (left Brooklyn College as junior in 1953), wins Fields Medal for showing that Hilbert's 1st problem could not be solved under existing axioms of set theory; taught at Stanford.


Paul J. Cohen

computer science) added to the Arts and Science area since World War II," Bowker said in a 1987 interview.

With ONR's financial support — and before he had even received his doctorate — Stanford hired Bowker to launch its statistics department. He scored a major coup by recruiting Arrow, who, he said "came in with a joint appointment between statistics and economics ... With Ken Arrow as a nucleus, we had really a very interesting and stellar group of mathematical economists," including other members of the City College Math Club. For many years, the Statistics Department at Stanford displayed a 1940 photograph of the club, "because half were faculty members there," Arrow noted.

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In 1972 the Nobel committee cited Arrow's work in equilibrium theory, which says there are prices for goods that balance supply and demand in a complex economy with numerous markets, and the related area of welfare theory. The Royal Swedish Academy of Sciences wrote: "As perhaps the most important of Arrow's many contributions to welfare theory appears his 'impossibility theorem,' according to which it is impossible to construct a social welfare function out of individual preference functions."


Hunter graduate Shari Levine is studying for a math Ph.D. at Oxford.

What does that mean? Consider, as Arrow did, an election with more than two candidates. The winner may not be the person whom the majority of voters really want, as in many primary elections, not to mention the 2000 presidential contest, when Al Gore and Ralph Nader together received far more votes than George W. Bush.

In 2005, Aumann shared the Nobel Prize with Thomas Schelling of the University of Maryland "for having enhanced our understanding of conflict and cooperation through game-theory analysis," the Royal Swedish Academy of Sciences wrote. "Why do some groups of individuals, organizations and countries succeed in promoting cooperation while others suffer from conflict?" Their work "established game theory — or interactive decision theory — as the dominant approach to this age-old question ... The repeated-games approach clarifies the *raison d'être* of many institutions, ranging from merchant guilds and organized crime to wage negotiations and international trade agreements."

Game theory helps explain countries' decisions to go to war — or to strive for peace. Aumann sees war as an infinitely repeated game. When both sides in a conflict refuse to compromise, neither gets anything. For example, he has said, Israeli Prime Minister Rabin's negotiations with the Syrians in the 1990s "blew up over a few meters [of land]."

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Some of the University's leading mathematics professors have come in through joint appointments at the Graduate Center and CUNY colleges, like Dennis Sullivan, who was named the Graduate Center's Albert Einstein Chair in Science in 1981, initially with Queens College. The winner of top mathematics prizes and the 2004 National Medal of Science, Sullivan leads a Graduate Center seminar on the relationship between algebraic topology and quantum field theory.

Linda Keen, recruited by Zippin and accomplished in a variety of mathematical fields, has developed a devoted following among both faculty and students. Each year since about 2000, she and associate professor Katherine St. John have run a National Science Foundation-funded scholarship program for 30 to 40 undergraduate and graduate students in math, computer science and computer graphics. She also partners with IBM, which offers paid internships in computer science. In both programs, she said, "We have gotten a lot to go to grad school. I feel I've made a real difference."

Other renowned faculty members include Lehman distinguished professor Victor Pan, who fled Soviet oppression for American freedom in 1976, already dubbed as "polynomial Pan" for his work on polynomial computations.

CUNY named the Graduate Center's library in Rees' honor in 1985, and when she died in 1997 at age 95, she left $1.7 million to endow a graduate chair in mathematics and pay for a fellowship. In 2002 the University appointed Victor A. Kolyvagin, a Soviet-born mathematician whose research fundamentally changed number theory, as the first Mina Rees Chair and as a distinguished professor.

CALCULATING THE FUTURE

Today's junior faculty, recent alumni and students at CUNY are engaged across the spectrum of mathematical investigation. Here's a brief look at a few of them:

First, try to understand this: There is an infinity of infinities. Think of all the whole numbers from one up. That's your first infinity; call it a set. Then think of all of the numbers you didn't include, like the real numbers, or endless decimals, between zero and one. That's another and bigger infinity; call it another set.

Second, realize that you need a way to count even infinite things in a set. This is called cardinality.

Third, recognize that cardinality involves concepts that would take a book or three to explain.

This is the world of Grigor Sargsyan, who received his CUNY Baccalaureate in 2003 and a U.C. Berkeley Ph.D. this year. Sargsyan explores an aspect of cardinality known as inner model theory. Suffice it to say that includes Kurt Gödel's model of the constructible universe, the continuum hypothesis of Georg Cantor and Zemelo-Fraenkel set theory. Call it really big numbers.

"Set theory may be *epsilon* more abstract than other areas of math," said Sargsyan,

1966
Linda Keen (CCNY 1960), recruited to Graduate Center by Zippin, joins Lehman College when it splits from Hunter. Research focuses on the interconnection between analysis, geometry and algebra. Heads programs to encourage students to pursue math degrees. Chaired boards of the American Mathematical Society and the Institute for Pure and Applied Math.


Linda Keen

1968
Cohen receives National Medal of Science.

1969
Bowker names Mina Rees as first Graduate Center president.

1969
Victor Pan, renowned for work on polynomials and computational math in Soviet Union, begins teaching at Lehman College and Graduate Center. His work applies to sciences, engineering and signal and image processing.


Victor Pan

City Tech's Hans Schoutens cofounded the CUNY Logic Workshop at the Graduate Center.

using a mathematical term for infinitesimally small. "The mathematics of infinity is so mysterious that sometimes even fundamental questions — such as what constitutes an answer to a given question — need to be addressed. On the other hand, infinities are just as concrete mathematical objects as anything, and the combinatorial structures existing on them are just as beautiful as they are on finite sets."

After emigrating from Armenia, he enrolled at Baruch College in part to take a graduate-level independent-study course with Arthur W. Apter, a set theorist specializing in large cardinals. They coauthored six papers and Apter co-directed his Ph.D. with John Steel of Berkeley.

Sargsyan switched to the CUNY Baccalaureate Program in order to study with professors at Queens and Lehman Colleges and the Graduate Center.

Through the CUNY Baccalaureate, he qualified for a Thomas W. Smith academic fellowship. With doctorate in hand, Sargsyan is heading to National Science Foundation-supported postdoctoral study at UCLA.

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Take logic, mix with geometry and stir in algebra. Specifically, use the logic of model theory to create an "ultraproduct," a structure that combines an infinite number of smaller structures in a way that allows you to simultaneously manipulate all of them when you manipulate the overall structure.

Then suppose you are curious about singularities — the points on geometric objects where something extraordinary happens, like self-intersection or sharp cusps — and suppose that algebraic rings describe the geometric objects. With the right operations, you could draw conclusions about the rings, the singularities and the ultraproduct's parts and whole.

If this sounds like Winston Churchill's description of the Soviet Union — a riddle wrapped in a mystery inside an enigma — you're not far wrong, but it makes perfect sense to Hans Schoutens, cofounder of the CUNY Logic Workshop at the Graduate Center. The workshop has become an East Coast magnet for logic, which is to mathematics what linguistics is to English.

It started in 1996, when Schoutens arrived in New York from his native Belgium with impressive credentials, no job, but a CUNY connection — logician Roman Kossak, then an adjunct at Bronx Community College and now a professor there. They teamed up with Joel Hamkins, then a fresh recruit to the College of Staten Island and now also a professor, to launch an ongoing seminar.

"People kept joining and becoming logicians because of our little group, and that has contributed to CUNY becoming one of the leading logic centers in the U.S.," said Schoutens, now an associate professor at New York City College of Technology (City Tech). "Once you have a critical mass, you get all of these students, and now we even have model theory and set theory divisions. It's led to a renaissance of logic at CUNY."

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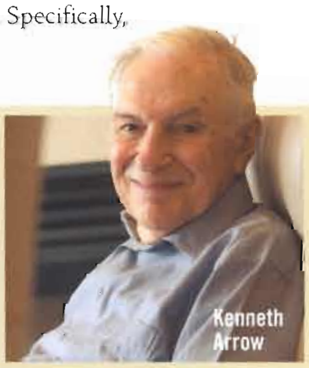
Katrina was an ordinary Category 3 hurricane as it entered the Gulf of Mexico from the Caribbean. There it passed over a vast, powerful eddy that rushed unseen beneath the waves. Far warmer than the surrounding water, this eddy quickly stoked Katrina into the raging Category 5 storm that drowned New Orleans.

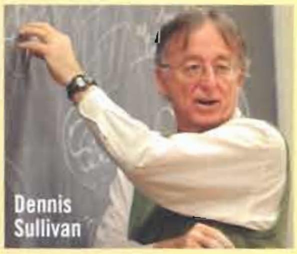
Associate professor Andrew Poje, a mathematician at the College of Staten Island and a physicist at the Graduate Center, collaborates with oceanographers to study fluid dynamics. He has focused

1972
Kenneth Arrow (CCNY 1940, math major) receives Nobel Prize in economics.

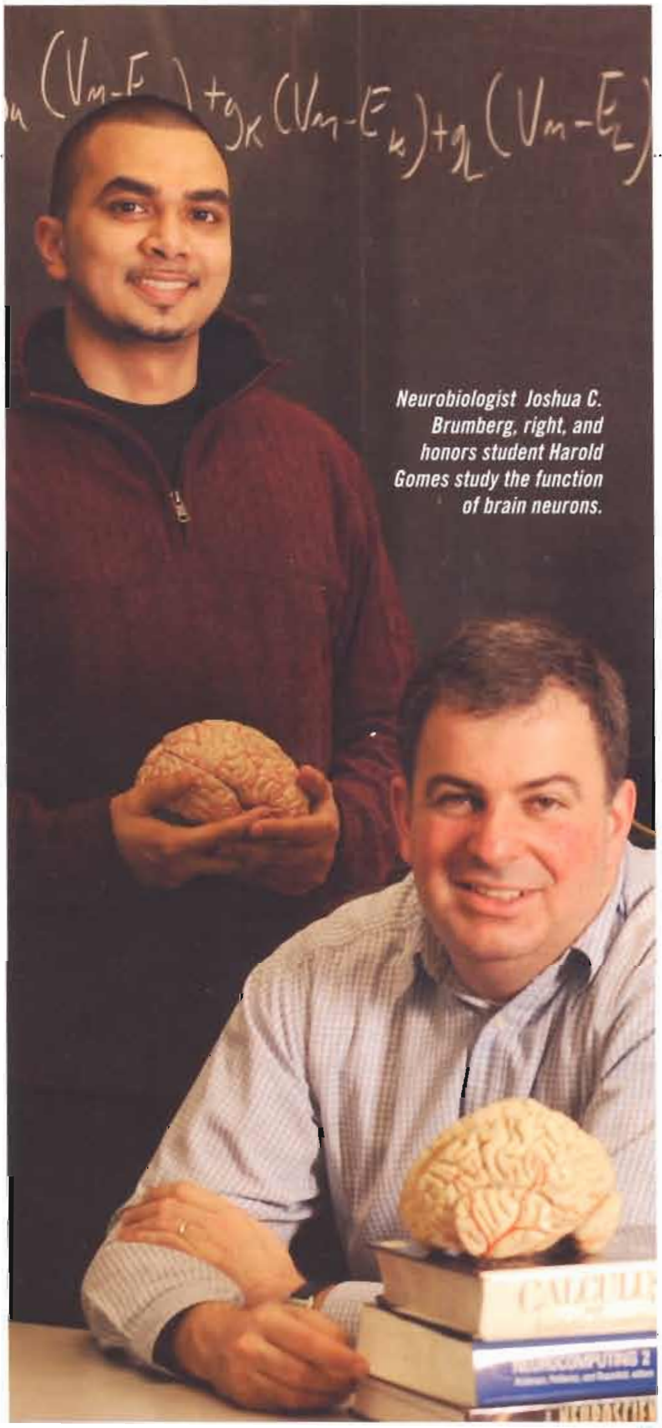


1973
Martin Davis (CCNY 1948) solves Hilbert's 10th problem; acclaimed for early computer work in 1950s; taught at NYU.

1974–1975
Davis wins Leroy P. Steele Prize, Chauvenet Prize and Lester R. Ford Prize for work on Hilbert's problem.



1981
Dennis Sullivan – winner of 1971 Oswald Veblen Prize in geometry – begins teaching at Queens College and Graduate Center and wins Prix Élie Cartan. Wins 2004 National Medal of Science and 2006 Steele prize.



Neurobiologist Joshua C. Brumberg, right, and honors student Harold Gomes study the function of brain neurons.

on the eddies, or rings, which are torrents up to 1,000 meters deep and hundreds of kilometers across that break off randomly from the Gulf's Loop Current, a warm-water branch of the Gulf Stream.

"The swell speeds of these rings are so fast that oil companies can't dig while they're passing their rigs. They'll bend the drill," Poje said. Writing in Yale's Journal of Marine Research, his team detailed the life cycle of three potentially devastating rings, which go by names like Juggernaut and Millennium.

Poje uses nonlinear dynamics and chaos theory to understand the rings' geometry. "If you plotted tracer trajectories driven by these eddies you'd get a spaghetti plot. I try to make sense of the spaghetti." Constantly moving, frequently splitting, the eddies get squashed and ripped apart. "I want to know what factors are responsible for the disintegration, as well as the most dangerous place to crash your oil tanker. Can a model predict where the oil will go if I dump a million gallons to the left of some line you can't see?"

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Think of the shape of a candle flame as it flickers, with constantly changing corners, surface, tips and curvature. Knowing a flame's dimensions can be important in a factory or spacecraft, where its position and shape are critical.

The same notion of curved surfaces applies to the universe. Near the Earth, explained Lehman College associate professor Christina Sormani, the universe looks like everyday, three-dimensional Euclidean space. Forward-backward, left-right and up-down are the familiar directions.

But near heavy stars and black holes, space curves in a phenomenon called gravitational lensing. Direction isn't quite what it seems to be and, due to curvature, there is more than one shortest distance between two points. The universe becomes what mathematicians call a Riemannian manifold that can exist in far more than three dimensions.

Sormani studies the Ricci curvature of Riemannian manifolds, that is, how the volume of a multidimensional manifold differs from the volume of a comparable region in Euclidean space. (Einstein popularized Ricci curvature in his theory of general relativity.) She is also interested in mirror symmetry and string theory, which help explain particle physics and cosmology, as well as manifolds. "It is very abstract," Sormani said.

More comprehensible is her work as principal investigator of Lehman's new Math Teacher Transformation Institute. Funded by the National Science Foundation, it focuses on better equipping Bronx junior high and high school teachers to teach algebra, geometry and other areas of mathematics. The institute also seeks to assess the best instructional practices, as measured by New York State Regents Exams.

Sormani teaches geometry to the first cohort of 40 state-certified math teachers. Geometry had faded from the classroom when many of them were in high school themselves, because the Regents kept changing the curriculum. With the state now reverting to a more traditional approach to algebra, geometry and trigonometry, the teachers have turned to the institute to expand their knowledge and skills.

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Does the shape of a neuron, or nerve cell, determine how it functions in the brain? Queens College neurobiologist Joshua C. Brumberg can learn only so much by examining tissue. But with mathematical models, "We can test hypotheses that we might not be able to do in a living system."

"Computational neuroscience gives us a leg up," said Brumberg, an associate professor and director of the Graduate Center's neuropsychology Ph.D. subprogram. And for mathematics he turns to talented undergraduates.

"Biology is the new discipline driving innovations in mathematics. It used to be physics," said Michael Schwemmer (Macaulay Honors College at Queens College 2005), who expects to earn his doctorate in applied mathematics from the University of California-Davis in 2010). Examining brain activity to discover how cognition works "is really cool stuff." His doctoral research probes the relationship

1985
Jerome Karle and **Herbert Hauptman** (both CCNY 1937, with Hauptmann a math major) receive Nobel Prize in chemistry for developing mathematical techniques through which X-ray crystallography can disclose 3-D structure.

1999
Statistician **Matthew Goldstein** (CCNY 1963) becomes CUNY chancellor.

2001
CCNY student **Jan Siwanowicz** (CCNY 2008) is among five to win Putnam Competition, the most prestigious U.S. undergraduate math prize.

between neurons' synchronized electrical activity and sensory information processing, motor skills and associative learning. "What are the fundamental biophysical mechanisms that make them synchronize their activity?"

Schwemmer, a guitarist, was first attracted to Queens College's Aaron Copeland School of Music, which he attended in high school. But math won out, thanks to a graduate-level class in number theory with assistant math chair Steven J. Kahan. "That made me appreciate how mathematics can be an art form."

With Brumberg, Schwemmer examined action potentials, or electrical discharges, in neurons, looking at how cell geometry affects firing. "It was amazing to use math to understand biology," he said. Upon graduation, he received the Claire and Samuel Jacobs Award for excellence in mathematics.

Brumberg is now working with Harold Gomes (Queens 2009), an honors student majoring in math and physics. He started at Queensborough Community College and his studies are supported by the National Institutes of Health Minority Access to Research Careers program. He wondered whether the shape and size of a neuron affect physiology and signal processing. "We showed that the geometry of the cell matters," said Gomes.

Or as Brumberg put it, "Neurons involved in one pathway have different properties than neurons in another pathway. That's what Harold's data is showing you." The next step will be to see whether those mathematical findings bear out in the laboratory.

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What if Romeo had fallen for Juliet at first sight and then discovered that she smelled bad?

"The play would have gone in a complete opposite direction, into extreme hatred or apathy to one another," said Shari Levine (Hunter 2008), who is studying for a math Ph.D. at Oxford. "The only way the story could explode into intense romance is if both were attracted from the start."

How does she know that? Differential equations tell her so.

Cornell mathematician Steven Strogatz first seized upon "Romeo and Juliet" in 1988 to inject drama into his teaching of differential equations. Levine gave "Romeo" her own spin in undergraduate research supported by the National Science Foundation and then wrote equations to explain "Hamlet," "Henry V" and "Midsummer Night's Dream." Graphing the equations shows how the play will end, but change the conditions and the graphs and endings will differ wildly.

"It surprised me how surprised people are that you could do this," she said. She presented her work at the 2007 Einsteins in the City International Student Research Conference, which alternates between CCNY and The Technical University of Vienna.

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As the financial world imploded this year, critics vilified financial engineers — the once-vaunted quantitative analysts, or "quants," who use mathematics to study and manage the market. Weren't they responsible for creating those toxic mortgage derivatives?

Partly, but there's plenty of blame to go around, and more should be heaped upon salespeople and rating agencies. Had the raters fairly valued those derivatives from the beginning, things might have turned out differently, most commentators agree.

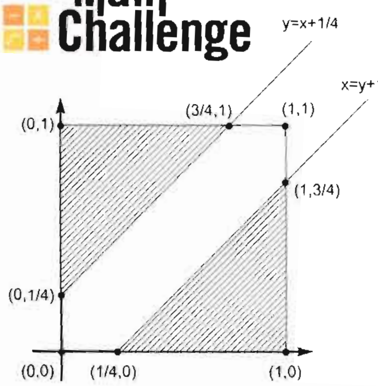
"The field is bound to continue growing," said Dan Stefanica, director of Baruch College's Master's of Financial Engineering (MFE) Program since it started in 2002. "With the advent of electronic trading, all transactions are recorded electronically. There are terabytes of information. You need models to sift through and process that information, which you can use to hedge your positions and invest more efficiently. You can't go back to pencil and paper."

Since the advent of financial engineers in the last decade, quants primarily determined exposure to risk and analyzed structured products. But today their algorithms also drive trading decisions, particularly at hedge funds.

The three pillars of financial engineering get equal emphasis in Baruch's highly competitive program — mathematics, which creates a model; finance, which employs the model; and computer programming, which runs the model.

Baruch's strategy of admitting only the most qualified candidates, not a predetermined number, appears to be paying off. Most students earn their degrees and quickly find work, if they aren't in the financial industry already. Consider the 22 graduates of December 2008: Five worked in the sector; by February 2009, 11 others had landed jobs guaranteed to pay an average of $94,000 in the first year — an impressive record, especially in these nail-biting times.

The CUNY Math Challenge



THE SOLUTION: There's a 44 percent (more precisely, 7/16) chance that the professors will meet.

Here's how to solve the problem:

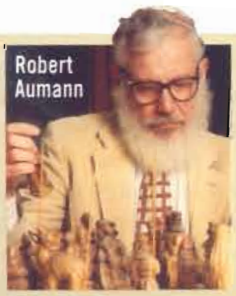
Associate each arrival time between 1 p.m. and 2 p.m. with a real number r such that $0 < r < 1$. The number r represents the part of the hour that has elapsed before the arrival. In this way the arrival times of the two professors determine a coordinate pair (x, y) that corresponds to a point in the unit square with $0 < x < 1$, $0 < y < 1$.

The pair (x, y) corresponds to a situation where the professors fail to meet if either $y > x + ¼$ or $x > y + ¼$ (see below).

In the first of these cases the point (x, y) lies in the triangle that lies above the line $y = x + ¼$. The area of this triangle is 1/2x3/4x3/4=9/32. Similarly, in the second case, the point (x, y) lies in the triangle with area 9/32 that lies below the line $x = y + ¼$. We deduce that the probability that the professors do not meet is 9/32+9/32=9/16.

Bearing in mind that a 100 percent guaranteed meeting would be 16/16, you subtract the probability you've derived of their not meeting (9/16) from that to get the probability that they will meet, 7/16.

2005
Robert Aumann (CCNY 1950, math major) receives Nobel Prize in economics.



2005
Goldstein announces **CUNY's Decade of Science** (2005-2015), resulting in hiring of many mathematicians and emphasizing math-heavy STEM fields— science, technology, engineering and math.

2008
Joseph Hirsch (Macaulay Honors College at Queens College 2008) wins National Science Foundation graduate research fellowship; now pursuing Ph.D. in math at CUNY Graduate Center.

2009
More than 2,700 undergraduates register for first **CUNY Math Challenge.**

2009
Six students in Baruch's Master's of Financial Engineering Program place in **2009 Interactive Brokers Trading Olympiad**, 10% of winners in this international graduate student competition.